Macroscopic blood supply to the hypophysis and hypothalamus of the ostrich (*Struthio camelus*)

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ABSTRACT

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The branching pattern of the *Aa. carotes internae* and the macroscopic blood supply to the hypophysis and hypothalamus of the ostrich were studied on ten dissected acrylic vascular-injected heads and ten corrosion preparations of acrylic vascular casts of the head. The *A. carotis cerebralis* was found to be the only source of blood supply to the hypophysis and hypothalamus. The neurohypophysis was supplied by the caudal hypophyseal and infundibular arteries. The pars distalis was supplied by portal vessels from the ventral hypothalamic region,and it also received arterial blood directly from the infundibular arteries. The hypothalamus received blood from the *Aa. infundibulares, A. ventralis tecti mesencephali* and *A. preopticae*.

Keywords: Hypothalamus, hypophysis, macroscopic blood supply, ostrich, *Struthio camelus*

INTRODUCTION

One of the many problems encountered by South African ostrich farmers, is the low hatchability of eggs produced under commercial farming conditions (Burger & Bertram 1981).

The hormones produced by the adenohypophysis in birds, including follicle-stimulating hormone (FSH) and luteinizing hormone (LH), are documented in the literature (Sturkie 1954). FSH and LH were isolated from the hypophysis of the ostrich and characterized by Papkof, Licht, Bona-Gallo, Mackenzie, Oelofsen & Oosthuizen (1982). An understanding of the role of LH and FSH in controlling the reproductive cycle and fertility in ostriches, coupled with a thorough knowledge of the blood supply to, and blood flow through the hypophysis, may provide important information relevant to this problem.

The anatomy and histology of the hypophysis, including its blood supply, has been thoroughly described in various mammals. A review of the blood supply of the hypothalamus and hypophysis of mammals, with a few references to birds, was presented by Daniel (1966) and later by Holmes & Ball (1974). In birds, the anatomy and histology of the hypophysis, including its blood supply, have been investigated in various species, including the pigeon (Bhaduri, Biswas & Das 1957), white-crowned sparrow (Vitums, Mikami, Oksche & Farner 1964; Vitums, Mikami & Farner 1965) and Japanese quail (Sharp & Follett 1969). Comparative studies of a number of avian species, including the ostrich, have also been carried out (Green 1951; Wingstrand 1951).

The morphology of the blood vessels supplying the hypophysis in avian species of commercial importance, is well documented for the chicken (Hughes

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1934–1935; Yasuda 1953; Duncan 1956; Hasegawa 1956; Kaku 1959; Okamoto & Ihara 1960; Richards 1967; Richards 1968) and the duck (Assenmacher 1952; 1953; 1958; Benoit 1964). Baumel & Gerchman (1968) studied the intercarotid anastomosis in various avian species, including the ostrich.

Despite the economic importance of the ostrich, its anatomy, including that of the blood vessels supplying the hypophysis, is poorly documented. The aim of the present study was to describe the gross anatomy of the blood vessels supplying the hypothalamus and hypophysis of the ostrich. The nomenclature used is based on "The Handbook of Avian Anatomy—Nomina Anatomica Avium" (Baumel, King, Breazile, Evans & Berge 1993).

MATERIALS AND METHODS

The heads of 20 sub-adult ostriches of both sexes were collected at the abattoir at the Klein Karoo Koöperasie, Oudtshoorn. A catheter was immediately inserted into the right common carotid artery and fixed in position by tying it with surgical silk. The vessels of the head were then rinsed with a physiological saline solution—via the catheter—until they were clear of blood. The heads were then transported to the Ostrich Research Centre, Oudtshoorn, for further treatment. After all the visible vessels had been tied with surgical silk, approximately 10 mℓ of red-coloured acrylic resin [Biodur E20 (BiodurTM Products)] was injected into the arterial system via the catheter and left to harden. Once the solution had set, the heads were transported to the Faculty of Veterinary Science, University of Pretoria. Ten heads were subsequently macerated in a 3–10% solution of potassium hydroxide (KOH). The resin casts of the blood vessels were studied and photographed with a stereo microscope.

The casts were subsequently trimmed to expose the vessels of the hypothalamus and hypophysis and prepared for Scanning Electron Microscopy (SEM). The specimens were suitably oriented and mounted on stubs with a quick-setting epoxy glue which, after it had dried, was overlayed with a conducting layer of carbon dag at the contact-mounting points. The mounted stubs were then gold-sputter-coated in three positions relative to the stub: one coating almost parallel to the face of the stub; another, with the stub turned 180°; and a final coating in a position perpendicular to the stub. This procedure helped to avoid charging when the specimens were viewed in the microscope. The prepared casts were viewed with a Phillips Scanning Electron Microscope operated at 8 KV.

The remaining ten heads were fixed in 10% formalin for 1 d and then dissected to expose the internal carotid arteries, the ventral, superficial vessels of the brain and the hypophysis (Fig. 1).

The description of the vessels that supply the hypothalamus and hypophysis was based mainly on the information gained from the corrosion vascular casts.

RESULTS

In the neck, the internal carotid arteries (*Aa. carotes internae*) lay in the ventral median plane, embedded in the ventral neck musculature (Longus colli muscles). In this position, the left internal carotid artery was usually superficial to the right internal carotid artery. In the cranial neck region, at the level of the cranial end of the third cervical vertebra (C3), the two vessels became superficial and diverged from each other. At the level of the Atlas, each internal carotid artery first gave off the ventro-rostrally directed external carotid artery and then the dorso-rostrally directed external ophthalmic artery. The continuation of the internal carotid artery beyond the origin of the external ophthalmic artery was the cerebral carotid artery (*A. carotis cerebralis)*. The cerebral carotid artery continued rostromedially and entered the cranium through the carotid canal of the sphenoid bone. Within the carotid canal the palatine and sphenomaxillary branches were given off (p and w in Fig. 1). The cerebral carotid arteries entered the cranium caudolaterally to the hypophysis. The two vessels were connected to each other caudo-dorsally to the hypophysis, by the intercarotid anastomoses (*Anastomosis intercarotica*) (b in Fig. 2, 3, 4 and 5). The intercarotid anastomosis and the two cerebral carotid arteries therefore encircled the caudo-dorsal and lateral aspects of the hypophysis.

The following vessels arose from the cerebral carotid arteries or the intercarotid anastomoses.

Caudal hypophyseal arteries

The caudal hypophyseal arteries (*Aa. hypophysiales caudales*) supplied the neurohypophysis. In five of the specimens, these arteries originated from the intercarotic anastomosis as one or two small branches (c in Fig. 2 and 3). In three specimens, they arose from the right cerebral carotid artery caudal to the intercarotic anastomoses (c in Fig. 4), and in two specimens, from the left cerebral carotid artery, rostral to the intercarotic anastomoses (c in Fig. 5).

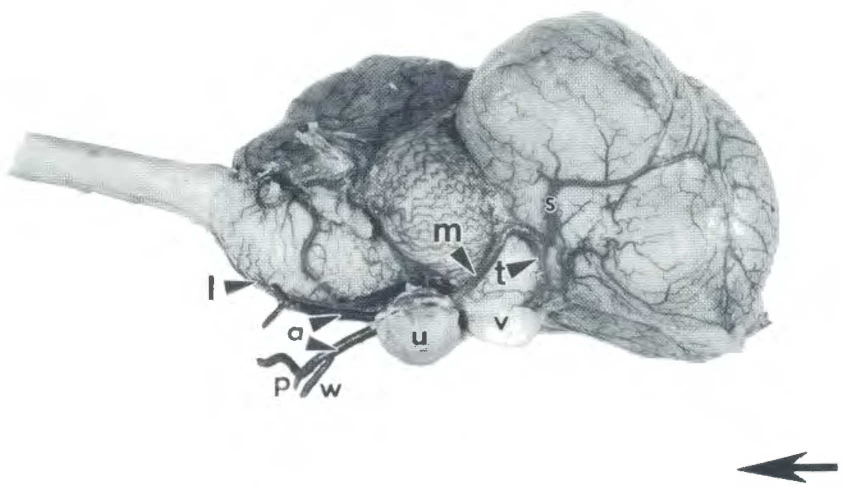
An inconstant branch to the surrounding bone and connective tissue

This small vessel arose from the intercarotid anastomoses in one specimen (d′ in Fig. 2) and from the right cerebral carotid artery before the intercarotic anastomoses in four of the specimens (d in Fig. 4).

From the intercarotid anastomosis, the cerebral carotid arteries continued rostro-dorsally along the dorsolateral border of the hypophysis, where they gave off the following branches (p. 250).

KEYS: FIG. 1–14

a *Arteria carotis cerebralis*
b *Anastomosis intercarotica*
c *Arteria hypophysialis caudalis*
d Branch from *A.carotis cerebralis* to the surrounding bone
d′ Branch from the *anastomosis intercarotica* to the surrounding bone
e *Arteria ophthalmica interna*
f Mesencephalic branches
g *Arteria infundibularis*
h Rostral directed branches from infundibular arteries
i *Venae portales*
j *Ramus caudalis a. carotidis cerebralis*
l *Arteria basilaris*
m *Ramus rostralis a. carotidis cerebralis*
n *Arteria ventralis tecti mesencephali*
o *Arteriae hypothalamicae ventrales*
p *Ramus palatinus*
q Independent branch to *pars distalis*
r *Arteria cerebralis caudalis*
s *Arteria cerebralis media*
t *Arteria cerebroethmoidalis*
u *Glandula pituitaria*
v *Chiasma opticum*
w *Ramus sphenomaxillaris*
x *Aa. preopticae*
z Ventral directed branches from infundibular arteries



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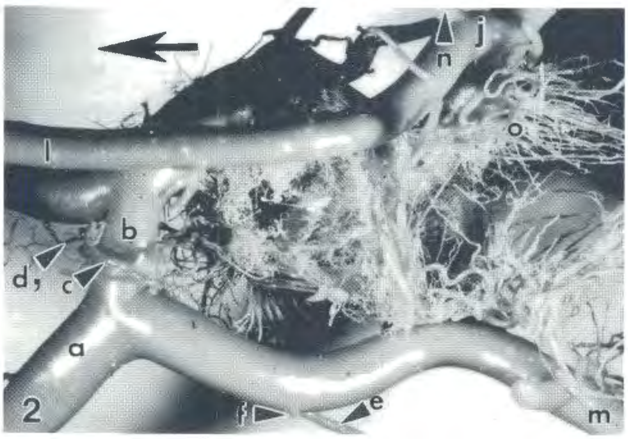


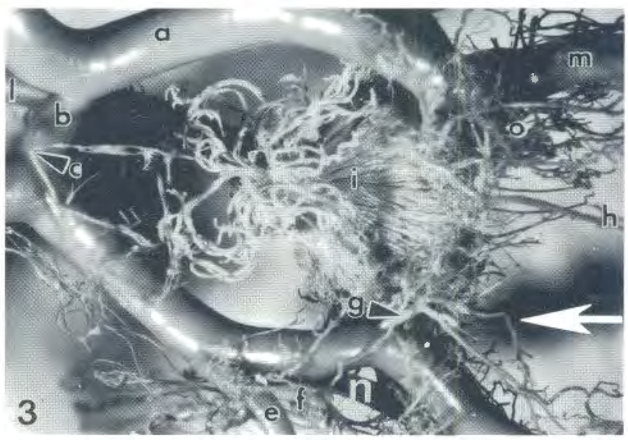


FIG. 1 Dissected brain displaying the cast of the superficial arteries. Ventrolateral view. Arrow indicates rostro-caudal direction in this figure and all subsequent figures. Life size

FIG. 2 Dorsal view of the vessels supplying blood to the hypophysis and hypothalamus. Corrosion cast. Stereomicrograph x7

FIG. 3 Ventral view of the vessels supplying blood to the hypophysis and hypothalamus. Corrosion cast. Stereomicrographs x7

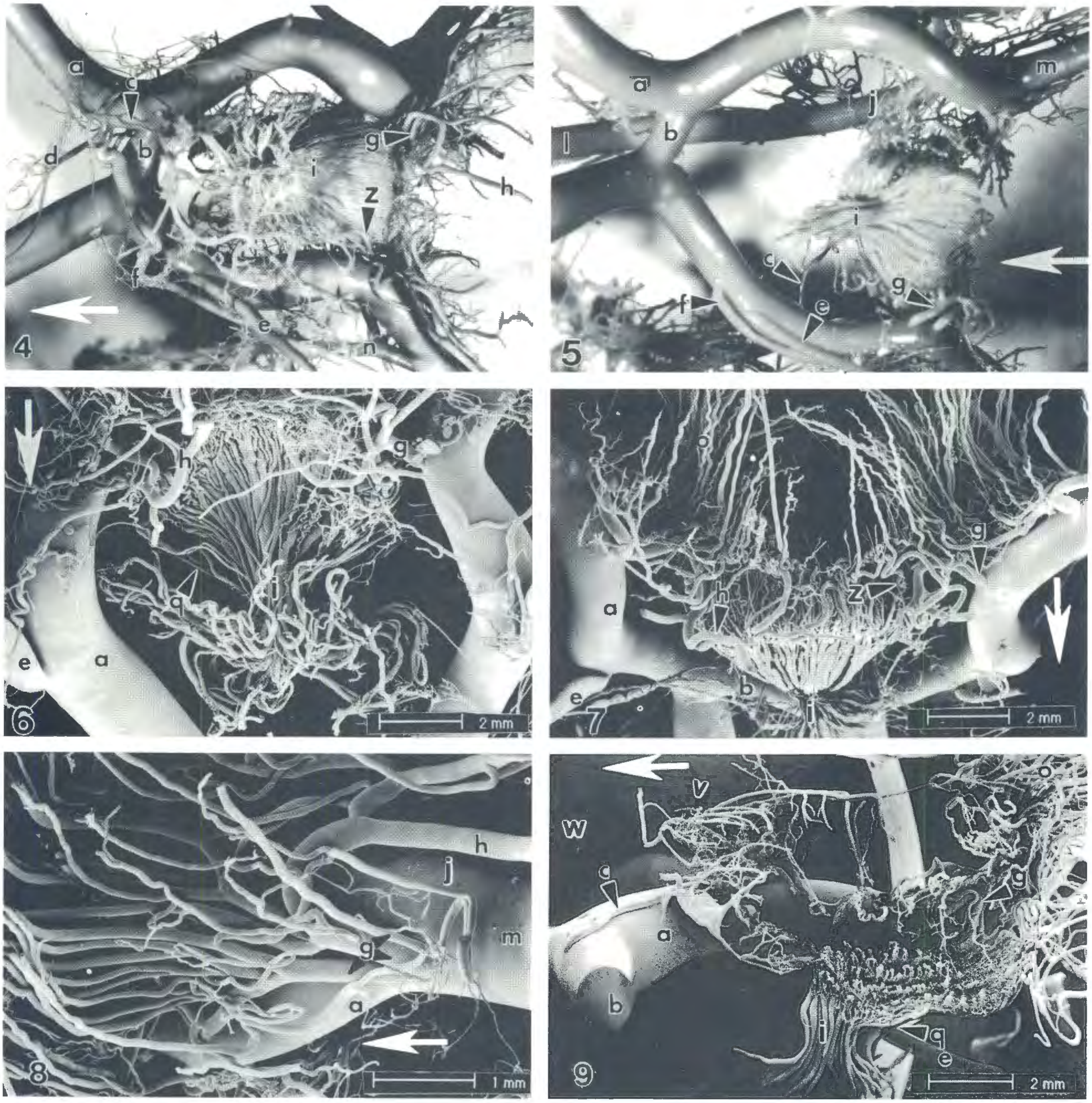


FIG. 4 and 5 Ventral view of the vessels supplying blood to the hypophysis and hypothalamus. Corrosion cast. Stereomicrographs x7

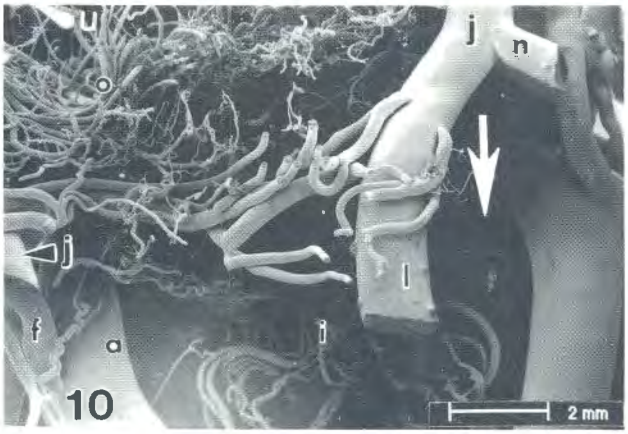
FIG. 6 and 7 Ventral view of the vessels supplying blood to the hypophysis and hypothalamus. Corrosion cast. Scanning Electron Micrographs x10

FIG. 8 Multiple origin of the infundibular artery. Corrosion cast. Scanning Electron Micrograph x24

FIG. 9 Medial view of the vessels supplying blood to the hypophysis and hypothalamus. Corrosion cast. Scanning Electron Micrograph x10

FIG. 10, 11, 12 and 13 Dorsal view of the vessels supplying blood to the hypophysis and hypothalamus. Corrosion cast. Scanning Electron Micrographs x10, x10, x8 and x8, respectively

FIG. 14 Ventral view of blood vessels to the hypophysis and hypothalamus demonstrating the pre-optic arteries. Corrosion cast. Micrograph x10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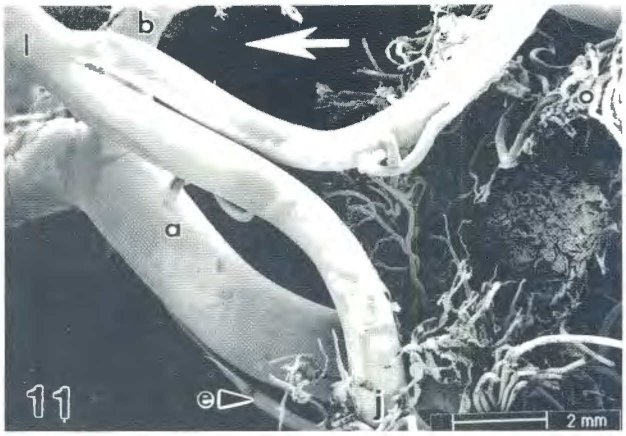
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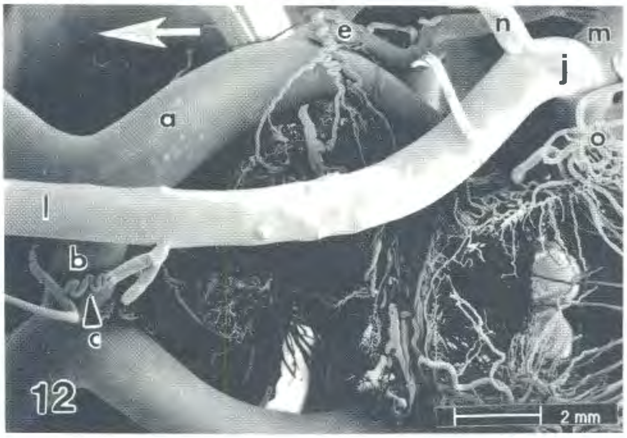
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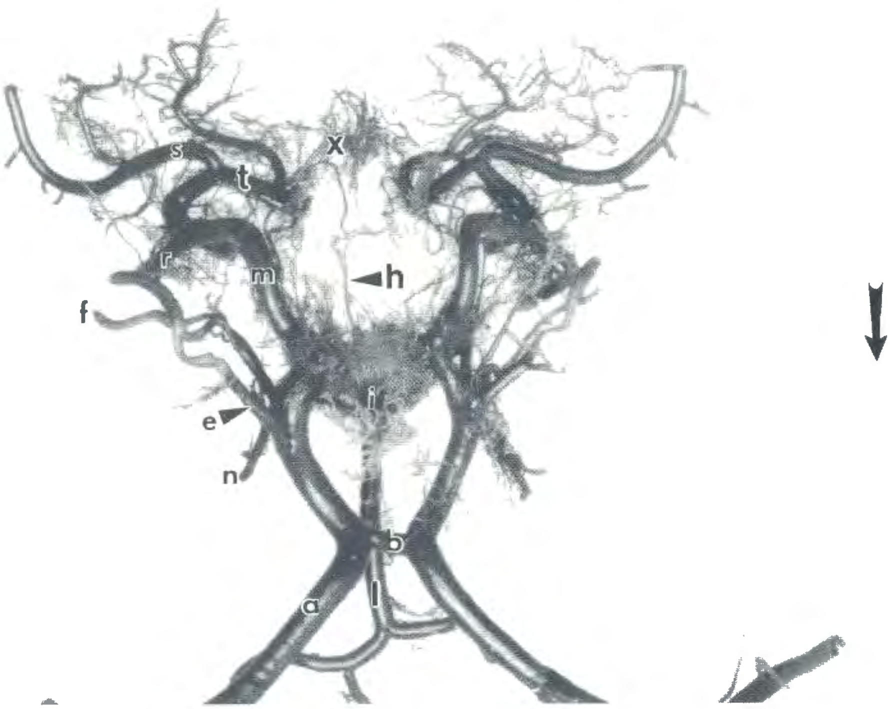
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Internal ophthalmic arteries

The left and right internal ophthalmic arteries (*Aa. ophthalmicae internae*) arose from the ventral aspect of the cerebral carotid arteries, laterally to the hypophysis (e in Fig. 6).

Mesencephalic branches

Branches to the mesencephalon arose from the same region as the internal ophthalmic arteries. In one specimen, they arose from the dorsal aspect of the cerebral carotid arteries, opposite to the origin of the internal ophthalmic arteries (f in Fig. 3 and 10). In two specimens, they arose from the ventral aspect and in one specimen, a single vessel arose from the lateral aspect of the left cerebral carotid artery (f in Fig. 5).

Infundibular arteries

The next pair of vessels that arose from the carotid cerebral arteries, were the left and right infundibular arteries (*Aa. infundibulares*) (g in Fig. 3, 4, 5, 6 and 7). In some of the specimens, more than two vessels were present (g in Fig. 5 and 8). They immediately divided into numerous smaller, dorsally directed arteries and a few ventrally directed vessels (o and z in Fig. 2, 3, 4 and 7). Most of the dorsally directed arteries formed part of the ventral hypothalamic vessels that supplied the hypothalamic region (o in Fig. 7), while others anastomosed with the capillary plexus from which the portal veins to the Pars distalis arose (o in Fig. 2 and 7). The ventrally directed vessels crossed the lateral surfaces of the infundibulum obliquely to supply the neurohypophysis. A small number of these vessels reached and supplied the Pars distalis (q in Fig. 6 and 9).

In seven specimens, a further set of vessels passed rostrally (h in Fig. 3) and anastomosed with the preoptic arteries (h and x in Fig. 14). From the latter anastomoses, a few vessels passed dorsally to supply the hypothalamic region.

After the infundibular arteries were given off, the cerebral carotid arteries divided into rostral and caudal branches (j and m in Fig. 12).

The caudal branch (*R. caudalis*) showed variations in its origin, size and presence. In one specimen, left and right caudal branches of approximately equal size were present (j in Fig. 11). In 16 specimens, only one vessel was present. Of these, six arose from the left (j in Fig. 2 and 12), and ten from the right cerebral carotid arteries (j in Fig. 5). Three specimens displayed a single, large caudal branch on one side and a rudimentary caudal branch on the opposite side (j in Fig. 10). The caudal branch gave off the ventral tectal mesencephalic artery and continued caudally along the ventral aspect of the myelencephalon as the basilar artery.

The ventral tectal mesencephalic artery (*A. tecti mesencephali ventralis*) passed dorsally to supply the tectum of the mesencephalon. Before it reached the mesencephalon, it gave off branches to the ventral hypothalamic region, including the median eminence. These vessels formed part of the ventral hypothalamic vasculature (n in Fig. 10 and 13).

The rostral branch (*R. rostralis*) continued rostrally, giving off the caudal cerebral artery, the middle cerebral artery and then the cerebro-ethmoidal artery (*A. cerebroethmoidalis*). A large number of caudally directed preoptic vessels (*Aa. preopticae*) arose from the cerebro-ethmoidal artery. Some of these vessels anastomosed with the ventral hypothalamic branches of the infundibular artery (x in Fig. 14).

Portal vessels of the hypophysis

The entire surface of the median eminence was covered by parallel-running portal vessels (*Vv. portales rostrales et caudales*) (i in Fig. 3, 4, 5, 6, 7 and 14). The rostral and caudal portal veins could not be separated from each other, as they formed a continuous mass of vessels on the surface of the median eminence. All the vessels converged towards the infundibulum, rostrally to the neurohypophysis. They crossed the lateral surfaces of the infundibulum and then entered the dorsal aspect of the Pars distalis.

The following is a summary of the blood supply to the hypophysis and ventral hypothalamus:

- *Neurohypophysis*

  Mainly from the caudal hypophyseal arteries (c in Fig. 2 and 3), with additional vessels from the infundibular artery (g in Fig. 9).

- *Pars distalis*

  Mainly portal vessels from the median eminence (i in Fig. 3, 4, 5, 6, 7 and 9), with additional vessels from the infundibular arteries.

- *Ventral hypothalamus*

  Mainly from the infundibular arteries, with additional vessels from the ventral tectal mesencephalic and pre-optic arteries (n, o and x in Fig. 2, 3, 4, 7, 10, 12, 13 and 14).

DISCUSSION

In the present study, the position of the internal carotid arteries in the ventral neck region of the ostrich was found to be similar to that reported by Glenny (1965) and Baumel (1964) for other avian species. Bhaduri *et al.* (1957) state that the internal carotid arteries of the pigeon diverge in the cranial neck region. In the present study, it was found that the internal carotid arteries became superficial to the ventral neck muscles and diverged from each other at the level of the cranial extremity of C3. The vessels therefore are easily accessible cranially to C3.

The origins of the external carotid arteries, external ophthalmic arteries and the cerebral carotid arteries of the ostrich, were found to be similar to those described for other avian species by Bhaduri & Biswas (1945), Baumel (1964; 1967) and Richards (1967). The course of the vessels, however, differed from those of the white-crowned sparrow, in which the internal carotid artery gave off the external carotid and occipital arteries (Vitums *et al.* 1965).

In some species of birds, two vessels, the palatine and sphenomaxillary arteries, arise from the cerebral carotid artery before the intercarotid anastomosis (Wingstrand 1951; Richards 1967; Baumel & Gerchman 1968). In the pigeon (Baumel 1967), the two vessels arise from a common trunk. In the present study, the two vessels were found to arise from the cerebral carotid artery within the carotid canal and independently of each other.

The left and right cerebral carotid arteries of most avian species are connected to each other by an intercarotid anastomosis (Green 1951; Wingstrand 1951; Vitums *et al.* 1964; Vitums *et al.* 1965; Baumel 1967; Richards 1967). Baumel & Gerchman (1968) identified three principal patterns of intercarotid anastomosis, namely H, X and I types. The latter authors included one ostrich in their study and found the intercarotid anastomosis to be of the H type. Their findings were confirmed in the present study.

According to Baumel *et al.* (1993) the caudal hypophyseal arteries arise from the intercarotid anastomosis and these vessels form the principal blood supply to the hypophysis. Vitums *et al.* (1964), however, could not demonstrate the presence of the caudal hypophyseal arteries in the white-crowned sparrow. Wingstrand (1951) studied the caudal hypophyseal arteries in a number of species and found that the vessels supply only the neurohypophysis. The vessels originate from the cerebral carotid arteries before or after the intercarotid anastomosis, or from the anastomosis itself, and were present in 15 of the families of birds that he examined. The latter author did not include the ostrich in his study. In the present study, the caudal hypophyseal arteries arose from the intercarotid anastomosis in five specimens, from the cerebral carotid arteries before the anastomosis in three specimens, and from the cerebral carotid arteries after the anastomosis in two specimens. The origin of the caudal hypophyseal arteries in the latter two specimens is considered to be an exception as previously noted by Wingstrand (1951). In the present study, the caudal hypophyseal arteries supplied the caudal part of the neurohypophysis in all the specimens examined.

The origin of the internal ophthalmic arteries is comparable with those reported by Wingstrand (1951) for other avian species. The vessels did not, however, contribute to the blood supply of the hypophysis in the ostrich.

The origin of the infundibular arteries is variable in different avian species. According to Wingstrand (1951), their origins are exclusively from the cerebral carotid arteries before the latter divides into rostral and caudal branches, while Vitums *et al.* (1964) report that they originate from the rostral branches of the cerebral carotid arteries. In the present study, the infundibular arteries were found to originate from the cerebral carotid arteries before the division of the latter into caudal and rostral branches. This is in agreement with Wingstrand (1951).

According to Wingstrand (1951), there are one to three infundibular arteries that supply the surface of the hypothalamus, the cranial part of the neurohypophysis (in some species) and the primary plexus of the median eminence (from which the portal vessels originate). He also found the vessels to be fairly small and variable. In the present study, the infundibular arteries were fairly large. In two specimens, more than two infundibular arteries were present. The infundibular arteries generally divided close to their origins, into several smaller vessels. Some of the vessels passed dorsally to supply the ventral hypothalamus and capillary plexus, while others passed ventrally to supply the cranial part of the neurohypophysis. In addition, some of the latter vessels passed ventrally along the lateral surfaces of the infundibulum to supply the Pars distalis directly. The Pars distalis, therefore, has three sources of blood supply: venous blood from the portal vessels; mixed venous and arterial blood from portal vessels that anastomose with vessels from the infundibular arteries; and arterial blood directly from the infundibular arteries.

The origin and size of the caudal branches of the cerebral carotid arteries show great variation in most avian species (Wingstrand 1951). However, Baumel & Gerchman (1968) reported bilateral symmetry in origin and size of these vessels in nine out of 82 species which they examined, representing 21 avian orders. One of the caudal branches of the cerebral carotid arteries will give rise to the basilar artery. In the white-crowned sparrow, the basilar artery generally originates from the right caudal branch (Vitums *et al.* 1964), while in the fowl, mainly from the left caudal branch (Hughes 1934–35; Richards 1967). The present study also confirmed the variation in origin and size of the caudal branch of the cerebral carotid artery in the ostrich.

The contribution of the ventral mesencephalic tectal arteries (ventral optic artery) to the hypothalamic vasculature is reported only in the Japanese quail (Sharp & Follett 1969). In the present study, branches from the ventral mesencephalic tectal arteries were found to contribute directly to the vasculature of the ventral thalamic region, including the median eminence.

The contribution of the preoptic arteries to the blood supply of the hypothalamus in the white-crowned sparrow, is described by Vitums *et al.* (1964; 1965). They found that branches of the preoptic arteries directly supply the supra-optic and paraventricular nuclei of the hypothalamus. The present study confirmed the contribution of the preoptic arteries to the blood supply of the supraoptic and paraventricular nuclei in the ostrich.

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