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THE LUMINIFEROUS ETHER.

I MUST in the first instance express my regret that we are disappointed with respect to an important paper which was to have been brought before you at our Anniversary Meeting. It was found almost at the last moment that the Author would be unable to bring it on, and at the request of the Council I have undertaken at short notice, and in the midst of various other engagements, to address you to-night.

In choosing a subject, I have been guided in part by the opinion I entertain of the proper functions of the Victoria Institute. It is not, I conceive, a society established for the prosecution of original research simply as such; the field in that respect was already occupied; in the first instance by the oldest scientific society in the kingdom, almost in the world—the Royal Society; and more recently by other societies which have sprung into existence for the special cultivation of divisions into which the general subject of science has been split, in consequence of the great extent which it has attained. A young Institute, like the present, cannot expect to rival these ancient or more recently established special scientific societies; nor is it desirable, in my opinion, that such an attempt should be made. I do not, therefore, regard it in the slightest degree as a rival to the Royal Society; and it was only because I was strongly impressed with the entire difference of the functions of the two Societies, that I felt it not incompatible with my position at the time as President of the Royal Society to accept the position which had been offered me of the Presidency of the Victoria Institute. The Society, as is proved by its original rules, was established more especially to examine from the scientific side

into any apparent conflict between what was supposed by some to be the legitimate conclusions of Science, and what was believed by others to be revealed. The two questions, therefore, of what is established by Science and what has been revealed to man come more or less into the functions of this Institute; but it is not a Society intended primarily for the production of original discoveries in Science—although an account of such, if it were offered, would not for that reason be rejected, still less is it intended to be a Society for the discussion of purely theological questions. Those who believe that a revelation has been made from God to man, and who believe also that the system of Nature and the laws which govern it are His work, must accept as an axiom that there can be no real antagonism between the two; that accordingly any apparent antagonism must be due to a mistake, either on the one side or on the other. It is with a view of investigating, as far as may be, the origin of such mistakes, and accordingly removing that appearance—for it can only be an appearance—of antagonism between the two, that this Institute was mainly founded. In order that it should be able to fulfil these offices, it is essential that those who endeavour to remove the apparent discrepancies to which I have alluded should come to the investigation with open mind, free from prejudice, desiring only to learn the truth according as it may appear on an impartial review of the whole of the evidence. Those who approach the investigation rather from the side of Science must not assume that everything in Nature is capable of explanation by purely scientific methods; nor must those who come to the investigation rather from the theological side consider that they are infallible in the interpretation which they are disposed to place upon what they believe to be revealed. Nor, again must these latter forget that as regards the real evidence bearing upon the question obtainable from the study of science they themselves may not always be the best judges, because as a rule perhaps they would not have made a very special study of the scientific questions which they imagine to come into conflict with what, on entirely different grounds, they believe to be the truth. There must be mutual toleration between those who approach the subject from the scientific, and those who approach it rather from the theological side, each being ready to modify, if sufficient reason be shewn, his preconceived opinions in the simple pursuit of truth.

The utility of the Institute depends, in my opinion, on the loyalty with which this principle is carried out. If it be true that there is occasionally a tendency on the part of the votaries of Science to regard scientific methods as the sole means of arriving at truth, and to disregard what claims to be the truth on the ground that that claim depends in good measure on the exercise of the feelings and moral faculties, it is, I think, no less true that there is occasionally a tendency on the part of those whose chief attention has been devoted to investigations of the latter class to attribute to their own apprehension of their subject that infallibility which they conceive to belong to the subject in itself; to summarily reject what claims to be supported by weighty scientific evidence, of the force of which they themselves may be ill able to judge, merely because it runs counter to the ideas which they had been led to adopt on evidence of quite a different nature.

But truth cannot be self-contradictory; and if there be conflict between conclusions obtained by methods of quite a different nature, and each supposed by those who respectively employ them to be sound, the fair thing evidently is to compare, if possible, the two modes of deduction, so as to trace the discrepancy in the conclusions to its origin, which must necessarily be some unwarranted assumption, or false step of reasoning, or, in the numerous cases in which the reasoning is not demonstrative, but a balance of probability has to be struck, in an exaggerated estimate of the probable evidence in favour of one conclusion, and a depreciation of that in favour of the opposite.

But here a difficulty arises. It may very well happen that a person who draws his conclusion in one way, by a method similar to those which he is in the habit of employing in other cases, may be ill qualified to judge of the evidence on the strength of which another person draws a different conclusion. In such cases the process which appears most conducive to attainment of the truth appears to be to compare notes in a friendly discussion, with the asistance, if it may be, of other persons who have studied the subject, and of whom some, perhaps, are more used to the employment of the one, some to that of the other, of the methods alluded to. Each party may thus learn something from the other, and thereby be enabled to form a sounder judgment on the whole of the evidence.

Opportunities for discussions of this kind are afforded by

our meetings; and through the publication of our Journal, containing the papers read before us, with an abstract of the discussions to which they gave rise, a far wider circle is reached than that of merely those who are assembled at the meeting.

I have said that I did not regard the Institute as primarily a Society for scientific research, and yet our objects bring us closely into connection with research of that kind. In what way can purely scientific questions be most properly brought before the Institute, considering the object for which it was established? For my own part I think that one of the most useful things that can be done by those who bring forward scientific matters is to present a general view of our scientific knowledge on those subjects to which they themselves have more particularly attended, or to expound the conclusions to which some special research of their own may have conducted them, when those conclusions may seem to have some bearing, even though it be remote, on the other branch of our subject. In pursuance of this idea, I intend to bring before you to-night a subject which the study of light has caused me to think a good deal about: I refer to the nature and properties of the so-called luminiferous ether.

This subject is, in one respect, specially fascinating, scientifically considered. It lies, we may say, in an especial manner on the border land between what is known and what is unknown. In the study of it it is quite conceivable that great discoveries may be made, and, in fact, great discoveries have already been made, and I may say even quite recently, and we do not at present know how much additional light on the system of Nature may be in store for the men of Science; possibly even in the near future, possibly not until many generations have passed away. I will assume, as what is familiarly known to you all, and what is well established by methods into which I will not enter, that the heavenly bodies are at an immense distance from our earth. More especially is this the case with the fixed stars. Their distance is so enormous that even when we take as a base line, so to speak, the diameter of the earth's orbit, which we know to be about 184 millions of miles, the apparent displacement of the stars due to parallax is so minute as almost to elude our investigation. Nevertheless that distance is more or less accurately determined in the case of a few of the fixed stars. But the vast majority, as we have every reason to believe, are at such an enormous distance that even this method fails with them.

To give a conception of the immense distance of the fixed stars, I will assume as known that light travels at the rate of about 186,000 miles in one second, a rate which would carry it nearly eight times round and round the earth in that time; and yet if we take the star which, so far as we know, is our nearest neighbour, it would take three or four years for light from that star to reach the earth. Now as we see the fixed stars there must be some link of connection between us and them in order that we should be able to perceive them. Probably all of you know that two theories have been put forward as to the nature of light, as to the nature accordingly of that connection of which I have spoken. According to one idea, light is a substance darted forth from the luminous body with an amazing velocity; according to the other, it consists in a change of state taking place, propagated through a medium, as it is called, intervening between the body from which the light proceeds and the eye of the observer. For a considerable time the first of these theories was that chiefly adopted by scientific men. It was that, as you know, which Newton himself adopted; and probably the prestige of his name had much to do with the favourable reception which for a long time it received. But more recent researches have so completely established the truth of the other view, and refuted the old doctrine of emissions, that it is now universally held by scientific men that light consists in an undulatory movement propagated in a medium existing in all the space through which light is capable of passing.

This necessity for filling all space, or at least, such an inconceivably great extent of space, with a medium, the office of which, so far as was known in the first instance, was simply that of propagating light, was an obstacle for a time to the reception by the minds of some of the theory of undulations. Men had been in the habit of regarding the inter-planetary and inter-stellar space as a vacuum, and it seemed too great an assumption to fill all this supposed vacuous space with some kind of medium for the sole purpose of transmitting light. Notwithstanding, even long ago strong opinions were entertained to the effect that there must be something intervening between the different heavenly bodies. In a letter to Bentley, Newton expresses himself in very strong language to this effect: "That gravity should be innate, inherent and essential to matter, so that one body may act upon another at a distance through a *vacuum*, without the mediation of anything else,

by and through which their action and force may be conveyed from one to another, is to me so great an absurdity, that I believe that no man who has in philosophical matters a competent faculty of thinking, can ever fall into it. Gravity must be caused by an agent acting constantly according to certain fixed laws; but whether this agent be material or immaterial, I have left to the consideration of my readers."

What the nature of the connection between the earth and the sun, for example, may be whereby the sun is able to attract the earth and thereby keep it in its orbit, in other words, what the cause of gravitation may be, we do not know; for anything we know to the contrary, it may be connected with this intermediate medium or luminiferous ether. There are other offices, we believe, which this luminiferous ether fulfils, to which I shall have occasion to allude presently.

In connection with the necessity for filling such vast regions of space with this medium, a curious question naturally presents itself. We cannot conceive of space as other than infinite, but we habitually think of matter as occupying here or there limited portions of space, as for example the different heavenly bodies. The intervening space we commonly think of as a vacuum, and it is only the phenomena of light that led us in the first instance to think of it as filled with some kind of material. The question naturally presents itself to the mind, is this ether absolutely infinite like space? This is a question to which Science can give no answer. Though we cannot help thinking of space as infinite, yet when we turn our thoughts to some material existing in space perhaps we more readily think of it as finite than infinite. But if the ether, however vast the portion of space over which it extends, be really limited, we can hardly fail to speculate what there may be outside its limits. Space there might be wholly vacuous, or possibly outside altogether this vast system of stars and ether there may be another system subject to the same laws, or subject to different laws, as the case may be, equally vast in extent; and if there be, then so far as we can gather from such phenomena as are open to our investigation, there can be no communication between that vast portion of space in part of which we live and an ideal system altogether outside the ether of which we have been speaking.

But the properties of the ether are no less remarkable

than its vast or even possibly limitless extent. Matter of which our senses give us any cognizance is heavy, that is to say, it gravitates towards other matter which agrees with it in so far as being accessible to our senses. The question presents itself to the mind, does the ether gravitate towards what we call ponderable matter? This is a question to which we are not able to give any positive scientific answer. If the ether be in some way or other connected with the cause of gravitation, it would seem more likely that it itself does not gravitate towards ponderable matter.

Again, we have very strong reason for believing that ponderable matter consists of ultimate molecules. First, that supposition accords in the simplest way with the laws of crystallography. Chemical laws afford still stronger confirmation of the hypothesis, through the atomic theory of Dalton, now universally accepted. Comparatively recently, the deduction of the fundamental property of gases from the kinetic theory, as it is called, affords strong additional confirmation of that view of the constitution of matter. Still more recently, the explanation which has been afforded by that theory of that most remarkable instrument the radiometer of Crookes has lent further confirmation in the same direction. None of these evidences apply to the ether, and accordingly we are left in doubt whether it too consists of ultimate molecules, or whether on the other hand it is continuous, as we cannot help conceiving space to be.

The undulatory theory of light was greatly promoted in the first instance by the known phenomena of sound, and the explanation which they received from the hydrodynamical theory. Accordingly, since sound, as we know, consists of an undulatory movement propagated through the air (or it may be through other media), and depending upon condensation and rarefaction, it was supposed naturally that light was propagated in a similar manner, by virtue of the forces brought into play by the condensation and rarefaction of the ether. But there is one whole class of phenomena which have actually no counterpart in those of sound; I refer to polarization and double refraction.

The evidence for the truth of the theory of undulations as regards the phenomena of common light depends in great measure upon the fact of interference and the explanation which the theory gives of the complicated phenomena of diffraction. But in studying the interference of polarized light, additional phenomena presented themselves which

ultimately pointed out that the vibrations with which we are concerned in the case of the ether differ altogether in their character from those which belong to sound. The phenomena of the interference of polarized light prove incontestably that there exists in light an element of some kind having relation to directions transverse to that of propagation, and admitting of composition and resolution in a plane perpendicular to the direction of transmission according to the very same laws as those of the composition and resolution of forces, or velocities, or displacements in such a plane. This requires us to attribute to the ether a constitution altogether different from that of air. It points out the existence of a sort of elasticity whereby the ether tends to check the gliding of one layer over another. Have we no example of such a force in the case of ponderable matter? We have. We know that an elastic solid, which for simplicity I will suppose to be uncrystalline, and alike in all directions, has two kinds of elasticity, by one of which it, like air, tends to resist compression and rarefaction, while by the other it tends to resist a continuous gliding of one portion over another, and to restore itself to its primitive state if such a gliding has taken place. There is no direct relation between the magnitude of these two kinds of elasticity, and in the case of an elastic solid such as jelly the resistance to compression is enormously great compared to the resistance to a gliding displacement.

If we assume that in the ether there is really an elasticity tending to restore it to its primitive condition when one layer tends to glide over another, an elasticity which it appears to be absolutely necessary to admit in order to account for the observed laws of interference of polarized light, the question arises, Can we thereby explain double refraction?

The earliest attempts to explain it in accordance with the theory of transverse vibrations were made by attributing to the ether a molecular constitution more or less analogous to that which we believe to exist in ponderable matter. Following out speculations founded upon that view, the celebrated Fresnel was led to the discovery of the actual laws of double refraction; the theory, however, which he gave was by no means complete, inasmuch as the results were not rigorously deduced from the premises. Cauchy and Neumann, independently and about simultaneously, took up Fresnel's view of the constitution of the ether and

applied it to explain the laws of double refraction. In their theory the conclusions arrived at were rigorously derived from the premises; but the results did not altogether agree with observation; that is to say, although they could by the adoption of certain suppositions be forced into a near accordance with the observed laws of double refraction, yet they pointed out the necessity of the existence of other phenomena which were belied by observation. Our own countryman Green was the first to deduce Fresnel's laws from a rigorous dynamical theory, although nearly simultaneously MacCullagh arrived at a theory in some respects similar, though on the whole I think less satisfactory.

Still all these theories followed pretty closely the analogy of ponderable matter; and at least in the first three mentioned the ether was even imagined to consist of discrete molecules, acting on one another, like the bodies of the solar system regarded as points, by forces in the direction of the joining line, and varying as some function of the distance. I have already quoted the very strong language in which Newton rejected the idea of the heavenly bodies acting on one another across intervening spaces which were absolutely void. But the conception has nothing to do with the magnitude of the intervening spaces; and the conception of action at a distance across an intervening space which is absolutely void, is not a bit easier when the space in question is merely that separating two adjacent molecules, when the ether is thought of as consisting of discrete molecules, than it is when the space is that separating two bodies of the solar system, though in this latter case it may amount to many millions of miles. If the ether be in some unknown manner the link of connection whereby two heavenly bodies are enabled to exert on one another the attraction of gravitation, then according to the hypothetical constitution of the ether that we have been considering, we seem compelled to invent an ether of the second order, so to speak, to form a link of connection between two separate molecules of the luminiferous ether. But since the nature of the ether is so very different as it must be from that of ponderable matter, it may be that the true theory must proceed upon lines in which our previous conceptions derived from the study of ponderable matter are in great measure departed from.

If we think of the ether as a sort of gigantic jelly, we can hardly imagine but that it would more or less resist the

passage of the heavenly bodies—the planets for instance—through it. Yet there appears to be no certain indication of any such resistance. It has been observed indeed in the case of Encke's comet, that at successive revolutions the comet returned to its perihelion a little before the calculated time. This would be accounted for by the supposition that it experienced a certain amount of resistance from the ether. Although at first sight we might be disposed to say that such a resistance would retard perihelion passage, yet the fact that it would accelerate it becomes easily intelligible, if we consider that the resistance experienced would tend to check its motion, and so prevent it from getting away so far from the sun at aphelion, and would consequently bring it more nearly into the condition of a planet circulating round the sun in a smaller orbit.

Many years ago I asked the highest authority in this country on Physical Astronomy, the late Professor Adams, what he thought of the evidence afforded by Encke's comet for the existence of a retarding force, such as might arise from the ether. He said to me that he thought we did not know enough as to whether there might not possibly be a planet or planets within the orbit of Mercury which would account for it in a different way. But quite independently of such a supposition it is worthy of note that the remarkable phenomena presented by the tails of comets render it by no means unlikely that even without the presence of a resisting medium, and without the disturbing force arising from the attraction of an unknown planet situated so near to the sun as not to have been seen hitherto, the motion of the head of a comet might not be quite the same as that of a simple body representing the nucleus, and being subject to the gravitation of the sun and planets and nothing else. It appears that the tails consist of some kind of matter driven from the comet with an enormous velocity by a sort of repulsion emanating from the sun. If the nucleus loses in this manner at each perihelion passage an exceedingly small portion of its mass, which is repelled from the sun, it is possible that the residue may experience an attraction towards the sun over and above that due to gravitation, and that possibly this may be the cause of the observed acceleration in the time of passing perihelion even though there be no resistance on the part of the ether. So that the question of resistance or no resistance must be left an open one.

The supposition that the ether would resist in this manner

a body moving through it is derived from what we observe in the case of solids moving through fluids, liquid or gaseous, as the case may be. In ordinary cases of resistance, the main representative of the work apparently lost in propelling the solid is in the first instance the molar kinetic energy of the trail of eddies in the wake. The formation of these eddies is, however, an indirect effect of the internal friction, or if we prefer the term viscosity, of the fluid. Now the viscosity of gases has been explained on the kinetic theory of gases, and in the case of a liquid we cannot well doubt that it is connected with the constitution of the substance as not being absolutely continuous but molecular. But if the ether be either non-molecular, or molecular in some totally different sense from ponderable matter, we cannot with safety infer that the motion of a solid through it necessarily implies resistance.

The luminiferous ether touches on another mysterious agent, the nature of which is unknown, although its laws are in many respects known, and it is applied to the every day wants of life, and its applications are even regulated by Acts of Parliament; I allude to Electricity. I said that the nature of electricity is unknown. More than forty years ago I was sitting at dinner beside the illustrious Faraday, and I said to him that I thought a great step would have been made if we could say of electricity something analogous to what we say of light, when we affirm that light consists of undulations; and he said to me that he thought we were a long way off that at present. But, as I said, relations have recently been discovered between light and electricity which lead us to believe that the latter is most closely connected with the luminiferous ether.

Clark Maxwell showed that the ratio of two electrical constants which are capable of being determined by laboratory experiments, and which are of such a nature that that ratio expresses a velocity, agrees with remarkable accuracy with the known velocity of light. This formed the starting point of the electro-magnetic theory of light which is so closely associated with the name of Maxwell.

According to this idea, light may be looked on as the propagation of an electro-magnetic disturbance, whatever the appropriate idea of such a thing may actually be. The theory has quite recently received remarkable confirmation by the investigations of Hertz, who has shown that what are incontestably electro-magnetic disturbances, and are investigated

by purely electrical means, exhibit some of the fundamental phenomena of light, such, for example, as interference and polarization. It appears that these electro-magnetic waves are strictly of a similar nature to the waves of light, though there is an enormous difference in the scale of wave lengths, which in the case of light range about the $\frac{1}{50000}$th part of an inch, while the electro-magnetic waves which have been investigated by purely electrical methods range from a few inches to many yards.

I have ventured to bring this interesting subject before you in the course of the address which I have just delivered. I have not attempted to lay before you the evidence on which scientific men rely for the truth of the conclusions which I have mentioned as well established. That would have required, not merely an evening address, but a whole course of lectures. Neither have I made any allusion to possible bearings of the scientific conclusions on questions relating to religious beliefs. Anything of that kind I leave to your own minds; my object has been simply to present to you very briefly the conclusions of science in that limited branch which I have selected, distinguishing as impartially as I could what is well established from what is debateable or even merely conjectural.

His Excellency the Hon. T. F. BAYARD (United States Ambassador).—Ladies and Gentlemen, I have great pleasure in moving "That our best thanks be presented to the President, Sir George Gabriel Stokes, for the Annual Address now delivered, and to those who have read papers during the Session."

Sir H. BARKLY, G.C.M.G., K.C.B., F.R.S.—I rise with much pleasure, Ladies and Gentlemen, to second the vote of thanks moved by His Excellency the American Ambassador, whose presence amongst us to-night so shortly after his arrival in this country cannot but be deemed a special compliment to the Victoria Institute. We must all rejoice to welcome a supporter and friend of the principles to further which this Society was founded. The object of the Institute is to show as far as possible that there is not necessarily any antagonism between the teachings of science and religious truth; and so long as we are fortunate enough to obtain the assistance of gentlemen of the

scientific eminence of Sir Gabriel Stokes and others who might be named, who have taken a leading part in our proceedings, I think the Society will be able to successfully accomplish its mission. (Applause.) I may mention that his subject was most kindly undertaken by Sir Gabriel Stokes in consequence of the illness of the gentleman who had announced his intention of giving the Address. The President, at very short notice, came to the rescue. (Applause.) I have no doubt that the value and importance of the Address, which has just been given, will be appreciated by all and especially by those who are most competent to understand the subject, and I am sure you will agree with me that the thanks of the members and associates of the Victoria Institute and of all present are justly due to the President for the Address which he has just delivered, and also to those gentlemen who have read papers during the Session. I will therefore ask those who are in favour of the motion to signify the same by holding up their hands.

The resolution was carried unanimously.

The PRESIDENT.—I rise partly on my own behalf and partly on behalf of those who have read papers during the Session, to return you thanks for this vote. As regards my own share, I feel deeply the deficiencies in the Address which I have just delivered. I have made allusions to various scientific conclusions, which perhaps, only a minority of those in the room are acquainted with, and that, therefore, much that I have said has not been fully intelligible to perhaps the majority. Still I hope even those who have not previously attended to the subject, may have gathered some ideas as to the nature of these very curious and interesting investigations on which scientific men throughout the world have been engaged. I do not know whether all of those who have read papers during the Session are here present, but I return you thanks on their behalf also.

The Rev. Canon GIRDLESTONE, M.A.—Ladies and Gentlemen, I have to remind you that Sir Gabriel Stokes is here in two capacities, as the reader of a paper, and as presiding over this meeting, and I have been asked to propose a vote of thanks to the President for presiding over the meeting. It was very easy for him no doubt to preside over himself, and, I suppose, easy to preside over us, because we were so wrapped in attention, while he took us through infinite space, and told us about finite matter that we

by purely electrical means, exhibit some of the fundamental phenomena of light, such, for example, as interference and polarization. It appears that these electro-magnetic waves are strictly of a similar nature to the waves of light, though there is an enormous difference in the scale of wave lengths, which in the case of light range about the $\frac{1}{50000}$th part of an inch, while the electro-magnetic waves which have been investigated by purely electrical methods range from a few inches to many yards.

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