THE NEW PHYSIOLOGY OF VISION

Chapter XII. Chromatic Sensations at High Luminosities

SIR C. V. RAMAN

THE chromatic sensations excited by light and the closely related topic of the progression of luminosity and colour in a well-dispersed spectrum play a highly important role in the physiology of vision. It emerged from the studies described in the preceding chapters that the sensations of luminosity and colour are so closely interrelated that they have of necessity to be considered together. At the lowest levels of illumination, they are both extremely feeble. They both gain strength as the flux of light reaching the retinæ of our eyes increases. These features naturally also manifest themselves when the light from a source of continuous radiation is dispersed into a spectrum and this is viewed by an observer. There is also a notable difference in the extent of the spectrum exhibited at the levels of illumination which we have referred to as dim light and as bright light respectively. These differences are attributable to the visual pigments which are present in the retina and function at the two levels being altogether different in their spectroscopic behaviours.

It is obviously of importance to carry the studies forward to levels of illumination higher than those which are normally made use of in vision. The results of such study may well be expected to throw fresh light on the nature of the visual processes. This indeed proves to be the case. The observations presently to be described lend impressive support to the findings set out in the two preceding chapters regarding the nature and functioning of the visual pigments.

Technique of Study.—A simple and yet highly effective method has been adopted by the author for investigations in the field outlined above. It consists in the use of a linear source of light and the observation of its first-order diffraction spectrum through a replica grating held by the observer before his eye. The grating employed had 6,000 rulings per centimetre and its first-order spectrum exhibits a dispersion and resolution more than adequate for the purpose in view. A convenient source of light is a tubular lamp along the axis of which is stretched a closely coiled tungsten filament twenty centimetres in length. The current carried by the filament can be varied with the aid of a rheostat so that the radiation emitted by it can be stepped up from a dull red glow to a brilliant white light. The spectrum is viewed by the observer who places himself at a suitable distance from the light source. This can be varied from the largest distance permitted by the dimensions of the laboratory down to quite small values. The brightness of the spectrum imaged on the retina is thereby enhanced roughly in inverse proportion to the distance. Even when the observer is ten metres away from the light source, the length of the glowing filament enables the width of the spectrum to be sufficient for its characters to be clearly perceived. The increase in luminosity which results from stepping up the heating current is very large for all parts of the spectrum. In particular, the blue-violet sector of the spectrum which is not observable when the tungsten wire emits a feeble red glow gains enormously in intensity when the temperature is raised and a brilliant white light is emitted. But, nevertheless, it continues to be the least luminous part of the spectrum. By the observer moving nearer to the source as also by raising the temperature of the filament, the observed luminosity of the spectrum can be raised from a barely perceptible value to one of considerable brilliance.

Still higher levels of brightness can be attained by using the special type of tungsten filament lamp which is commercially available and is employed for cinematographic projections. In these lamps, the source of light is a coiled-coil of fine tungsten wire placed inside a glass bulb which has a flattened shape. The rear part of the bulb is silvered externally and it acts as a reflecting mirror and brings the emitted light to a focus just outside the bulb. A slit cut in a metal plate and held at the focus allows the light to emerge and functions as a linear source of great intensity. The first-order diffraction spectrum of the illuminated slit can be viewed by the observer from any desired distance.

The Results of the Study.—**In the two preceding chapters, the parts of the spectrum between 7,000 and 5,000 angstroms and between 5,000 and 4,000 angstroms in wavelength were separately dealt with and discussed. This bifurcation of the spectrum was justified by the fact that the visual pigments functioning in the two cases are altogether different. It need not therefore surprise us to find that the effect of high luminosities on the visual sensations experienced are of a totally different nature in** the two cases. Accordingly in the present chapter, we shall consider only the spectral region between 5,000 and 7,000 angstroms. The part of the spectrum between 4,000 and 5,000 angstroms will be discussed in the chapter immediately following. As already stated, the techniques of observation enable us to cover a great range of luminosities in the spectrum, from the weakest observable to the strongest attainable. It is convenient therefore to describe the observed effects stage by stage in the same order.

First Stage.—With the tubular lamp emitting a dim red glow and the observer far away from it, the spectrum is at its weakest. The blue-violet sector is entirely absent and the red part of the spectrum also lies outside the range of visual perception. What is then actually observed is the region between 500 $m\mu$ and 600 $m\mu$. Despite the dimness of the spectrum, the greenish hue of the part that is visible is recognisable. If now the observer comes nearer the lamp, the red of the spectrum reappears and progressively gains in strength.

Second Stage.—The character of the spectrum is now totally different from that observed in the first stage. The red sector of the spectrum appears in full strength, while the green has gained both in colour and in brightness. These colours are fully saturated and are strikingly contrasted. The transition from the red to the green is fairly rapid and can be located in the spectrum with considerable accuracy. But where the two colours come closest to each other, the progressive change in hue from one to the other with the yellow between them can be readily perceived.

Third Stage.—Further conspicuous alterations in the character of the spectrum are observed when we pass from the second to the third stage. The band of yellow which separates the red from the green is now both broader and brighter. With increasing luminosity, the yellow becomes much the brightest part of the spectrum. The green and the red sectors also exhibit an altered appearance. The changes they exhibit are best described as the result of a progressively increasing superposition of the yellow sensation on the green and on the red sensations. Such superposition would result in altering the perceived colour from green to a greenish-yellow and from red to an orange. These changes spread outwards from the yellow part of the spectrum on both sides to a greater and greater extent with increasing luminosity.

Fourth Stage.—At this stage, the yellow strip in the spectrum attains great brilliance and appears as a band which is far brighter than the regions on either side of it. These latter exhibit the features already described for the third stage.

Fifth Stage.—At this stage, the yellow of the spectrum becomes extremely brilliant and also spreads out to include within itself both the green and the orange tracts of the spectrum. It has then the appearance of an intensely luminous band of an yellowish-white colour with strips of blue and of red of relatively low intensity extending outwards from it on the two sides.

It should be mentioned that the third, fourth and fifth stages can all be quickly traversed and their characteristics noted by an observer with the slit and projection lamp described earlier, merely by varying his distance from the slit or alternatively by varying the electric current through the lamp. These observations establish in a very striking fashion that both in normal circumstances and at the higher levels of illumination, the yellow of the spectrum is the dominant visual sensation and transcends all the other parts of the spectrum in its impact on the centres of perception. Likewise, the visual pigment which enables the perception of the yellow region of the spectrum is clearly the most important of them all.

COLLAGEN ANALYSIS FOR ARCHAEOLOGICAL DATING

The value of archæological bone samples depends in large measure upon the accuracy with which they can be dated. Unfortunately, an age derived from radiocarbon dating of bone calcium carbonate is usually suspect. It is always possible that the original carbonate has been replaced by that of ground-water ; and ground-water carbonate can be of varying date. Radiocarbon dating, therefore, has been primarily carried out on charcoal found near skeletal remains.

Archæologists have long realized that collagen analysis, if it were possible, would provide a more reliable technique. About 25% of total bone material is composed of collagen, a protein which contains about 50% organic carbon. Recently W. Libby *et al.* have found a method for isolating collagen carbon for dating.

Basically, the method consists of treating a sample of the bone in a weak HCl solution. This dissolves the mineral but leaves the collagen behind. The collagen is then dried and exposed to a stream of oxygen. The oxygen combines with the carbon and forms carbon dioxide, which is then chemically purified ; it is on this form that the carbon is dated.—[*The Sciences* (*N.Y. Acad. Sci.*), 1964, 4 (6), 23.]