Part III

Hypothalamo-hypophysial vascular relationship in *Clarias batrachus*

1. Introduction

Detailed information on the vascularisation of the pituitary gland and hypothalamo-hypophysial vascular relationship in fishes is meagre. It has been, therefore, considered desirable to make a detailed study of the blood supply of the head region in *Clarias batrachus*, with particular reference to the pituitary and hypothalamus. Such investigation has further significance as the hypothalamus, especially its nucleus preopticus, forms a well defined hypothalamo-hypophysial system with the pituitary gland. There is vast literature regarding the hormonal control which this system exerts over the body of animals, especially in the mammals. Since there does not seem to be any nervous contact between the cells of the glandular regions of the pituitary and the neurohypophysis, the stimulation of these cells appears to be only hormonal in nature.

The study of the hypothalamo-hypophysial vascular relationship would do a great deal in understanding the pituitary regulation by the hypothalamic secretions.

The vascularisation of the teleostean pituitary has been studied by Florentin (1936) in cyprinoids and salmonoids, Miller (1944)

Besides this, the hypothalamo-hypophysial vascular relationship has been studied by Green (1951) and Lagait (1957) in a number of teleosts and by Wingstrand (1957) in *Protopterus*. Follenius (1961) gave a comparative account of the hypothalamo-hypophysial vascular relationship in fish belonging to *Cypriniformes*, *Cyprinodontiformes* and *Perciformes*. Bhargava (1966 and 1968) has given a detailed account of the blood supply to the pituitary, its intra-vascularisation and its vascular relationship with the hypothalamus especially the pre-optic nucleus, in the minnow *Phoxinus phoxinus*. Hill and Henderson
(1968) gave vascular account of the hypothalamo-hypophysial region of the eastern brook trout *Salvelinus fontinalis*. Recently, Sundararaj and Vishwanathan (1971) in *Heteropneustes fossilis* and Raizada (1971) in *Rasbora daniconius* have described the hypothalamo-hypophysial vascular system.

2. Observations

The vascularisation of the pituitary and the hypothalamo-hypophysial vascular relationship in *Clarias batrachus* has been studied from serial sections (both transverse and vertical longitudinal). The blood vessels were graphically reconstructed in a ventral view from serial transverse sections of a fish 5.2 cm. in length at which stage the fish has almost reached the adult condition. The fingerling attains the post-larval stage at 10 mm. length and the entire metamorphosis is completed at 20 mm. length stage (Mookerjee, 1950) when it attains all the structural characteristics of the adult fish. Serial transverse sections of fingerling 2.5 cm., 3.2 cm., 4.3 cm. and 6.2 cm. in length and vertical longitudinal sections of a large number of fingerling heads have been examined in order to confirm the results obtained in fish 5.2 cm. in length.

At 5.2 cm. stage (Fig. 12, p. 79) the distribution of the blood vessels is as follows:
Fig. 12 - General plan of the blood vessels of the head region of *Clarias batrachus* with special reference to the pituitary gland (based on the graphical reconstruction from serial transverse sections of a fish 5.2 cm. in length)

**Abbreviations:**

- **A.C.V.** - Anterior cerebral vein
- **A.NPO.** - Artery to nucelus preopticus
- **A.R.A.** - Anterior retinal artery
- **D.A.** - Dorsal aorta
- **E.C.** - External carotid artery
- **EF.B.1-4** - Efferent branchial arteries 1-4
- **H.A.** - Hypophysial artery
- **H.C.V.** - Hypocranial vein
- **H.M.V.** - Hyomandibular vein
- **H.V.** - Head vein
- **H.Y.A.** - Hypothalamic artery
- **I.C.** - Internal carotid artery
- **I.C.E.A.** - Infra cerebral artery
- **I.O.S.** - Inferior orbital sinus
- **O.M.A.** - Ophthalmica magna artery
- **O.P.A.** - Optic artery
- **P.** - Pituitary gland
- **P.C.A.** - Posterior cerebral artery
- **S.O.S.** - Superior orbital sinus
- **T.A.** - Telencephalic artery
- **V.H.A.** - Ventral hypothalamic artery
Fig. 13 - Diagrammatic sagittal longitudinal section of the brain of *Clarias batrachus* to show the blood supply of the nucleus preopticus and the pituitary gland

**Abbreviations:**

- **A.C.** - Anterior commissure
- **A.NPO** - Artery to nucleus preopticus
- **CE.** - Cerebellum
- **EP.A.** - Pineal organ
- **G.H.** - Habenular ganglion
- **H.A.** - Hypophysial artery
- **HY.A.** - Hypothalamic artery
- **I.C.** - Internal carotid artery
- **I.C.E.A.** - Infra cerebral artery
- **I.R.** - Infundibular recess
- **L.I.** - Lobii inferiores
- **NPO** - Nucleus preopticus
- **O.N.** - Optic nerve
- **P.** - Pituitary gland
- **P.C.** - Posterior commissure
- **P.C.A.** - Posterior cerebral artery
- **T.** - Telencephalon
- **T.A.** - Telencephalic artery
- **TE.** - Tegmentum
- **TR.C.** - Transverse commissure
- **III.V.** - Third ventricle
- **V.H.A.** - Ventral hypothalamic artery
Arterial supply

The dorsal aorta, the lateral dorsal aortae, their efferent branchial arteries and the head vein follow the typical teleostean pattern. The dorsal aorta is divided into two dorsal lateral aortae each of which receives the four efferent branchial arteries. At a level just anterior to the pituitary gland, the dorsal lateral aorta of each side, after receiving the first efferent branchial artery, gives rise to two arteries the external carotid or orbital artery and the internal carotid artery (Fig. 14 A, p. 84). The internal carotid of each side runs anteriorly ventro-lateral to the cranium and gives rise to the hypophysial artery. The hypophysial artery becomes intra-cranial, enters the brain and runs along the dorsal surface of the lobi inferiores to supply the pituitary gland from behind (Fig. 14 B, C, p. 84). Just anteriorly the internal carotid artery gives off another blood vessel, the posterior cerebral artery which runs backwards, becomes intracranial and enters the brain along the dorsal surface of the inferior lobes and supplies blood to dorsal thalamus, lateral thalamus and also the ependymal lining of the third ventricle (Fig. 13, p. 81). It also supplies blood to the inferior lobe. Just anterior to the origin of the posterior cerebral artery, the internal carotid gives off a branch the ophthalmica magna artery supplying the choroid gland of the eye. More anteriorly the internal carotid gives out an optic artery which runs to the eye of its own side along with the optic nerve. Further forwards, the internal
Fig. 14 - Photomicrographs of the transverse section of *Clarias batrachus* 5.2 cm. in length -

A. - Showing the formation of internal carotid and external carotid arteries (Heidenhain's Azan)
B. - Showing the hypophysial arteries in between the inferior lobes (Heidenhain's Azan)
C. - Showing the hypophysial artery entering the pituitary gland (Heidenhain's Azan)

Abbreviations:

E.C. - External carotid artery
H.A. - Hypophysial artery
H.C.V. - Hypocranial vein
I.C. - Internal carotid artery
L.I. - Inferior lobe
P. - Pituitary gland
carotid artery gives rise to an **anterior retinal artery** which supplies the retina of the eye. A little forward the internal carotid artery becomes intracranial and gives off a **telencephalic artery** supplying the telencephalon region of the brain. Just anterior to this, the internal carotid artery joins with the fellow of the opposite side to form a **median infracerebral artery** which runs forwards mid-ventral to the telencephalon. At the place where the two internal carotids of each side join, a blood vessel, the **ventral hypothalamic artery** arises which runs backwards and through an artery supplies the nucleus preopticus (Fig. 15 A, p. 87). Posteriorly, the ventral hypothalamic artery passes through the optic chiasma and is continued as the **hypothalamic artery**. The latter runs backward and enters the brain just anterior to the transverse commissure to supply the hypothalamus.

The important feature of the hypothalamo-hypophysial vascularisation in the cat fish under study is the absence of a portal circulation between the hypothalamus and the pituitary gland.

**Venous drainage**

The pituitary is drained off its blood supply posteriorly by the **median hypocranial vein** and postero-laterally by the paired **pituitary veins**. The hypocranial vein runs posteriorly within the cranium up to the auditory region. In the posterodorsal
Fig. 15 - Photomicrographs of

A. - Vertical longitudinal section of the brain of *Clarias batrachus*, 13.8 cm. in length, showing the telencephalic artery and the artery to the nucleus preopticus (Heidenhain's Azan)

B. - Vertical longitudinal section of the brain of *Clarias batrachus*, 15.5 cm. in length, showing the pituitary vein draining the blood from the posterior part of the pituitary gland (Heidenhain's Azan)

C. - Transverse section of the brain of *Clarias batrachus*, 5.2 cm. in length, showing the two pituitary veins running laterally after draining the blood from the pituitary gland (Heidenhain's Azan)

Abbreviations:

A.NPO. - Artery to nucleus preopticus
NPO. - Nucleus preopticus
P. - Pituitary gland
P.I. - Pars intermedia
P.V. - Pituitary vein
T. - Telencephalon
T.A. - Telencephalic artery
region of the pituitary, it splits into two pituitary veins. Soon after the splitting the pituitary vein of each side joins a blood vessel which drains the pituitary. The pituitary vein after draining blood from the pituitary gland (Fig. 15 B, C, p. 27) runs laterally, becomes extracranial, and joins with the infraorbital and supraorbital sinuses behind the eye region to form the head vein. More anteriorly the supraorbital sinus receives an anterior cerebral vein which drains blood from different parts of the brain including nucleus-preopticus.

Inside the pituitary gland the blood vessels are abundantly present only in the neurohypophysial tissue and are never seen freely in the glandular region of the pituitary. The neurohypophysis interdigitates with the rostral and proximal pars distalis but its main arborisation takes place in the pars intermedia. The blood sinusoids are able to traverse into the entire glandular region of the pituitary gland along with these profuse digitations of the neurohypophysis. In the pituitary gland, vascularisation is richest in the processes of the neurohypophysis in the region of the pars intermedia and poorest in its digitations of the rostral pars distalis region.

Considering the thickness and number of the blood capillaries present in the different regions of the neurohypophysis, the degree of vascularisation in different seasons of the year can be estimated. It is easily observed that during the spawning and post-spawning periods, the blood vessels are large in calibre
as compared to other periods of the reproductive cycle.

3. **Discussion**

According to Folkenius and Porte (1962) the most characteristic feature of the teleost pituitary gland is that the blood reaching the adenohypophysis passes through the capillary in the neurohypophysis and there is no independent venous drainage except for a posterior connection to the hypophysial vein in some species and in these respects it differs greatly from the tetrapod condition (Wingstrand, 1959 and 1966; Green and Maxwell, 1959; Green, 1966). Folkenius (1963) and Jasinski (1961 and 1962) have described a collection of capillaries in the neurohypophysis forming a vascular plexus in the neurohypophysial core and this has been designated as primary longitudinal plexus or 'System of Folkenius' (Folkenius, 1965). From this plexus a series of capillaries passes into the adenohypophysis forming an elaborate network of capillaries and sinuses between the endocrine cells. This has been given the name of "Secondary centrifugal system" (Folkenius, 1965). The vessels of this system came into intimate association with the adenohypophysial cells and are the only source of blood to these cells.

There seems to be fair measure of uniformity in the teleosts studied so far regarding this modern concept of the presence of a primary longitudinal plexus and a secondary
centrifugal system formed from the former. However, the manner in which the primary longitudinal plexus receives the blood supply shows variations in the different fishes. In most cases a paired or single hypophysial artery derived from the anterior carotid artery passes directly to the neurohypophysis without receiving any branches from the hypothalamic vessels. Da Lage (1958) in *Hippocampus* and Baker (1962) in *Cichlasoma* have shown that other branches from the internal carotid may first pass through the rostral pars distalis before entering the primary longitudinal plexus. Follenius (1961, 1965) and Jasinski (1961 and 1962) however, have shown that a very few capillaries from hypothalamic vessels may supply the pituitary in addition to the hypocranial artery which forms the only source of blood in the primary capillary plexus.

There are few interesting exceptional cases where the hypothalamic vessels form more important source of blood supply to the pituitary. In *Phoxinus phoxinus*, Barrington (1960) reported a lateral pituitary artery running along the infundibular floor which is present in some and absent in others. However, according to Bhargava (1966 and 1968) a median ventral infundibular artery (a hypophysial artery?) supplies the ependymal floor of the infundibular recess and just above the pituitary stalk it forms connections with a pair of ring vessels which are derived from the ventral hypothalamic artery. In *Rhodeus amarus*, the hypophysial artery breaks up into a rete mirabile,
a superficial capillary network on the outer face of the pituitary stalk, from which capillaries arise forming the primary longitudinal plexus in the neurohypophysial core (Dudok de Wit and Bretschneider, 1947). According to Belsare (1965) in *Channa punctatus* all the blood in the pituitary is said to be derived from the hypothalamus. Raizada (1971) has shown the blood supply to the pituitary in *Rasbora daniconius* by a median ventral hypothalamic artery.

In *Clarias batrachus* the internal carotid artery of each side gives rise to a hypophysial artery which supplies the pituitary gland. This confirms the findings of Dudok de Wit and Bretschneider (1947) and Da Lage (1958) regarding a direct blood supply from internal carotids to the pituitary gland, in *Rhodeus amarus* and *Hippocampus guttulatus*, respectively. Further, the arterial blood supply to the pituitary in *Clarias batrachus* is in conformity with those of the majority of teleosts in which the main course of blood supply is from the hypophysial artery without receiving any contribution through the hypothalamic vessels.

Meurling (1960) has described a pituitary portal system in *Scyllium canicula, Squalus acantias, Raia batis* and *Raia radiata*. He has reported its presence in developing *Scylliorhinus*. According to Sathyanesan (1965) a portal system has been shown to be present in *Hydrolagus colliei* as the median eminence is intimately connected with the pars distalis by a network of
capillaries in this fish. Jasinski and Gorbman (1966) have shown in *Hydrolagus collesi* a hypothalamic control of anterior pituitary function through the pituitary portal system. Meurling (1967) has suggested a hypophysial portal system functioning in the hypothalamic control of the anterior pituitary in *Chimaera monstrosa*. Florentin (1936) has also shown the possibility of the presence of a portal system in teleostean fish. Green (1951) is of the opinion that the blood capillaries or sinuses lying between the adenohypophysis and neurohypophysis in fish may perform the same function as the portal system in higher vertebrates. He further compared the neurohypophysis of the fish with the median eminence of higher vertebrates and has shown that a portal system comparable to that of higher vertebrates is absent in fishes. Lagait (1957), Da Lage (1958) and Jasinski (1961, 1962 and 1964) have also shown the absence of the hypophysial portal circulation in teleost fish studied by them. There is no such hypophysial portal system in *Clarias batrachus* because no close association between the hypothalamic neurosecretory nerve endings and the blood capillaries outside the pituitary has been observed in this fish. The neurohypophysis is profusely interdigitated with the glandular regions of the pituitary (a characteristic feature of the teleostean pituitary) and the hormones can be easily diffused into the glandular region through the blood sinusoids of the neurohypophysis.

Kerr (1942), Olivereau (1954) and Da Lage (1958) have reported hypothalomo-hypophysial vascular relationship to be
feebly present or almost absent in teleostean fishes. An extremely short account of the vascular relationship was first given for Corydora palliatus (Miller, 1944). Dudok de Wit and Bretschneider (1947) have described a definite hypothalamic-hypophysial vascular relationship through the arteria infundibularis superficialis and internae which perhaps, have been referred to as the sub-hypothalamic cephalic artery by Pickford and Atz (1957). According to Follenius (1961) a certain relationship exists between the arterial circulation of hypophysis and hypothalamus in Cypriniformes and Cyprinodontiformes. However, Jasinski (1962) is of the opinion that direct interaction of the hypothalamus-pituitary system in the teleosts by way of blood vessels is doubtful because there is a very small number of blood capillaries or even none connecting the pituitary with the hypothalamus. Jasinski (1964) has shown the absence of a vascular contact in between the hypothalamus and hypophysis in *Channa punctatus*, *Acipenser stellatus*. But Belsare (1965) has reported that the cerebral arteries derived from the internal carotid arteries show vascularisation with that region of the hypothalamus which is in close contact with the infundibulum and on the basis of this he concluded that the richly vascularised hypothalamus is in close vascular contact with the pituitary gland. Bhargava (1966, 1968) has shown that the branches of the ventral infundibular artery are related with the neurosecretory fibres of the preoptico-hypophysial tract in the ventral wall of the hypothalamus and thus have functional significance in the minnow,
**Phoxinus phoxinus.** In the present study on *Clarias batrachus* no blood vessels from the hypothalamus have been found entering the pituitary gland and thus the pituitary receives no blood which has first been exposed to the neurosecretory terminals in the hypothalamus. A close hypothalamo-hypophysial vascular relationship in *Clarias batrachus* is lacking thus confirming the similar observations of Jasinski (1962 and 1964) and Raizada (1971).

(1966)

In *Phoxinus phoxinus*, Barrington described the presence of blood capillaries which form loops connecting the two ring vessels which are associated with the cells containing Gomori chrome-alum haematoxylin positive (GCH +ve) granules above the pituitary stalk. Based on the above, he concluded that this part of the hypothalamus bears a suggestive resemblance to the median eminence of higher vertebrates. Bhargava (1966, 1968) working on the same fish has pointed out that GCH +ve granule containing cells lie posterior to the infundibular recess which is morphologically not comparable with the median eminence of the higher vertebrates. The median eminence in the higher vertebrates lies in front of the stalk region as well as the infundibular region. Moreover, the part of the infundibular floor bearing these cells lies posterior and dorsal to the preoptico-hypophysial track and not anterior and ventral as is true of the median eminence of higher vertebrates. Bhargava (1966, 1968) has suggested that the stalk region of the pituitary
may be regarded as functionally analogous to the median eminence of higher vertebrates.

Belsare (1965) has compared the richly vascularised region of the hypothalamus in _Channa punctatus_ with the median eminence of higher vertebrates on the functional basis. Sathyanesan (1965) has reported that the median eminence is intimately connected with the pars distalis by a network of capillaries in _Hydrolagus collii_. Jasinski (1967) in a review has, however, denied the presence of a portal circulation in the teleosts. In _Clarias batrachus_ no region of the hypothalamus can be homologised with the median eminence of higher vertebrates on morphological or functional basis.

According to Kerr (1942), the neurohypophysis is poorly vascularised in _Phoxinus phoxinus_, _Blennius viviparous_ and _Zoarces viviparous_. Olivieriau (1954) reported the absence or almost so of the blood vessels in meta-adenohypophysis and profuse blood supply of the neurohypophysis as a characteristic feature of the teleostean pituitary. Jasinski (1961) has shown that neither the blood vessels penetrate between the cells of intermediate lobe nor they come in contact with them in _Anguilla anguilla_. Bhargava (1966, 1968) has shown a rich vascularisation of the neurohypophysis which profusely interdigitates the adenohypophysis and supplies blood to the same by diffusion. According to him, the adenohypophysis as such does not possess any blood capillaries. The direct
arterial supply of the pro-adenohypophysis such as in *Rhodeus amarus* (Dudok de Wit and Bretschneider, 1947) may be present in those, where the ramification of the neurohypophysis is insufficient. In *Clarias batrachus* many blood vessels are present in the neurohypophysial branches entering the glandular lobes. The neurohypophysis gives off branches to rostral and proximal pars distalis and arborises extensively in the pars intermedia. Along these digitations of the neurohypophysis, the blood vessels traverse into the different parts of the pars distalis and pars intermedia. In *Clarias batrachus*, therefore, vascularisation depends on the ramification of the neurohypophysis which is found to be progressively better developed as one passes from the rostral pars distalis to proximal pars distalis and it is maximum in the pars intermedia.

Dudok de Wit and Bretschneider (1947) described the venous blood supply of the proximal pars distalis and the pars intermedia in *Rhodeus amarus* by the perihypophysial blood sinus. Baker (1962) described a somewhat similar condition of the venous supply to the pituitary in *Herichthys cyanoguttulatus*. According to Bhargava (1966 and 1968), the venous supply in the pituitary of *Phoxinus phoxinus* is by a very tiny blood vessel at the posterior end of the gland. The present study on *Clarias batrachus* is in conformity with the condition present in *Rasbora daniconius* (Raizada, 1971) where the venous supply of the pituitary gland has not been reported.