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748TH ORDINARY GENERAL MEETING,

HELD IN COMMITTEE ROOM B, THE CENTRAL HALL, WESTMINSTER, S.W.1, ON MONDAY, JUNE 15TH, 1931, AT 4.30 P.M.

DR. JAMES W. THIRTLE, M.R.A.S., IN THE CHAIR.

The Minutes of the last Meeting were read, confirmed, and signed, and the HON. SECRETARY announced the following elections:—As a Life Member, Miss A. M. Hodgkin, and as Members, Miss E. A. Everett, the Rev. H. L. Jennins, L.Th., the Rev. A. H. Finn, and the Rev. H. Temple Wills, M.A., B.Sc. As Life Associates, the Rev. Norman G. Dunning and the Rev. Joseph I. Brice, and as an Associate, George E. Dancer, Esq.

The CHAIRMAN then called on Sir Ambrose Fleming, D.Sc., F.R.S., the President, to give the Annual Address on "Light."

LIGHT.

(Hebrew, *'or*; Greek, *phōs*; Latin, *lumen*; Italian, *luce*; French, *lumière*; German, *licht.*)

By SIR AMBROSE FLEMING, F.R.S. (*President*).

IT has generally been the custom, at least of late, to select for this Annual Address some special topic and not to make it merely a review of the year's progress or the state of this Institute. Accordingly I propose to offer you a brief account of modern views and ideas concerning the most ancient thing or agency in this Universe, namely, a ray of Light, in the hope that such information may prove of some slight interest to my audience.

1.—Light the Revealer.

In that sublime account of the process of Creation given us in the first Chapter of the Book of Genesis the narrative opens with the general statement that in some far distant past there was a "beginning" to the heaven and the earth, that is to all things invisible and visible by creative Acts of Divine Power and Wisdom.

We are thus informed that there was a "beginning" and not an infinite past duration to the Universe, and that this beginning was not the result of any automatic process or spontaneous evolution or self-development, but an Act of Will by which the Thoughts in the Abysmal depths of the Divine Mind received in some way, quite incomprehensible by us, objective existence so as to become the subject of cognizance by other created Intelligences and Minds.

The chief agency which reveals to us objects not ourselves, which philosophic realism postulates exist apart from, or independently, of our own minds, is called Light; and hence the first distinctive fiat of creation is contained in the magnificent utterance, "And God said, Let there be Light and there was Light." These words, so to speak, draw up the curtain and place us in the position of spectators of the great successive Divine Acts in the drama of Creation which pass before us on the stage of the Universe. Light then is the revealer or agency by which we obtain in our own minds, ideas or perceptions of external things and of their right relation to each other.

The word *Light* as a noun or substantive occurs about 125 times or more in various parts of the Bible, and is sometimes used as a name for the physical agency which affects our bodily eyes by which we see material objects, and sometimes in a symbolical or spiritual sense as in such phrases: "The Lord is my Light and Salvation." (Ps. xxvii, 1.) "The entrance of thy Words giveth Light." (Ps. cxix, 130.)

In this latter use it is still claimed as a revealer, as opening to us or making known essential truths or facts in their right relation to each other.

In regions in which there is an entire absence of physical light we are unable to govern our own movements or actions with safety and certainty because we are unable to assure ourselves of the relation of surrounding material objects to each other

and to ourselves. In an unfamiliar place or in a strange country we have to move or travel with extreme care in darkness lest we fall into some kind of danger, and only when the light comes or day dawns can we make sure of our steps and walk in safety.

The same thing holds good in the case of moral actions, or walk and of conduct generally. It is necessary for us to have some means of ascertaining right action or the true relations of things in the ethical and spiritual fields so as to avoid danger and guide our steps aright. As the Psalmist says: "O send out Thy Light and Thy truth; let them lead me; let them bring me unto Thy holy hill and to Thy tabernacles." (Ps. xliii, 3.)

Hence those agencies which give us this guidance, our conscience, or the inspired Scriptures, or the direct influence on us of the Divine Spirit are called also by the same name, Light; and we are enjoined to walk as "children of Light," and in this sense our Lord declares "I am the Light of the world: he that followeth me shall not walk in darkness but have the light of life." (St. John viii, 12.)

2.—The Nature of Wave Motion.

One of the great subjects of scientific enquiry has for several centuries past been the exploration of the true nature of physical Light and how it renders objects visible to us. Certain agencies emit Light, such as the sun, various flames, or incandescent solids, lightning, electric sparks, and some living phosphorescent beings such as glow-worms, fireflies, or certain deep-sea fish. These we call illuminants. Others only scatter or reflect irregularly part of the light that falls upon them from illuminants, and it is this scattered light which entering our eyes renders the object visible to us. But that scattering is selective. Nothing except a surface we call perfectly white, such as newly fallen snow, reflects or scatters all the light which falls upon it.

Other surfaces absorb some of the incident light and scatter a portion, and it is this discriminating reflection which determines what we call the colour of the object.

The first fact regarding Light which assists us towards an interpretation of its nature is that it takes time to travel from one place to another. We know also that this is the case with

Sound. We hear the thunderclap after we see the lightning flash, and the sound of the explosion of a gun at a distance arrives later than the appearance of the smoke or flash from the gun, except when we are very close to the storm or the gun.

Experiment shows that in air at ordinary temperature Sound travels at the rate of about 1,100 feet per second or about 700 miles an hour; more than ten times the speed of an express train.

The speed of Light is, however, nearly 900,000 times greater than Sound and hence the fact that Light takes time to travel was not discovered until after astronomical observations began to be made with the telescope and the clock. Galileo made, it is true, a crude experiment with two lanterns, but it was only sufficient to show that the velocity of Light is enormously greater than that of Sound. Galileo discovered with his first telescope that the planet Jupiter has four moons revolving round it which are periodically eclipsed by passing into the shadow cast behind Jupiter. The period of revolution of each moon being then noted it was easy to predict the times of future eclipses.

A Danish Astronomer, Roemer, however, noticed that the eclipses of any one moon generally took place either earlier or later than the predicted time, and that the extreme range of this difference was about a quarter of an hour or about 1,000 seconds. It is clear that when the earth is on that side of its orbit which brings it nearest to Jupiter and when it is on the opposite side of its orbit the difference in its distance from Jupiter is nearly equal to twice the earth's distance from the sun, or 186 million miles, nearly. Roemer correctly surmised that the extreme difference between the predicted times of an eclipse of one of Jupiter's satellites at these two positions of the earth in its orbit, viz., 15 minutes or about 1,000 seconds is the time taken by light to travel 186 million miles. From which it is at once seen that the speed of light must be close to 186,000 miles per second.

Later on, methods of measuring the speed experimentally were devised by the French physicists, Fizeau and Foucault, and increasingly exact measurements have been made by others, one of the latest being by Michelson in America. The best results are very close to 299,800 kilometres or 186,295 miles per second.

When an effect takes time to travel it can only be one of

two things: it may be some article which is transmitted bodily, like a letter by post or a bullet from a gun; or else it may be a particular state in some medium which is handed on from point to point in it. This is called wave transmission. Thus in the case of Sound the air is the medium. If an explosion is made at one point the air there is driven outwards and the particle compressed or squeezed closer together over a certain limited zone or region. Then this compressed air expands and squeezes together a layer of air laying beyond it and so on. Hence a region of compression is handed on from layer to layer, but the actual motion of any particular particle of air is very small. It is a *state* and not a *thing* which progresses.

A similar process takes place in the case of surface waves on water, only here it is not a state of compression in a mass but an elevation of the surface or hump on a surface that progresses. We can measure the velocity with which this state of the medium is propagated through it and this is called the wave or *phase velocity.*

There are two other terms we shall often have to employ. The term *wave-length* means the shortest distance from one wave crest or hump or condensation to the next. It is not the distance measured along the hump, but across from hump to hump if we are considering surface waves on water.

Then at any one point there is an oscillation of the particles of the medium, and by the term *frequency* we mean the number of complete cycles of oscillation or vibrations per second that take place.

There is also a simple connection between these three quantities in all cases of wave motion, and it is expressed by the statement: *The wave velocity is numerically equal to the product of the wave-length and the wave-frequency.*

Thus, for instance, in music, the note called the Middle C on the piano is created by 256 vibrations per second of the string. But we know from experiment that the velocity of sound in air at ordinary temperatures is close to 1,100 feet per second. Hence dividing 1,100 by 256 we have the quotient 4·3 feet, in other words the wave-length or distance from one condensation to the next in the air for this note is 4 feet 4 inches, nearly.

The frequency of the notes used in music varies from about 30 to 4,000 per second, and the wave-length therefore from about 40 feet for the deepest bass notes to about 3 inches for the highest treble notes in the scale.

There is one peculiar effect which enables us to decide whether we are dealing with a wave motion or with some transmission of matter. This depends upon what is called wave interference. It is possible to create two sets of waves in the same medium, and to so locate the place where the waves originate that at some other point the second set of waves generated cancels out or destroys the first set of waves, because the humps or crests or condensations of one set arrive at that point at the same time as the hollows or rarefactions of the second set. Accordingly the existence of this phenomena of interference has always been held to be a proof that we are dealing with a wave motion and not the translation of a substance.

3.—Hypothesis as to the Nature of Light.

The human mind desires above all things not merely the collection of facts or records of phenomena in Nature, but what we call explanations of them, by which we mean an analysis which results in showing them to be the necessary consequence of more fundamental or simple elements or actions.

When Sir Isaac Newton admitted a slender beam of sunlight into his darkened room through a hole in a shutter and interposing a wedge-shaped piece of clear glass in its path, he found projected on a white screen the rainbow coloured band we call a solar spectrum.

Wollaston and Frauenhofer subsequently found that if the hole was a very narrow slit the spectrum was crossed by a number of black lines which indicate missing rays.

It was, and even is still, sometimes supposed that these different coloured rays exist mixed up in white light, but that is not entirely the true interpretation. The prism has some share in creating the spectrum out of the very complex and irregular vibration which constitutes the so-called white light.

In seeking for an explanation of the nature of Light Newton was well aware of the only alternatives possible, but the fact that in his mind operated against the assumption that in Light we are concerned with some kind of wave motion was the fact that sharp shadows can be formed.

We know that the air waves which constitute Sound bend round obstacles, so that we can, for instance, hear a band of music playing even when a row of houses stands between us and

the band. In the same manner we can hear a person speaking when the speaker is hidden behind a door or by some large piece of furniture. Hence Newton thought that if Light was a wave motion shadows would not be formed, but that the waves of Light like waves of Sound would bend round opaque objects. As a matter of fact they do so bend, but that bending is extremely slight on account of the very short wave-length of visible lights. Therefore Newton felt compelled to commit himself to the hypothesis that Light consists in certain exquisitely small particles he called *corpuscles* which are shot out in all directions from luminous bodies like bullets from a battery of machine guns.

This theory explained quite easily the reflection of Light because the corpuscles striking the surface of a mirror were sent off again at an equal angle just as a billiard ball is reflected when it strikes the cushion of the table. So far all was simple for the corpuscular theory. But now there is another optical effect called refraction not so easily explained. If you dip an oar or stick partly into clear water they appear to be bent at the water surface. Or, otherwise, suppose you put a coin into a deep empty basin and then move backward until the edge of the basin just conceals the coin from your eye. If, then, without moving your head, another person fills the basin with water the coin will again become visible to you.

We have then to explain the bending of rays of light when they pass from one medium (air) to another denser medium (water). Newton had to assume that in this case his luminous corpuscles were attracted or drawn towards the denser medium, and this implies as consequence that the corpuscles must move faster in water than in air. This as we shall see presently is contrary to fact.

The corpuscular theory explained then easily the formation of shadows and the law of reflection, and with a few additional and arbitrary assumptions some other optical phenomena.

On the other hand the wave theory of Light began to be developed first by Huyghens, a contemporary of Newton, and he gave a satisfactory explanation of reflection and refraction on this theory, and the latter effect was shown to be due to the reduced velocity of the waves in the denser medium.

A simple illustration will make this plain. Suppose a line of soldiers to be marching over a smooth common and then to come upon a piece of very rough ground separated from the smooth part by a straight margin inclined to the line of march.

As each soldier in turn steps on to the rough ground his marching speed is retarded, and a little thought will make it clear that when all the soldiers have stepped over the margin the line will still be "dressed," as a soldier would say, but the direction of march will have been slewed round towards the normal to the dividing lines.

About 1849 and 1850 two French physicists, MM. Fizeau and Foucault, devised methods of experimentally measuring the velocity of Light in the laboratory, and one of the results was to show that Light travels more slowly in water than in air. This result was held to be a crucial experiment entirely in favour of the undulatory theory of Light.

4.—The Postulate of the Ether.

The question, however, at once arose, if Light is an undulation, what is it that undulates? It must be an elastic medium or one in which a strain or displacement is resisted by a force of some nature, which strain tends to disappear when the stress, or force is removed. Now it can be shown that the velocity of a wave in any medium depends on the ratio of its elasticity to its density. It may perhaps be well to point out that the meaning of the word elastic is somewhat different in science and in common life. In the latter case we call anything elastic which is like an indiarubber band and can be much stretched by a slight force, provided it springs back when released. In scientific language we call a thing very elastic when it requires a large force to strain it sensibly, but springs back when released, like steel.

Since the velocity of light is very large, the undulatory medium must be very elastic or else have an extremely small density. Moreover, since Light travels to us from the sun and stars across empty, or nearly empty, space, it cannot be ordinary matter with vibrates, but must be some very special intangible material not having weight that is not subject to gravitation. Moreover, it can be shown that the vibrations which constitute light are different in one particular from those in air which create sound or music. In the latter case the air particles vibrate to and fro in the direction in which the sound is travelling, but in the case of Light the oscillations must take place across, or perpendicular to, the direction of propagation. The full reason for this is rather too long to give here. They are therefore called transverse

vibrations. This kind of distortional vibration can only take place in a solid substance, but a solid can also transmit longitudinal vibrations, as for instance those of sound. Noises and speech are heard through a wall or floor.

In the case of earthquakes the solid strata of the earth transmit the two kinds of vibrations. The longitudinal vibrations create what are called waves of compression and the transverse waves of distortion. These travel with different speeds in the crust of the earth, and when detected by instruments called seismographs enable an estimate to be made of the probable place of origin of the earthquake.

Now the fact that the vibrations of Light must be transverse necessitated the assumption of some very remarkable properties in this light-conveying medium or ether. It must have the properties of an elastic solid and yet apparently offer no resistance to the earth and other planets when moving through it at speeds of 70,000 to 100,000 miles an hour. Also it had to be entirely intangible and not detectable by any of our senses or scientific instruments. This medium then was called the ether, and must be, according to these necessary assumptions, something quite different from ordinary matter.

Nevertheless these postulates, extraordinary though they were, enabled mathematicians in the early and middle part of last century to give most excellent explanations of many optical phenomena, and the great physicists of that period, such as Thomas Young, Fresnel, Arago, Airy, Brewster, MacCullagh, Hamilton, Kelvin, and Stokes explained nearly all known optical facts by the aid of this hypothesis of an elastic solid ether and Light being its undulations.

But now, as Thomas H. Huxley once said, the great and ever-recurring tragedy of science is that of a beautiful hypothesis killed by an ugly fact. So common indeed, is this painful occurrence, that the past history of science might almost be described as a cemetery filled with the graves of dead and buried scientific theories.

Amongst them for nearly half a century this undulatory theory of Light based on the hypothesis of an elastic solid ether reigned as a queen. She had a large circle of admirers who praised the elegant and satisfying manner in which she explained all optical phenomena.

But then as in other cases some stubborn facts sprang up in unexpected places and besmirched her reputation, and she is now

forsaken and forlorn and her name is no longer mentioned in that scientific society where she formerly received so much attention.

5.—Varieties of Radiation.

Before discussing the modifications which have had to be made in the theory in Light to make it fit the facts of experience, it may be well to explain a few things with regard to radiation generally.

We know that in the case of air our ears can perceive a certain range of vibration as sound. In music we call one note the octave of another if the second has twice or else half the frequency of the first. The musical gamut or range is comprised within about 8 or 9 octaves, and a piano has a keyboard generally of 7 or 8 octaves.

Imagine then a kind of gigantic piano with a keyboard having a range of 60 to 80 octaves. Suppose our ears could hear as music only notes from one single octave about the middle of the keyboard and were deaf to all above or below it. This would give us some analogy with the case of Light. Our eyes are sensitive to, and appreciate as, Light vibrations in the ether lying between about 400 billion and 700 billion per second, that is to a single octave of ether vibration. These tremendous numbers convey no real idea to the mind, and yet it is quite certain they are not incorrect.

If you counted the numerals 1, 2, 3, 4, etc., at the rate of 60 per minute without stopping day and night it would take you $11\frac{1}{2}$ days each of 24 hours to count a million. It would take you $12\frac{1}{2}$ years, counting without stopping, to count 400 million and you would have to live about 12 million years to count up to 400 billion. Yet this stupendous number of ether or light waves enter your eye in one second when you look at any red object and about double that number when you look at a violet object. But beyond these limits, greater and less, there lie 30 octaves or more of radiation which cannot affect the eye yet travel at the same rate as visible light and have very similar properties.

Beyond the violet there lie the ultra-violet rays now used in medicine, and the X-rays or Röntgen rays used in Surgery. Also the Gamma rays given out by Radium, and the extremely

short Cosmic rays which come to us from the confines of the Universe.

Beyond the red end of the spectrum there are the Dark Heat rays, the Hertzian rays and that great range of vibrations used in wireless Telegraphy up to waves of 10 miles or so in wave-length. Whatever hypothesis or theory we may form as to the nature of visible light, the same kind of explanation must be valid for all that range of radiation just mentioned, because all of it is of identical nature and has properties of a very similar kind.

6.—Electromagnetic Radiation.

Almost exactly one hundred years ago (within 2 days) there was born on June 13th, 1831, at Edinburgh, a boy destined to become one of the small but noteworthy band of scientific pioneers, who in an all too brief life left his indelible mark on the history of scientific investigation. That boy was James Clerk Maxwell, and the field in which he did his greatest work was as a follower and exponent of Faraday in the region of electromagnetic phenomena.

On December 8th, 1864, Maxwell read to the Royal Society of London a paper entitled, "A dynamical Theory of the Electromagnetic Field," in which he embodied the result of years of profound thought, and put on record the reasoning which led him to the conclusion that Light was an electromagnetic vibration.

After Maxwell's early and lamented death an eminent Cambridge mathematician said to me that he considered this paper, by its profound originality, was one of the very greatest productions of the human mind. In this paper Maxwell showed that if a conductor, say for example a metal ball, is electrified it produces throughout all space a state called electric displacement or otherwise electric force. We cannot form any mental image of this effect in terms of mere mechanical motions or displacements. It must be accepted as an ultimate irresolvable idea. If that electric charge is suddenly created or destroyed at any one place the resulting electric displacement throughout space does not make its appearance or vanish everywhere at once, but the state is propagated throughout space with a speed which Maxwell proved as identical with the known velocity of

Light. Hence he inferred that Light is a periodic electric displacement, periodic in space and time, taking place at right angles to the direction of propagation of the ray. It is therefore said to be a wave of electric force or displacement.

This electromagnetic theory of Light dominated the field of physical explanations for thirty-five years, and then it also began to fail under the attacks of newly discovered facts. When a beam of white light is expanded by a prism into a rainbow-coloured strip or spectrum, we can measure in a certain way the energy of each of the coloured rays and we find that energy is small at both ends of the spectrum, viz., for the extreme red and extreme violet, and greatest for some intermediate point. No yet formulated wave theory of light could explain this fact. They all predicted that the greatest energy would be found accumulated in the shortest waves. Again, it had been found that some metals, such as potassium, sodium, cæsium, and others gave off particles of negative electricity or electrons when exposed to violet or ultra-violet light and calculation showed that on the assumption of a wave theory in which the energy in a wave front was uniformly distributed over wave front it could not provide energy enough in an area of surface equal to an atom to make it discharge an electron from the atom.

Some of these difficulties were removed by a very important theory due to Professor Max Planck, of Berlin University, enunciated in December, 1900, which amounted to the novel suggestion that energy in the form of radiation like matter and electricity, is built up of atoms, and that only a whole number of these atoms can therefore be absorbed or emitted at once by an atom of matter.

The energy of radiation in this respect something like such articles as cigars or cigarettes we can only buy and sell them in whole numbers. We can have 1, 10, or 1,000 or more, but we cannot buy a fraction of a cigar or a part of a cigarette. These atoms of energy are, however, not all of the same size. The energy atom associated with violet light is larger or more powerful than that associated with red light. This is the reason that violet light or ultra-violet light can produce such vigorous effects. It spoils or fogs our photographic plates, it liberates electrons from photo-electric metals, it has therapeutic or medical properties when it falls on the human skin, and it ionizes or breaks up atoms of gases when it passes through them. It is therefore possible to give a scientific proof that a beam of light

cannot be simply a set of waves with the energy distributed uniformly over what is called the wave front. The energy must be located or concentrated in some places more than others so that the wave front has a speckled or irregular distribution of energy. In short the result of modern investigation has been to show that a beam of light resembles in some respects a shower of rain. A shower of rain consists of little drops of water of various sizes, and a beam of light is now regarded as being made up of little droplets of light energy, or as they are now called *phōtons* from the Greek word (*phōs*) for Light.

We know nothing about the absolute size of the photons, but we know that they each contain a store of energy which we might liken to a coiled-up clock or watch-spring, and this energy is proportional to the frequency of the Light ray which those particular photons create. That is to say each photon energy is larger in the case of violet light than for red light, and vastly larger for the photons which compose the X-rays than for those which compose the radiation made use of in wireless telegraphy and broadcasting.

It will be seen then that this latest theory of Light is a return to a sort of corpuscular theory as imagined by Newton, but with great differences. When a luminous source emits light, that is sends out photons, the photons of large energy are much more sparse or scarce than those of small energy. Hence when we analyse with the prism the white light sent out from a source we find that total energy in the form of red light is small, because the photons of that kind though numerous have each small energy. Also the total energy sent out in the form of violet light is small, because the photons of that kind are very scarce though each contains much energy. The photons of yellow or green light holding an intermediate amount of energy are intermediate in total number taken together convey a maximum amount of energy. Hence in this way the distribution of energy in the spectrum is explained. This photon theory also explains the photo-electric effect of emission of electrons from certain metals and other properties of short wave Light.

On the other hand it presents more difficulty in giving an explanation of the effects called interference, already mentioned. If a ray of light proceeding from a single point source is divided into two parts which travel along by two routes slightly unequal in length and are re-united at the terminal point, then if these two paths differ in length by a distance equal to an odd number

of half a wave-length for that light, then the two parts of the divided ray will neutralize each other at the terminus so that light added to light will produce darkness.

We cannot explain this kind of effect except by the assumption we are dealing with waves of some kind, and the only conclusion we can come to is that the photons are accompanied by waves or else that the photons are themselves groups of waves. Now this latter conclusion is one that modern physics favour. It is supported by the recent discovery that electrons or atoms of negative electricity which build up atoms of matter also behave sometimes as particles and sometimes as waves. Matter, Electricity, and Light, are each made up of atoms of some kind, and are all essentially of the same nature.

We now know, or have good reason for believing, that the radiation or Light from sun and stars is generated by the destruction or melting away of their Matter of Mass. Our sun, for instance, uses up 250 million tons a minute of its own mass to supply the heat and light it pours out. The merest fraction of all that radiation is caught up and utilized by our earth and the other planets, and most of the sun's radiation is cast out into empty space.

What becomes of all this energy? Is it wasted or is it in some way captured and again used to re-create Matter? These are questions Science cannot yet answer.

What we can say up to the present is that some optical phenomena necessitate the assumption that in Light we are concerned with a system of waves of some nature. But other effects indicate that Light involves some kind of particles or corpuscles. Hence neither Newton nor Huyghens were entirely right and neither entirely wrong. Our problem at the present moment is to search for a theory of Light which may explain how it can act both as a set of discreet particles and as continuous waves. The theory which has obtained a certain limited acceptance at the present time is that Light involves both waves and corpuscles or particles. The waves guide the particles or photons in such manner that the photons are most numerous where the amplitude or height of the waves is greatest, and absent in those places where the amplitude is zero.

The photons convey the chief part of the energy of the light, but the waves convey little energy. The waves consist of electric force which is periodic in space and time; that is large in some places and small or absent in others. The photons

always tend to accumulate in places where the force is large and avoid those where it is small. Also we must presuppose that photons like electrons repel each other and therefore tend to arrange themselves as much as possible spaced apart equally on the wave front. Nevertheless we have not yet completely found a key to the puzzle, and hence as regards the true nature of Light we are still very much in the dark.

7.—Light, Celestial and Terrestrial.

A question, however, which may be asked in conclusion is whether there are not more kinds of Light than one ? We believe that distinct from this material world of three dimensional space and one dimensional time in which we now live and move there exists another distinct from, but perhaps interpenetrating, this one, which we speak of as " the other world."

There are many mentions in Scripture of Light which certainly did not proceed from the combustion, incandescence, or phosphorescence of ordinary matter, but which could under some conditions affect many human eyes at once, and, therefore, was not merely a subjective phenomenon. Neither can we regard them as events wholly fictitious and non-occurrent.

One of these was the " pillar of fire " over the tabernacle which guided and guarded the hosts of Israel during their wanderings in the wilderness. This was replaced by a cloud by day, and must therefore have been visible to hundreds of thousands of persons at once. (Exod. xl, 38.) Also at the giving of the Law on Sinai the mountain " burned with fire," (Deut. ix, 15), and was seen by all the hosts of Israel.

Another luminous phenomena which in the same way was visible to many was the shining light on the face of Moses when he came down from Mount Sinai after his Communion with God for forty days. So brilliant was it that he had to shield his face with a veil. (Exod. xxxiv, 29, 33, 34.)

Then again the angel of the Resurrection whose " face was like lightning " struck terror into the hearts of the Sentry Guard, in which there were perhaps four to six or more men.

There must have been something unearthly in this light so to alarm these hardened Roman soldiers.

In these luminous phenomena we do not include the appearance to Abraham of the " smoking furnace and burning lamp "

(Gen. xv, 17), nor that of the "bush burned with fire which was not consumed" that Moses saw (Exod. iii, 2).

Nor do we include the visions granted to Daniel and to John in Patmos, which were manifestations to single men and hence we can hardly say how far they were objectively real. It is, however, clear that there have been manifestations of Light which were supernatural. That some form of superlative light, of which science knows nothing, exists seems indicated in those grand concluding chapters of the Revelation to St. John, unless they are wholly symbolical, in which he sees in vision the City that "lieth foursquare" the heavenly Jerusalem whose "light was like a stone most precious," which had no need of the sun neither of the moon to shine in it . . . and the Lamb was the light thereof. The blessed inhabitants of that City need no candle neither light of the sun for the Lord God giveth them light." (Rev. xxi, 23; xxii, 5.)

Enquiry into these mysteries, however, lies far beyond our present powers; we can hope nevertheless to know something more about the nature of the Light by which our bodily eyes are stimulated.

Newton gathered a great harvest in that field of investigation, and his statue in the antechapel of Trinity College, Cambridge, shows him with the prism in his hand by which he first analysed white Light into a rainbow band.

You will perhaps remember Wordsworth's lines written when an undergraduate of St. John's College (which is only separated by a narrow lane from Trinity College Chapel) wherein he says :—

> From my pillow looking forth by light of moon or
> favouring stars I could behold
> The antechapel, where the statue stands, of Newton
> with his prism and his silent face,
> The marble index of a mind for ever
> Voyaging through strange seas of Thought; alone.

But although Newton's mind and those of all his great followers in physical investigation have voyaged for long years o'er strange seas of Thought in search of the secrets of the sunbeam, neither he nor they have been able to yet reveal to us more than the smallest fraction of all the mysteries which lie enshrined in a ray of Light.

On the call of the CHAIRMAN, a hearty vote of thanks was accorded to Sir Ambrose for his address.