THE BLOOD SUPPLY OF THE OPTIC NERVE AND CHIASMA IN MAN

By E. J. STEELE and M. J. BLUNT*

Department of Anatomy, Royal Free Hospital School of Medicine

Though numerous observations have been made on the blood supply of the optic nerve in man and there is general agreement on its gross arrangement, the recorded evidence is conflicting in several important details, particularly touching the part played by the central retinal artery in the nutrition of the nerve.

All authors are agreed that the central retinal artery contributes branches to the pial plexus before entering the nerve. An intraneural distribution of branches of the central retinal artery has been described by some authors (Beauvieux & Ristitch, 1924; Duke-Elder, 1932; Traquair, 1946) and denied by others (François, Neetens & Colette, 1955). The most proximal of the branches distributed intraneurally and said to arise from the central retinal artery in its extraneural course, enters the nerve as a branched or unbranched collateral of the main artery. Branches of the central retinal artery arising in the substance of the optic nerve have also been reported (Duke-Elder, 1932; Abbie, 1938; Wolff, 1940; Bignell, 1952), and some authors have described a direct arterial anastomosis between the most distal of these and branches from the anastomotic circle of posterior ciliary arteries, the circle of Zinn (Duke-Elder, 1932; Sauter & Seitz, 1952). Other authors deny the existence of any intraneural branches (Magitot, 1908, quoted by Poirier & Charpy, 1912; Beauvieux & Ristitch, 1924).

François *et al.* (1955) have described the detailed intrinsic vascular anatomy of the optic nerve. Cristini (1951) has reported on the intrinsic vascular anatomy of forty nerves taken from patients with glaucoma, and his incidental references to the normal vascular pattern do not agree with the findings of the last-named workers.

Abbie (1938) and Dawson (1948) both investigated the arterial supply of the optic chiasma and Xuereb, Pritchard & Daniel (1954) commented on certain features of the supply to the chiasma and optic tract. Dawson alone briefly described the pattern of capillaries in the chiasma.

The potential clinical significance of the blood supply of the optic nerve and chiasma is now increasingly appreciated, as, for example, in the aetiology of glaucoma and in connexion with the surgery of the pituitary gland. It was considered necessary, therefore, to reinvestigate the vascular pattern of the nerve and chiasma, both with a view to resolving the doubts and contradictions apparent in the literature and to clarifying the descriptive vascular anatomy of these structures.

* Present address: Department of Anatomy, Medical College of St Bartholomew's Hospital.

MATERIAL AND METHODS

Fresh human autopsy material was obtained from thirty-six subjects, males and females whose ages ranged from 10 weeks to 88 years and who were free from known ocular disease.

(*a*) In seventeen subjects the vessels were injected; in fourteen of these injection was made simultaneously into both internal carotid arteries in the neck, and in the remaining three cases directly into each opthhalmic artery *in situ*. Coloured 'Neoprene' was used for ten injections into the internal carotid arteries and for the injections into the ophthalmic arteries, a pressure of 200 mm. of mercury being used. In the remaining four, coloured 'Micropaque' was injected at a pressure of 100 mm. of mercury.

In three subjects the entire contents of the orbit were subsequently removed *en bloc*, and in fourteen the posterior third of the eyeball with the optic nerve was removed with as much surrounding tissue as possible. The chiasma was removed in continuity with the optic nerves in six subjects, and in the remaining eleven the brain, chiasma, pituitary body and surrounding bone were removed together. All excised material was fixed immediately in 10% formol saline and was then dissected under the microscope.

(*b*) In a second group of seventeen subjects, the optic nerves and chiasmata were removed, fixed in hypertonic formol saline for a minimum of 3 days and embedded in gelatin as described by Blunt (1954). Longitudinal frozen sections, from 200 to 300μ thick, were cut from the nerves of sixteen of these subjects and transverse sections were cut from the nerves of the remaining subject. Horizontal sections of corresponding thicknesses were cut from sixteen chiasmata and one chiasma was cut sagittally. All sections were treated with sodium nitroprusside and benzidene as described by Pickworth (1934), and then cleared and mounted on ringed slides in Spalteholz's fluid, a convenient medium for mounting thick sections stained by this method (Scott, 1955, personal communication).

The nerves and chiasma from a single subject were fixed in 10% formol saline and embedded in paraffin. Serial sections at 10μ were cut longitudinally from one nerve and transversely from the other, the chiasma being cut horizontally. Alternate slides were stained with haematoxylin and Biebrich Scarlet and with Mallory's triple stain.

The nerves and chiasma from a subject in which injection had been unsuccessful were embedded in paraffin and sectioned at 80 and 100μ; the nerves were sectioned longitudinally and the chiasma horizontally, and the sections stained with van Gieson's stain.

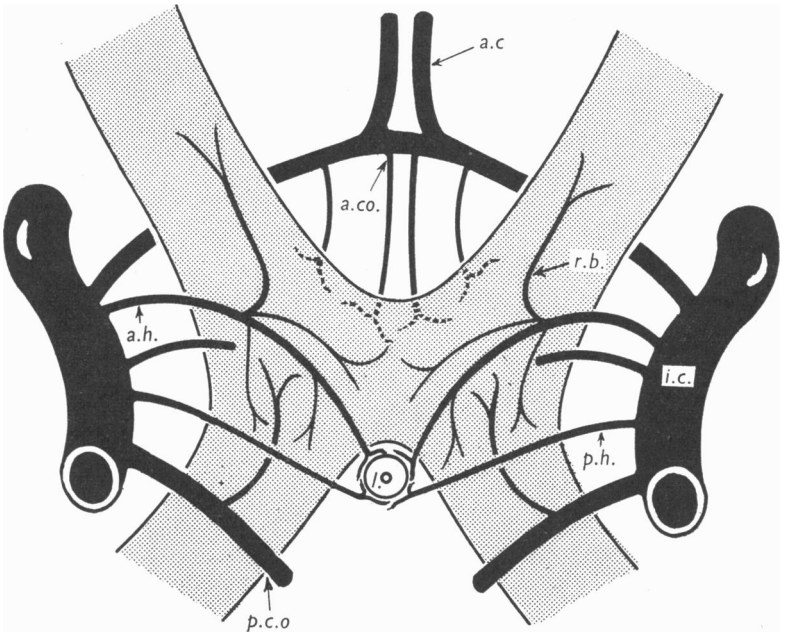
FINDINGS

Blood supply of the chiasma (Text-fig. 1)

The chiasma was, in general, supplied by vessels which ramified in the overlying pial network. On its inferior surface the largest vessel contributing to the network was the anterior superior hypophyseal artery which constantly gave off a recurrent branch along the infero-medial border of the proximal part of the optic nerve. The internal carotid and posterior communicating arteries also supplied the pial plexus (Pl. 1, fig. 1). The posterior superior hypophyseal artery gave no branches to the

chiasma in this series. On the superior surface of the chiasma the pial plexus received vessels from the anterior cerebral and anterior communicating arteries (Pl. 1, fig. 2).

Venous networks along the antero-inferior border of the chiasma were connected by transverse branches and they drained into the basal veins; those from the superior surface of the chiasma drained into the anterior cerebral veins. These chiasmal veins were clearly visible to the naked eye although, as expected, they were not filled with the injection masses used.



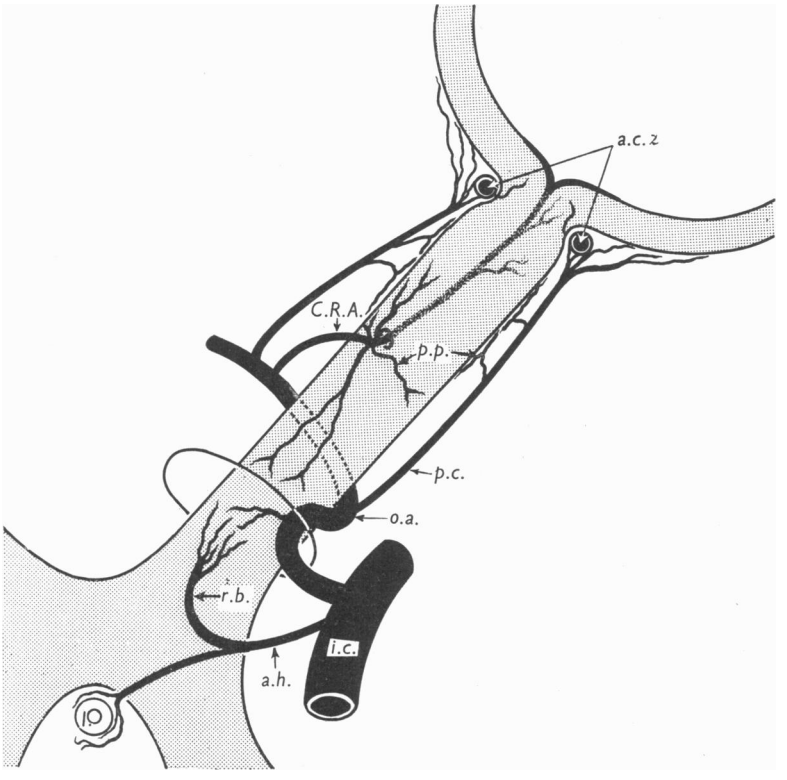
Text-fig. 1. The arterial blood supply of the optic chiasma.

In all sections of the seventeen chiasmata stained by the sodium nitro-prusside-benzidine technique the intrinsic capillary plexus was seen to be connected with vessels in the overlying pial network. The capillary vessels within the chiasma crossed from side to side and anastomosed freely in the mid-line. Vessels within the medial part of the optic nerve were continuous with those within the anterior part of the chiasma, but the intrinsic vessels from the lateral part of the nerve tended to course within the lateral margin of the chiasma into the corresponding optic tract. Posteriorly the capillaries of the optic chiasma were directly continuous with those of the hypothalamus (Pl. 2, fig. 6). The glial septa in the chiasma were sparse and irregular, and their arrangement bore no resemblance to that of the capillaries.

Blood supply of the optic nerve (Text-fig. 2)

For convenience, details of the arterial supply of the nerve will be described separately for its intracranial, intracanalicular and intraorbital parts. Like the chiasma all three parts of the nerve were supplied through a continuous overlying pial plexus.

The intracranial part of the nerve was constantly supplied by the recurrent branch of the anterior superior hypophyseal artery (Pl. 1, fig. 1) and by small recurrent branches of the ophthalmic artery which joined the pial network. The intracanalicular part of the nerve received its blood supply from small branches of the ophthalmic artery given off just distal to the optic canal (Pl. 1, fig. 4).



Text-fig. 2. Diagrammatic representation of findings on the blood supply to the optic nerve. Left side, seen from below.

The pial plexus of the intraorbital part of the nerve received branches from the posterior ciliary arteries throughout its course. The central retinal artery was seen to give branches to the pial network close to its entry into the nerve (Pl. 1, fig. 4) in fifteen out of seventeen nerves in which injection was satisfactory up to this point.

The central retinal artery arose from the ophthalmic in twenty-eight out of thirty dissections and from a posterior ciliary artery in two. It entered the infero-medial surface of the nerve at a distance varying from 7 to 17 mm. behind the optic disc. In all of nine nerves in which the central retinal artery was fully injected, intraneural branches were found. In seven of these a single branch left the artery midway along its intraneural course and in the other two nerves two such intraneural branches were given off (Pl. 1, fig. 5). This intraneural branching of the artery was confirmed in transverse sections of the nerves (Pl. 2, fig. 9). In no instance were any intraneurally distributed direct branches of the central retinal artery observed in the region of the lamina cribrosa, neither was any cilio-retinal artery seen.

The intrinsic and extrinsic veins draining the optic nerve were readily visible though unfilled by the injection masses, the central retinal vein regularly accompanying its companion artery. The former left the nerve just posterior to the point of entrance of the artery. In both longitudinal and transverse sections, the vein was seen to receive numerous tributaries throughout its intraneural course (Pl. 1, fig. 3; Pl. 2, fig. 9).

In all the nerves stained by the sodium nitroprusside-benzidine technique constant regional variations were found in the pattern of the intrinsic capillary plexus. In the intracranial part of the nerve the capillaries were found to be irregularly disposed and to exhibit frequent spiral formations (Pl. 2, fig. 8). Thick sections stained by van Gieson's method demonstrated a remarkable correspondence between the arrangement of the glial septa and these vessels. In both the intracanalicular and the intraorbital parts of the nerve, the capillaries were arranged in a definite box pattern (Pl. 2, fig. 10) which also corresponded to the local arrangement of the glial septa (Pl. 2, fig. 7).

In the region of the lamina cribrosa small branches from the posterior ciliary arteries entered the pial plexus and choroid (Pl. 1, fig. 3). The largest of these vessels were of not more than pre-capillary size. Examination of all sections failed to reveal any evidence of the existence of direct arterial anastomoses between branches of the central retinal artery and branches from the anastomotic circle of posterior ciliary arteries. The capillaries in the lamina cribrosa were closely packed (Pl. 1, fig. 3) and were in direct continuity anteriorly with those of the choroid and retina and posteriorly with those of the retrolaminar portion of the optic nerve.

DISCUSSION

As is well known, the results of most injection techniques are variable, and more reliance can be placed upon positive than upon purely negative findings. In the present investigation conclusions have been drawn only from preparations in which there was evidence of an injection sufficiently complete to justify their inclusion in the series. The results of sodium nitroprusside-benzidine staining have proved remarkably constant, so that the findings reported here have been observed in every relevant specimen. They provide valuable confirmatory evidence of the results obtained from injection methods.

The findings on the gross blood supply of the optic chiasma accorded with those of Dawson (1948). The main features of interest, and of possible practical significance, were that the largest, most numerous and most extensive branches to the pial network on the inferior surface of the chiasma and intracranial part of the optic nerve were regularly supplied by the anterior superior hypophyseal artery. The pial network on the inferior surface did, however, provide a means of free intercommunication between adjacent arteries of supply. The capillary vessels of the intrinsic plexus tended in general to follow the course of the nerve fibres through the chiasma rather than to follow the disposition of the glial septa. The free intercommunication of the intrinsic capillary vessels of the chiasma with those of the hypothalamus was most striking.

The present investigation has shown that the main supply of the intracranial part of the optic nerve was dependent upon the recurrent branch of the anterior superior

hypophyseal artery with a few additional twigs from the ophthalmic artery. Dawson (1948) attributed greater importance to these latter branches, regarding them as the main supply of the intracranial portion of the nerve. Though the total number of his specimens was larger, the findings in the present more limited series were invariable. Wolff's (1954) statement that the internal carotid, anterior cerebral and anterior communicating arteries played a part in the supply of this region of the nerve received no confirmation from the present investigation; his observation that the intracanalicular part of the nerve was supplied by the ophthalmic artery was, however, confirmed.

The present work also confirmed previous statements regarding the arterial supply to the pial plexus (Poirier & Charpy, 1912; Duke-Elder, 1932; Wolff, 1939). In fifteen specimens in which the extraneural pial branches were filled there was no evidence of an extraneural branch of the central retinal artery accompanying it into the nerve (Beauvieux and Ristitch, 1924; Duke-Elder, 1932; Traquair, 1946). In nine of these specimens the central retinal artery was completely filled throughout its course, thus indicating that any collateral branch is far from constant. On the other hand, there was unequivocal support for those (Duke-Elder, 1932; Abbie, 1938; Wolff, 1940; Bignall, 1952) who described branches of the central retinal artery in the substance of the optic nerve. In no instance, either in adequately injected specimens or in sodium nitroprusside-benzidine preparations, was there any evidence of a direct arterial anastomosis between the central retinal artery and vessels derived from the circle of Zinn.

A cilio-retinal artery, a common feature of certain mammals including Carnivora, Marsupials and some Ungulates (Nettleship, 1905; Duke-Elder, 1932), is sometimes found in man. Its incidence, as estimated from the results of ophthalmoscopic examination, is variously given as 16·7% of forty-eight eyes by Lang & Barrett (1889), 14·2% of 120 eyes by Veasey, 8·7% of 439 eyes by Yoshida (Adachi, 1928), and 'at least 25%' by Mann (1937). No evidence of this vessel has, however, been found in the present investigation.

François *et al.* (1955) used micro-arteriography as a means of investigation of the blood supply to the optic nerve. Although this difference in technique should not make it impossible to compare results, it is nevertheless difficult to do so. They stated that the capillary network was 'not so rich' as the lamina cribrosa was approached, and 'towards the papilla at the region of the physiological excavation of the cup they disappear', and later in the same paper that 'the vascularization of the nerve becomes gradually less dense from the papilla to the optic foramen'. In the light of these apparently irreconcilable statements it is difficult to interpret their findings.

Although in this present investigation no direct arterial anastomosis has been found between branches of the central retinal artery and those from the anastomotic circle of Zinn, the dense capillary plexus in the region of the lamina cribrosa was noted to be in direct continuity with the choroidal capillary vessels. This suggests that under conditions of raised intra-ocular tension, the choroidal capillaries connected with those of the lamina cribrosa might possibly be compressed against the spur of sclera which projects into the nerve head (Pl. 1, fig. 3), thus impairing the nutrition of the nerve fibres in the lamina.

SUMMARY

The gross blood supply and the intrinsic vascular anatomy of the optic nerve and chiasma have been described and the findings discussed in relation to previously reported observations; the significance of some of the results has been suggested.

The authors are grateful to Prof. R. E. M. Bowden for her constant advice and encouragement and helpful criticism of the manuscript, to Prof. A. J. E. Cave who has also kindly criticized the manuscript, and to Dr Francis Camps and his staff who provided the material for the investigation. Valuable technical assistance was provided by Mr L. V. Grayson and Mr W. Matthews. The photographs are the work of Mrs J. M. Thomas and the text-figures that of Mrs A. Besterman. The Augustus and Alice Waller Research Trust provided part of the photographic apparatus. One of us (E.J.S.) is grateful to the Council of the Royal Free Hospital School of Medicine for help afforded by the award of the Julia Ann Hornblower Cock Scholarship and the Mabel Webb and A. M. Bird Research Scholarship.

REFERENCES

ABBIE, A. A. (1938). Blood supply of the visual pathways. *Med. J. Aust.* **2**, 199–202.

ADACHI, B. (1928). *Das Arteriensystem der Japaner*, **1**, 109–110. Kyoto.

BEAUVIEUX, J. & RISTITCH, K. (1924). Les vaisseaux centraux du nerf optique. Étude anatomique. *Arch. ophtal., Paris*, **41**, 352–369.

BIGNELL, J. L. (1952). Investigations into the blood supply of the optic nerve with special reference to the lamina cribrosa region. *Trans. ophthal. Soc. Aust.* **12**, 150–158.

BLUNT, M. J. (1954). The blood supply of the facial nerve. *J. Anat., Lond.*, **88**, 520–526.

CRISTINI, G. (1951). Common pathological basis of the nervous ocular symptoms in chronic glaucoma. *Brit. J. Ophthal.* **35**, 11–20.

DAWSON, B. H. (1948). *On the blood vessels of the human optic chiasma, hypophysis and hypothalamus.* M.D. Thesis, Manchester.

DUKE-ELDER, S. (1932). *Textbook of Ophthalmology*, vol. I. London: Kimpton.

FRANÇOIS, J., NEETENS, A. & COLETTE, J. M. (1955). Vascular supply of the optic pathway. II. Further studies by microarteriography of the optic nerve. *Brit. J. Ophthal.* **39**, 220–232.

LANG, W. & BARRETT, J. W. (1889). On the frequency of cilio-retinal vessels and of pulsating veins. *Roy. Lond. Ophthal. Hosp. Rep.* **12**, 59–60.

MANN, I. (1937). *Developmental abnormalities of the eye.* Cambridge University Press.

NETTLESHIP, E. (1905). Notes on blood vessels of the optic disc in some lower animals. *Trans. ophthal. Soc. U.K.* **25**, 338–359.

PICKWORTH, F. A. (1934). A new method of study of brain capillaries and its application to the regional localization of mental disorder. *J. Anat., Lond.*, **69**, 62–71.

POIRIER, P. & CHARPY, A. (1912). *Traité d'anatomie Humaine*, tome **5**, fasc. II. Paris: Masson.

SAUTER, H. & SEITZ, R. (1952). Untersuchungen über die Beziehungen zwischen Zentral- und Ciliargefässystem im Bereich der Lamina Cribrosa. *Graefes Arch. Ophthal.* **152**, 413–424.

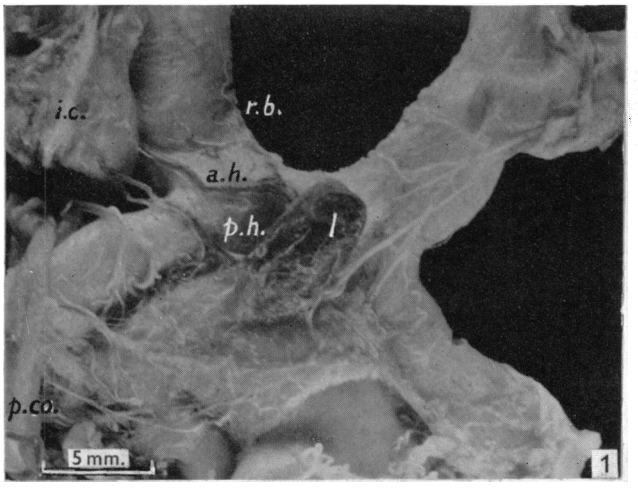
TRAQUAIR, H. M. (1946). *An introduction to clinical perimetry.* London: Kimpton.

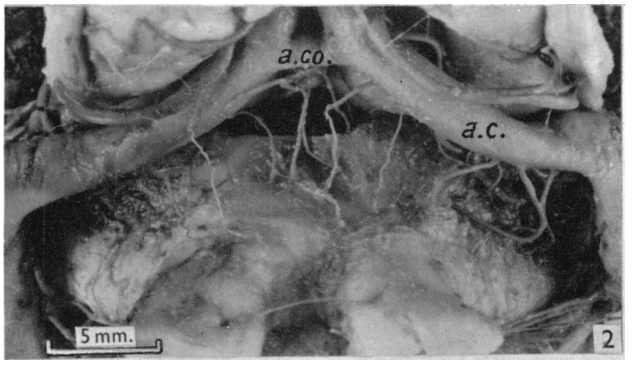
WOLFF, E. (1939). Some aspects of blood supply of the optic nerve. *Trans. ophthal. Soc. U.K.* **59**, 157–162.

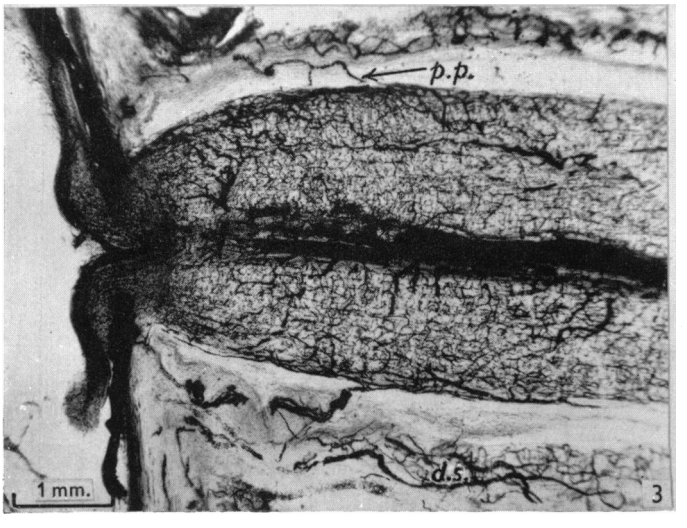
WOLFF, E. (1940). The blood supply to lamina cribrosa (a correction). *Trans. ophthal. Soc. U.K.* **60**, 69.

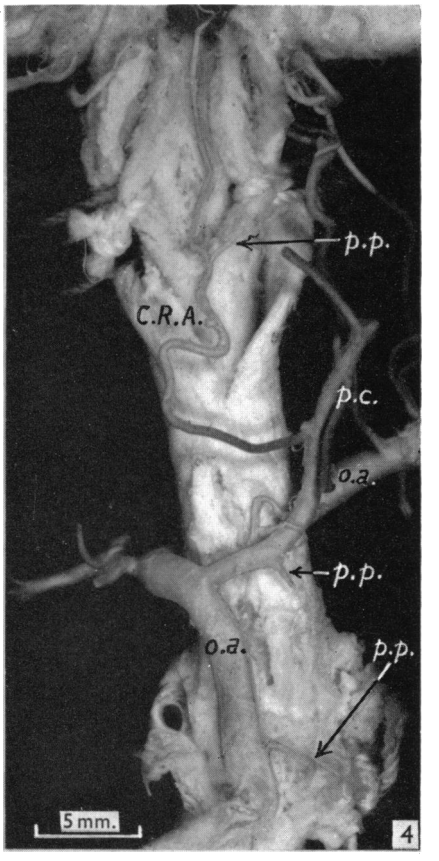
WOLFF, E. (1954). *Anatomy of eye and orbit*, 4th ed. London: Lewis.

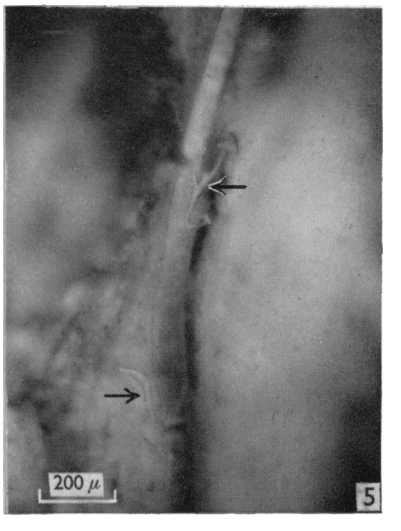
XUEREB, G. P., PRITCHARD, M. L. & DANIEL, P. M. (1954). Arterial supply and venous drainage of the human hypophysis cerebri. *Quart. J. exp. Physiol.* **39**, 199–217.





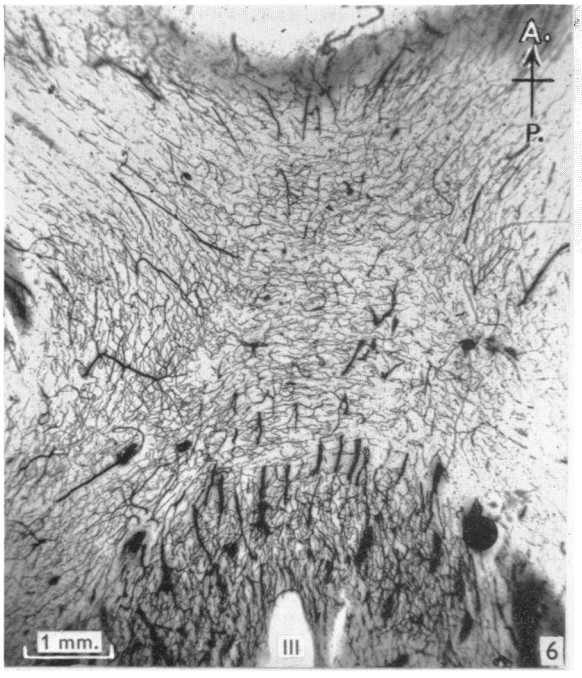


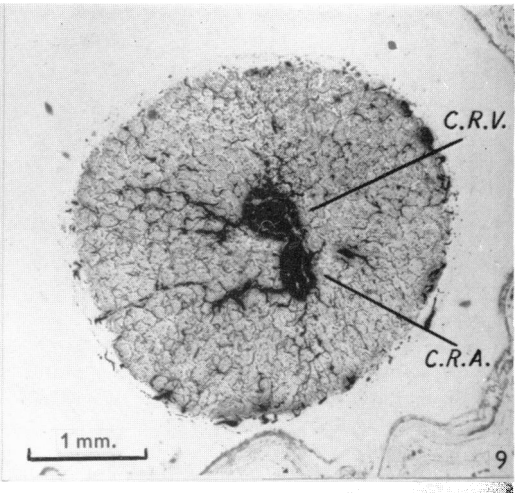


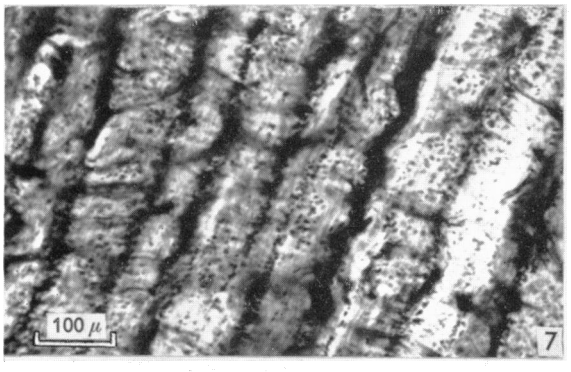


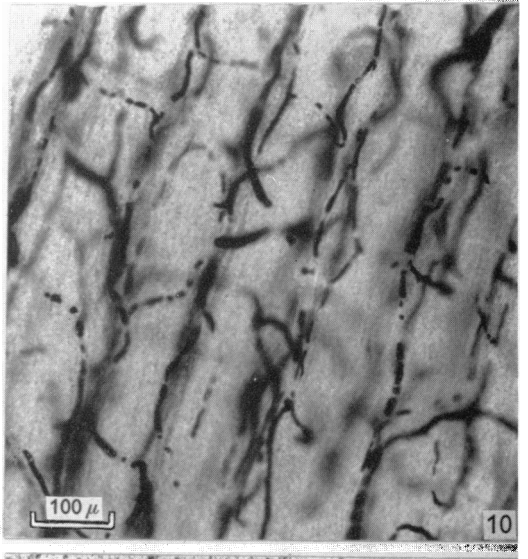
STEELE AND BLUNT—THE BLOOD SUPPLY OF THE OPTIC NERVE AND CHIASMA IN MAN

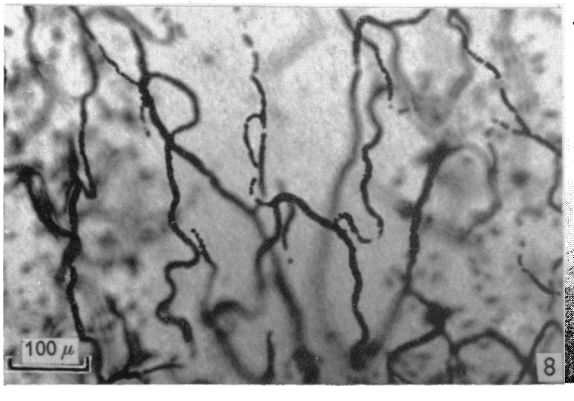
(*Facing p.* 492)

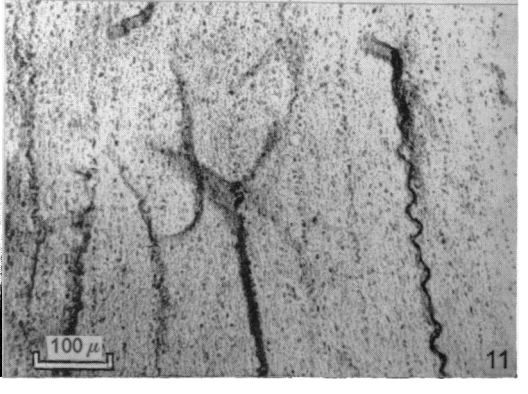

A.
P.
1 mm.
III
6


C.R.V.
C.R.A.
1 mm.
9


100 μ
7


100 μ
10


100 μ
8


100 μ
11

EXPLANATION OF PLATES

Key to abbreviations used in text-figures and in Pls. 1 *and* 2

a.c.	anterior cerebral artery.	*i.c.*	internal carotid artery.
a.co.	anterior communicating artery.	*o.a.*	ophthalmic artery.
a.c.z.	arterial circle of Zinn.	*O.N.*	optic nerve.
a.h.	anterior superior hypophyseal artery.	*p.c.*	posterior ciliary artery.
C.R.A.	central retinal artery.	*p.co.*	posterior communicating artery.
C.R.V.	central retinal vein.	*p.h.*	posterior superior hypophyseal artery.
d.s.	dural sheath.	*p.p.*	arterial branch to pial plexus.
I.	infundibulum.	*r.b.*	recurrent branch of anterior superior hypophyseal artery.

Plate 1

Fig. 1. Lower surface of chiasma. Micropaque injection.
Fig. 2. Upper surface of chiasma. Neoprene injection.
Fig. 3. Longitudinal section of the anterior end of optic nerve. Sodium nitroprusside-benzidine preparation.
Fig. 4. Vessels of the right optic nerve seen from below. In this specimen the central retinal artery is a branch of a posterior ciliary artery. Neoprene injection.
Fig. 5. Two intraneural branches of central retinal artery from specimen in fig. 4.

Plate 2

Fig. 6. Horizontal section of chiasma passing through the hypothalamus. Note third ventricle (III) and periventricular capillary plexus. Sodium nitroprusside-benzidine preparation.
Fig. 7. Longitudinal section through intraorbital part of nerve, showing box pattern of glial septa (cf. fig. 10). Van Gieson's stain.
Fig. 8. Longitudinal section through intracranial part of nerve, showing irregular form and spiral twisting of capillaries (cf. fig. 11). Sodium nitroprusside-benzidine preparation.
Fig. 9. Transverse section through intraorbital part of nerve. Sodium nitroprusside-benzidine preparation.
Fig. 10. Longitudinal section through intraorbital part of nerve, showing box pattern of capillaries (cf. fig. 7). Sodium nitroprusside-benzidine preparation.
Fig. 11. Longitudinal section through intracranial part of nerve, showing irregular form and spiral twisting of glial septa (cf. fig. 8). Van Gieson's stain.