THE

FIRST & THE LAST CATASTROPHE;

A CRITICISM

ON SOME RECENT SPECULATIONS ABOUT THE DURATION OF THE UNIVERSE.

A Lecture

DELIVERED BEFORE THE

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BY

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SYLLABUS.

Professor Clerk Maxwell, in his lecture on "Molecules," delivered to the British Association at Bradford, argued from the absolute similarity of certain molecules in the Sun and Stars and upon the earth's surface, that they can neither have been evolved by any natural process nor have existed from all eternity. In the first part of the lecture it will be argued that we have no evidence of such absolute exactness as would warrant the first conclusion, and that a theory of the evolution of matter may yet be looked upon as a possibility.

Sir William Thomson has remarked that if, assuming Fourier's laws of the conduction of heat, we endeavour to calculate the past history of any portion of matter, this calculation is only successful for a limited time, and that at a certain date this portion of matter must have been in a state which cannot have resulted by the conduction of heat from any previous state. Some writers (Mr. Murphy, 'Scientific Bases of Faith;' Professor Jevons, 'Principles of Science,' p. 438) have inferred from this that we have evidence either of a beginning of the universe or of a change in the laws of nature at a distant date. The Second Part of the Lecture will be devoted to showing that this inference is not a valid one, and that we have no such evidence of a beginning of the present order of things.

Finally, it will be pointed out that the field of healthy human interest is limited to so much of the past as can serve as guide to our actions, and so much of the future as may be appreciably affected by them.

THE

FIRST & THE LAST CATASTROPHE;

A CRITICISM

ON SOME RECENT SPECULATIONS ABOUT THE DURATION OF THE UNIVERSE.

I PROPOSE in this lecture to consider speculations of quite recent days about the beginning and the end of the world. The world is a very interesting thing, and I suppose that from the earliest times that men began to form any coherent idea of it at all, they began to guess in some way or other how it was that it all began, and how it was all going to end. But there is one peculiarity about these speculations which I wish now to consider, that makes them quite different from the early guesses of which we read in many ancient books. These modern speculations are attempts to find out how things began, and how they are to end, by consideration of the way in which they are going on now. And it is just that character of these speculations that gives them their interest for you and for me; for we have only to consider these questions from the scientific point of view. By the scientific point of view, I mean one which attempts to apply past experience to new circumstances according to an observed order of nature. So that we shall only consider the way in which things began, and the way in which they are to end, in so far as we seem able to draw inferences about those questions from facts which we know about the way in which things are going on now. And, in fact, the great interest of the subject to me lies in the amount of illustration which it offers of the degree of knowledge which we have now attained of the way in which the universe is going on.

The first of these speculations is one set forth by Professor Clerk Maxwell, in a lecture on Molecules, delivered before the British Association at Bradford. By a coincidence, which to me is a happy one, at this moment Professor Maxwell is lecturing to the Chemical Society of London upon the evidences of the molecular constitution of matter.* Now, this argument of his, which he put before the British Association at Bradford, depends entirely upon the modern theory of the molecular constitution of matter. I think this the more important, because a great number of people appear to have been led to the conclusion that this theory is very similar to the guesses which we find in ancient writers—Democritus and Lucretius. It so happens that these ancient writers did hold a view of the constitution of things which in many striking respects agrees with the view which we hold in modern times. This parallelism has been brought recently before the public by Professor Tyndall in his excellent address at Belfast. And it is perhaps on account of the parallelism, which he pointed out at that place, between the theories held amongst the ancients and the theory now held amongst the moderns, that many people who are acquainted with classic literature have thought that a knowledge of the views of Democritus and Lucretius would enable them to understand and criticise the modern theory of matter. That, however, is a mistake. The difference between the two is mainly this: the atomic theory of Democritus was a guess, and no more than a guess. Everybody around him was guessing about the origin of things, and they guessed in a great number of ways; but he happened to make a guess which was more near the right thing than any of the others. This view was right in its main hypothesis, that all things are made up of elementary parts, and that the different properties of different things depend rather upon difference of arrangement than upon ultimate difference in the substance of which they are composed.

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* See *Nature*, vol. viii., pp. 441, and vol. xi., pp. 357, 374.

Although this was contained in the atomic theory of Democritus, as expounded by Lucretius, yet it will be found by any one who examines further the consequences which are drawn from it, that it very soon diverges from the truth of things, as we might naturally expect it would. On the contrary, the view of the constitution of matter which is held by scientific men in the present day is not a guess at all.

In the first place I will endeavour to explain what are the main points in this theory. First of all we must take the simplest form of matter, which turns out to be a gas,—such, for example, as the air in this room. The belief of scientific men in the present day is that this air is not a continuous thing, that it does not fill the whole of the space in the room, but is made up of an enormous number of exceedingly small particles. There are two sorts of particles: one sort of particle is oxygen, and another sort of particle nitrogen. All the particles of oxygen are as near as possible alike in these two respects; first in weight, and secondly in certain peculiarities of mechanical structure. These small molecules are not at rest in the room, but are flying about in all directions with a mean velocity of seventeen miles a minute. They do not fly far in one direction; but any particular molecule, after going over an incredibly short distance—the measure of which has been made—meets another, not exactly plump, but a little on one side, so that they behave to one another somewhat in the same way as two people do who are dancing Sir Roger de Coverley; they join hands, swing round, and then fly away in different directions. All these molecules are constantly changing the direction of each other's motion; they are flying about with very different velocities, although, as I have said, their mean velocity is about seventeen miles a minute. If the velocities were all marked off on a scale, they would be found distributed about the mean velocity just as shots are distributed about a mark. If a great many shots are fired at a target, the hits will be found thickest at the bull's-eye, and they will gradually diminish as we go away from that, according to a certain law, which is called the law of error. It was first stated clearly by La Place; and it is one of the most remarkable consequences of theory that the molecules of a gas have their velocities distributed amongst them precisely according to this law of error. In the case of a liquid, it is believed that the state of things is quite different. We said that in the gas the molecules are moved in straight lines, and that it is only during a small portion of their motion that they are deflected by other molecules; but in a liquid we may say that the molecules go about as if they were dancing the grand chain in the Lancers. Every molecule after parting company with one finds another, and so is constantly going about in a curved path, and never gets quite clear away from the sphere of action of the surrounding molecules. But notwithstanding that, all molecules in a liquid are constantly changing their places, and it is for that reason that diffusion takes place in the liquid. Take a large tank of water and drop a little iodine into it, and you will find after a certain time all the water turned slightly blue. That is because all the iodine molecules have changed like the others and spread themselves over the whole of the tank. Because, however, you cannot see this, except where you use different colours, you must not suppose that it does not take place where the colours are the same. In every liquid all the molecules are running about and continually changing and mixing themselves up in fresh forms. In the case of a solid quite a different thing takes place. In a solid every molecule has a place which it keeps; that is to say, it is not at rest any more than a molecule of a liquid or a gas, but it has a certain mean position which it is always vibrating about and keeping fairly near to, and it is kept from losing that position by the action of the surrounding molecules. These are the main points of the theory of the constitution of matter as at present believed.

It differs from the theory of Democritus in this way. There is no doubt that in the first origin of it, when it was suggested to the mind of Daniel Bernouilli as an explanation of the pressure of gases, or to the mind of Dalton as an explanation of chemical reactions, it was a guess; that is to say, it was a supposition which would explain these facts of physics and chemistry, but which was not known to be true. Some theories are still in that position; other theories are known to be true, because they can be argued back to from the facts. In order to make out that your supposition is true, it is necessary to show, not merely that that particular supposition will explain the facts, but also that no other one will. Now, by the efforts of Clausius and Clerk Maxwell, the molecular theory of matter has been put in this other position. Namely, instead now of saying, Let us suppose that such and such things are true, and then deducing from that supposition what the consequences ought to be, and showing that these consequences are just the facts which we observe; instead of doing that, I say, we make certain experiments, we show that certain facts are undoubtedly true, and from these facts we go back by a direct chain of logical reasoning, which there is no way of getting out of, to the statement that all matter is made up of separate pieces or molecules, and that in matter of a given kind, in oxygen, or in hydrogen, or in nitrogen, these molecules are of very nearly the same weight, and have certain mechanical properties which are common to all of them. In order to show you something of the kind of evidence for that statement, I must mention another theory which, as it seems to me, is in the same position; namely, the doctrine of the luminiferous ether, or that wonderful substance which is distributed all over space, and which carries light and radiant heat. By means of certain experiments upon interference of light, we can show, not by any hypothesis, not by any guess at all, but by a pure interpretation of the experiment—we can show that in every ray of light there is some change or other, whatever it is, which is periodic in time and in place. By saying it is periodic in time, I mean that at a given point of the ray of light, this change increases up to a certain instant, then decreases, then increases in the opposite direction, and then decreases again, and so on alternately. That is shown by experiments of interference; it is not a theory which will explain the facts, but it is a fact which is got out of observation. By saying that this phenomenon is periodic in space, I mean that, if at any given instant you could examine the ray of light, you would find that some change or disturbance, whatever it is, has taken place all along it in different degrees. It vanishes at certain points, and between these it increases gradually to a maximum on one side and the other alternately. That is to say, in travelling along a ray of light there is a certain change (which can be observed by experiments, by operating upon a ray of light with other rays of light), which goes through a periodic variation in amount. The height of the sea, as you know if you travel along it, goes through certain periodic changes; it increases and decreases, and increases and decreases again at definite intervals. And if you take the case of waves travelling over the sea, and place yourself at a given point, say you put a cork upon the surface, you will find that the cork will rise up and down, that is to say, there will be a change or displacement of the cork's position, which is periodic in time, which increases and decreases, then increases in the opposite direction, and decreases again. Now, this fact, which is established by experiment, and which is not a guess at all, the fact that light is a phenomenon, periodic in time and space, is what we call the wave theory of light. The word theory here does not mean a guess; it means an organised account of the facts, such that from it you may deduce results which are applicable to future experiments, the like of which have not yet been made. But we can see more than this. So far we say that light consists of waves, merely in the sense that it consists of some phenomenon or other which is periodic in time and in place; but we know that a ray of light or heat is capable of doing work. Radiant heat, for example, striking on a body, will warm it and enable it to do work by expansion; therefore this periodic phenomenon which takes place in a ray of light is something or other which possesses mechanical energy, which is capable of doing work. We may make it, if you like, a mere matter of definition, and say: Any change which possesses energy is a motion of matter; and this is perhaps the most intelligible definition of matter that we can frame. In that sense, and in that sense only, it is a matter of demonstration, and not a matter of guess, that light consists of the periodic motion of matter, of something which is between the luminous object and our eyes.

But that something is not matter in the ordinary sense of the term, it is not made up of such molecules as gases and liquids and solids are made up of. This last statement again is no guess, but a proved fact. There are people who ask, Why is it necessary to suppose a luminiferous ether to be anything else except molecules of matter in space, in order to carry light about? The answer is a very simple one. In order that separate molecules may carry about a disturbance, it is necessary that they should travel at least as fast as the disturbance travels. Now we know by means that I shall afterwards come to, that the molecules of gas travel at a very ordinary rate, about twenty times as fast as a good train. But, on the contrary, we know by the most certain of all evidence, by five or six different means, that the velocity of light is 200,000 miles a second. By that very simple consideration we are able to tell that it is quite impossible for light to be carried by the molecules of ordinary matter, and that it wants something else that lies between those molecules to carry the light. Now remembering the evidence which we have for the existence of this ether, let us consider another piece of evidence, let us now consider what evidence we have that the molecules of a gas are separate from one another and have something between them. We find out, by experiment again, that the different colours of light depend upon the various rapidity of these waves, depend upon the size and upon the length of the waves that travel through the ether, and that when we send light through glass or any transparent medium except a vacuum, the waves of different lengths travel with different velocities. That is the case with the sea; we find that long waves travel faster than short ones. In much the same way, when light comes out of a vacuum and impinges upon any transparent medium, say upon glass, we find that the rate of transmission of all the light is diminished, that it goes slower when it gets inside of a material body; and that this change is greater in the case of small waves than of large ones. The small waves correspond to blue light and the large waves correspond to red light. The waves of red light are not made to travel so slowly as the waves of blue light, but, as in the case of waves travelling over the sea, when light moves in the interior of a transparent body the largest waves travel most quickly. Well, then, by using such a body as will separate out the different colours—a prism—we are able to affirm what are the constituents of the light which strikes upon it. The light that comes from the sun is made up of waves of various lengths; but making it pass through a prism we can separate it out into a spectrum, and in that way we find a band of light instead of a spot coming from the sun, and to every band in the spectrum corresponds a wave of a certain definite length and definite time in vibration. Now we come to a very singular phenomenon. If you take a gas such as chlorine and interpose it in the path of that light, you will find that certain particular rays of the spectrum are absorbed, while others are not. Now how is it that certain particular rates of vibration can be absorbed by this chlorine gas while others are not? That happens in this way, that the chlorine gas consists of a great number of very small structures, each of which is capable of vibrating internally. Each of these structures is complicated, and is capable of a change of relative position amongst its parts of a vibratory character. We know that molecules are capable of such internal vibrations, for this reason, that if we heat any solid body sufficiently it will in time give out light; that is to say, the molecules are got into such a state of vibration that they start the ether vibrating, and they start the ether vibrating at the same rate at which they vibrate themselves. So that what we learn from the absorption of certain particular rays of light by chlorine gas, is that the molecules of that gas are structures which have certain natural rates of vibration which they absorb, precisely those rates of vibration which belong to the molecules naturally. If you sing a certain note to a string of a piano, that string if in tune will vibrate. If, therefore, a screen of such strings were put across a room, and you sang a note on one side, a person on the other side would hear the note very weakly or not at all, because it would be absorbed by the strings; but if you sang another note, not one to which the strings naturally vibrated, then it would pass through, and would not be eaten up by setting the strings vibrating. Now this question arises. Let us put the molecules aside for a moment. Suppose we do not know of their existence, and say, is this rate of vibration which naturally belongs to the gas, a thing which belongs to it as a whole, or does it belong to separate parts of it? You might suppose that it belongs to the gas as a whole. A jar of water if you shake it has a perfectly definite time in which it oscillates, and that is very easily measured. That time of oscillation belongs to the jar of water as a whole. It depends upon the weight of the water and the shape of the jar. But now, by a very certain method, we know that the time of vibration which corresponds to a certain definite gas, does not belong to it as a whole, but belongs to the separate parts of it, for this reason: that if you squeeze the gas you do not alter the time of vibration. Let us suppose that we have a great number of fiddles in a room which are all in contact, and have strings accurately tuned to vibrate to certain notes. If you sang one of those notes all the fiddles would answer; but if you compress them you clearly put them all out of tune. They are all in contact, and they will not answer to the note with the same precision as before.

But if you have a room which is full of fiddles, placed at a certain distance from one another, then if you bring them within shorter distances of one another, so that they still don't touch, they will not be put out of tune, they will answer exactly to the same note as before. We see, therefore, that since compression of a gas within certain limits does not alter the rate of vibration which belongs to it, that rate of vibration cannot belong to the body of gas as a whole, but it must belong to the individual parts of it. Now, by such reasoning as this it seems to me that the modern theory of the constitution of matter is put upon a basis which is absolutely independent of hypothesis. The theory is simply an organised statement of the facts, a statement, that is, which is rather different from the experiments, being made out from them in just such a way as to be most convenient for finding out from them what will be the results of other experiments. That is all we mean at present by scientific theory.

Upon this theory Professor Clerk Maxwell founded a certain argument in his lecture before the British Association at Bradford. It is a consequence of the molecular theory, as I said before, that all the molecules of a certain given substance, say oxygen, are as near as possible alike in two respects—first in weight, and secondly in their times of vibration. Now Professor Clerk Maxwell's argument was this. He first of all said that the theory required us to believe not that these molecules were as near as may be alike, but that they were exactly alike in these two respects—at least the argument appeared to me to require that. Then he said all the oxygen we know of, whatever processes it has gone through—whether it is got out of the atmosphere, or out of some oxide of iron or carbon, or whether it belongs to the sun or the fixed stars or the planets or the nebulæ—all this oxygen is alike. And all these molecules of oxygen we find upon the earth must have existed unaltered, or appreciably unaltered, during the whole of the time the earth has been evolved. Whatever vicissitudes they have gone through, how many times they have entered into combination with iron or carbon and been carried down beneath the crust of the earth, or set free and sent up again through the atmosphere, they have remained steadfast to their original form unaltered, the monuments of what they were when the world began. Now Professor Clerk Maxwell argues that things which are unalterable, and are exactly alike, cannot have been formed by any natural process. Moreover, being exactly alike, they cannot have existed for ever, and therefore they must have been made. As Sir John Herschell said, "they bear the stamp of the manufactured article."

Now, into these further deductions I do not propose to enter at all. I confine myself strictly to the first of the deductions which Professor Clerk Maxwell made from the molecular theory. He said that because these molecules are exactly alike, and because they have not been in the least altered since the beginning of time, therefore they cannot have been produced by any process of evolution. It is just that question which I want to discuss. I want to consider whether the evidence that we have to prove that these molecules are exactly alike is sufficient to make it impossible that they can have been produced by any process of evolution.

The position, that this evidence is not sufficient, is evidently by far the easier to defend; because the negative is proverbially hard to prove; and if any one should prove that a process of evolution was impossible, it would be an entirely unique thing in science and philosophy. In fact, we may see from this example precisely how great is the influence of authority in matters of science. If there is any name among contemporary natural philosophers to whom is due the reverence of all true students of science, it is that of Professor Clerk Maxwell. But if any one, not possessing his great authority, had put forward an argument founded apparently upon a scientific basis, in which there occurred assumptions about what things can and what things cannot have existed from eternity, and about the exact similarity of two or more things established by experiment, we should say, "Past eternity; absolute exactness; this won't do;" and we should pass on to another book. The experience of all scientific culture for all ages during which it has been a light to men, has shown us that we never do get at any conclusions of that sort. We do not get at conclusions about infinite time or infinite exactness. We get at conclusions which are as nearly true as experiment can show, and sometimes which are a great deal more correct than direct experiment can be, so that we are able actually to correct one experiment by deductions from another; but we never get at conclusions which we have a right to say are absolutely exact; so that even if we find a man of the highest powers saying that he had reason to believe a certain statement to be exactly true, or that he believed a certain thing to have existed from the beginning exactly as it is now, we must say, "It is quite possible that a man of so great eminence may have found out something which is entirely different from the whole of our previous knowledge, and the thing must be inquired into. But, notwithstanding that, it remains a fact that this piece of knowledge will be absolutely of a different kind from anything that we knew before."

Now let us examine the evidence by which we know that the molecules of the same gas are as near as may be alike in weight and in rates of vibration. There were experiments made by Dr. Graham, late Master of the Mint, upon the rate at which different gases were mixed together. He found that if he divided a vessel by a thin partition made of black-lead or graphite, and put different gases on the two opposite sides, they would mix together nearly as fast as though there was nothing between them. The difference was that the plate of graphite made it more easy to measure the rate of mixture; and Dr. Graham made measurements and came to conclusions which are exactly such as are required by the molecular theory. It is found by a process of mathematical calculation that the rate of diffusion of different gases depends upon the weight of the molecules. A molecule of oxygen is sixteen times as heavy as a molecule of hydrogen, and it is found upon experiment that hydrogen goes through a septum or wall of graphite four times as fast as oxygen does. Four times four are sixteen. We express that rule in mathematics by saying that the rate of diffusion of gas is inversely as the square root of the mass of its molecules. If one molecule is thirty-six times as heavy as another—the molecule of chlorine is nearly that multiple of hydrogen—it will diffuse itself at one-sixth of the rate.

This rule is a deduction from the molecular theory, and it is found, like innumerable other such deductions, to come right in practice. But now observe what is the consequence of this. Suppose that, instead of taking one gas and making it diffuse itself through a wall, we take a mixture of two gases. Suppose we put oxygen and hydrogen into one side of a vessel which is divided into two parts by a wall of graphite, and we exhaust the air from the other side, then the hydrogen will go through this wall four times as fast as the oxygen will. Consequently, as soon as the other side is full there will be a great deal more hydrogen in it than oxygen—that is to say, that we shall have sifted the oxygen from the hydrogen, not completely, but in a great measure, precisely as by means of a screen we can sift large coals from small ones. Now, suppose when we have oxygen gas unmixed with any other, the molecules are of two sorts and of two different weights. Then you see that if we make that gas pass through a porous wall, the lighter particles would pass through first, and we should get two different specimens of oxygen gas, in one of which the molecules would be lighter than in the other. The properties of one of these specimens of oxygen gas would necessarily be different from those of the other, and that difference might be found by very easy processes. If there were any perceptible difference between the average weight of the molecules on the two sides of the septum, there would be no difficulty in finding that out. No such difference has ever been observed. If we put any single gas into a vessel, and we filter it through a septum of black-lead into another vessel, we find no difference between the gas on one side of the wall and the gas on the other side. That is to say, if there is any difference it is too small to be perceived by our present means of observation. It is upon that sort of evidence that the statement rests that the molecules of a given gas are all very nearly of the same weight. Why do I say *very nearly?* Because evidence of that sort can never prove that they are exactly of the same weight. The means of measurement we have may be exceedingly correct, but a certain limit must always be allowed for deviation; and if the deviation of molecules of oxygen from a certain standard of weight were very small, and restricted within small limits, it would be quite possible for our experiments to give us the results which they do now. Suppose, for example, the variation in the size of the oxygen atoms was as great as that in the weight of different men, then it would be very difficult indeed to tell by such a process of sifting what that difference was, or in fact to establish that it existed at all. But, on the other hand, if we suppose the forces which originally caused all those molecules to be so nearly alike as they are, to be constantly acting and setting the thing right as soon as by any sort of experiment we set it wrong, then the small oxygen atoms on one side would be made up to their right size, and it would be impossible to test the difference by any experiment which was not quicker than the processes by which they were made right again.

There is another reason why we are obliged to regard that experiment as only approximate, and as not giving us any exact results. There is very strong evidence, although it is not conclusive, that in a given gas—say in a vessel full of carbonic acid—the molecules are not all of the same weight. If we compress the gas, we find that when in the state of a perfect gas, or nearly so, the pressure increases just in the ratio that the volume diminishes. That law is entirely explained by means of the molecular theory. It is what ought to exist if the molecular theory is true. If we compress the gas further, we find that the pressure is smaller than it ought to be according to this law. This can be explained in two ways. First of all we may suppose that the molecules are so crowded that the time during which they are sufficiently near to attract each other sensibly becomes too large a proportion of the whole time to be neglected; and this will account for the change in the law. There is, however, another explanation. We may suppose, for illustration, that two molecules approach one another, and that the speed at which one is going relatively to the other is very small, and then that they so direct one another that they get caught together, and go on circling, making only one molecule. This, on scientific principles, will account for our fact, that the pressure in a gas which is near a liquid state is too small—that instead of the molecules going about singly, some are hung together in couples and some in larger numbers, and making still larger molecules. This supposition is confirmed very strikingly by the spectroscope. If we take the case of chlorine gas, we find that it changes colour—that it gets darker as it approaches the liquid condition. This change of colour means that there is a change in the rate of vibration which belongs to its component parts; and it is a very simple mechanical deduction that the larger molecules will, as a rule, have a slower rate of vibration than the smaller ones —very much in the same way as a short string gives a higher note than a long one. The colour of chlorine changes just in the way we should expect if the molecules, instead of going about separately, were hanging together in couples; and the same thing is true of a great number of the metals. Mr. Lockyer, in his admirable researches, has shown that several of the metals and metalloids have various spectra, according to the temperature and the pressure to which they are exposed; and he has made it exceedingly probable that these various spectra, that is, the rates of vibration of the molecules, depend upon the molecules being actually of different sizes. Dr. Roscoe has, a few months ago, shown an entirely new spectrum of the metal sodium, whereby it appears that this metal exists in a gaseous state in four different degrees of aggregation, as a simple molecule, and as three or four or eight molecules together. Every increase in the complication of the molecules—every extra molecule you hang on to the aggregate that goes about together, will make a difference in the rate of the vibration of that system, and so will make a difference in the colour of the substance.

So then we have an evidence, you see, of an entirely extraneous character, that in a given gas the actual molecules that exist are not all of the same weight. Any experiment which failed to detect this would fail to detect any smaller difference. And here also we can see a reason why, although a difference in the size of the molecules does exist, yet we do not find that out by sifting. Suppose you take oxygen gas consisting of single molecules and double molecules, and you sift it through a plate; the single molecules get through first, but when they get through, some of them join themselves together as double molecules; and although more double molecules are left on the other side, yet some of them separate up and make single molecules; so the process of sifting, which ought to give you single molecules on the one side and double on the other, merely gives you a mixture of single and double on both sides; because the reasons which originally decided that there should be just those two forms are always at work, and continually setting things right.

Now let us take the other point in which molecules are very nearly alike; viz., that they have very nearly the same rate of vibration. The metal sodium in the common salt upon the earth has two rates of vibration; it sounds two notes as it were, which are very near to each other. They form the well-known double line D, in the yellow part of the spectrum. These two bright yellow lines are very easy to observe. They occur in the spectra of a great number of stars. They occur in the solar spectrum as dark lines, showing that there is sodium in the outer rim of the sun, which is stopping and shutting off the light of the bright parts behind. All these lines of sodium are just in the same position in the spectrum, showing that the rates of vibration of all these molecules of sodium all over the universe, so far as we know, are as near as possible alike. That implies a similarity of molecular structure, which is a great deal more delicate than mere test of weight. You may weigh two fiddles until you are tired, and you will never find out whether they are in tune; the one test is a great deal more delicate than the other, Let us see how delicate this test is. Lord Rayleigh has remarked that there is a natural limit for the precise position of a given line in the spectrum, and for this reason. If a body which is emitting a sound comes towards you, you will find that the pitch of the sound is altered. Suppose that omnibuses run every ten minutes in the streets, and you walk in a direction opposite to that in which they are coming, you will obviously pass more omnibuses in an hour than if you walked in an opposite direction. If a body emitting light is coming towards you, you will find more waves in a certain direction than if it was going from you; consequently, if you are approaching a body emitting light, the waves will come at shorter intervals, the vibration will be of shorter period, and the light will be higher up in the spectrum—it will be more blue. If you are going away from the body, then the rate is slower, the light is lower down on the spectrum, and consequently more red. By means of such variations in the positions of certain known lines, the actual rate of approach of certain fixed stars to the earth has been measured, and the rate of going away of certain other fixed stars has also been measured. Suppose we have a gas which is glowing in a state of incandescence, all the molecules are giving out light at a certain specified rate of vibration; but some of these are coming towards us at a rate much greater than seventeen miles a minute, because the temperature is higher when the gas is glowing, and others are also going away at a much higher rate than that. The consequence is, that instead of having one sharply defined line on the spectrum, instead of having light of exactly one bright colour, we have light which varies between certain limits. If the actual rate of the vibration of the molecules of the gas were marked down upon the spectrum, we should not get that single bright line there, but we should get a bright band overlapping it on each side. Lord Rayleigh calculated that, in the most favourable circumstances, the breadth of this band would not be less than one-hundredth of the distance between the sodium lines. It is precisely upon that experiment that the evidence of the exact similarity of molecules rests. We see, therefore, from the nature of the experiment, that we should get exactly the same results if the rates of vibration of all the molecules were not exactly equal, but varied within certain very small limits. If, for example, the rates of vibration varied in the same way as the heads of different men, then we should get very much what we get now from the experiment.

From the evidence of these two facts, then, the evidence that molecules are of the same weight and degree of vibration, all that we can conclude is that whatever differences there are in their weights, and whatever differences there are in their degrees of vibration, these differences are too small to be found out by our present modes of measurement. And that is precisely all that we can conclude in every similar question of science.

Now, how does this apply to the question whether it is possible for molecules to have been evolved by natural processes? I do not understand, myself, how, even supposing we knew that they were exactly alike, we could infer, for certain, that they had not been evolved; because there is only one case of evolution that we know anything at all about—and that we know very little about yet—namely, the evolution of organised beings. The processes by which that evolution takes place are long, cumbrous, and wasteful processes of natural selection and hereditary descent. They are processes which act slowly, which take a great lapse of ages to produce their natural effects. But it seems to me quite possible to conceive, in our entire ignorance of the subject, that there may be other processes of evolution which result in a definite number of forms,—those of the chemical elements,—just as these processess of the evolution of organised beings have resulted in a greater number of forms. All that we know of the ether shows that its actions are of a rapidity very much exceeding anything we know of the motions of visible matter. It is a possible thing, for example, that mechanical conditions should exist, according to which all bodies must be made of regular solids, that molecules should all have flat sides, and that these sides should all be of the same shape. I suppose that it is just conceivable that it might be impossible for a molecule to exist with two of its faces different. In that case we know there would be just five shapes for a molecule to exist in, and these would be produced by process of evolution. Now the forms of various matter that we know, and that chemists call elements, seem to be related one to another very much in that sort of way; that is, as if they rose out of mechanical conditions which only rendered it possible for a certain definite number of forms to exist, and which, whenever any molecule deviates slightly from one of these forms, would immediately operate to set it right again. I do not know at all—we have nothing definite to go upon —what the shape of a molecule is, or what is the nature of the vibration it undergoes, or what its condition is compared with the ether; and in our absolute ignorance it would be impossible to make any conception of the mode in which it grew up. When we know as much about the shape of a molecule as we do about the solar system, for example, we may be as sure of its mode of evolution as we are of the way in which the solar system came about; but in our present ignorance all we have to do is to show that such experiments as we can make do not give us evidence that it is absolutely impossible for molecules of matter to have been evolved out of ether by natural processes.

The evidence which tells us that the molecules of a given substance are alike, is only approximate. The theory leaves room for certain small deviations, and consequently if there are any conditions at work in the nature of the ether, which render it impossible for other forms of matter than those we know of to exist, the great probability is, that when by any process we contrive to sift molecules of one kind from molecules of another, these very conditions at once bring them back and restore to us a mass of gas consisting of molecules whose average type is a normal one.

Now I want to consider a speculation of an entirely different character. A remark was made about thirty years ago, by Sir William Thomson, upon the nature of certain problems in the conduction of heat. These problems had been solved by Fourier, many years before, in a beautiful treatise. The theory was that if you knew the degree of warmth of a body, then you could find what would happen to it afterwards, you would find how the body would gradually cool. Suppose you put the end of a poker in the fire and make it red hot, that end is very much hotter than the other end, and if you take it out and let it cool, you will find that heat is travelling from the hot end to the cool end, and the amount of this travelling, and the temperature at either end of the poker can be calculated with great accuracy. This comes out of Fourier's theory. Now suppose you try to go backwards in time, and take the poker at any instant when it is about half cool, and say, "this equation,—does it give me the means of finding out what was happening to it before this time, in so far as the present state of things has been produced by cooling?" You will find the equation will give you an account of the state of the poker before the time when it came into your hands, with great accuracy up to a certain point, but beyond that point it refuses to give you any more information, and it begins to talk nonsense. It is in the nature of a problem of the conduction of heat, that it allows you to trace the forward history of it to any extent you like; but it will not allow you to trace the history of it backward, beyond a certain point. There is another case in which a similar thing happens. There is an experiment in the excellent manual, 'The Boy's Own Book,' which tells you that if you half fill a glass with beer, and put some paper on it, and then pour in water carefully, and draw the paper out without disturbing the two liquids, the water will rest on the beer. The problem then is to drink the beer without drinking the water, and it is accomplished by means of a straw. Let us suppose these two liquids resting in contact; we shall find they begin to mix, and it is possible to write down an equation which is exactly of the same form as the equation for the conduction of heat, which would tell you how much water had passed into the beer at any given time after the mixture began. So that given the water and the beer half mixed, you could trace forward the process of mixing, and measure it with accuracy, and give a perfect account of it; but if you attempt to trace that back you will have a point where the equation will stop, and will begin to talk nonsense. That is the point where you took away the paper, and allowed the mixing to begin. If we apply that same consideration to the case of the poker, and try to trace back its history, you will find that the point where the equation begins to talk nonsense is the point where you took it out of the fire. The mathematical theory supposes that the process of conduction of heat has gone on in a quiet manner, according to certain defined laws, and that if at any time there was a catastrophe, one not included in the laws of the conduction of heat, then the equation could give you no account of it. There is another thing which is of the same kind, namely, the transmission of fluid friction. If you take your tea in your cup, and stir it round with a spoon, it won't go on circulating round for ever, but will come to a stop; and the reason is that there is a certain friction of the liquid against the sides of the cup, and of the different parts of the liquid with one another. Now the friction of the different parts of a liquid or a gas is precisely a matter of mixing. The particles which are going fast, and are in the middle, not having been stopped by the side, get mixed, and the particles at the side going slow, get mixed with the particles in the middle. This process of mixing can be calculated, and it leads to an equation of exactly the same sort as that which applies to the conduction of heat. We have, therefore, in these problems a natural process which consists in mixing things together, and this always has the property that you can go on mixing them for ever, without coming to anything impossible; but if you attempt to trace the history of the thing backward, you must always come to a state which could not have been produced by mixing, namely, a state of complete separation.

Now upon this remark of Sir W. Thomson's, the true consequences of which you will find correctly stated in Mr. Balfour Stewart's book on the 'Conservation of Energy,' a most singular doctrine has been founded. These writers have been speaking of a particular problem, on which they were employed at the moment. Sir W. Thomson was speaking of the conduction of heat, and he said this heat problem leads you back to a state which could not have been produced by the conduction of heat. And so Professor Clerk Maxwell, speaking of the same problem, and also of the diffusion of gases, said there was evidence of a limit in past time to the existing order of things, when something else than mixing took place. But a most eminent man, who has done a great deal of service to mankind, Professor Stanley Jevons, in his very admirable book, the 'Principles of Science,' which is simply marvellous for the number of examples illustrating logical principles which he has drawn from all kinds of regions of science, and for the small number of mistakes that occur in it, takes this remark of Sir W. Thomson's, and takes out two very important words, and puts in two other very important words. He says, "We have here evidence of a limit of a state of things which could not have been produced by the previous state of things according to the known laws of nature." It is not according to the known laws of nature, it is according to the known laws of conduction of heat, that Sir William Thomson is speaking; and from this we may see the fallacy of concluding, that if we consider the case of the whole universe we should be able, suppose we had paper and ink enough, to write down an equation which would enable us to make out the history of the world forward, as far forward as we liked to go, but if we attempted to calculate the history of the world backward, we should come to a point where the equation would begin to talk nonsense, we should come to a state of things which could not have been produced from any previous state of things, by any known natural laws. You will see at once that that is an entirely different statement. The same doctrine has been used by Mr. Murphy, in a very able book, 'The Scientific Basis of Faith,' to build upon it an enormous superstructure—I think the restoration of the Irish Church was one of the results of it. But this doctrine is founded, as I think, upon a pure misconception. It is founded entirely upon forgetfulness of the condition under which the remark was originally made. All these physical writers, knowing what they were writing about, simply drew such conclusions from the facts which were before them as could be reasonably drawn. They say, here is a state of things which could not have been produced by the circumstances we are at present investigating. Then your speculator comes, he reads a sentence and says, Here is an opportunity for me to have my fling. And he has his fling and makes a purely baseless theory about the necessary origin of the present order of nature at some definite point of time which might be calculated. But if we consider the matter, we shall see that this is not in any way a consequence of the theory of the conduction of heat; because the conduction of heat is not the only process that goes on in the universe.

If we apply that theory to the case of the earth, we find that at present there is evidence of a certain distribution of temperature in the interior of it; there is a certain rate at which the temperature increases as we go down, and no doubt if we made further investigations, we should find that if we went deeper an accurate law would be found, according to which the temperature increases in the interior.

Now, assuming this to be so, taking this as the basis of our problem, we might endeavour to find out what was the history of the earth in past times, and when it began cooling down. That is exactly what Sir William Thomson has done. When we attempt it, we find that there is a definite point to which we can go, and at which our equation talks nonsense. But we do not conclude that at that point the laws of nature began to be what they are; we only conclude that the earth began to solidify. Now solidification is not a process of the conduction of heat, and so the thing cannot be given by our equation. That point is given definitely as a point of time, not with great accuracy but still as near as we can expect to get it with such means of measuring as we have, and Sir William Thomson has calculated that the earth must have solidified at some time a hundred millions or two hundred millions of years ago; and there we arrive at the beginning of the present state of things; the process of cooling the earth which is going on now. Before that it was cooling as a liquid, and in passing from the liquid to the solid state there was a catastrophe which introduced a new rate of cooling. So that by means of that law we do come to a time when the earth began to assume its present state. We do not find the time of the commencement of the universe, but simply of the present structure of the earth. If we went farther back, we might make more calculations and find how long the earth had been in a liquid state. We should come to another catastrophe, and say at that time, not that the universe began to exist, but that the present earth passed from the gaseous to the liquid state. And if we went farther back still we should probably find the earth falling together out of a great ring of matter surrounding the sun and distributed over its orbit. The same thing is true of every body of matter: if we trace its history back, we come to a certain time at which a catastrophe took place, and if we were to trace back the history of all the bodies of the universe in that way we should continually see them separating up into smaller parts. What they have actually done is to fall together and get solid. If we could reverse the process we should see them separating and getting fluid, and, as a limit to that, at an indefinite distance in past time, we should find that all these bodies would be resolved into molecules, and all these would be flying away from each other. There would be no limit to that process, and we could trace it as far back as ever we liked to trace it. So that on the assumption, a very large assumption, that the present constitution of the laws of geometry and mechanics has held good during the whole of past time, we should be led to the conclusion that at an inconceivably long time ago the universe did consist of ultimate molecules, all separate from one another, and approaching one another. Then they would meet together and form a great number of small hot bodies. Then you would have the process of cooling going on in these bodies, exactly as we find it going on now. But you will observe that we have no evidence of such a catastrophe as implies a beginning of the laws of nature. We do not come to something of which we cannot make any further calculation; we find that however far we like to go back, we approximate to a certain state of things, but never actually get to it.

Here, then, we have a doctrine about the beginning of things. First, we have a probability, about as great as science can make it, of the beginning of the present state of things on the earth, of the fitness of the earth for habitation; and then we have a probability about the beginning of the universe as a whole which is so small, that it is better put in this form, that we do not know anything at all about it. The reason why I say that we do not know anything at all of the beginning of the universe, is that we have no reason whatever for believing that what we at present know of the laws of geometry and mechanics are exactly and absolutely true at present, or that they have been even approximately true for any period of time, further than we have direct evidence of. The evidence we have of them is founded on experience, and we should have exactly the same experience of them now, if those laws were not exactly and absolutely true, but were only so nearly true that we could not observe the difference. So that in making the assumption we may argue upon the absolute uniformity of nature, and suppose these laws to have remained exactly as they are, we are assuming something we know nothing about. My conclusion then is, that we do know, with great probability, of the beginning of the habitability of the earth about one hundred or two hundred millions of years back, but that of a beginning of the universe we know nothing at all.

Now let us consider what we can find out about the end of things. The life which exists upon the earth is made by the sun's action, and it depends upon the sun for its continuance. We know that the sun is wearing out, that it is cooling, and although this heat which it loses day by day is made up in some measure, perhaps completely at present, by the contraction of its mass, yet that process cannot go on for ever. There is only a certain amount of energy in the present constitution of the sun, and when that has been used up, the sun cannot go on giving out any more heat. Supposing, therefore, the earth remains in her present orbit about the sun, seeing that the sun must be cooled down at some time, we shall all be frozen out. On the other hand, we have no reason to believe that the orbit of the earth about the sun is an absolutely stable thing. It has been maintained for a long time that there is a certain resisting medium which the planets have to move through, and it may be argued from that, that in time all the planets must be gradually made to move in smaller orbits, and so to fall in towards the sun. But, on the other hand, the evidences upon which this assertion was based, the movement of Encke's comet and others, has been quite recently entirely overturned by Professor Tait. He supposes that these comets consist of bodies of meteors. Now, it was proved a long time ago, that a mass of small bodies travelling together in an orbit about a central body, will always tend to fall in towards it, and that is the case with the rings of Saturn. So that, in fact, the movement of Encke's comet is entirely accounted for on the supposition that it is a swarm of meteors, without regarding the assumption of a resisting medium. On the other hand, it seems exceedingly natural to suppose that some matter in a very thin state is diffused about the planetary spaces. Then we have another consideration,—just as the sun and moon make tides upon the sea, so the planets make tides upon the sun. If we consider the tide which the earth makes upon the sun, instead of being a great wave lifting the mass of the sun up directly under the earth, it is carried forward by the sun's rotation; the result is, that the earth instead of being attracted to the sun's centre, is attracted to a point before the centre. The immediate tendency is to accelerate the earth's motion, and the final effect of this upon the planet is to make its orbit larger. That planet disturbing all the other planets, the consequence is that we have the earth gradually going away from the sun, instead of falling into it.*

In any case, all we know is that the sun is going out. If we fall into the sun then we shall be fried; if we go away from the sun, or the sun goes out, then we shall be frozen. So that, so far as the earth is concerned, we have no means of determining what will be the character of the end, but we know that one of these two things must take place in time. But in regard to the whole universe, if we were to travel forward as we have travelled backward in time, consider things as falling together, we should come finally to a great central mass, all in one piece, which would send out waves of heat through a perfectly empty

* I learn from Sir W. Thomson that the ultimate effect of tidal deformation on a number of bodies is to reduce them to two, which move as if they were rigidly connected.

ether, and gradually cool itself down. As this mass got cool it would be deprived of all life or motion; it would be just a mere enormous frozen block in the middle of the ether. But that conclusion, which is like the one that we discussed about the beginning of the world, is one which we have no right whatever to rest upon. It depends upon the same assumption that the laws of geometry and mechanics are exactly and absolutely true; and that they will continue exactly and absolutely true for ever and ever. Such an assumption we have no right whatever to make. We may therefore, I think, conclude about the end of things that so far as the earth is concerned, an end of life upon it is as probable as science can make anything; but that in regard to the universe we have no right to draw any conclusion at all.

So far, we have considered simply the material existence of the earth; but of course our greatest interest lies not so much with the material life upon it, the organised beings, as with another fact which goes along with that, and which is an entirely different one—the fact of the consciousness that exists upon the earth. We find very good reason indeed to believe that this consciousness in the case of any organism is itself a very complex thing, and that it corresponds part for part to the action of the nervous system, and more particularly of the brain of that organised thing. There are some whom such evidence has led to the conclusion that the destruction which we have seen reason to think probable of all organised beings upon the earth, will lead also to the final destruction of the consciousness that goes with them. Upon this point I know there is great difference of opinion amongst those who have a right to speak. But to those who do see the cogency of the evidences of modern physiology and modern psychology in this direction, it is a very serious thing to consider that not only the earth itself and all that beautiful face of nature we see, but also the living things upon it, and all the consciousness of men, and the ideas of society, which have grown up upon the surface, must come to an end. We who hold that belief must just face the fact and make the best of it; and I think we are helped in this by the words of that Jew philosopher, who was himself a worthy crown to the splendid achievements of his race in the cause of progress during the Middle Ages, Benedict Spinoza. He said, "The free man thinks of nothing so little as of death, and his wisdom is a meditation not of death but of life." Our interest lies with so much of the past as may serve to guide our actions in the present, and to intensify our pious allegiance to the fathers who have gone before us and the brethren who are with us; and our interest lies with so much of the future as we may hope will be appreciably affected by our good actions now. Beyond that, as it seems to me, we do not know, and we ought not to care. Do I seem to say, "Let us eat and drink, for to-morrow we die?" Far from it; on the contrary I say, "Let us take hands and help, for this day we are alive together."

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