THE NEW PHYSIOLOGY OF VISION

Chapter II. Visual Sensations and the Nature of Light

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THE special organs of sense are the gateways through which a knowledge of external circumstances and events finds its way into the domain of human consciousness. Such knowledge is, of course, a prime requisite for the work-a-day activities of the individual. There is another role which the sense-organs play which is also of high significance, *viz.*, the special contributions they make to aesthetic values in human life. We may mention here music as perceived through the organs of hearing, perfumes through the sense of smell, and colour through the organs of vision. The study of these special aspects of perception naturally takes a very prominent place in the physiology of the respective sense-organs. It is significant that all the three faculties of perception exhibit certain common features, *viz.*, their ability to function over a wide range of intensities of the external stimuli and the capacity, in appropriate circumstances, to notice them even when they are excessively feeble. We may also mention the rapidity with which the sense-organs function and the power which they possess of recognising even subtle differences in the characters of the exciting stimulus. All these features enhance the usefulness of the sense-organs in human life and activity.

The position of exceptional importance which vision takes amongst the faculties of perception is attributable to the special properties of the physical agency, *viz.*, light, which our eyes make use of and which enables them to function. There are obvious relationships between these properties and the services which the faculty of vision can render. For example, light can travel swiftly through vast distances in space and still reach us and not disappear on the way. We are thereby enabled with our unaided vision, to perceive very distant objects, even those lying outside our own galactic universe, as for example, the Great Nebula in Andromeda. The rectilinear propagation of light in space is evidently also what makes it possible for us to locate various near objects around us. The differences in the spectral character of the light which reaches us, either from the original sources or from the objects which reflect, scatter or diffuse the light falling on them is likewise the basis on which rests the special faculty of colour perception.

From all that has been said it follows that the physiology of vision is greatly concerned with the nature and properties of light, and unless these are known and correctly understood, those pursuing the subject would be wandering about on false trails.

Light Plays a Dual Role.—At the end of the nineteenth century, the nature of light was regarded as an issue which had been settled once for all. The view adopted was that light is wave-motion which travels in free space with a velocity approaching 3,00,000 kilometres per second. The electric and magnetic forces constituting the disturbance are mutally perpendicular and appear in a plane transverse to the direction of propagation of the waves. Monochromatic light is in the wave-theory characterised by a definite wave-length in vacuum and a correspondingly high but definite frequency of variation of the electric and magnetic forces. In view of what has been said above, one need not be surprised that the great leaders of scientific thought in the nineteenth century who were principally responsible for advancing and establishing the wave-theory of light also sought to interpret our visual perceptions on the same basis. They could not have foreseen that all such attempts were foredoomed to failure.

As is well known, a revolutionary change in our ideas regarding the nature of light was brought by the work of Albert Einstein in the early years of the twentieth century. Einstein revived the idea favoured by Newton in an earlier epoch of science, *viz.*, that light is corpuscular in nature, but he put it forward in a modified form having both substance and definiteness. The light-corpuscles of Einstein represent specific amounts of energy in the radiation field, the quantum of energy being the smallest for light appearing at the red end of the spectrum and increasing continually as we proceed towards its violet end, being in fact proportional to the light-frequency. The support forthcoming for these concepts from many different directions has been so overwhelming that Einstein's ideas are now a well-established part of scientific knowledge.

The corpuscular and wave-theoretical descriptions of light seem at first to be mutually contradictory. But as they are both supported by great arrays of factual evidence, a way of reconciling them has necessarily to be found. Such reconciliation becomes easiest if it be assumed that the two concepts are valid in completely different and mutally exclusive fields of experience. Wave-optics successfully describes the propagation of light in free space, its reflection and refraction at the boundaries between the two media, and the special effects known as interference and diffraction which are characteristic of wave-motion and which arise from the superposition of wave-disturbances from the same original source. The corpuscular concept, on the other hand, is essential for the consideration of all phenomena in which there is a transference of the energy of radiation to or from material bodies. The emission and absorption of light are examples of such phenomena, and they can be successfully described and explained only on that basis.

The corpuscular concept of light involves a further and quite fundamental change in our modes of scientific thinking. This also we owe to Einstein. The emission or absorption of light by an atom or molecule in the corpuscular concept is not a continuous process but an individual event, and whether this occurs or not is a matter of chance. All that we can specify about it is the probability of its occurring, and hence the observable phenomena arising from such events can only be described in statistical terms.

What has been stated above is of the utmost significance in relation to vision. The dioptrics of the eye and the formation of focused images of external objects on the retina clearly fall within the scope of wave-optics. But wave-optics is irrelevant in all considerations regarding the actual perception of light. Interactions of some kind between the incident light and the material present in the visual receptors are clearly needed for such perception to be possible. It follows that all aspects of vision, including the perception of space and form, the perception of luminosity and the perception of colour, can only be understood in terms of the corpuscular concept of the nature of light.

It needs here to be stated and emphasised that the quantum of energy which a corpuscle of light represents is an exceedingly small quantity by all ordinary standards. For example, for light of the wave-length 555 $m\mu$ which lies in the green part of the spectrum, it is $3 \cdot 566 \times 10^{-12}$ of an erg. For longer and shorter wave-lengths, the quantum is respectively smaller and larger, being in an inverse proportion to the wave-length. From these figures, and the known mechanical equivalent of light energy, a simple calculation enables us to find the number of light-quanta falling per second on unit area of an illuminated screen. Taking the strength of the illumination to be one metre-candle, in other words, one lumen per square metre, and that one lumen of illumination with light of wave-length 555 $m\mu$ is equivalent to $0 \cdot 00154$ watts of energy, the quantum of light energy of that wave-length comes out $3 \cdot 566 \times 10^{-19}$ watt-seconds. Hence, the screen would receive per second

$4 \cdot 3 \times 10^{15}$ quanta per second per square metre of its area. This is an enormously large number.

In the following chapter we shall survey broadly the consequences which follow from a recognition of the corpuscular nature of light and discuss the role that it plays in our visual perceptions. In doing so, we shall not hesitate to draw the various inferences which follow as logical consequences of that concept, taken either by itself or taken in conjunction with certain well-established results of experiment.