ABSTRACT OF LECTURE ON LIGHT AND VISION

By Freeland Fergus, M.D.

[Read 10th December, 1912].

The subject of light has interested thinking minds from the earliest dawn of civilization. To take only two examples. Pythagoras wrote on light and Aristotle was almost prophetic when he said that light was not a substance but a motion. Thus he practically held the essentials of the present view that light is the mental interpretation of certain movements of an undulatory character in an all pervading medium which is generally called the luminiferous ether.

One of the most important steps towards our present knowledge of light was the discovery by Römer, a Danish astronomer, that light took a definite time to travel. He estimated the speed at which light travels as about 186,000 miles in a second. If we take the diameter of the earth at the equater as about 8,000 miles, light would go round the earth between 7 and 8 times in a second. The distance of the Sun from the earth is 93,000,000 of miles, which means that light takes something between 8 and 9 minutes to come from the Sun to the earth. Considerations such as these give some idea as to the rapidity with which light travels. Yet astronomers tell us that some stars are so far distant that the light which at present reaches our planet must have left them many hundreds of years ago. That gives us some idea of the immensity of interstellar space. If we take a star at such a distance that it will take light a thousand years exactly to reach the earth, if also we take the year as equal to three-hundred and sixty-five days then as in a thousand years of

365 days there are 31,536,000,000 seconds, the number of miles between us and that star is given by multiplying 31,536,000,000 by 186,000. An important question at once arises—What is it that travels? Physicists inform us that it must either be matter or energy. Till recent times it was generally thought that it was matter and on this idea was based what is generally known as the corpuscular theory of light. This was the theory held by Newton himself although he narrowly missed at one point being the discoverer of the modern or undulatory theory of light. The corpuscular theory of light taught that it consists of extremely small particles of matter which are emitted like small projectiles by all visible bodies and that these small bodies impinging on the eye were the cause of sight.

Various objections have with great power been advanced against this theory. To begin with, the energy of any moving body is the mass of the body multiplied by the square of its velocity. Therefore no matter how small the corpuscle may be its mass multiplied by the square of 186,000 means an enormous amount of energy and therefore it is inconceivable that if the human eye is bombarded by millions of such bodies for every second of time that the tissue of which it is composed could stand the strain. Further, it has been shown that if this theory is true then in the case of refraction from a less dense medium into a denser one that the angle of incidence should be less than the angle of refraction. But the reverse is the case.

For these and other reasons the corpuscular theory of light is not now accepted and has been replaced by the undulatory or wave theory of light,

If a stone be dropped into a pool of still water circular waves are seen to spread out from the point at which the stone struck the surface. The energy of the falling stone has been communicated to the particles of water. The particles themselves do not move to any appreciable extent horizontally, only vertically Now the wave theory of light predicates that light is a wave motion somewhat similar to that seen on the surface of the water only much more complex. This theory explains all the observed phenomena of light in a very thorough manner and has therefore come to be universally accepted.

The waves of light are propagated with the enormous velocity of 186,000 miles in a second but themselves are extremely small. Those given by red light are the largest visible to the eye but they are only ·00003 of an inch. Each part of the spectrum gives a different wave length. The colour of any object depends on what is called the wave frequency which depends upon the wave length.

The eye is an optical instrument adapted for the reception and focussing on the retina of these small waves and sight is the mental interpretation of the images received on the retina.

This is not the place nor is the time at my disposal sufficient to enter into any details as to the processes which take place in the eye. Suffice it to say that sight depends on the fact that a well defined image of the external world is formed by the various refractive media of the eye on the retina. The images formed on the retina cause certain disturbances of a physical and chemical nature ; these in turn are transmitted by various nerve structures to the brain and there give rise to consciousness. The connecting link between the physical and the mental is quite unknown. It is quite impossible to imagine that thought and all that that implies is a mere function of matter. It is the mind that sees or at any rate gets information from these physical stimuli. No doubt the mental picture depends upon and to some extent is conditioned by the physical phenomena but after all it is the person that sees and not the retina nor yet his brain cells, although it is definitely known that certain parts of the brain are specially and specifically associated with vision.

Now the information which we obtain by sight concerning objects is very varied. We talk of the sense of sight but in reality it is not a single sense but a combination of senses,

It consists of (a) Visual Acuteness, (b) the Form Sense, (c) the Colour Sense, (d) the Light Sense, (e) Perspective which is one of the means by which we determine the relative positions in space of various objects. Hitherto it has been quite common to confound the form sense with visual acuteness but the following considerations will show that the two must be definitely separated in thought from each other. Up till now physiologists have for the most part classed (a) and (b) together under the term of the Form Sense. They have not in any way differentiated between the two. A difference however must be made if anything like accuracy is to be obtained. By visual acuteness I mean the power of distinguishing letters of type or of reading notes of a score of music and such other things. If a person looks at a word in the centre of a page of printed matter he will find that he only sees that word, and that the rest of the page cannot be deciphered unless he changes his point of fixation. If anyone in the audience will be so good as to look intently at one word at the centre of a page he will find that he cannot make out a single other word at the same moment on that page. He sees the word on account of his visual acuteness. While however he is steadily looking at it he can see other objects perfectly well : thus, he can tell that there are other persons in the room and may be able to make out whether they are men or women. He could not however recognize them but he could count them. The power of recognition is another example of visual acuteness. The power by which persons see objects in a less defined manner I call the form sense. Most occupations such as labouring work, navigational work, require the form sense rather than visual acuteness. It is obvious, however, that there are some forms of employment which demand visual acuteness. For example, a watchmaker must have it, a tailor must have it or he would not see to thread his needle, all persons who read and write ; but a great deal of work is done by each one of us simply through the form sense and not through the visual acuteness. Take for example a man quarrying a piece of stone. He separates it quite readily from the clay and other material in its neighbourhood simply by the form sense. He does not require visual acuteness at all for work of that kind. Did he wish however to examine the texture of the stone much in the same way as a geologist would do then visual acuteness becomes necessary. Visual acuteness generally speaking in this country is tested by the letters of Professor Snellen of Utrecht. In the main they are quite satisfactory although from a strictly scientific point of view the tests of Landolt, of Paris, are much more delicate. According to Snellen's investigations the standard visual angle is one of five minutes. If a letter which subtends an angle of five minutes at the first nodal point of the eye is clearly seen when the letter is placed at 20 feet from the person then the vision is said by Snellen to be normal. That however is a perfectly arbitrary standard and by no means indicates the average vision of mankind, which is in fact a great deal lower than that.

It is also by eyesight that we obtain our ideas of colour. Light coming from the Sun is generally called white and as everyone knows, can be broken up into various components which are called the colours of the spectrum. Physicists have been able to show that a difference in colour is associated with a difference in wave length. Thus, the wave length of a certain quality of red lights is ·00003 of an inch, for a certain shade of blue it is ·000017 of an inch. Each particular shade of the spectrum has its own particular wave length. Strictly speaking, it is the wave frequency which causes the different colours to be seen but as frequency is a function of wave length there is no essential error in saying that the colour depends upon the wave length. Now at each end of the spectrum there are disturbances which are not visible to the eye. For example, if a spectrum is formed on a screen and a thermo-pile be introduced just a little beyond the point at which the red end of the spectrum ceases to be seen then the deflection of the galvanometer needle will show that there are certain waves incident at that part of the screen which although invisible, have thermic effects. At the other end there are also rays which are not visible. If a photographic plate be exposed beyond the blue part of the spectrum then it is found that there are rays there which have very strong chemical properties. These are called the actinic rays.

But the perception of colour demands a suitable receptor for these various disturbances. It is not certain where that receptor is ; whether the differences of wave length produce definite differences in the retina or on those parts of the brain which are associated with vision, but one thing is quite certain and that is, that all people do not see colours in a similar manner. Hence the various forms of what is known as colour blindness. Probably the most frequent variety of that affection is the confusion between red and green ; the person who is afflicted not being able to distinguish between one and the other of these pigments. That of course renders a person so afflicted unable to undertake the duties where recognition of these pigments is essential. A man who is colour blind in that way is not fit for the duties of navigation nor for those of locomotive driving.