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The new physiology of vision—Chapter XLI. Photography in colour

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Pictorial photography is made immensely more interesting by the additional feature of colour, thereby making the record resemble more nearly what we observe with our eyes. It is not surprising, therefore, that photography in colour has attained great popularity and that it has received attention from numerous industrial corporations who have sought to provide the means for making it possible, viz., special cameras, photographic films and plates, methods of copying and multiplying the pictures taken, and finally also, projection apparatus for viewing films in colour as transparencies. Numerous techniques have been evolved for obtaining pictures in colour, and several of them have achieved a considerable measure of success and have accordingly been received into popular favour. It is not possible, nor is it proposed here to list these processes or to describe any of them in howsoever cursory a manner. What we are concerned with here is the role played by the characteristics of human vision in colour photography and the extent to which photography in colour can or does succeed in reproducing the appearance of objects as seen with our eyes.

It is evident that the two issues stated above are closely interrelated. For colour photography to be even reasonably successful, it has to take account of and be based upon the characteristics of human vision in respect of the sensations of colour. These characteristics fall into two broad divisions, viz., the sensations excited by the monochromatic radiation appearing in different parts of the spectrum, and the sensations excited by spectrally composite radiation. In most cases, we are concerned with composite radiation, the perceived colour of which is determined by the visual synthesis of the different spectral components of the light which is perceived. These remarks apply equally to the colours of the objects photographed and to their colours as exhibited in a photographic picture. The subject of the visual synthesis of colour thus plays an extremely important role in the field of colour photography.

Colour has such a powerful aesthetic and emotional appeal that a picture or a painting which makes no claim to be a faithful colour-rendering of the object depicted may nevertheless be admired and even highly valued. Fidelity in the reproduction of colour by photography may to some extent therefore be regarded as being only of academic interest. But this is by no means always the case, especially when colour photography is made use of to convey to a possible purchaser as exact a picture as possible of the article which he desires to obtain. Reproductions of celebrated works of art, of coloured textiles, of ceramic wares and different varieties of favourite flowers may be cited as examples of this situation.

A critical examination of the success or failure of colour photography, in other words, a determination of the measure of success actually achieved by any given process in reproducing colour and of the reasons for its failures, if any, evidently demands a proper choice of the test-objects made use of in the study. It is necessary that the object should display a wide range of colours, and that the spectral composition of the light which emerges from each point of the object should be precisely known and is precisely reproducible. Such a test-object is provided by the colours of interference, produced either in the Newtonian fashion between two polished surfaces of glass having different radii of curvature or between two flat plates of glass very slightly inclined to each other or in some other way. In earlier chapters the results which emerge from the study of such patterns in various other contexts have already been set out and described, viz., studies of the visual synthesis of colour and studies of defective colour-vision. From these instances, it is evident that the photography of interference patterns in colour would enable us to determine whether the processed colour-films do exhibit the same features as those visually observed in the patterns themselves, and if not, why not.

We begin with interference patterns of the Newtonian type. As usually produced and observed between two spherical surfaces of large radii of curvature, the rings are rather closely spaced and can be properly seen only through a magnifier. Much better suited for our present purpose are the rings produced on a much larger scale between two flat thick plates of glass of the kind ordinarily used for glazing large windows. The processes used in manufacturing such glass plates result in extensive areas appearing as cylindrical surfaces of very large radius. If two pieces of such glass, each about 5 cm square, are cut out and their edges are smoothed and the faces are placed in contact with their cylindrical axes in crossed positions, perfect circular interference-rings of the Newtonian type on a large scale are produced between the surfaces. These rings exhibit the colour sequence in a very striking fashion and do not need a magnifier for enabling them to be critically examined and studied.

Newtonian interference patterns produced in the manner described above have been photographed, using the white light of a tungsten-filament lamp and with colour-films bearing the well-known name of Kodak, and also with different exposures, in view of the influence which the exposure-time is known to exert on the final picture as seen in the processed film. The very striking result then emerged that the photographed colour-film of the interference pattern does not exhibit the colour-sequence in the pattern as seen directly, but differs therefrom in a very conspicuous manner. In seeking for an explanation of these differences, a comparison was made between the features seen in the processed film, and the original patterns as viewed through a piece of neodymium glass, which, as is well known, exerts a powerful absorption in the wavelength range between 570 and 600 mμ and thereby effectively excludes the yellow sector of the spectrum, its absorption in the rest of the spectrum being relatively negligible. The interference pattern as seen in white light through the neodymium glass, and the same pattern as recorded on the colour-film without the neodymium filter showed many features in common, and could indeed be described as resembling each other closely.

The facts stated above are evidently of such high significance that it seems desirable to proceed to some further detail. The extremely important role played by the yellow sector of the spectrum in determining the features of the Newtonian interference pattern may be demonstrated in the following manner. The pattern is viewed by reflected light, one-half of it as seen with white light, and the other as seen with monochromatic yellow light, e.g., the light of a sodium lamp. The two halves appear in juxtaposition, and there is an astonishingly close coincidence between the two sets of rings. Indeed, the rings as seen with sodium light appear as continuations of the rings seen with white light, the first five minima of illumination which are conspicuously evident in the white-light pattern appearing in positions indistinguishable from the dark rings of the sodium-light pattern.

As viewed through the neodymium glass, as also in the white-light pattern as photographed on a colour-film, we observe in the first place, that the rings which are visible are far more numerous. Further, the entire field of interferences exhibits alternate regions which are totally different in their observable characters. In one region, we find vivid colours, and this is followed by another in which there is a succession of dark and bright rings with no noticeable colour and this again is followed by a region in which colours are distinctly visible. The removal of the yellow sector by the neodymium filter evidently produces these effects on the interference pattern as seen visually. That the same effects are noticeable in the pattern recorded in the colour film indicates that the photographic technique employed for recording colour takes no account of the existence of an independent and extremely powerful yellow sector in the spectrum of white light.

Essentially similar differences are also noticed between the interference pattern of a wedge-shaped air-film as observed visually with white light and as photographed in colour with a Kodak film. Likewise, the pattern visible in white light but with a neodymium glass filter interposed shows a remarkably close correspondence with the features noticed in the photographic colour film record of the white-light pattern. We draw the same inference, viz., that the photographic techniques used for the reproduction of colour fail to take into account the existence of an independent and extremely powerful yellow sector in the spectrum. In other words, they make the mistake of assuming that the yellow of the spectrum is adequately taken care of when it is regarded as a superposition of the green and the red of the spectrum. This, of course, is one of the fundamental errors which vitiates the trichromatic theory of colour, as has already been demonstrated in other ways in earlier chapters. The extraordinarily important role that the yellow sector of the spectrum plays in the visual synthesis of colour has been illustrated in those chapters by numerous examples, viz., the colours of flowers, the colours of dyed silks, of natural and synthetic gemstones, as also structural colours of various sorts. One need not therefore be surprised that the reproduction of colour by photographic processes is, in general, only an approximation to the reality.