J. Anat. (1977), **124**, 3, pp. 689–699
With 13 *figures*
Printed in Great Britain

Observations on the intracranial carotid rete and the hypophysis in the mature female pig and sheep

PHILOMENA McGRATH
Department of Anatomy, University of Sydney, N.S.W. 2006

(*Accepted* 25 *October* 1976)

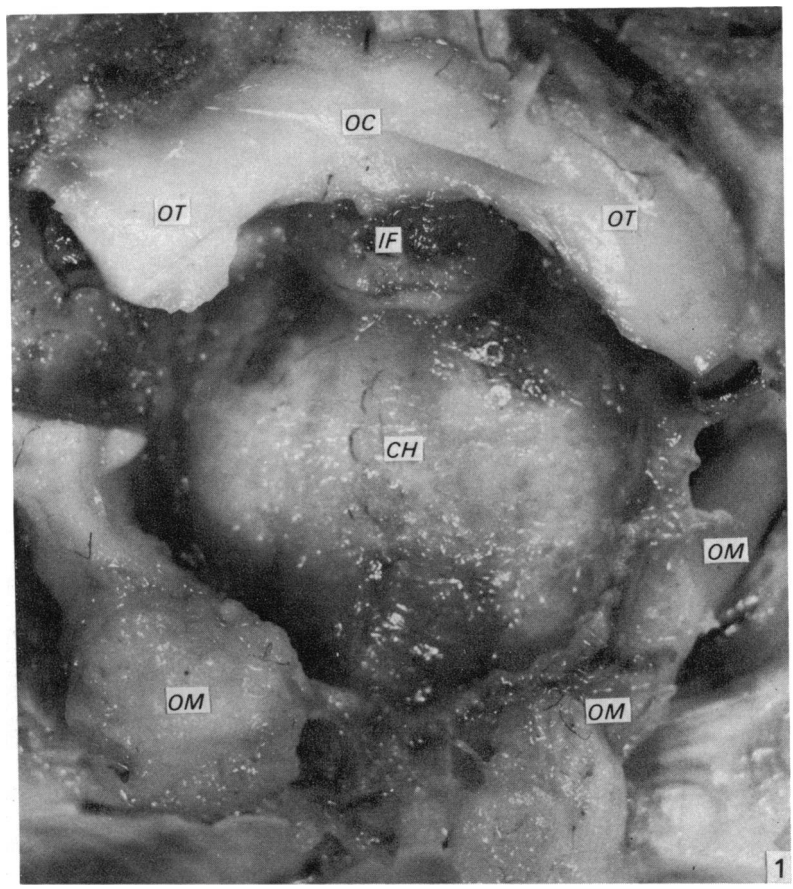
INTRODUCTION

It has been established that a well developed carotid rete lying within the cavernous sinus is present in some members of the order of Artiodactyla, including the pig and the sheep. The carotid rete in these species consists of a compact network of intertwined freely anastomosing arteries. In the sheep the two retia are connected across the midline by a few vessels of variable calibre, but in the pig the anastomosis between the retia is extensive, giving the retia the appearance of a single structure. In these species the internal carotid artery is absent proximal to the rete. The main vessel supplying the rete in the pig is the ascending pharyngeal artery, and in the sheep the internal maxillary artery. A distal segment of the internal carotid artery is formed from vessels of the rete in the antero-superior part of the cavernous sinus (Daniel, Dawes & Prichard, 1953; Gillilan, 1974). While the carotid retia are described as lying on either side of the hypophysis (Baldwin, 1964; Bourdelle, 1964) there is no specific comment in the literature as to the relationship between the hypophysis and the vessels connecting the retia across the midline in these species. In an investigation into the pharyngeal hypophysis (McGrath, 1974), *en bloc* segments of the sphenoid of the mature female sheep were studied in serial section. As an extension of the investigation into the pharyngeal hypophysis the hypophyseal region and related structures of the mature female pig have been studied by gross dissection and serial sectioning. The main purpose of the present paper is to present observations on the carotid rete and the hypophysis in the pig which were made during this recent study. Sections of the sheep already available have been reviewed and relevant observations are also presented.

MATERIALS AND METHODS

The heads of eight mature female pigs were obtained from the abattoirs. Two heads were fixed in 10 % formalin and gross dissection of the hypophyseal region was carried out from above and from the lateral aspect. Specimens of the body of sphenoid were removed *en bloc* from the remaining heads. Each specimen was decalcified, embedded in paraffin and sectioned in either the sagittal or the coronal plane at 15 μm. Alternate slides were stained with PAS-orange G. Selected sections were stained with Verhoeff's elastin stain.

The dimensions of the cranial hypophysis in the pig were determined using a millimetre rule and an ocular micrometer. Length was measured as the maximum extent in the sagittal plane while the width and depth were taken as the maximum extent in the lateral and vertical directions respectively. A mean of each measurement was taken. The volume was calculated from the means, and must be taken as no



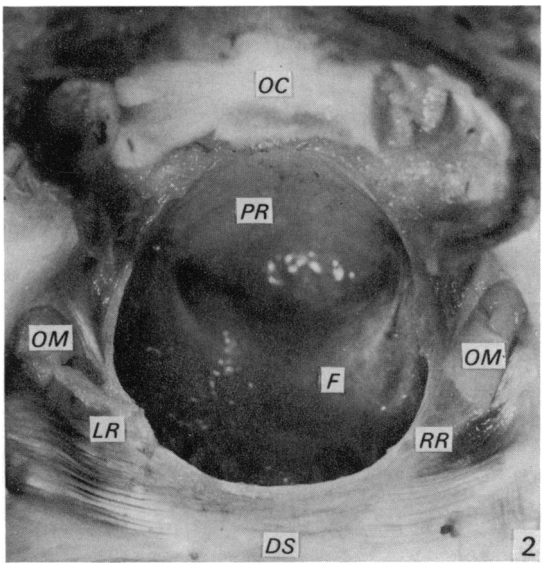
Figs. 1–3 are illustrations of progressive stages in the gross dissection of the hypophyseal region from above in a mature female pig. Anterior is above. Optic chiasma, *OC*; oculomotor nerve, *OM*; cranial hypophysis, *CH*; dorsum sellae, *DS*; roof of cavernous sinus on either side, *LR*, *RR*.

Fig. 1. Hypophyseal region after removal of the brain. Infundibulum, *IF*; optic tract, *OT*. The hypophysis (*CH*) presents as a bulky mass covered superiorly by the diaphragma sellae presenting as a thin membrane with indefinite margins. × 6.

more than a rough approximation. As in a previous investigation (McGrath, 1974), the term 'pharyngeal hypophysis' has been used on developmental grounds to describe a structure with specific histological features in the roof of the pharynx in the median plane. The dimensions of the pharyngeal hypophysis were determined as for the cranial hypophysis.

The maximum internal diameter, and the maximum width, of the tunica media of particular arteries were determined in each sectioned specimen with the aid of an ocular micrometer. A mean for each measurement was taken.

Sections of *en bloc* segments of the sphenoid of the sheep prepared previously (McGrath, 1974) were available for study. The dimensions of particular arteries in the sheep were determined as in the pig.



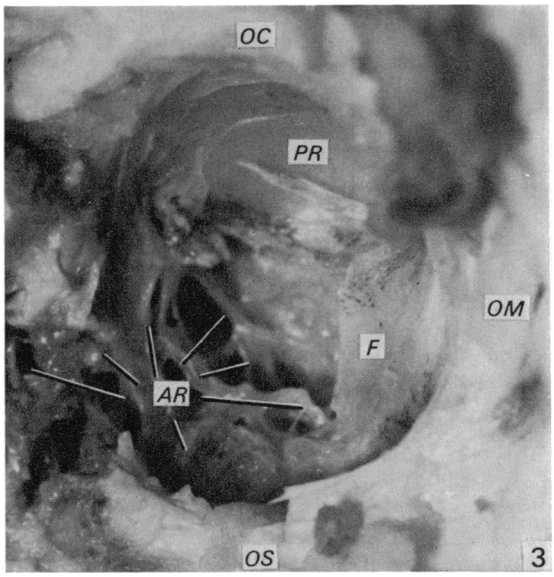


Fig. 2. Hypophyseal region after removal of the hypophysis. Presphenoid covered with fibrous tissue (*PR*). Dura mater forming a thick fibrous sheet (*F*) is attached anteriorly to the presphenoid, posteriorly to the dorsum sellae (*DS*) and is continuous laterally with the roof of the cavernous sinus on either side (*LR*, *RR*). The roof of the cavernous sinus is pierced by the oculomotor nerve (*OM*). ×4.

Fig. 3. Hypophyseal region after partial removal of the fibrous sheet of dura mater (*F*) and the roof of the left cavernous sinus. An extensive arterial rete (*AR*) is seen inferior to the fibrous sheet and to the roof of the left cavernous sinus. ×4·4.

FINDINGS

Gross dissection of the hypophyseal region in the pig

Dissection from above

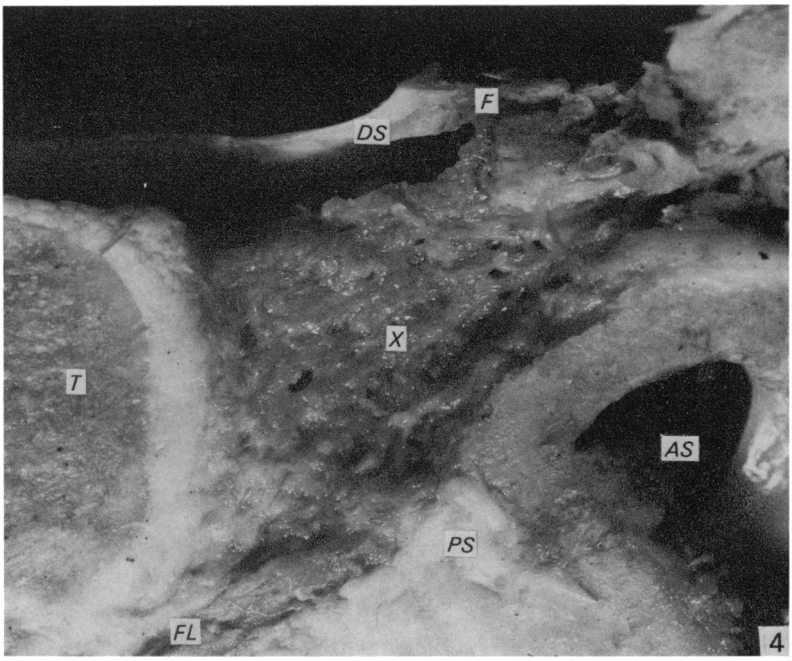
After removal of the brain the cranial hypophysis presents as a bulging mass surrounded by the optic chiasma, the optic tracts and the oculomotor nerves. The diaphragma sellae presents as a thin membrane covering the superior aspect of the hypophysis (Fig. 1). After removal of the hypophysis, dura mater can be seen forming a fibrous layer adherent to the presphenoid anteriorly and extending posteriorly to the dorsum sellae and laterally into the roof of the cavernous sinus on either side (Fig. 2). Partial removal of this fibrous layer and the roof of the cavernous sinus exposes an extensive arterial rete (Fig. 3).

Dissection from the lateral aspect

In parasagittal sections through the foramen lacerum the regions of the cavernous sinus and the sella turcica are seen to be filled with a mass of tissue (Fig. 4). On partial dissection this mass is seen to be composed mainly of an arterial rete (Fig. 5).

Histological examination of en bloc specimens of the sphenoid in the pig

Examination of serial sagittal sections in the mature female pig indicates that the region inferior to the roof of the cavernous sinus, as well as the greater part of the deep sella turcica, contains numerous arteries running in all planes and forming an extensive intercranial rete (Figs. 6–8). This intracranial rete is continuous through



Figs. 4 and 5 are illustrations of progressive gross dissection of the right cavernous sinus region. Right parasagittal section, anterior to the right.

Fig. 4. Dura mater (*F*) extends anteriorly from the dorsum sellae (*DS*). Right temporal bone, *T*; region of the right foramen lacerum, *FL*; postsphenoid sphenoid, *PS*; sphenoidal air sinus, *AS*. The region of the right cavernous sinus and the sella turcica are occupied by a mass of tissue (*X*). ×6.

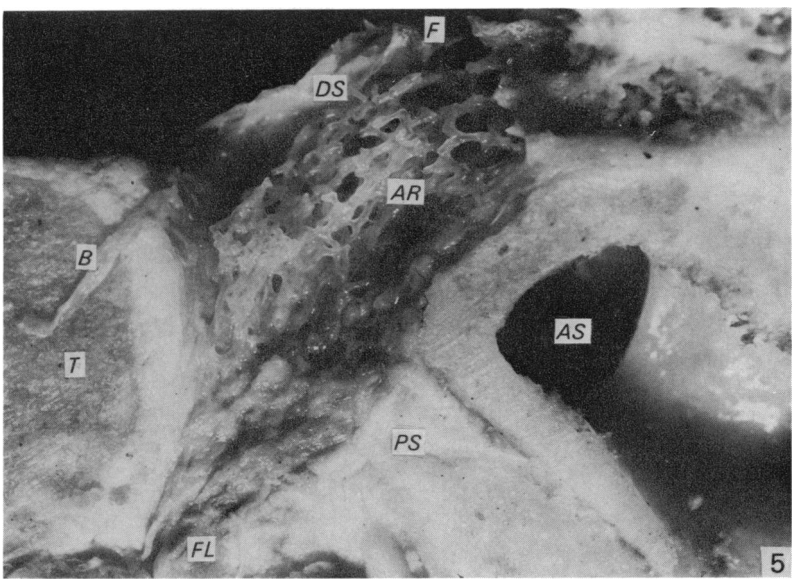
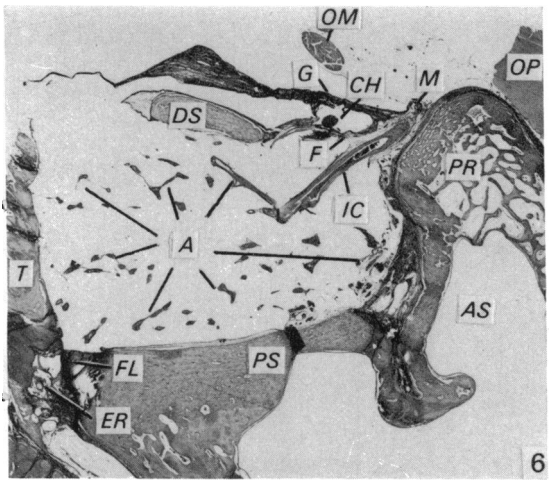
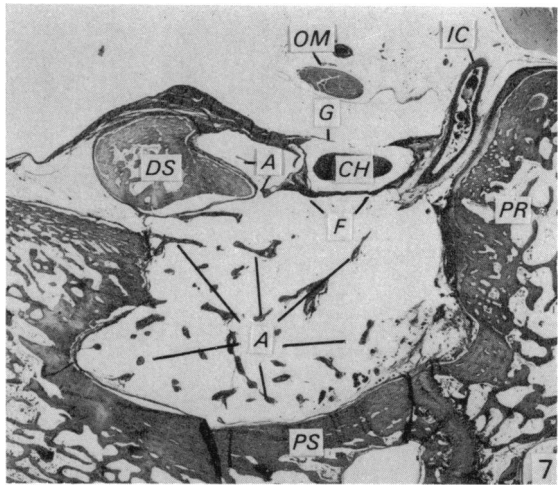


Fig. 5. The abducent nerve (*B*) has been severed and turned back over the right temporal bone (*T*). An arterial rete (*AR*) is seen occupying the region inferior to the dorsum sellae (*DS*) and the sheet of dura mater (*F*), and superior to the right foramen lacerum (*FL*) and the post-sphenoid (*PS*). ×6·1.





Figs. 6–8 are sagittal sections from a right paramedian plane to the median plane. Anterior to the right. Oculomotor nerve, *OM*; optic nerve, *OP*; diaphragma sellae, *G*; dorsum sellae, *DS*; cranial hypophysis, *CH*; internal carotid artery, *IC*; arteries of the intracranial rete, *A*; temporal bone, *T*; foramen lacerum, *FL*; postsphenoid, *PS*; presphenoid, *PR*; sphenoidal air sinus (*AS*).

Fig. 6. Right parasagittal section. Level similar to that in Figs. 4 and 5. The cranial hypophysis (*CH*) rests on a sheet of dura mater (*F*) which is connected with the diaphragma sellae (*G*) and the dorsum sellae (*DS*). The sella turcica contains numerous arteries (*A*) running in the horizontal, coronal and sagittal planes forming an intracranial arterial rete. Antero-superiorly three arteries of the rete are joining to form the right internal carotid artery (*IC*) which is about to pierce the roof of the cavernous sinus at *M*. Postero-inferiorly an extracranial arterial rete (*ER*) lies inferior to the plane of the right foramen lacerum (*FL*). ×3.

Fig. 7. Right parasagittal section, medial to that in Fig. 6. A thin diaphragma sellae (*G*) lies superior to the cranial hypophysis (*CH*). The well-defined sheet of dura mater (*F*) is penetrated anteriorly by the right internal carotid artery (*IC*) and posteriorly by an artery (*A*) of the arterial rete. Arteries forming the arterial rete are seen inferior and posterior to the cranial hypophysis (*A*). ×4·5.

the foramen lacerum with an extracranial rete lying immediately inferior to the foramen. Antero-superiorly arteries of the rete join to form the distal segment of the internal carotid artery which almost immediately penetrates the dura mater antero-lateral to the cranial hypophysis (Figs. 6, 7). The arteries of the rete lie within the cavernous and intercavernous sinuses. The arteries are concentrated inferior to the hypophysis, but are also seen posterior to the hypophysis (Fig. 7). The cranial hypophysis rests in an almost suprasellar position on a well defined sheet of dura mater which is attached anteriorly to the presphenoid and posteriorly to the anterior aspect of the dorsum sellae below its upper margin. In all specimens sectioned in the sagittal plane the upper part of the prominent dorsum sellae is seen to be angulated posteriorly (Fig. 8). The diaphragma sellae is well defined laterally (Fig. 6) but towards the median plane it presents as a thin film of tissue (Figs. 7, 8).

This description was confirmed and amplified by examination of the sella turcica and the cavernous sinus region in serial coronal sections (Figs. 9–11). The sheet of dura mater supporting the cranial hypophysis is seen to be in the same plane as the roof of the cavernous sinus on either side. The diaphragma sellae is attenuated over the cranial hypophysis (Fig. 10). The number and size of the arteries crossing the median plane are demonstrated (Figs. 9, 10). In the more anterior coronal sections

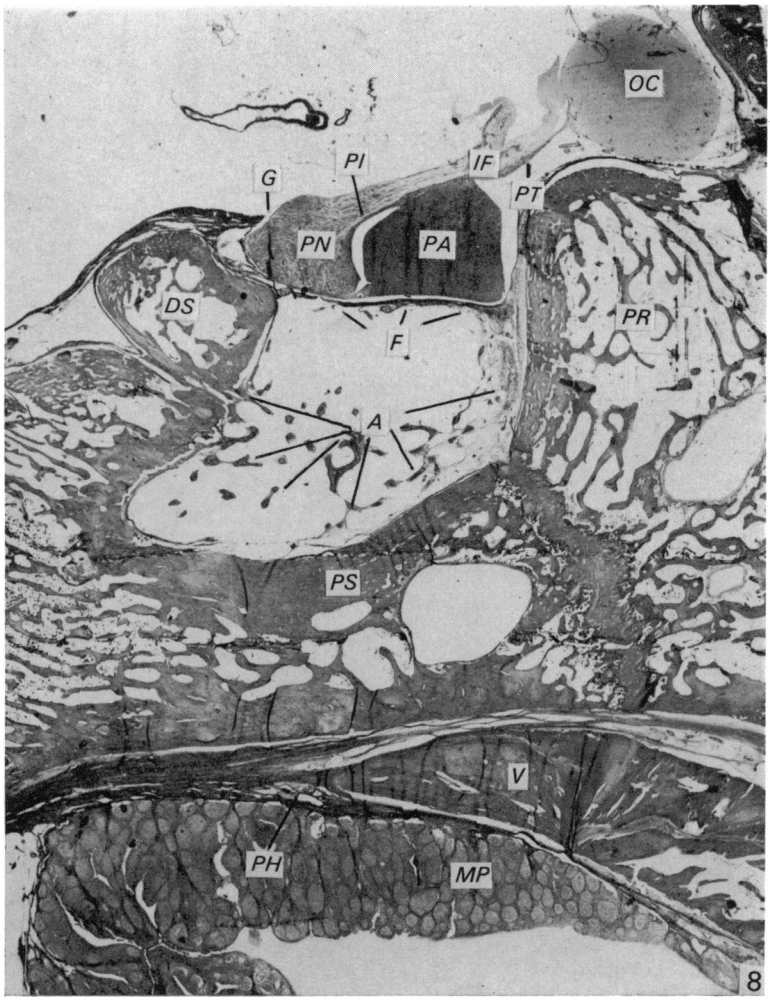
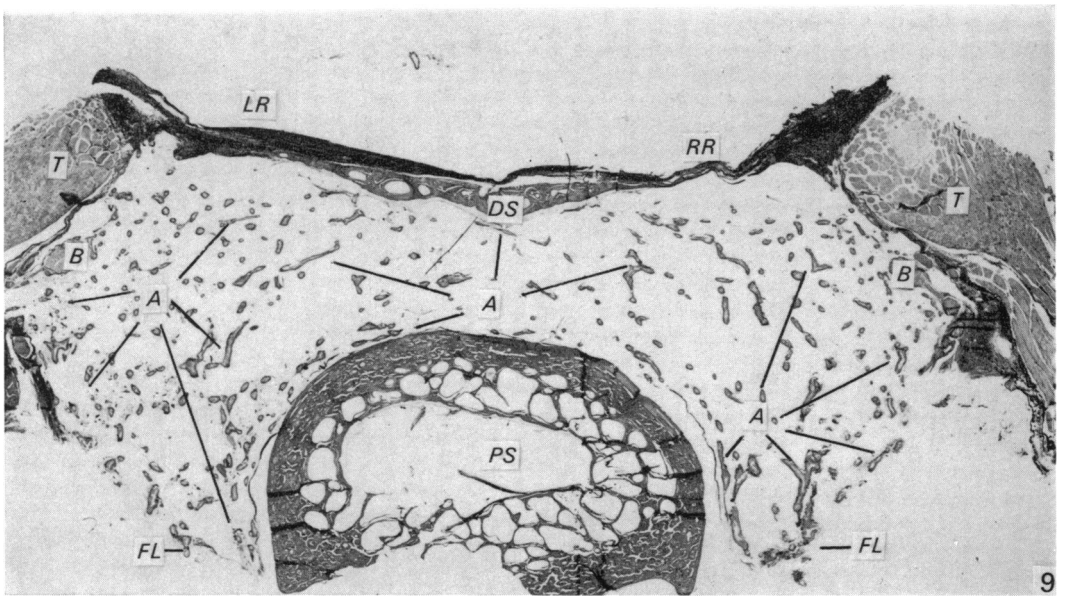


Fig. 8. Median sagittal section. Pars anterior, *PA*; pars intermedia, *PI*; pars tuberalis, *PT*; pars nervosa, *PN*; infundibulum, *IF*. The cranial hypophysis rests on a well-defined sheet of dura mater (*F*) attached anteriorly to the presphenoid and posteriorly to the dorsum sellae (*DS*) inferior to its superior margin. The upper margin of the dorsum sellae is angulated posteriorly. The sella turcica is very deep and contains arteries of the arterial rete (*A*). Optic chiasma, *OC*; diaphragma sellae, *G*. The pharyngeal hypophysis (*PH*) presents as an elongated cellular body in the mucoperiosteum underlying the posterior tip of the vomer (*V*) in the roof of the nasopharynx. ×4.

it can be seen that the cranial hypophysis is more closely related to the sphenoid and that the internal carotid artery, formed by the arteries of the rete, lies in the roof of the cavernous sinus immediately lateral to the hypophysis (Fig. 11).

The arteries of the intracranial rete in the mature female pig have a mean internal diameter of 74 μm and a mean tunica media width of 36 μm. Corresponding dimensions of the internal carotid artery as it pierces the roof of the cavernous sinus are 370 μm and 148 μm. The tunica media is predominantly muscular, but some elastic tissue is present.

The subdivisions of the cranial hypophysis in the pig are clearly demarcated in the stained section (Fig. 8). In three specimens sectioned in the sagittal plane pars



Figs. 9–11 are coronal sections through the sella turcica and cavernous sinuses of a mature female pig from posterior to anterior. The right side is to the right.

Fig. 9. Coronal section at the level of the foramen lacerum. Postsphenoid, *PS*; trigeminal nerve, *T*; abducent nerve, *B*. The region inferior to the roof of the cavernous sinus on either side (*LR*, *RR*) and the dorsum sellae (*DS*) contain numerous arteries (*A*) running in coronal, sagittal and horizontal planes forming an intracranial arterial rete. The vessels are concentrated in the vicinity of the foramen lacerum (*FL*). × 5.

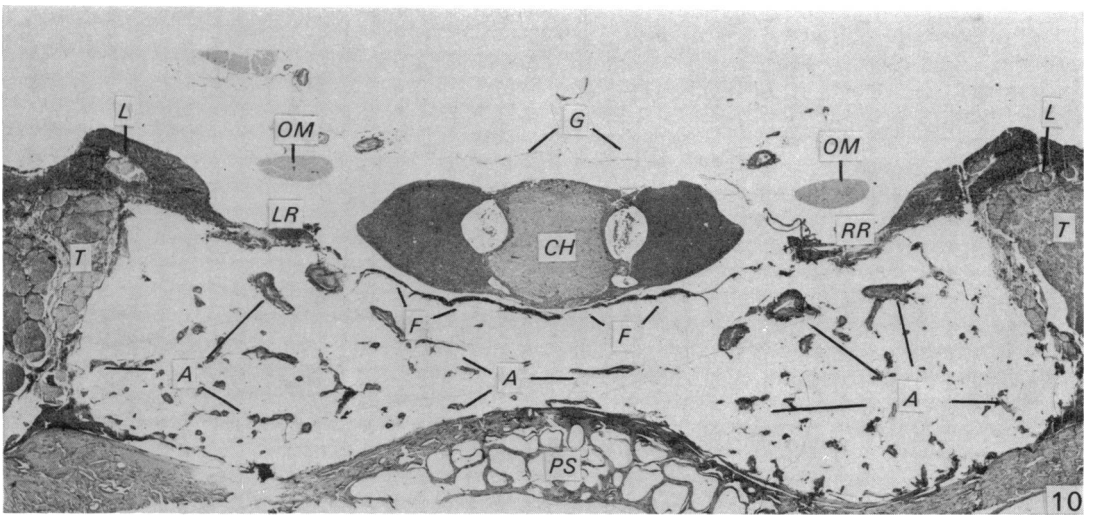


Fig. 10. Coronal section anterior to Fig. 9. A thin diaphragma sellae (*G*) extends laterally and downward to fuse with the roof of the right cavernous sinus (*RR*). The cranial hypophysis (*CH*) rests on a well-defined sheet of dura mater (*F*) which is directly continuous laterally with the roof of the cavernous sinus on either side (*RR*, *LR*). The region inferior to the cranial hypophysis and the roof of the cavernous sinus on either side contains arteries (*A*) forming an arterial rete. Oculomotor nerve, *OM*; trochlear nerve, *L*; trigeminal nerve, *T*; postsphenoid, *PS*. × 5.

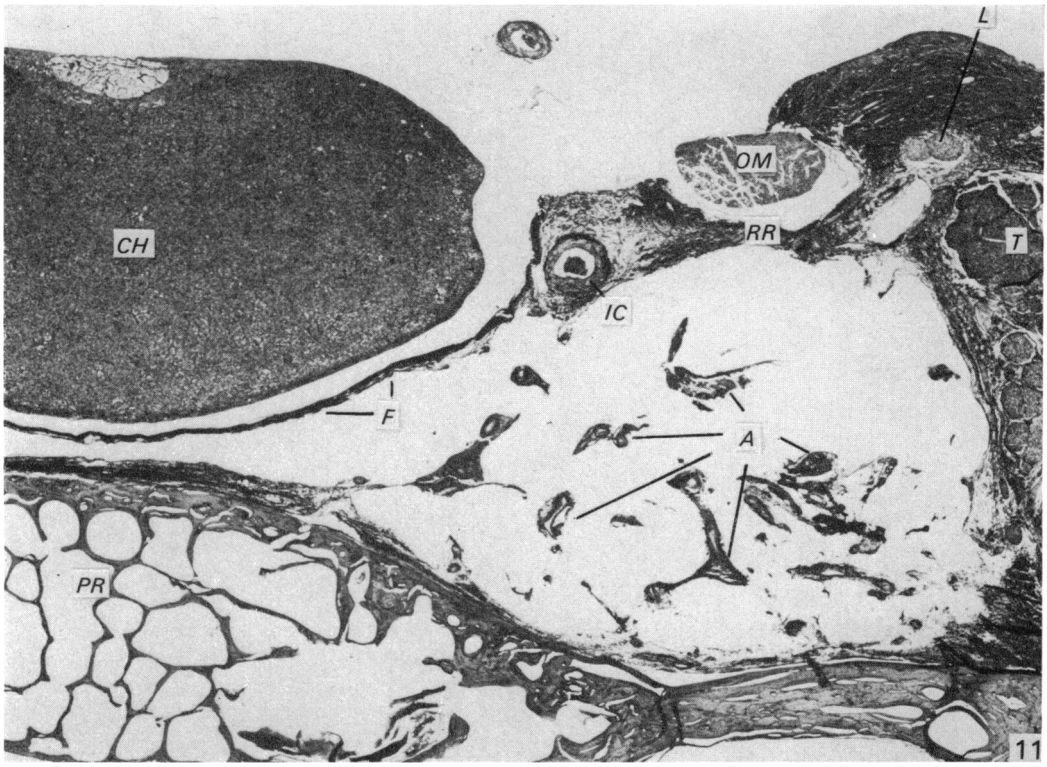


Fig. 11. Coronal section anterior to Fig. 10. Arteries (*A*) forming an intracranial rete lie in the region inferior to the roof of the right cavernous sinus (*RR*) and the sheet of dura mater (*F*) supporting the cranial hypophysis (*CH*). The internal carotid artery (*IC*) has formed immediately lateral to the cranial hypophysis. Oculomotor nerve, *OM*; trochlear nerve, *L*; trigeminal nerve, *T*; presphenoid, *PR*. ×12.

Table 1. *Dimensions* of the cranial and pharyngeal hypophyses in the mature female pig*

Dimension	Cranial hypophysis		Pharyngeal hypophysis
	Adenohypophysis	Total	
Length (mm)	5·0	7·5	1·1
Depth (mm)	5·0	4·5	0·1
Width (mm)	7·3	7·3	0·3
Volume $(mm)^3$	182·5	246·4	0·03

* See text.

intermedia tissue is seen to penetrate the supporting sheet of dura mater and spread out on the inferior aspect of the latter. In some sections this tissue is closely related to small branches of the retial arteries which penetrate the sheet of dura mater from below. The dimensions of the cranial hypophysis are shown in Table 1. A pharyngeal hypophysis, presenting as an elongated cellular collection surrounded by a fibrous capsule and lying in the mucoperiosteum of the roof of the nasopharynx in the median plane, is evident in three specimens. The dimensions of the

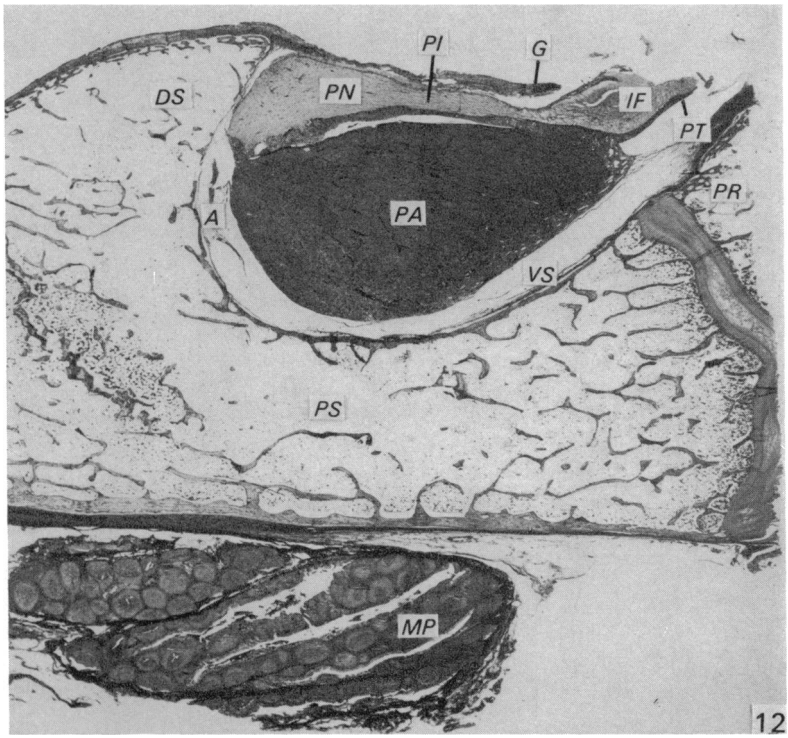


Fig. 12. Median sagittal section through an *en bloc* specimen of the sphenoid in the mature female sheep. A well defined diaphragma sellae (*G*) lies superior to the cranial hypophysis. The cranial hypophysis lies within the sella turcica. Pars anterior, *PA*; pars intermedia, *PI*; pars tuberalis, *PT*; pars nervosa, *PN*; infundibulum, *IF*. Small arteries (*A*) are evident posterior to the cranial hypophysis. Venous sinuses, *VS*; dorsum sellae, *DS*; postsphenoid, *PS*; presphenoid, *PR*; mucoperiosteum of the nasopharynx, *MP*. ×6.

pharyngeal hypophysis in the pig are shown in Table 1. Differentiated endocrine cells in the pharyngeal hypophysis in the pig cannot be identified.

Histological examination of en bloc specimens of the sphenoid in the sheep

In the mature female sheep the cranial hypophysis occupies the sella turcica. The sella turcica is deep, with a dorsum sellae directed upwards and slightly forwards. An intracranial rete lies within the cavernous sinus lateral to the cranial hypophysis. The retia are connected by a few arteries which cross the midline in the intercavernous sinus posterior and, occasionally, inferior to the hypophysis (Fig. 12). The arteries of the rete converge antero-superiorly to form the distal segment of the internal carotid artery, which penetrates the roof of the cavernous sinus lateral to the hypophysis (Fig. 13). The arteries of the rete have a mean internal diameter of 93 μm and mean tunica media width of 19 μm. Corresponding dimensions of the internal carotid artery as it pierces the roof of the cavernous sinus are 740 μm and 70 μm. The tunica media is predominantly muscular but a small amount of elastic tissue is present.

Fig. 13. Coronal section through the cranial hypophysis and the right cavernous sinus in the mature female sheep. A well defined diaphragma sellae (*G*) extends laterally into the roof of the cavernous sinus. The cranial hypophysis (*CH*) rests in the hypophyseal fossa separated from the postsphenoid (*PS*) by the intercavernous sinus. The cavernous sinus is filled with venous sinuses (*VS*) and numerous arteries (*A*). An internal carotid artery (*IC*) has formed lateral to the hypophysis and is in the process of penetrating the roof of the cavernous sinus. In the infero-lateral angle of the cavernous sinus an artery can be seen entering the region (*W*). Oculomotor nerve, *OM*; trochlear nerve, *L*; trigeminal nerve, *T*; abducent nerve, *B*. ×14.

DISCUSSION

The calculated volume of the cranial hypophysis in the mature female pig is less than that in the mature female sheep. A pharyngeal hypophysis has not been found in the sheep. The incidence and dimensions of the pharyngeal hypophysis in the pig are similar to those found previously in the rat (McGrath, 1974). The features of the sella turcica in the pig and the sheep observed in the present investigation confirm published data (Sisson & Grossman, 1953; Bourdelle, 1964). However, the almost suprasellar position of the cranial hypophysis, and the angulation of the upper margin of the dorsum sellae observed in the pig in the present study have not been reported previously.

Observations on the intracranial carotid rete in the pig and in the sheep are in general agreement with published established data. The functional significance of the interconnexions between the carotid retia in the pig has not been elucidated. The significance of such interconnexions in other artiodactyla, e.g. the sheep, ox and goat, is equally uncertain; however it has been established that in these species passage of blood between the two retia only occurs if the pressure relationships are disturbed (Gillilan, 1974).

It is of interest to compare the carotid rete and its relationship to the cranial hypophysis in the pig and the sheep. The carotid rete in both species lies within the cavernous sinus, and is closely related to the third, fourth, fifth and sixth cranial nerves. In both species the arteries forming the rete are medium-sized muscular arteries, those in the pig having a smaller lumen and a thicker muscular wall. The anastomosis between the retia in the pig is extensive, while that in the sheep is limited to a few arteries. In the pig the extensive retial interconnexions lying within the intercavernous sinus fill the deep sella turcica and the cranial hypophysis occupies an almost suprasellar position, while in the sheep there are only a few anastomotic arteries (passing posterior to the hypophysis) and the gland lies wholly within the sella turcica. These facts suggest that the high position of the cranial hypophysis in the mature female pig results from the inward and upward pressures exerted on the hypophysis by the carotid retia and their extensive interconnexions in this species.

SUMMARY

It is accepted that in the pig the intracranial carotid retia are connected across the midline by numerous arteries lying within the intercavernous sinus. The present study has demonstrated that these vascular elements fill the greater part of the very deep sella turcica, the cranial hypophysis occupying an almost suprasellar position. In the sheep the anastomosis between the carotid retia is limited to a few arteries crossing the midline posterior to the hypophysis, and the gland lies wholly within the sella turcica. It is suggested that the position of the cranial hypophysis in the mature female pig results from the inward and upward pressures exerted on the hypophysis by the carotid retia and their extensive interconnexions in this species.

Thanks are due to Professors A. R. Currie and J. Swanson Beck for advice, and to Dr P. H. McCarthy for help with the bibliography. The technical assistance of Mr D. Joy, Mrs K. Jakes and Mr B. Bowdern is gratefully acknowledged. This work was supported by the Medical Research Committee of the University of Sydney.

REFERENCES

BALDWIN, B. A. (1964). The anatomy of the arterial supply to the cranial regions of the sheep and the ox. *American Journal of Anatomy* **115**, 101–118.

BOURDELLE, E. (1964). In *Anatomie Regionale des Animaux Domestiques*, III, Le Porc. 2nd edition (ed. L. Montané, E. Bourdelle and C. Bressou). Paris: Baillière et Fils.

DANIEL, P. M., DAWES, J. D. K. & PRICHARD, M. M. L. (1953). Studies of the carotid rete and its associated arteries. *Philosophical Transactions of the Royal Society*, B **237**, 173–208.

GILLILAN, L. A. (1974). Blood supply to brains of ungulates with and without a rete mirabile caroticum. *Journal of Comparative Neurology* **153**, 275–290.

MCGRATH, P. (1974). The pharyngeal hypophysis in some laboratory animals. *Journal of Anatomy* **117**, 95–115.

SISSON, S. & GROSSMAN, J. D. (1953). *The Anatomy of the Domestic Animals*, 4th edition. Philadelphia: Saunders.