RETINAL OXYGEN SUPPLY AND MACULAR PIGMENTATION

IN their recent communication under the above title, Drs. Dartnall and Thomson[1] write that the presence of the yellow pigment in the fovea of the human eye will make it less efficient for vision; they suggest that the pigment is there to carry oxygen to those regions of the fovea which have no capillaries.

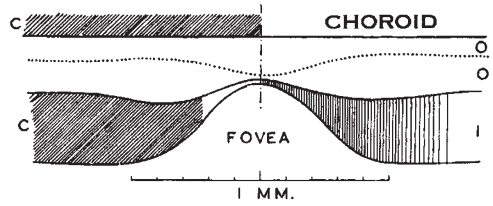
The presence of a pigment with a strong absorption in the blue may, however, be an advantage, rather than a disadvantage, from the point of view of visual acuity, because chromatic aberration becomes greatly disturbing at the short-wave end of the spectrum. Fick[2] as early as 1875 stated that it is the chromatic aberration which will set a natural short-wave limit to the human visible spectrum. It would therefore seem appropriate that the region of the highest acuity should be made less sensitive to short-wave radiation.

In blue or violet light the human 'emmetropic' eye is actually myopic, to the extent of about 1 dioptre[3,4]. Absorption of the blue and violet radiations on their way to the photo-receptors should therefore be beneficial for accurate focusing of the retinal image in ordinary daylight. It is true that objects which reflect blue or violet radiations will then tend to look darker than they would otherwise look; but this is not necessarily always a disadvantage. On the contrary, when they are seen against a bright background of another colour, this will increase the brightness contrast and improve acuity. Thus it is not unreasonable to suppose that the function of the yellow pigment of the macula may be to absorb these short-wave radiations in order to improve foveal acuity.

The suggestion that the yellow pigment may be concerned in the respiration of the tissues of the fovea receives little support from a consideration of its distribution, as shown in the accompanying diagram. First, according to Schultze[5] and Polyak[6], the pigment is only found in the inner layers of the retina, being absent from the outer layers which contain the photo-receptors. The respiration of these outer layers, which account for most of the retina's thickness in the capillary-free area of the fovea, must therefore be carried out without the aid of the pigment. Secondly, the major part of the yellow pigment is found in the foveal slopes[5,6] which have capillaries[7,8], and in which it should apparently not be needed for respiration.

In the extra-macular region, it is probable that respiration depends on oxygen supplied to the tissues by diffusion from the capillaries of the choroid and of the inner retinal layers. Referring to the geometrical conditions as shown in the diagram, one may wonder whether foveal tissues cannot be supplied in the same way. In view of the lack of information on the oxygen requirements of the various retinal layers and of the diffusion constant of oxygen through them, it is not possible to establish this point by quantitative calculations[9]. However, Wagenmann[10] showed that the outer layers depend mostly on the choriocapillaries for their nutrients. On this basis, if we take it that these layers receive a sufficient oxygen supply from the choriocapillaries alone, the supply should also be adequate for the whole of the fovea—since the capillary-free part of the fovea is little or no thicker than the outer retinal layers at the edge of the yellow spot.

In any event, while a pigment in the retinal tissues could store oxygen, it is not clear how it could increase the *rate* of supply of oxygen to them under the *steady-state* conditions which must generally prevail in daylight.



Distribution of capillaries and of yellow pigment in the macular region

On the left, the areas containing capillaries are shaded with diagonal lines (*C*, *C*). This shading does not bring out the fact that there is a dense sheet of capillaries in the choroid next to the outer retinal layers[11], while capillaries are more sparsely distributed in the inner layers[8,12]. On the right, vertical shading gives a rough indication of the pigment concentration. The outer retinal layers are denoted by *OO* and the inner layers by *I*. Dimensions and yellow pigment distribution after Schultze[6] (compare with Polyak[13]). Size of capillary-free area according to Weale[7]

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[1] Dartnall, H. J. A., and Thomson, L. C., *Nature*, **164**, 876 (1949).
[2] Fick, A., in Hermann's "Handbuch der Physiologie", 3, Pt. 1, 182 (1879).
[3] Shlaer, S., Smith, E. L., and Chase, A. M., *J. Gen. Physiol.*, **25**, 553 (1942).
[4] Wald, G., and Griffin, R. D., *J. Opt. Soc. Amer.*, **37**, 321 (1947).
[5] Schultze, M., *Arch. mikr. Anat.*, 2, 175 (1866).
[6] Polyak, S. J., "The Retina", 198 (Chicago, 1941).
[7] Weale, R. A., quoted by Dartnall and Thomson, ref. 1. In the latter paper, 1° 30″ is a misprint and should read 1 degree 30 minutes (personal communication from Dr. Dartnall).
[8] Polyak, ref. 6, p. 207.
[9] Hill, A. V., *Proc. Roy. Soc.*, B, **104**, 39 (1928–29).
[10] Wagenmann, *Arch. f. Ophth.*, **36** (4), 1 (1890), quoted in Duke-Elder, ref. 11, p. 481.
[11] Duke-Elder, Sir Stewart, "Textbook of Ophthalmology", 1, 55 (1932).
[12] Duke-Elder, ref. 11, p. 142.
[13] Polyak, ref. 6, p. 447.

IN their letter in *Nature* of November 19, Dr. Dartnall and Dr. Thomson advance the view that the macular pigment plays the part of an oxidation-reduction system in the human macula and fovea. I do not feel that a satisfactory case has been made out for the existence of this pigment at the fovea; nor for the need for an auxiliary oxygen-carrying system.

(1) Dartnall and Thomson do not refer in their letter to the fact that the retina has a double blood supply: a superficial supply by means of the retinal vessels, and a deep supply by means of the choroidal vessels. The former consists of a coarse net of narrow bore blood vessels with few widely spaced capillaries. The latter consists of a dense feltwork of blood vessels which supply arches of capillaries so closely meshed that few parts of the adult human body present a similar picture. In consequence, these vessels provide the outer side of the retina with a blood supply of a richness probably not exceeded anywhere else. Thus the statement which Dartnall and Thomson make is true, namely, that there are no retinal vessels at the foveal centre. But the