Colour Vision.*

By Prof. H. E. ROAF.

THE physiological problem in colour vision is to determine the varieties of receptors which are present in the retina. An experimental investigation of some aspects of this problem is summarised below.

The best starting point is the result of some investigations on hypochromats (colour-blind individuals).[1] The object was to find out if there was any particular region of the spectrum in which they differed from the 'normal'. They were asked to copy geometrical designs in colour, and the copies were compared with the originals in the light of a recombined spectrum from which any specified region could be eliminated. It was found that agreement could be obtained only if the long wave-length end of the spectrum was eliminated. The cases varied in the extent to which the spectrum must be cut down, but it is not certain whether this was due to differences in the degree of the defect or to mere chance: that is, they might make different mistakes in making another copy. At the same time, there is not necessarily any diminution in sensitivity to light (rise in threshold) even to those parts that they fail to discriminate.[2] This is one of the main objections to the Young-Helmholtz hypothesis.

The graph relating wave-length to change in wave-length necessary to produce a visible difference in colour shows two minima (maxima of discriminating power), one about 5800 A. and the other about 4900 A.[3] In hypochromats the former is absent, whilst the latter is as well marked as in 'normals'. This is further evidence that there is a failure to discriminate between the long wave-length and neighbouring parts of the spectrum. It can be said that the hypochromat fails to discriminate what affects the normal as a red element; thus a yellow by loss of red value is matched with green.

To explain the phenomena revealed by the preceding series of experiments, we have to imagine some system whereby the differences between 'red' and 'green' are diminished or abolished without an alteration in the threshold to light from the long wave-length end of the spectrum. On the other hand, the difference between 'green' and 'blue' (neutral region of hypochromats) is as great as with normal individuals.

A type of experiment which ought to show to what extent separate receptors are stimulated by different regions of the spectrum is to shine two lights on the same area of the retina and to measure to what extent they interfere with each other. Quite different results were found for central and peripheral vision.[4]

For central vision, long wave-lengths raise the threshold for all regions of the spectrum, whilst shorter wave-lengths have comparatively little effect on longer ones. Fig. 1 shows an experiment of this sort with three different backgrounds. The ordinates show the multiple of the absolute threshold which is necessary in order to produce a noticeable difference against the background. It is clear that a background of 6214 A interferes with the visibility of all parts of the spectrum, whilst backgrounds of 5404 A. and 4708 A. have comparatively little effect on the 'red' end of the spectrum. An additional point is that the curves are horizontal down to about 6000 A., which suggests that this part of the spectrum varies only in brightness, and not in colour, with alteration in the wave-length.

With peripheral vision, short wave-lengths raise the threshold for the whole spectrum.

These experiments suggest that there is some common underlying factor in all sensations of light: a fact which is recognised by Hering's assumption that there is a black-white substance and by the spreading out and overlapping of the sensation curves in the Young-Helmholtz hypothesis.

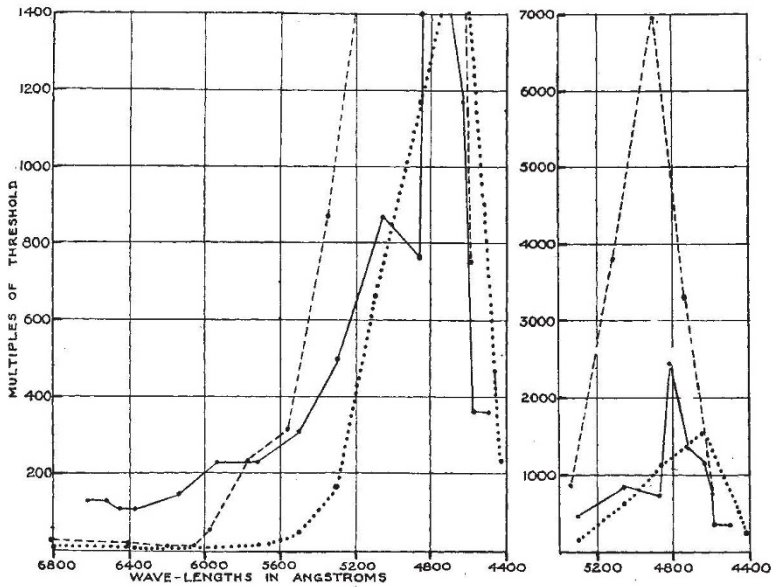

FIG. 1.—Ordinates, multiples of absolute threshold; abscissæ, wave-lengths in A. In order to show the higher values a part of the range is reproduced in one-fifth of the scale. Continuous line, background of 6214 A.; interrupted line, background of 5404 A.; dotted line, background of 4708 A.

It is possible to explain the facts of colour vision on the assumption that there are three sets of receptors (see Fig. 2):

(*a*) One which is stimulated by the whole of the visible spectrum and this may correspond with the sensation curve of the dark adapted eye;

(*b*) One which is stimulated by long and medium wave-lengths from the extreme 'red' end to about 4900 A.;

(*c*) One which is stimulated by long wave-lengths from the extreme 'red' end to about 5800 A.

As shown by the diagrams in Fig. 2, the long wave-length end of the spectrum stimulates all three sets of receptors and the short wave-length end stimulates only one set. That the short wave-length end of the spectrum stimulates a special mechanism is shewn by measurements of visual acuity.[5] Wave-lengths less than 4900 A. have a low ratio of intensity to brightness and to visual acuity. Additional evidence that the 'blue' mechanism is stimulated by the whole spectrum is that blue is seen when a pure long wave-length stimulus is looked at slightly eccentrically.[6]

* Substance of a contribution to a joint discussion—"In what Sense can we speak of Primary Colours?"—of Section I (Physiology) and Section J (Psychology) of the British Association at Bristol on Sept. 8.

The three sets of receptors might be explained on the basis of three photochemical substances or that there is one photochemical substance with coloured filters in front of the receptors. The second suggestion receives support from comparative anatomy, as amphibians, reptiles, birds, and marsupials all have

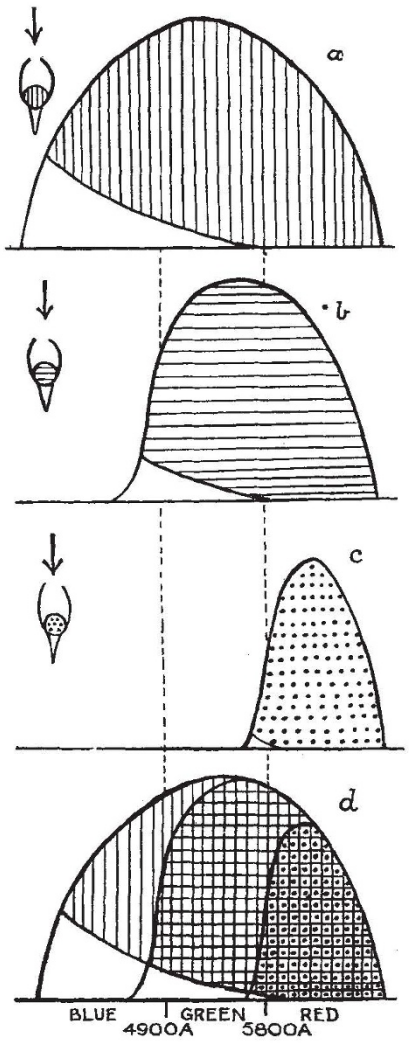

FIG. 2.—(*a*) Sensation curve for receptors sensitive to the whole of the visible spectrum.
(*b*) Sensation curve for receptors which fall off rapidly in sensitivity about 4900 A.
(*c*) Sensation curve for receptors which fall off rapidly in sensitivity about 5800 A.
(*d*) Superposition of the three sensation curves. The clear area indicates the photochromatic interval. The shift of maximum brightness with increase in intensity may be due to the effect of stimulating more than one set of receptors at the long wavelength end of the spectrum. For the hypochromat the dots would be deleted, leaving the other two sets of receptors active as in the 'green' area.
Insets: cones from hen's retina with corresponding coloured globules. The arrows show the direction of light.

coloured globules in front of the cones. As shown by the insets on the diagrams, those for the hen (red, yellow, and almost colourless) agree with the sensation curves deduced from experiments on human vision.[7] If such coloured globules should be discovered in the fovea of the human retina, the facts of colour vision would be explained. Perhaps, instead of cones with almost colourless globules, the rods may be the structures stimulated by the whole of the visible spectrum in the peripheral part of the eye. That cases of *retinitis pigmentosa* are blue blind is in favour of the blue sensation being the result of stimulation of rods.

This view is as sound from the photochemical point of view as the Young-Helmholtz hypothesis. It does not require quite so much unsupported speculation and it agrees better with the facts.

[1] Roaf, *Quart. Jour. Exp. Physiol.*, **14**, p. 151; 1924.
[2] Bradbrooke and Roaf, *ibid.*, **15**, p. 447; 1925.
[3] Roaf, *ibid.*, **16**, p. 379; 1927.
[4] Roaf, *ibid.*, **18**, p. 243; 1928.
[5] Roaf, *Proc. Roy. Soc.*, B, **106**, p. 276; 1930.
[6] Roaf, *Jour. Physiol.*, **69**, proc. p. 1; 1929.
[7] Roaf, *Proc. Roy. Soc.*, B, **105**, p. 371; 1929.

Preservation of Fish at Sea.*

FISH, even when kept in ice, soon show signs of deterioration which gives rise to 'staleness'. There are degrees of staleness, and a stale fish is not necessarily unfit for human consumption, but it is nevertheless of poor quality in the eyes of the market buyer and fetches a correspondingly lower price. If, therefore, means could be found to bring fish to market in a fresher condition after voyages of several days, the fish would sell at a better price, and the consumer enjoy a better article.

The deterioration of the fish may be caused either by intrinsic changes or by the effects of bacteria; it was one of the first aims, then, of the research to find to what degree either of these two causes was responsible for the staleness of fish. Research was carried out on board two steam trawlers specially fitted for the purpose. It has been shown that by far the more important factor in the staling of the fish is bacterial action, and that aseptic methods go far to keep the fish in good condition while at sea. This finding gives much satisfaction, as it shows at the start that results which may be of economic value to the fishermen can be obtained.

Cooling with ice does not stop bacterial action; it merely slows it down. It is therefore of importance that the fish should be thoroughly washed, after gutting, under aseptic conditions so far as possible. This, although it by no means sterilises the fish, reduces the initial contamination to a minimum and tends to keep the fish from rapid deterioration when stowed under suitable conditions. Full details and suggestions are given in the report for the equipment of trawlers with the necessary plant, and it is estimated that a capital expenditure of about £500 would be entailed and the running costs increased by about £400 a year. It remains to be seen whether the fishing trade will consider this outlay a financial proposition.

Since the introduction of the aseptic method would only extend the period during which a fish will keep fresh from 6-7 days to 10-12 days, it follows that it will only be of real value to short-distance vessels. While it would help towards keeping a larger proportion of the catches of long-distance vessels fresh, there would still be a large amount of fish caught early during the voyage that would inevitably become stale, or even bad. For the vessels making long voyages the possibilities of brine-freezing are being explored. The possible commercial advantages of this method are, however, not so sure, because, although the good flavour of the fish is preserved, the fish itself loses much in appearance; it can therefore only be taken by the salt-curers and smoke-curers.

* Department of Scientific and Industrial Research: Food Investigation. Special Report No. 37: The Handling and Stowage of White Fish at Sea. By Adrian Lumley, J. J. Piqué and Dr. George A. Reay. (London: H.M. Stationery Office.)