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The new physiology of vision—Chapter XXIX. The reproduction of colour

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We live in a colourful world and we are educated by our environment to love and admire colour. The blue sky, the red glows of sunrise and sunset, the green colour of vegetation and the varied hues of flowers are always with us as a reminder of our ability to perceive colour and to distinguish even subtle differences in colour. Inevitably, therefore, man has sought to emulate Nature and to surround himself with various products of his own handiwork which display colours rivalling those of Nature. We need only mention a few examples. The dyeing of textiles and the production of ceramic wares are fields in which human ingenuity has sought to produce works of art which, while they derive their inspiration from the products of Nature, differ from many of them in exhibiting the quality of permanency.

A further consequence of the love of colour is the desire to record the fleeting scenes of colour with which Nature provides us in a more enduring form. The art of painting in colour had its origin in this desire, but has developed into one of the highest forms of expression of the human spirit comparable in its value and appeal to any others which could be mentioned. But this way of reproducing colour has its limitations. It is laborious and time-consuming, and the excellence of the final product is a highly variable and uncertain quantity. Further, when a picture has been painted which has an enduring value, those who wish to see it have to travel—if necessary to the other end of the earth—to the place where it has found a resting place.

The foregoing is an attempt to explain the reasons why the reproduction of colour by quasi-mechanical processes has, at the present time, assumed an importance comparable with that of the closely allied art of printing. The development of the processes by which colour is reproduced has been essentially on an empirical basis in which trial and error have played the major role. Nevertheless, useful guidance has been forthcoming from experience gathered in other fields of activity in the production of colour, viz., painting and dyeing. To some extent also, it has benefited by the reported results of the studies on colour mixing made by physicists and others in the nineteenth century.

We shall here approach the subject of colour-reproduction from the new points of view indicated by the studies on colour described in our preceding chapters.

We shall choose a specific case of a physical phenomenon in which we observe colour and which has the merit that it can be called into existence exhibiting identical characters whenever desired. We then set ourself to the problem of how a picture of it can be made which can claim some measure of resemblance to the original.

The phenomenon which is here referred to is that of the colours of interference, the best-known example being that of Newton's rings as seen in white light under sufficient magnification. A detailed description of these rings has been given in an earlier chapter in which the highly important role played by the yellow sector of the spectrum in the effects observed has been clearly set out. The major feature of these rings is the fluctuations of luminosity which exhibit themselves as a regular succession of maxima and minima of illumination. The positions of these maxima and minima are determined by the wavelength of yellow light and this is shown by actual measurement of the positions of the minima of illumination to be 579 mμ. The minima of illumination are highly pronounced: in particular the first minimum is almost perfectly black, and the second minimum is also very dark.

If now it is proposed to produce a picture of the rings as we see them on a piece of white card with a small brush and using coloured inks of different sorts, it is evident that a minimum of *four* inks of different colours would be needed: black ink, yellow ink, red ink and green ink. The black ink would be needed for exhibiting the central black area in the ring system, and the first two or three of the minima of illumination which cannot otherwise be represented. The yellow ink would be needed to exhibit the colour of the brightest part of the first three rings in the pattern. The red and the green inks would be needed to represent the colours in the regions respectively preceding and following the circles of minimum illumination in the first few rings. They would also be needed to represent the alternations of colour perceived in the outer rings of the pattern.

It is obviously not an accidental circumstance that in the processes of colour printing, it is also customary to use four colours, viz., yellow, magenta, cyan and black in the order stated. Usually, the first printing is with the yellow ink, the second printing is with the magenta ink, the third printing is with the cyan ink, while the fourth printing is with black ink. The last printing completes the picture which would otherwise fail to exhibit the local contrasts in respect of brightness exhibited by the object itself.

Some remarks may be made here regarding the three coloured inks used in process-colour printing. White printed on with magenta ink may be described as exhibiting a colour which is predominantly red. But spectroscopic examination reveals that while the green and yellow sectors are both much weakened, the red sector is accompanied by the blue sector with quite appreciable intensity. Likewise, the cyan ink shows both the green and the blue sectors in great strength while the yellow and red sectors are both much weakened. A white surface which has been printed upon with yellow ink when examined spectroscopically shows that the observed colour is the result of the nearly complete extinction of the blue sector, while the green, yellow and red sectors are all present in practically undiminished strength.

It is necessary to indicate how the four blocks used respectively for the four printings are prepared. The negative for the yellow printer is made by using a blue filter when photographing the object. Likewise, for the magenta printer a green filter is used and for the cyan printer, a red filter. For the black printer several alternative procedures are available, the simplest being the use of a yellow filter. The choice of the filter used in making the three colour-separation negatives is based on the idea that the colour which is transferred to the paper by the printer should be complementary to that transmitted by the filter used in making the negative.

It should also be mentioned that the printing blocks are prepared by the half-tone process. The cross-line screen used in the process results in the breaking up of the picture into thousands of dots of light of varying sizes. These dots would appear in the impressions recorded on the paper by each of the four printing blocks. It should be emphasised that it is not the intention that the sets of dots in the impressions left by the four blocks should be coincident. On the other hand, to avoid such coincidences as far as possible, the half-tone screens are set at different angles to each other, these being so chosen as to avoid the appearance of moire patterns or other objectionable features in the reproductions. To secure these results it is sometimes found desirable to use a different screen-ruling for the yellow plate than for the plates of other colours.

If, in the picture as finally printed, the dots of different colours do not actually overlap, the eye is presented with a mosaic in which areas of white, black, yellow, magenta and cyan of varying sizes are interspersed. It would evidently be not possible for the eye to take note of their individual presence and the visual impression would therefore be a synthesis in which the effects of the individual areas are integrated into a single sensation. This sensation would depend on the relative proportions of the five areas exhibiting different colours. As the absorption spectra of the three coloured inks are very different, we may expect that a wide range of colours would be exhibited in various cases.

When photographic reproductions in colour are viewed through a magnifier, the structures which appear in them as areas of colour are immediately recognisable. In some cases, they exhibit hexagonal outlines, in others they appear as squares. The sizes of the individual dots and the colours which they show can readily be related to the colour exhibited to the eye by the entire group. Where the colour is yellow or blue-green or magenta, the dots of those colours are naturally predominant. In areas exhibiting other colours, the presence of dots of two or three different colours is evident and their influence on the perceived colour is readily traceable.

Summing up, we may say that when we view a photographic reproduction in colour, in general we perceive hues which are not really there, but represent a synthesis effected within the eye of the observer. The actual processes employed and especially the need for a fourth block which prints in black and white is a clear disproof of the idea that the reproduction of colour is based on the trichromatic hypothesis of colour perception.