Proc. Indian Acad. Sci. **A58** 57–61 (1963)

Floral colours and the physiology of vision—Part I. Introductory

SIR C V RAMAN
(Memoir No. 137 of the Raman Research Institute, Bangalore-6)

Received June 4, 1963

The physiology of the sense-organs aims at bringing the physical and psychological aspects of sense-perception into an intelligible relationship with each other. In particular, the physiology of vision seeks to connect the physical nature and properties of light with the sensations which it excites in our visual organs. For this purpose, it is necessary at the very outset to recognise that light consists of discrete units or quanta of energy. For, the interplay of light and matter is a process in which the quanta or energy-units of the radiation are transferred from the field to the material body or *vice versa*. Unquestionably, therefore, the quantum theory is the proper basis for the interpretation of the facts of visual experience.

The faculty that our eyes possess of perceiving colour bring the phenomena of vision into the closest relationship with the basic notions of the quantum theory. Light which appears as a sharply-defined line in the spectrum is composed of energy-quanta which are all equal. The quantum of energy varies with the position of the spectral line, being the lowest when it is at the red end and largest when it is at the violet end of the spectrum. Thus, the magnitude of the energy quantum varies *pari passu* with the colour of the perceived light. Every one of the different colours we can perceive in the spectrum—and, of course, they are very numerous—has thus an equal claim with the rest to be considered as a primary colour and as a fundamental visual sensation.

Thus, the sensations excited by monochromatic light which is physically the simplest form of radiation play the basic role in physiological optics. These sensations are of two sorts, viz., the luminosity and the colour. When a continuous spectrum, as for instance that of a brightly illuminated cloud in daytime, is viewed through a pocket spectroscope, it is seen that the luminosity is a maximum somewhere in the greenish-yellow part of the spectrum and falls off to very low values as we approach either end of it. Figure 1 in the text represents the variation of the luminous efficiency of radiation over the entire spectrum as determined by various observers. The spectrum has for convenience been demarcated in the figure into six different sectors of colour, violet, blue, green,

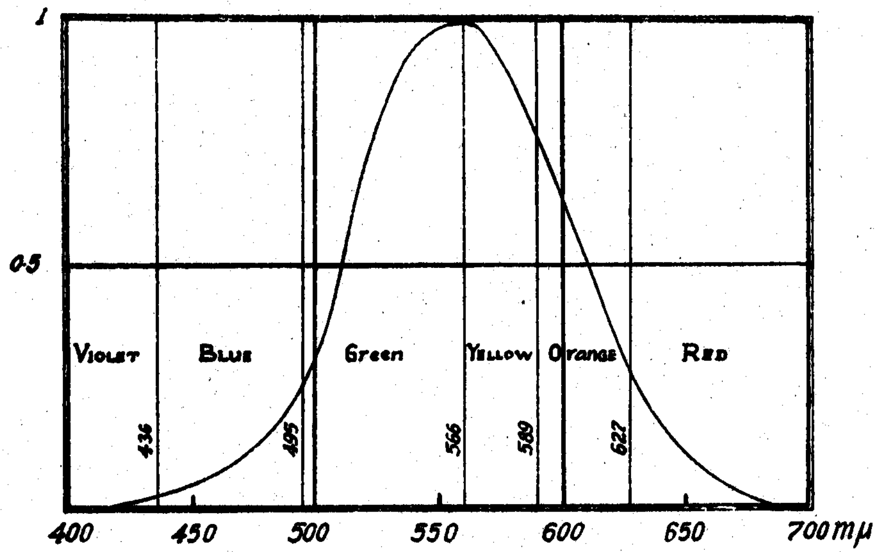

Figure 1. Colour and luminous efficiency in the spectrum.

yellow, orange and red, the wavelength limits between which have been taken as 436, 495, 566, 589 and 627 mμ respectively.

A highly significant feature of the visual perception of monochromatic light is the ability displayed to distinguish between the colours of closely adjacent regions in the spectrum. This is exhibited in figure 2 which shows the smallest change in wavelength that suffices in different parts of the spectrum to produce an observable change in colour. It will be seen from the diagram that a change of 3 mμ in wavelength suffices for the purpose over the greater part of the spectrum. The curve shows a series of dips at 436, 495 and 589 mμ. These dips appear at the locations in the spectrum where the observed colour changes from violet to blue, from blue to green and yellow to orange respectively. The very high sensitivity displayed in the latter two regions is particularly remarkable.

In his address on "Light, Colour and Vision" to the XIX International Ophthalmological Congress held at New Delhi (Reference 1), the author summed up the results of his earlier investigations on the physiology of vision published in these *Proceedings* (References 2 and 3). Those investigations sought to discover the role of the retina in vision and the mechanism of its functioning in the perception of colour. The facts of observation embodied in figures 1 and 2 and the results of a detailed study of the visual process using a new and powerful method devised by the author formed the basis of the researches. We shall not go over the same ground here. The present memoir concerns itself with a different but highly important subject, viz., the colours of non-homogeneous light, in other words, with the visual sensations excited by polychromatic radiation.

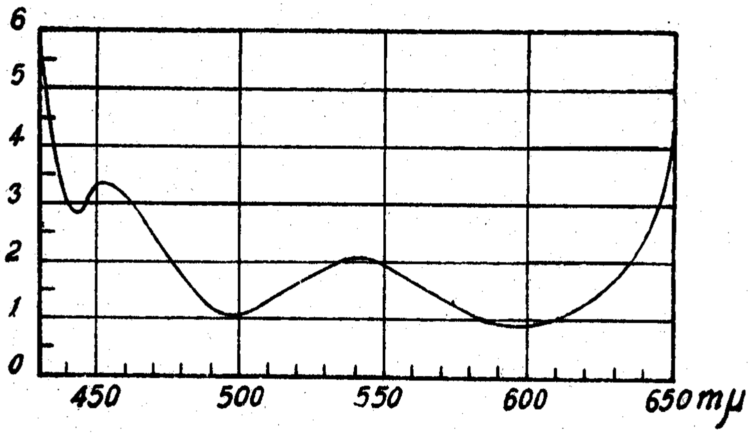

Figure 2. Colour discrimination in the spectrum.

A familiar example of the dependence of the colour of non-homogeneous light on its spectral composition is furnished by the thermal radiation from a heated body at various temperatures. The energy distribution in the continuous spectrum of such radiation alters with rise of temperature in such manner that the perceived colour passes through the well-known sequence ranging from a dark red at low to a brilliant white at high temperatures. This is a particularly simple case. In general, however, the spectral character of polychromatic radiation is capable of an unlimited range of variation. The energy density may vary from point to point in the spectrum and such variations may be of large magnitude. We have to consider the nature of the visual sensations excited by the light in all such cases.

The practical importance of giving an accurate description of the colour of commercial products has resulted in a great deal of attention being given in the past to the subjects of colour specification and colour measurement. We shall not here stop to discuss the methods adopted for such purposes and the ideas on which they are based. We shall also defer comment on the various conclusions of a general nature which have been arrived at from the earlier studies on colour. The approach to the subject in the present memoir is of an altogether different nature. It is based on the following considerations. *Firstly*, it is clear that in dealing with a subject of such complexity, it is necessary to base ourself on observational data of a comprehensive character obtained by methods which do not involve any particular assumptions regarding the visual mechanism and what it is or is not capable of achieving. For, only by such unbiassed observations that we can obtain a true picture of the reality. *Secondly*, it is evident that a vast mass of material suitable for investigations on colour and its perception is available to us in the products of plant life. The leaves, flowers and fruits of trees, shrubs and other forms of vegetation are indeed the most familiar objects manifesting colour met with in the organic world. They are objects of profound interest to us from various other points of view, but, to the student of colour, they are invaluable. Being products of biological activity, they conform to set patterns and there is therefore no difficulty in repeating observations made with any particular type of material and comparing the results with those given by other materials. Further, a great range of colours is available for study and this is particularly so in the case of flowers where efforts of horticulturists have succeeded in producing a great many new varieties exhibiting fresh hues and patterns of colour.

In the course of the studies described in the memoir, several surprising observations were made regarding the spectral composition of the light which gives rise to the observed colour in various cases. These observations indicated the need for a fresh consideration of the mechanism of the perception of the colour of polychromatic radiation. In presenting the results, however, it appeared desirable to set out the actual facts of observation in detail. This has been done in the various individual parts into which the memoir is divided, each part dealing with a particular case or a set of cases with special features of their own. The concluding parts of the memoir bring together the results and discuss the problem of polychromatic colour perception in the light of the actual facts and the principles of the quantum theory.

Summary

Monochromatic light is composed of energy-quanta which are all equal. Our perception of colour is thereby brought into the closest relationship with the notions of the quantum theory. Polychromatic light, however, stands on a different footing and the problem of the colour which it exhibits demands separate consideration. The relationship between the spectral composition of such light and its observed hues can only be ascertained only by the observational study of a great number of cases. It is pointed out that a vast mass of material exhibiting colour and highly suitable for investigations of this nature presents itself to us in the products of the biological activity of trees and plants, viz., their leaves, flowers and fruits.

References

1. Raman, Sir C V 1962 "Light, Colour and Vision," *Curr. Sci.*, **31**, 489.
2. Raman, Sir C V 1960 "The Perception of Light and Colour and the Physiology of Vision," Memoir No. 125 of the Raman Research Institute, *Proc. Indian Acad. Sci.*, **A52**, 255, **B52**, 253.
3. Raman, Sir C V 1962 "The Role of the Retina in Vision," Memoir No. 133 of the Raman Research Institute, *Proc. Indian Acad. Sci.*, **B56**, 77.