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THE CILIO-RETINAL ARTERIES*

BY

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THE cilio-retinal vessels, which supply a localized area of the retina, have been described in the literature by a large number of authors. They were discovered by Müller (1856). Loring (1872) described them in his three cases, and they were first demonstrated histologically by Nettleship (1877), who considered them as communications between retinal and ciliary vessels (1876a). Lang and Barrett (1888) defined a cilio-retinal vessel as "one which dips into the nerve near the margin of the optic disc and which can be seen to arch outwards", and did not regard a vessel without this curve as cilio-retinal. Nettleship (1876b) also found that the vessel turned sharply back on reaching the temporal margin of the disc to disappear under the rim of the choroid, and Jackson (1911) stated that the artery curved as it emerged. This sharp loop was described as a diagnostic feature of this artery by Salzmann (1912) and Duke-Elder (1938).

The incidence of the presence of the cilio-retinal vessels has been given variably by various authors (20 per cent. by Randall, 1887; 16·7 per cent. by Lang and Barrett, 1888; 14 per cent. by Elschnig, 1897, 1898; 19·1 per cent. by Jackson, 1911; small macular vessels in 11 per cent. and arteries of some size in 6 per cent. by Salzmann, 1912; 19 per cent. by Bailliart, 1923; 8·7 per cent. by Adachi, 1928; 16 per cent. by Bullwinkel, 1954; 14·2 per cent. by Veasey (cited by Blunt, 1956); 15 to 20 per cent. by Bonamour and Gaillot, 1956; 21·6 per cent. by Collier, 1957; more than 25 per cent. by Mann, 1957). It was pointed out by Mann (1957) that it is so common in man that its existence may be regarded as normal. In contrast to this, in 72 eyes examined anatomically by Blunt (1956) and Steele and Blunt (1956), no cilio-retinal artery was seen. Duke-Elder (1932) described the existence of the cilio-retinal arteries in man as exceptional. Nettleship (1876b) generally found it in one eye only. Jackson (1911) saw it equally distributed on the two sides, but Collier (1957) found it bilateral in 18 per cent., on the left in 60 per cent., and on the right in 40 per cent. Bullwinkel (1954) found it on the left side in 56 per cent. Müller (1858) could not decide whether the vessel was an artery or a vein. Nettleship (1876b) found these vessels to be more often veins than arteries, and Elschnig (1897), Jackson (1911), and Salzmann (1912) found veins to be very rare. This latter view is held by the majority. No case with both artery and vein present simultaneously in the same eye has been reported in the literature. A single vessel is usually described (Nettleship, 1876b; Lang and Barrett, 1888; Jackson, 1911) and at times even two (Nettleship, 1876b; Jackson, 1911) or three (Jackson, 1911). Nettleship (1876b), Randall (1887), and Parsons

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(1903) described them as usually small in size though rarely equal to one of the main divisions of the central vessels. Jackson (1911) found large arteries in 22·5 per cent., medium in 28·3 per cent., and small in 49·2 per cent. Coats (1913b) stated that the cilio-retinal artery might be too small to be of any use in cases of central retinal artery occlusion, but Collier (1957) found 93·7 per cent. of them to be functionally available. These errant vessels were seen going to the choroid or sclera by Nettleship (1876b). Randall (1887) found that most of them arose directly from the short posterior ciliaries and passed through or around the edge of the choroid, having no communication with the latter. Birnbacher (1887) found one arising from the choroidal artery in a histological section and similar formations were seen by Czermak (1888), Elschnig (1897), and Fuchs (1923). Elschnig (1897) further stated that they might arise from an artery communicating with the circle of Zinn and with the choroid. Fuchs (1919), Bailliart (1923), and Duke-Elder (1938) stated that they usually arose from the circle of Zinn. According to Bailliart (1923) they arose at times from the posterior ciliaries and very rarely from the choroidal artery, but Elschnig (1898) did not find one arising directly from the posterior ciliaries. According to Parsons (1903), they were mostly derived from the ciliary vessels and not from the choroidal artery.

Nettleship (1876b), Birnbacher (1887), Lang and Barrett (1888), Parsons (1903), Salzmann (1912), Fuchs (1919), Bailliart (1923), Duke-Elder (1938, 1940), and Duke-Elder and Wybar (1961) described them as situated on the temporal side of the disc and supplying macula, but Randall (1887) stated that they might be seen other than on the temporal side and might pass to widely separated areas of the retina. Jackson (1911) found one like a hook in the disc in 44·5 per cent., running from the edge of the disc in 38·7 per cent., starting from the choroid in 16·8 per cent., and distributed to the macula in 98·4 per cent., an incidence which he thought too great to be accidental. Salzmann (1912) and Duke-Elder (1938) described them as occurring on the nasal side very rarely. Collier (1957) in a series of 250 eyes with cilio-retinal arteries found them in the superior temporal quadrant in 47 per cent., inferior temporal in 25 per cent., macular in 15 per cent., superior nasal in 10 per cent., inferior nasal in 3 per cent., and all over the retina in one case.

Nettleship (1876b) found no anastomosis between the cilio-retinal arteries and the other retinal vessels. Collier (1957) stated that such anastomoses were rare, but found them on the papilla in 4·5 per cent., between the stem of the central retinal artery and the cilio-retinal artery in 1·8 per cent., with a branch of the central retinal artery in 1·5 per cent. and between the retinal and choroidal systems in 0·6 per cent. Parsons (1903), Duke-Elder (1938), and Wybar (1956) considered the cilio-retinal arteries to be end-arteries.

Loring (1872) stated that these vessels were seen where the nutrition of the retina had suffered from morbid processes, but Nettleship (1876b) found no association with any disease. Salzmann (1912) stated that a nasal

cilio-retinal artery was associated with anomalies of the papilla. Glees (1956) suggested some genetic association between cilio-retinal vessels and various abnormalities of the retinal vessels, cerebral angiomata, and aneurysms of the cranial vessels, and stressed their value as diagnostic signs. Collier (1957) demonstrated an association of cilio-retinal arteries with congenital anomalies of the optic disc and fundus and with refractive errors (he found ametropia in 195 eyes, of which 47 per cent. were astigmatic; 40·2 per cent. had hypermetropia, with or without astigmatism, and 32·5 per cent. had myopia). Some regard these vessels as possibly newly formed and the result of inflammatory processes.

Nettleship (1905) found that, in lower mammals with a well-developed retinal blood supply, the cilio-retinal vessels took a major part in the retinal circulation and in some species even of the whole of the retina; even when a large number of cilio-retinal arteries were seen, a rudimentary central retinal artery lying in the central fibrous tract of the optic nerve near the eye was always observed. In some species (lemur, camel, otter), the central vessels enter the nerve very close to the eye, suggesting that they are cilio-retinal vessels from the sclera or choroid rather than separate twigs; according to him, the system of retinal blood vessels is the same in monkeys as in man. Mann (1957) has stated that cilio-retinal vessels are very commonly seen in lower animals. Mann (1928) described the development of the cilio-retinal artery by the enlargement of an anastomosis of one of the posterior ciliary arteries with a small branch from the hyaloid artery on the disc. This anastomosis is located in man at the edge of the optic disc where traces of the short ciliaries enter the nerve near the lamina cribrosa in the 3–4 months old human foetus, but these seldom reach the disc (Mann, 1957). She has further added (Mann, 1928) that the presence of the cilio-retinal artery in man may have some atavistic implication. Johnson (1905) thought it might be a vestigial relic in the human eye. Duke-Elder (1932) stated that, in the lower mammals, the ciliary system tends to assume more and more importance, so that in some the whole of the retina is supplied by it. Franck (1893) and Bach (1894) described the absence of the true central retinal artery, and Langenbacher (1880) and Mindelberger (1905) found it anastomosing with the ciliary arteries. In the dog, cat, and the fox there are many ciliary vessels in addition to the retinal vessels (Johnson, 1901; Stockmayer, 1905). In man the absence of the central retinal artery is rare, but many arteries may emerge from the margin of the disc (Lawford, 1895; Bloch, 1906; Salzmann, 1912; Kraupa, 1924), and these are probably due to a division of the central artery within the nerve substance. Schnabel and Sachs (1885) regarded the existence of the cilio-retinal vessel as highly improbable on developmental grounds, and doubted whether retinal branches could ever arise from the ciliary arteries. Salzmann (1953) reported the disappearance of the cilio-retinal arteries in his own eyes with age and he believed the process to be similar to the disappearance of the hyaloid artery.

Benson (1883) described the existence of a retino-ciliary artery arising from the retinal artery and dipping into the disc.

Recently, while studying serial sections of the optic nerve and the adjoining part of the eyeball in Rhesus monkeys, two very interesting specimens have been obtained from one monkey, having multiple and atypical cilio-retinal arteries with abnormalities of the central retinal arteries. Since no such specimen giving anatomical proof of the presence of the cilio-retinal arteries and the absence of the central retinal artery is recorded in the literature so far, these are considered worth reporting.

Observations

In a young Rhesus monkey, weighing about five lb., repeated fundus examinations were made to look for fundus changes in the course of an experiment. The only abnormality noted in the record was the more peripheral location of the main arteries on the disc. Not much significance was attached to this because the rest of the vascular pattern was normal. The peripheral visualization of the main arteries on the disc was thought to be due either to a slightly early division of the central retinal artery in the optic nerve, or to an overlapping of the thick veins of the fundus over the initial part of the arteries near the centre of the disc; also the Bergmeister papilla hid the structures in the centre of the disc (Fig. 1). In retrospect, the gaps between the upper and lower arteries and their adjoining veins on the disc were so small, particularly on the left side, that the fact that they were separate from one another on ophthalmoscopic examination was completely missed. The fundus was considered to be nearly normal, except for the somewhat peripheral location of the arteries. Two very small cilio-retinal arteries on the right side and one on the left were noticed emerging on the temporal margin of the disc.

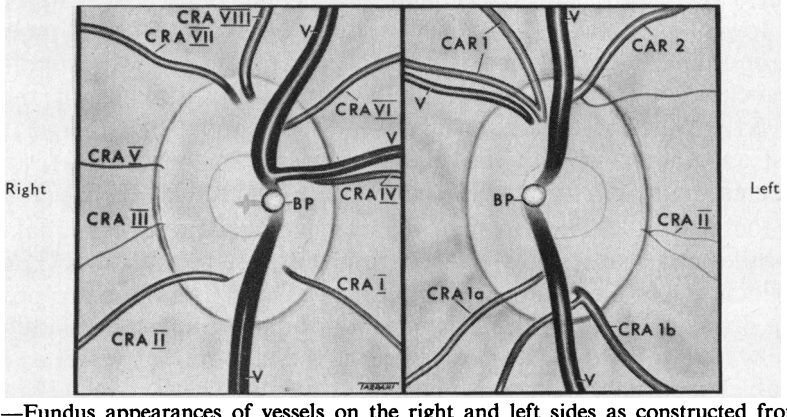

FIG. 1.—Fundus appearances of vessels on the right and left sides as constructed from serial sections—longitudinal on the right and transverse on the left. ×25. No fundus picture was taken.

BP	Bergmeister papilla	CRA	Cilio-retinal artery
CAR	Central artery of retina	I–VIII	Numbered CRA
1, 2	Branches of CAR	a, b	Branches of CRA I in left eye
		V	Vein on optic disc or retina

Both optic nerves with the adjoining parts of the eyeball were serially sectioned at 10μ, the right longitudinally and the left transversely. They are shown diagrammatically as from the medial side with the dural sheath removed in Figs 2 and 3.

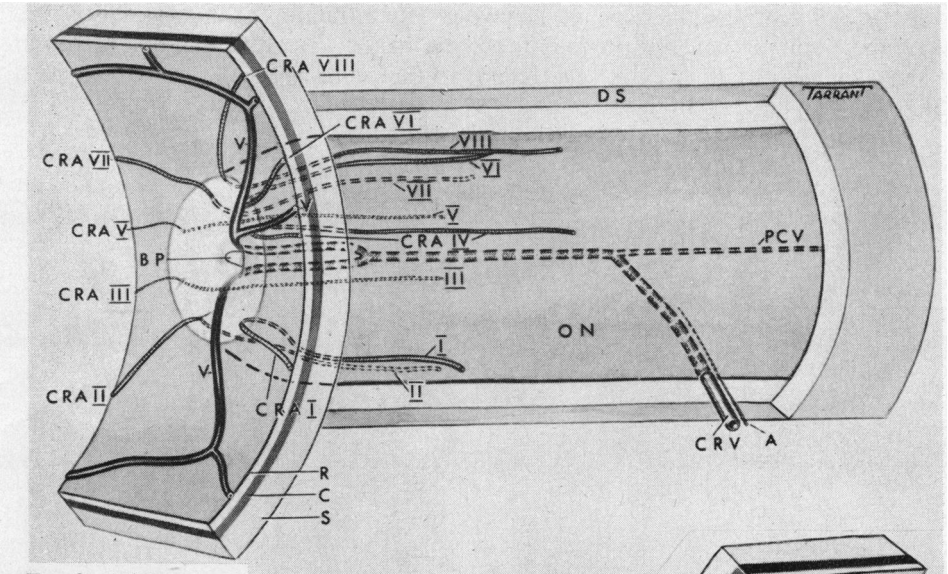

FIG. 2.—Right

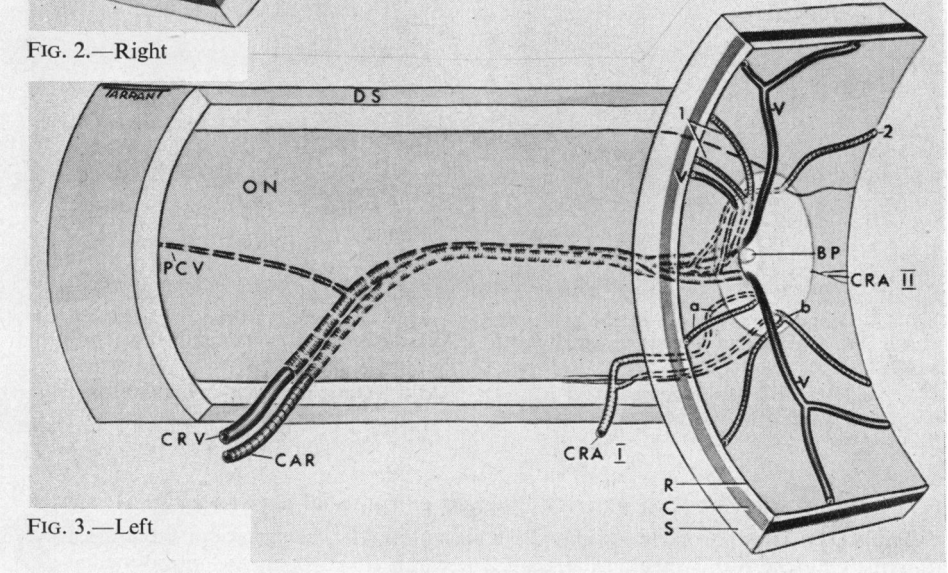

FIG. 3.—Left

FIG. 2.—Diagrammatic representation of vessels of right eye as seen from medial side on removal of dural sheath. Constructed from longitudinal serial sections.

FIG. 3.—Diagrammatic representation of vessels of left eye as seen from medial side on removal of dural sheath. Constructed from transverse serial sections.

C	Choroid	PCV	Posterior central vein
DS	Dural sheath of optic nerve	R	Retina
ON	Optic nerve	S	Sclera

Right Side: In this specimen the central retinal vein had the normal course and pattern but the central retinal artery was absent (Fig. 2).

A very small artery accompanied the central retinal vein within the optic nerve a little distance before its exit from the nerve, and the two pierced the dural sheath of the optic nerve together (shown as "A" in Fig. 2). This artery seemed to be a rudimentary central retinal artery occupying only a fraction of the normal course near the point of penetration into the optic nerve. Near the lamina cribrosa a mass of fibrous tissue was seen lateral to the central retinal vein in that part (Fig. 4).

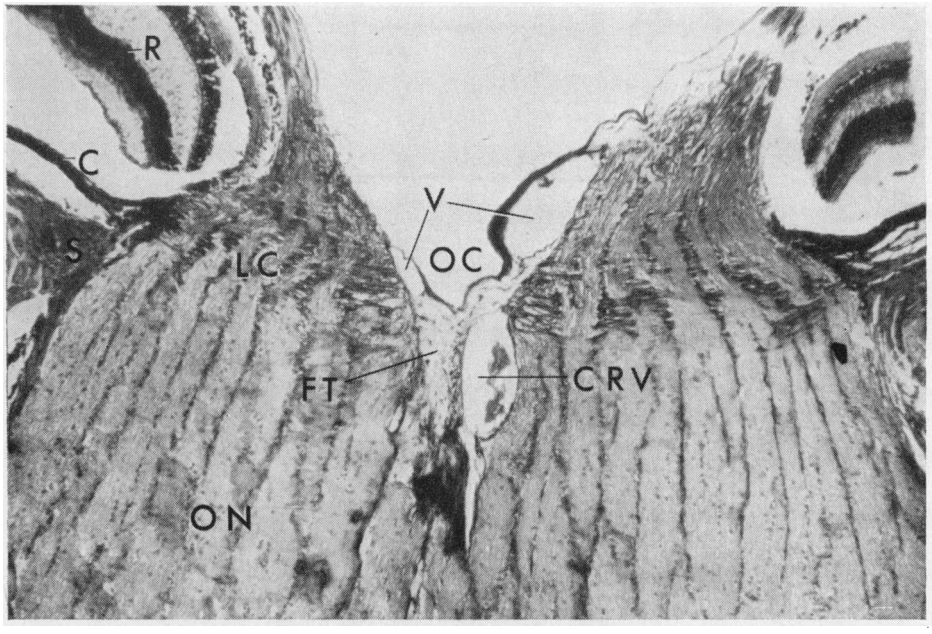

FIG. 4.—Longitudinal section of the right optic nerve head showing a deep physiological cup, central retinal vein, and fibrous tissue lateral to it, representing the central retinal artery, in the lamina cribrosa region. ×75.

CRV Central retinal vein
FT Fibrous tissue
LC Optic nerve in lamina cribrosa
OC Physiological cup

The retina was supplied entirely by eight cilio-retinal arteries (Fig. 1):

(I) and (II): These two arteries joined the pia on the inferior surface of the optic nerve, after piercing the dural sheath (Fig. 2). These ran forward on the infero-medial and infero-lateral aspects of the nerve. In the region of the lamina cribrosa, these lay at first in the border tissue of Elschnig (Fig. 5, opposite) and later entered the optic nerve substance to go to the optic disc (Fig. 6, opposite).

(III): This small artery ran at first on the lateral surface of the nerve in the pia (Fig. 2), and later on in the border tissue of Elschnig to reach the lateral margin of the disc (Fig. 1, and Fig. 7, overleaf).

FIGS 5–12.—Longitudinal sections of right optic nerve and adjoining part of eyeball, showing various cilio-retinal arteries. The sections are arranged serially from the inferior to the superior aspect.

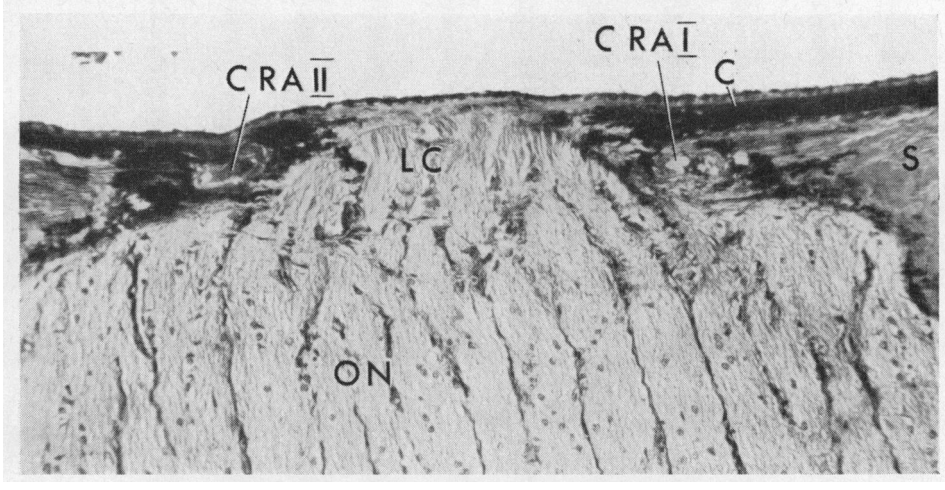

FIG. 5.—Cilio-retinal arteries I and II. ×150.

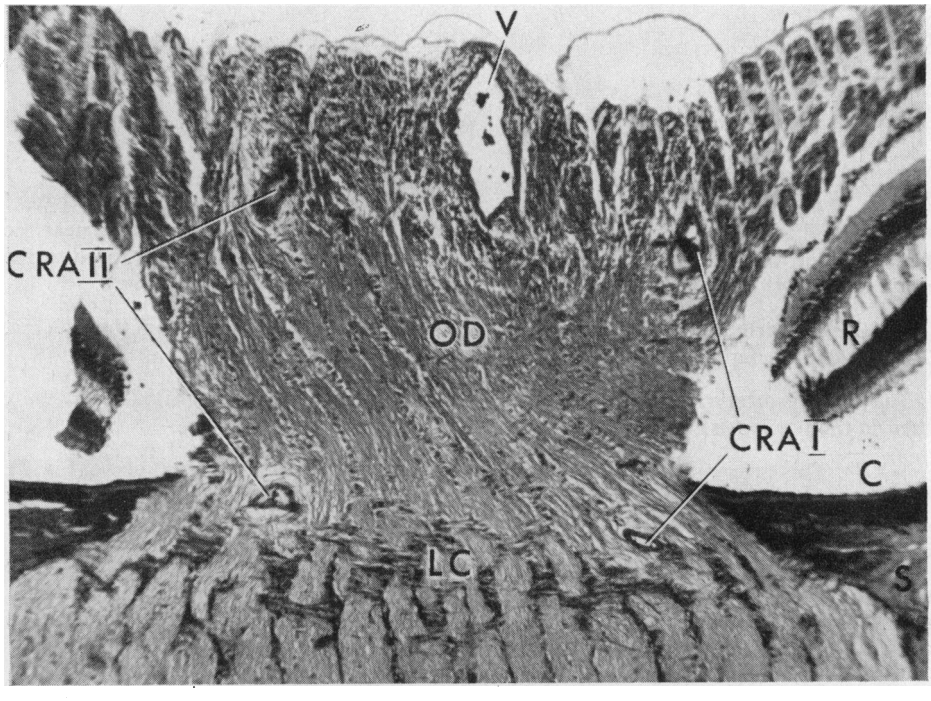

FIG. 6.—Cilio-retinal arteries I and II, 110μ from Fig. 5. ×105.
OD Optic disc

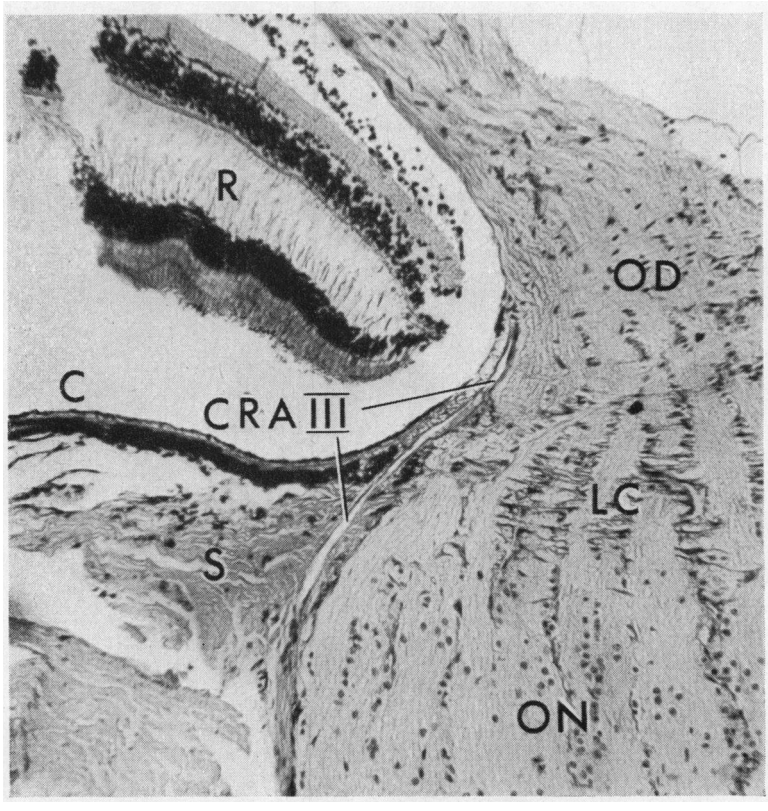

FIG. 7.—Cilio-retinal artery III, 500μ from Fig. 6. $\times$130.

(*IV*): This artery ran in the optic nerve in the region of the lamina cribrosa near the border tissue on the medial side (Fig. 10, overleaf) from the pia (Fig. 2) to go to the optic disc a little distance from the margin (Fig. 1, and Figs 8 and 9, opposite).

(*V*): This artery ran on the lateral side in the border tissue (Fig. 9) from the pia (Fig. 2) to reach the lateral margin of the optic disc (Fig. 1).

(*VI*): This artery ran on the medial side, first in the pia (Fig. 2, and Fig. 11, overleaf), then in the border tissue, and finally reached the disc (Fig. 1).

(*VII*): This artery ran at first in the pia on the lateral side of the optic nerve (Fig. 2), then in the border tissue (Fig. 12, overleaf, p. 81), and reached the disc near its upper margin (Fig. 1).

(*VIII*): This artery arose in common with VI (above) and branched off on the pia to run on the supero-medial surface of the optic nerve (Fig. 2), then in the border tissue, and thence into the optic nerve substance (Fig. 12), to emerge near the upper border of the disc (Fig. 1).

The sites of penetration of the dural sheath by these arteries varied from about 2 to 3 mm. from the eyeball.

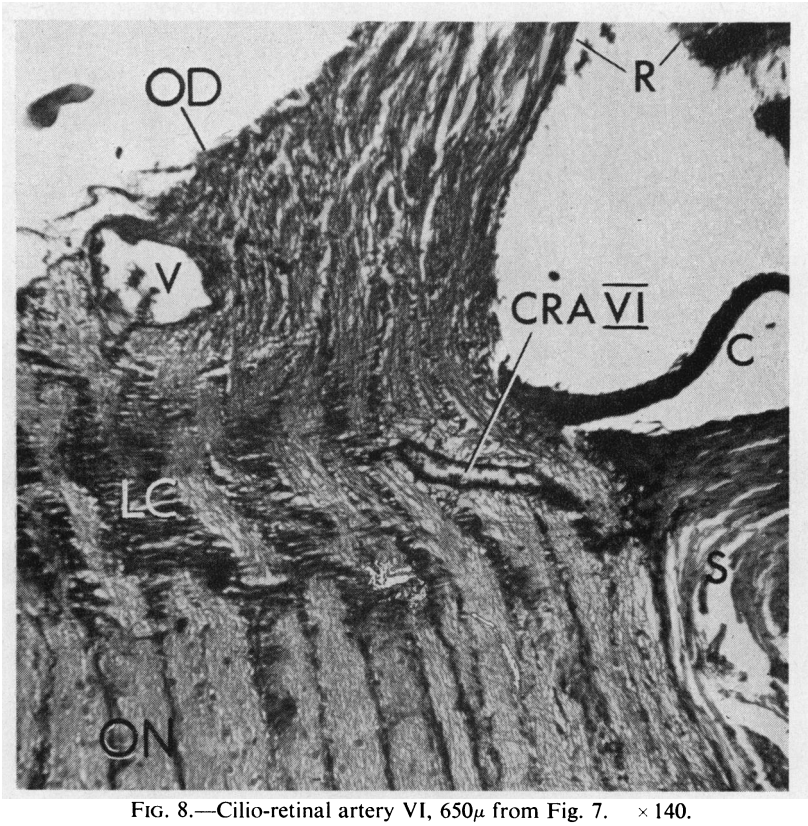

FIG. 8.—Cilio-retinal artery VI, 650μ from Fig. 7. $\times$ 140.

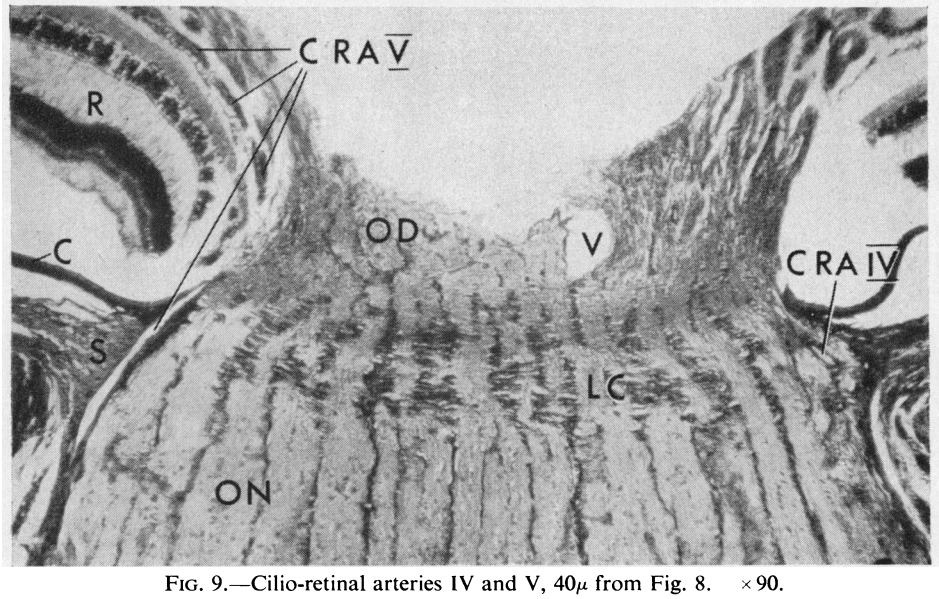

FIG. 9.—Cilio-retinal arteries IV and V, 40μ from Fig. 8. $\times$ 90.

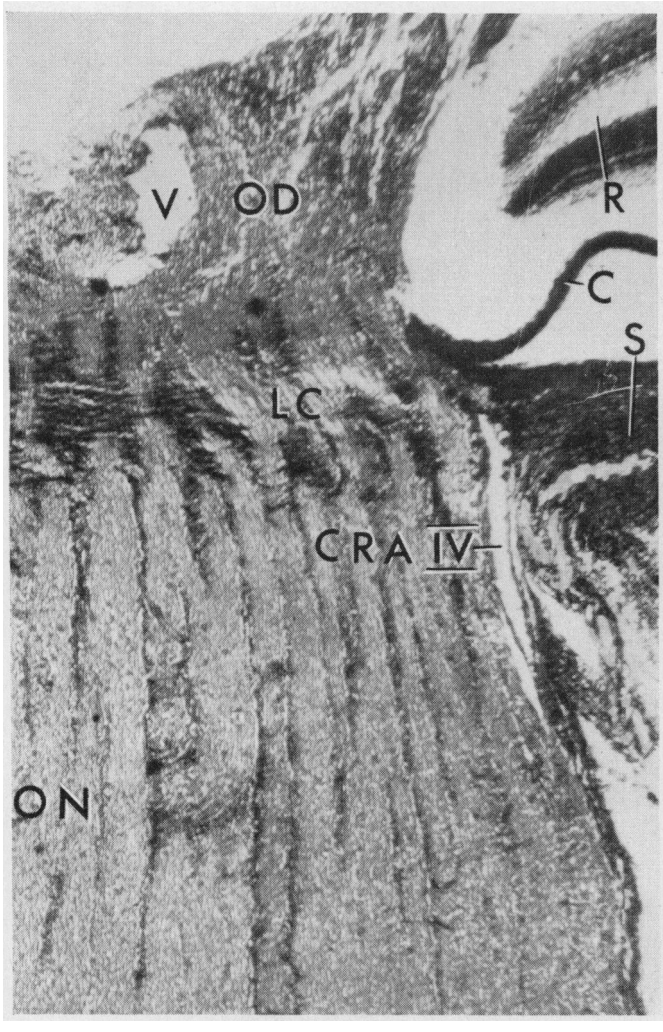

FIG. 10.—Cilio-retinal artery IV, 40μ from Fig. 9. ×130.

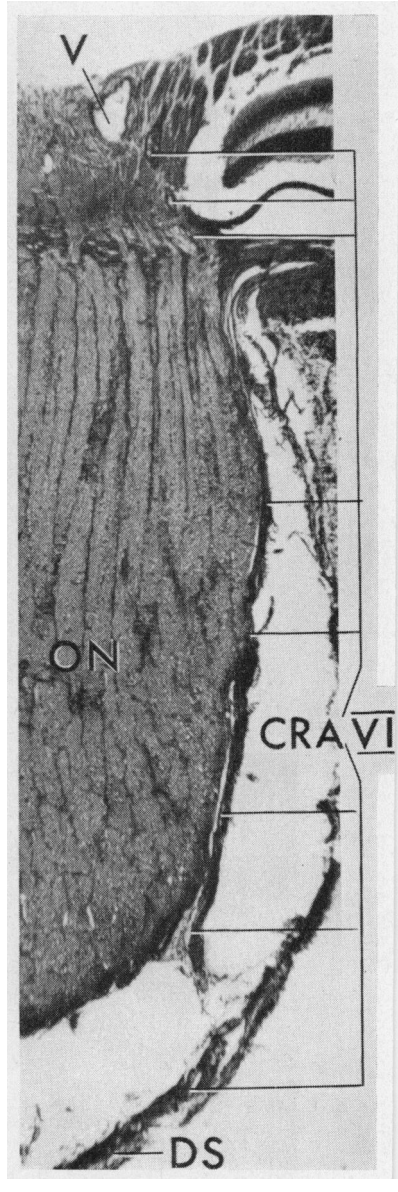

FIG. 11.—Cilio-retinal artery VI, 110μ from Fig. 10. ×70.

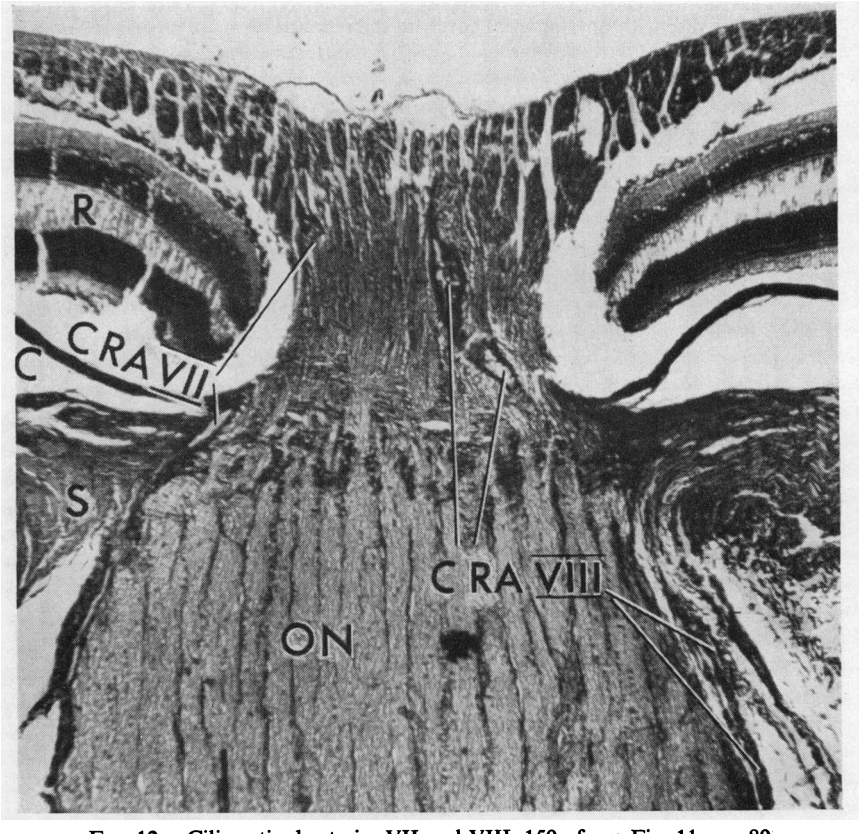

FIG. 12.—Cilio-retinal arteries VII and VIII, 150μ from Fig. 11. ×80.

Left Side: In this specimen, the central retinal artery and vein followed the normal course of the vessels in the optic nerve (Fig. 3). In the region of the lamina cribrosa, the central retinal artery, when it lay between the two divisions of the central retinal vein, divided into two branches, both of which ran upwards into the optic disc and emerged on its surface near the periphery on either side of the superior division of the vein (CAR–1,2 in Fig. 1). So the central artery supplied only the upper part of the retina in this case, and the lower part was supplied by two cilio-retinal arteries:

(*I*): A little behind the eyeball a prominent cilio-retinal artery, arising from the posterior ciliary artery, pierced the dural sheath of the optic nerve and joined the pia on the nerve (CRA–I in Fig. 13, overleaf), where it immediately divided into two branches which ran forwards close together in the pia on the inferior surface (Fig. 3). Before running forwards, it gave off two very small branches to the optic nerve behind. In the lamina cribrosa region, the cilio-retinal arteries were located in the border tissue of Elschnig (CRA–Ia, b in Fig. 14, overleaf, and Fig. 15, overleaf, p. 84).

FIGS 13–16.—Transverse sections of left optic nerve, showing various cilio-retinal arteries and central retinal vessels. The sections have been cut slightly obliquely so that Figs 14 and 15 show, from the lateral to the medial side, the optic nerve just posterior to the lamina cribrosa (ON), in the region of the lamina cribrosa (LC), and in the anterior part of the lamina cribrosa. Fig. 16 shows, from the lateral to the medial side, the choroid, the anterior part of the lamina cribrosa, the optic disc with physiological cup, and the retina.

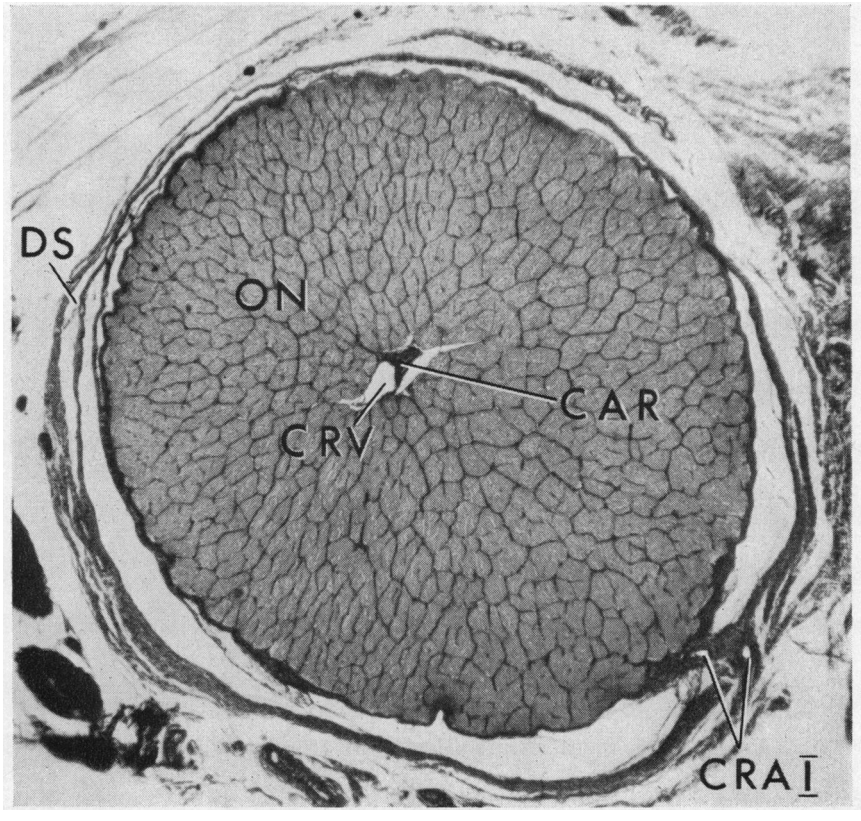

FIG. 13.—Cilio-retinal artery I. ×120.

(*Ia*): In this region, the medial branch bent up sharply to enter the optic nerve substance (CRA–Ia in Fig. 15), and passed into the optic disc nearly midway between the centre of the disc and the periphery (CRA–Ia in Fig. 1). It emerged from the disc under cover of the inferior division of the central retinal vein to run medially and downwards.

(*Ib*): The other branch ran at the periphery and emerged from the disc a little distance from its margin and close to the vein (CRA–Ib in Fig. 1, and Fig. 16, overleaf, p. 85). A branch from it on the disc passed downwards and medially deep to the vein. The cilio-retinal artery thus supplied the whole of the lower part of the retina (Fig. 1).

(*II*): In addition, another small cilio-retinal artery arose from the choroidal arteries (CRA–II in Fig. 16, overleaf), emerged along the lateral margin of the disc, and reached the adjoining retina.

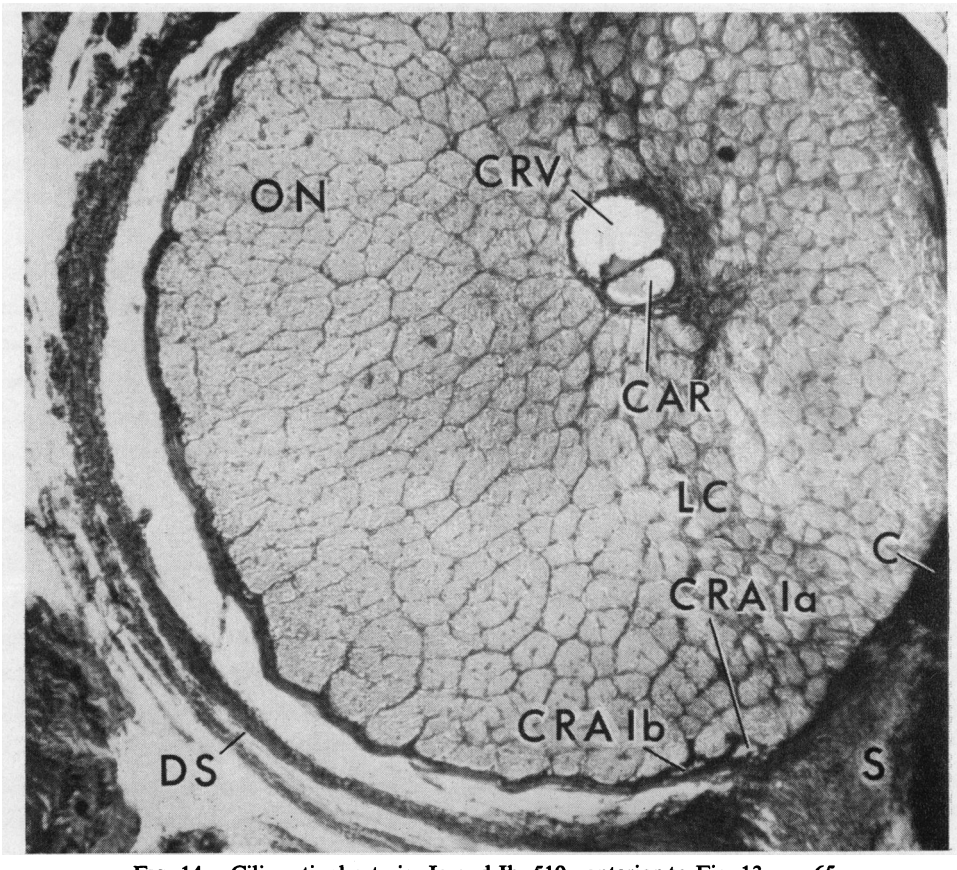

FIG. 14.—Cilio-retinal arteries Ia and Ib, 510μ anterior to Fig. 13. ×65.

Discussion

These two specimens are interesting for many reasons. The number of cilio-retinal arteries seen in the present specimens were eight on the right and three on the left (Figs 1, 2, 3). Such a high number does not seem to have been recorded previously either in man or in the Rhesus monkey though one does come across reports of large numbers in lower species. The cilio-retinal arteries in the two specimens arose directly from the posterior ciliary arteries in the orbit, except for the small temporal branch on the left which arose from the choroidal vessels. These arteries travelled all the way to the retina from the pia of the optic nerve through the border tissue of Elschnig, usually without any communication with the choroidal vessels or circle of Zinn (the latter did not exist in the two specimens).

The location of the cilio-retinal arteries on the optic disc in these two specimens also differed from the characteristic temporal location described in the literature. In the right eye, they emerged on all parts of the disc, *i.e.* large ones situated above, below, and medially, and fine ones on the

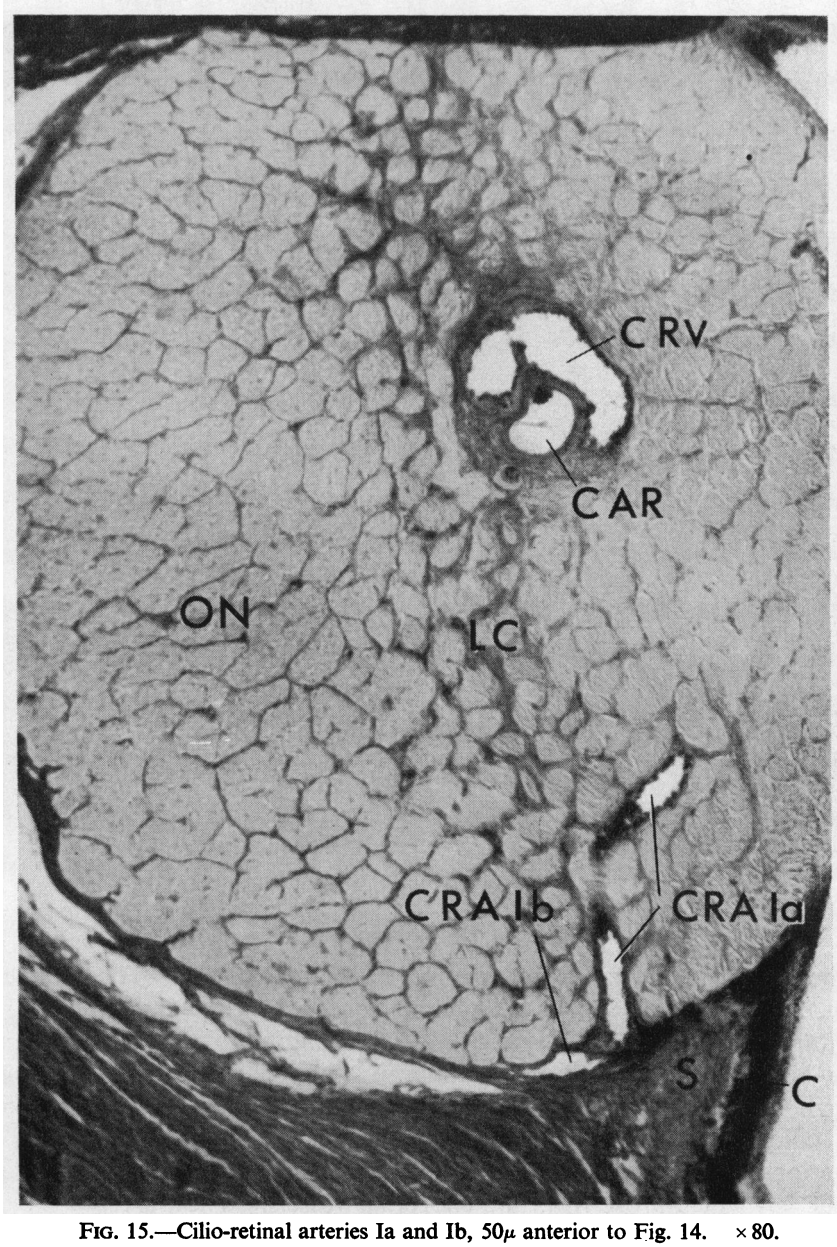

FIG. 15.—Cilio-retinal arteries Ia and Ib, 50μ anterior to Fig. 14. ×80.

temporal side (Fig. 1). In the left eye the large ones were located on the disc inferiorly and the fine choroidal one emerged at the temporal margin (Fig. 1).

The right eye had no central retinal artery (Fig. 2), but its tract was represented anteriorly by fibrous tissue lying lateral to the central retinal vein

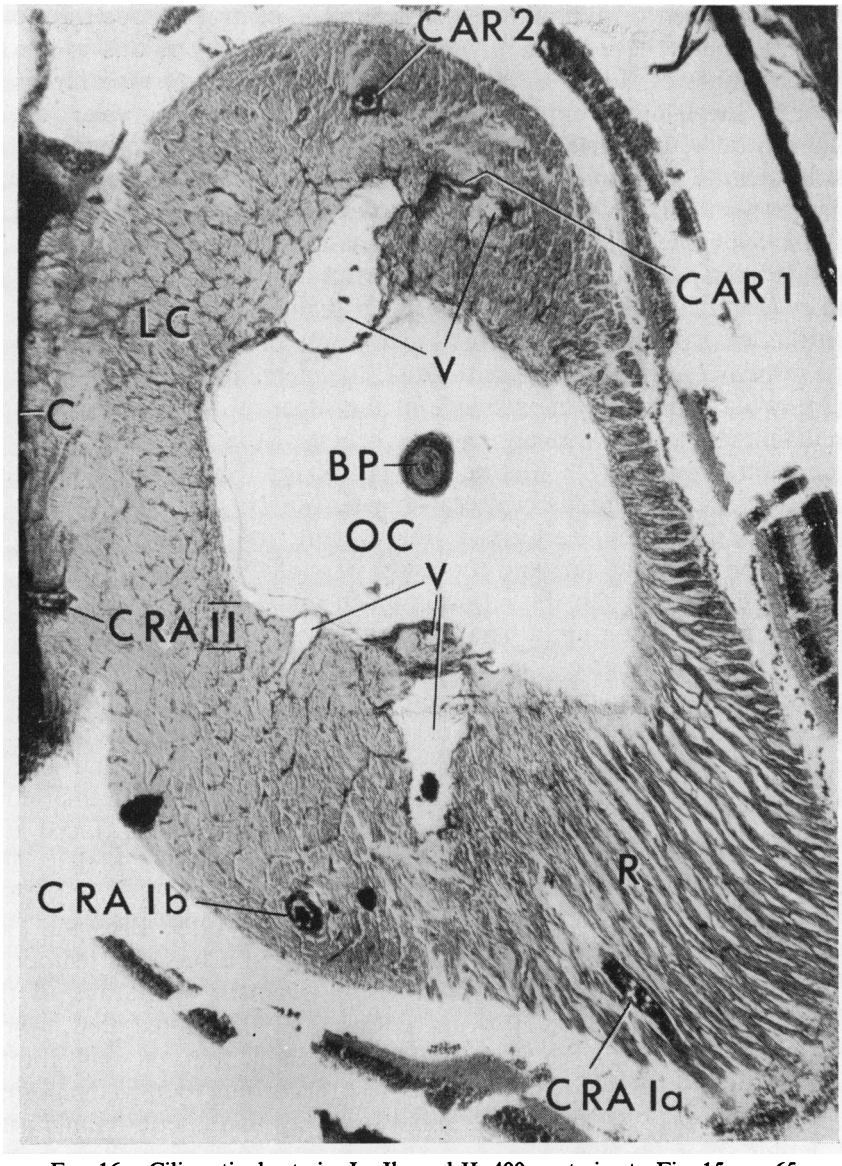

FIG. 16.—Cilio-retinal arteries Ia, Ib, and II, 400μ anterior to Fig. 15. ×65.

just behind the lamina cribrosa (Fig. 4). Posteriorly it was represented by a very small artery accompanying the vein during its vertical intra-neural course and at its point of exit from the optic nerve and dural sheath (Fig. 2). The absence of the central retinal artery here is in sharp contrast to the findings of Nettleship (1905), who was of the opinion that, even when large numbers of cilio-retinal arteries were seen and even in the lower mammals,

a rudimentary central retinal artery lying in the central fibrous tract of the optic nerve near the eye was always present. Moreover, this is the only proved example of the absence of the central retinal artery so far seen in man or in the Rhesus monkey; Collier (1957) described complete absence of the central retinal artery in one case observed ophthalmoscopically but without definite anatomical proof. In a previous study of the central retinal artery in man (Hayreh, 1958; Hayreh and Dass, 1959; Singh and Dass, 1960a, 1960b), the central retinal artery was never seen to be absent in 106 eyes. Similarly, in a recent study of the central retinal artery in the Rhesus monkey (Hayreh, 1962b), no example other than this has been seen.

On the left side the central retinal artery was present but it ran upwards in the optic nerve substance near the disc, to emerge in the upper part of the disc as two arteries one on each side of the superior division of the central retinal vein (Figs 1, 3), instead of at the centre of the disc.

The central retinal vein was normal except for its formation within the optic nerve near the lamina cribrosa on each side (Figs 2, 3).

Hence the cilio-retinal arteries in the present case supplied the whole of the retina on the right side and the lower part of the retina on the left side (Fig. 1). This supply to the retina is much more extensive than has been described in the literature. The clinical appearance of occlusion of the central retinal artery or of one of the cilio-retinal arteries in such a case is likely to be very atypical and to present a complex, unusual, and problematical picture. The preservation of central vision in some cases of central retinal artery occlusion through the function of the cilio-retinal artery is well recognized in the literature. Thirteen cases of cilio-retinal artery occlusion with a normal central retinal artery have also been traced in the literature (Hirsch, 1896; Zentmayer, 1906; Krauss, 1907; Meller, 1909; Levy, 1909; Trappe, 1914; Levitt, 1948; Bottasso, 1948; Gill and Mahaffy, 1949; Marin Amat, 1949; Wittich, 1953; Friedman, 1959; Brosnan, 1962). In all these cases, the distribution of the cilio-retinal artery was temporal to the optic disc and defects of central vision occurred. The age of these patients was mostly about 20 years. Krauss (1907) stated that, when a cilio-retinal artery was large, it was much more liable than the central retinal artery to be occluded by an embolus, because (according to him) the posterior ciliary arteries were among the terminal branches of the ophthalmic artery. This latter observation was incorrect because the posterior ciliary arteries are never terminal branches of the ophthalmic artery (Hayreh, 1962a; Hayreh and Dass, 1962). He attributed the improvement of vision in his case of cilio-retinal artery occlusion to collateral circulation between it and the central retinal artery, a possibility denied by various other authors (*vide supra*). It is just possible that the occlusion of a cilio-retinal artery which is supplying only a small localized area of the retina may occur without the patient's knowledge, if it entails no loss of central vision and the vision of the other eye is good. The very low recorded incidence of cilio-

retinal artery occlusion may be due either to this fact or to the rarity of the true cilio-retinal artery.

Birnbacher (1887) stated that every artery which appeared at or near the disc margin was not necessarily a cilio-retinal artery. Duke-Elder and Wybar (1961) described the division of the central retinal artery within the substance of the optic nerve into two, four, or even eight arteries, which emerged separately at the disc, no parent trunk being visible ophthalmoscopically. Bloch (1906) and Salzmann (1912) saw patients with arteries at the periphery of the disc and no central artery which seems to belong to this category. Rarely the cilio-retinal artery seen ophthalmoscopically may be in reality a branch of the central retinal artery arising within the optic nerve, and in such cases a normal central retinal artery would also be seen. According to Parsons (1903), this possibility cannot always be eliminated. Blunt (1956) found the central retinal artery bifurcating 0·4 mm. behind the papilla in one case, and one of the branches passed to the margin of the lamina cribrosa to emerge from the disc at the periphery. The condition described resembles somewhat the left side of the present case. Hence no absolute reliance can be placed on the ophthalmoscopic appearances of the fundus and the location of the arteries on the disc in reaching a correct diagnosis of the cilio-retinal arteries. Similarly, in the present case it was not possible to predict by ophthalmoscopy the actual pattern discovered by histological sectioning.

The typical and diagnostic loop of the cilio-retinal artery on the disc, which has been described by various authors (Nettleship, 1876b; Jackson, 1911; Salzmann, 1912; Duke-Elder, 1938), was not seen ophthalmoscopically in these two instances.

Anatomical proof of the presence of the cilio-retinal artery is very rare in the literature Anatomical examinations were made by Müller (1858) in one, Nettleship (1877) in one, Randall (1887) in one, Birnbacher (1887) in one, Fuchs (1923) in five, Beauvieux and Ristitch (1924) in one, and Wybar (1956) in one. Only the last-named has followed the whole course of a cilio-retinal artery in latex casts, and has conclusively proved it to be in fact a cilio-retinal artery. In the present two cases also it has fortunately been possible to trace the arteries to their origin from the posterior ciliary arteries in serial sections of the optic nerve, thus definitely proving them to be true cilio-retinal arteries. However, most previous authors have based their statistics and conclusions on ophthalmoscopic appearances only, but as mentioned above, no absolute reliance can be placed on the ophthalmoscopic findings. Those who have based their observations on the ophthalmoscopic appearances have found the cilio-retinal arteries to be very common, whereas a detailed anatomical examination of 72 eyes (Blunt, 1956; Steele and Blunt, 1956) revealed no such artery (though such a negative observation is to be taken cautiously). Similarly, the anatomically-based reports of the incidence of cilio-retinal arteries in the Rhesus monkey also

seem to be low, because no other example was found in about twenty eyes examined both ophthalmoscopically and either histologically or by latex injection, though a somewhat similar fundus picture has been seen with a normal vascular pattern in some. It seems, therefore, that ophthalmoscopic examination is **not** a true guide to the presence or absence of the cilio-retinal artery but may be quite misleading.

It may be worth mentioning here that the basic vascular pattern of the eye and optic nerve in the Rhesus monkey is closely similar to that in man (Hayreh, 1962b), so that the findings in one may be applicable to the other for all practical purposes.

The existence of the cilio-retinal arteries is a congenital anomaly rather than an acquired one due to some disease, inflammatory, or other morbid process, and no such evidence was seen in the present case. On the right side the optic physiological cup was abnormally deep in the centre (Fig. 4) going deep into the lamina cribrosa, but it was normal at the periphery and was not pathological in origin; the Bergmeister papilla is so commonly seen in the Rhesus monkey (Fig. 16) as to be considered normal in them.

Summary

In a Rhesus monkey both eyes showed multiple cilio-retinal arteries (in the right, eight, and in the left, three). The central retinal artery was absent on the right side, and on the left it supplied only the upper part of the retina. Ophthalmoscopic examination showed nothing grossly abnormal except the peripheral location of the arteries on the disc, but a detailed anatomical examination revealed the true picture. The past literature on the cilio-retinal arteries is reviewed.

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REFERENCES

ADACHI, B. (1928). "Das Arteriensystem der Japaner", vol. 1. Kyoto (*Cited by* Blunt, 1956).
AMAT, M. MARIN (1949). *Arch. Soc. oftal. hisp.-amer.*, **9**, 91 (*Ophthal. Lit.* (*Lond.*), **3**, 43, 1949).
BACH, L. (1894). *Arch. wiss. prakt. Tierheilk.*, **20**, 241 (*Cited by* Duke-Elder, 1932).
BAILLIART, P. (1923). "La circulation rétinienne", pp. 10–12. Doin, Paris.
BEAUVIEUX, J., and RISTITCH, K. (1924). *Arch. Ophtal.*, **41**, 352 (*Cited by* Blunt, 1956).
BENSON, A. H. (1883). *Trans. ophthal. Soc. U.K.*, **3**, 101, pl. IV, fig. 1.
BIRNBACHER, A. (1887). *Arch. Ophthal.* (*N.Y.*), **16**, 32.
BLOCH, H. (1906). *Klin. Mbl. Augenheilk.*, **44** (2), (n.s. 2), 413 (*Cited by* Duke-Elder, 1938).
BLUNT, M. J. (1956). *Proc. roy. Soc. Med.*, **49**, 433.
BONAMOUR, G., and GAILLOT (1956). "Les artères cilio-rétiniennes". Numéro special des conférences lyonnaises d'ophtalmologie, Septembre (*Cited by* Collier, 1957).
BOTTASSO, G. (1948). *Rass. ital. Ottal.*, **17**, 384 (*Ophthal. Lit.* (*Lond.*), **2**, 638, 1948).
BROSNAN, D. W. (1962). *Amer. J. Ophthal.*, **53**, 687.
BULLWINKEL, H. G. (1954). *N.Y. St. J. Med.*, **54**, 1462.
COATS, G. (1913a). *Roy. Lond. ophthal. Hosp. Rep.*, **19**, 71.
——— (1913b). *Ibid.*, **19**, 78.

COLLIER, M. (1957). *Bull. Soc. Ophtal. Fr.*, p. 598.
CZERMAK, W. (1888). *Wien. klin. Wschr.*, **1**, 251 (*Cited by* Duke-Elder and Wybar, 1961).
DUKE-ELDER, S. (1932). "Text-book of Ophthalmology", vol. 1, p. 149. Kimpton, London.
——— (1938). *Ibid.*, vol. 2, p. 1389.
——— (1940). *Ibid.*, vol. 3, p. 2561.
——— and WYBAR, K. C. (1961). "System of Ophthalmology", vol. 2, pp. 345, 369. Kimpton. London.
ELSCHNIG, A. (1897). *v. Grae es Arch. Ophthal.*, **44**, 144 (*Cited by* Duke-Elder and Wybar, 1961).
——— (1898). *Klin. Mbl. Augenheilk.*, **36**, 55, 93 (*Cited by* Duke-Elder, 1938; Duke-Elder and Wybar, 1961).
FRANCK, L. (1883). "Handbuch der Anatomie der Hausthiere", 2nd ed. Stuttgart. (*Cited by* Duke-Elder, 1932).
FRIEDMAN, M. W. (1959). *Amer. J. Ophthal.*, **47**, 684.
FUCHS, E. (1919). "Text-book of Ophthalmology", trans. A. Duane, 7th ed., p. 44. Lippincott, Philadelphia.
——— (1923). *Klin. Mbl. Augenheilk.*, **71**, 583 (*Cited by* Duke-Elder and Wybar, 1961).
GILL, E. G., and MAHAFFY, S. R. (1949). *Bull. Ophthal. Otol.*, **2**, 17.
GLEES, M. (1956). *Klin. Mbl. Augenheilk.*, **128**, 580. (*Ophthal. Lit.* (*Lond.*), **10**, 340, 1956).
HAYREH, S. S. (1958). Thesis for M.S., Panjab University.
——— (1962a). *Brit. J. Ophthal.*, **46**, 212.
——— (1962b). Personal observation, to be published.
——— and DASS, R. (1959). "Acta XVIII Conc. Ophthal. 1958, Belgica", vol. 2, p. 1345. Imprimerie Médicale et Scientifique, Bruxelles.
——— ——— (1962). *Brit. J. Ophthal.*, **46**, 212.
HIRSCH, C. (1896). *Arch. Augenheilk.*, **33**, Ergänzungsheft (Festscrift J. Schnabel), p. 139 (*Cited by* Duke-Elder, 1940).
JACKSON, E. (1911). *Ophthal. Rev.*, **30**, 264.
JOHNSON, G. L. (1901). *Philos. Trans. B.*, **194**, 1 (*Cited by* Duke-Elder, 1932).
——— (1905). *Trans. ophthal. Soc. U.K.*, **25**, 359.
KRAUPA, E. (1924). *Klin. Mbl. Augenheilk.*, **72**, 724 (*Cited by* Duke-Elder, 1938).
KRAUSS, F. (1907). *Ophthal. Rec.*, **n.s. 16**, 196.
LANG, W., and BARRETT, J. W. (1888). *Roy. Lond. ophthal. Hosp. Rep.*, **12**, 59.
LANGENBACHER, L. (1880). *Öst. Viert.-Jb. Veterinärk.*, **53** (2), 121 (*Cited by* Duke-Elder, 1932).
LAWFORD, J. B. (1895). *Trans. ophthal. Soc. U.K.*, **15**, 195.
LEVITT, J. M. (1948). *Arch. Ophthal.* (*Chicago*), **40**, 152.
LEVY, A. (1909). *Trans. ophthal. Soc. U.K.*, **29**, 130.
LORING, E. G. (1872). *Arch. Ophthal. Otol.*, **2**, No. 2, p. 1.
MANN, I. (1928). "The Development of the Human Eye", pp. 233, 234. University Press, Cambridge.
——— (1957). "Developmental Abnormalities of the Eye", 2nd ed., pp. 136. B.M.A., London.
MELLER, J. (1909). *v. Graefes Arch. Ophthal.*, **72**, 456 (*Cited by* Duke-Elder, 1940).
MINDELBERGER, A. (1905). Diss., Tübingen (*Cited by* Duke-Elder, 1932).
MÜLLER, H. (1856). *Z. wiss. Zool.*, **8**, 1 (*Cited by* Duke-Elder, 1938).
——— (1858). *v. Graefes Arch. Ophthal.*, **2**, 1.
NETTLESHIP, E. (1876a). *Brit. med. J.*, **1**, 161.
——— (1876b). *Roy. Lond. ophthal. Hosp. Rep.*, **8**, 512.
——— (1877). *Ibid.*, **9**, 161.
——— (1905). *Trans. ophthal. Soc. U.K.*, **25**, 338.
PARSONS, J. H. (1903). "The Ocular Circulation" (Arris and Gale Lectures), p. 31. Bale, Sons and Danielsson, London.
RANDALL, B. A. (1887). *Trans. Amer. ophthal. Soc.*, **4**, 511.
SALZMANN, M. (1912). "The Anatomy and Histology of the Human Eyeball", trans. E. V. L. Brown, pp. 183, 184. University of Chicago Press, Chicago.
——— (1953). *v. Graefes Arch. Ophthal.*, **153**, 451 (*Ophthal. Lit.* (*Lond.*), **7**, 308, 1953).
SINGH, S., and DASS, R. (1960a). *Brit. J. Ophthal.*, **44**, 193.
——— ——— (1960b). *Ibid.*, **44**, 280.
SCHNABEL and SACHS, T. (1885). *Arch. Augenheilk.*, **15**, 11.
STEELE, E. J., and BLUNT, M. J. (1956). *J. Anat.* (*Lond.*), **90**, 486.
STOCKMAYER (1905). Diss., Tübingen (*Cited by* Duke-Elder, 1932).
TRAPPE, E. (1914). *Z. Augenheilk.*, **32**, 124 (*Cited by* Levitt, 1948).
VEASEY (*Cited by* Blunt, 1956).
WITTICH, K. (1953). *Klin. Mbl. Augenheilk.*, **123**, 356 (*Ophthal. Lit.* (*Lond.*), **7**, 472, 1953).
WYBAR, K. C. (1956). *Brit. J. Ophthal.*, **40**, 65.
ZENTMAYER, W. (1906). *Ophthal. Rec.*, **n.s. 15**, 613.