Anatomical studies on the cranial nerves of *Tilapia zillii* I-Eye muscle nerves and ciliary gangalion

[1]Mahgoub, A.F. and [2]Issa, A.Z.

[1]Zoology Department, Faculty of Science, Cairo University, Egypt.
[2]Zoology Department, Faculty of Science, Sert University, Sert, Lybia
dakrory2001@yahoo.com

Abstract: The nervus oculomotorius leaves the cranial cavity through its own foramen and divides into rami superior and inferior. It carries pure somatic motor fibres as well as parasympathetic one. The radcix ciliaris brevis is present and it is fused with the radix ciliaris longa forming a common ciliary root. The ciliary ganglion has sympathetic root. There is only one ciliary nerve arising from the ciliary ganglion. The nervus trochlearis passes outside the cranial cavity through its own foramen. It has no connection with the other cranial nerves. It carries pure somatic motor fibres. The nervus abducens leaves the cranial cavity through its own foramen dorsal to the lateral margin of the prootic bridge. It enters the posterior eye muscle canal (myodome) and it has no connection with the other cranial nerves.

[Mahgoub, A.F. and Issa, A.Z. **Anatomical studies on the cranial nerves of *Tilapia zillii* I-Eye muscle nerves and ciliary gangalion**. *Life Sci J* 2013;10(3):2292-2303] (ISSN: 1097-8135). http://www.lifesciencesite.com. 337

Key words: *Tilapia zillii*- nervi oculomotorius, trochlearis, abducens- ciliary gangalion**.**

1. Introduction:

Although several authors carried out many studies on the extrinsic eye muscles, their nerves and the ciliary ganglion of vertebrates in general, yet their studies on the fishes have not been given much attention.

From the early works done on the cranial nerves of bony fishes are those that carried on the morphology and structure of the cranial nerves in the genus *Gadus, Acipenser* and *Pleuronectes* were done by Cole (1898), Johnston (1898) and Cole and Johnston (1901), respectively. Although these studies are classical, yet they are still useful to the investigators. The most valuable works from these early ones were that carried out by Allis (1897, 1903, 1909& 1922) and Herrick (1899&1901).

Several authors published their works on the cranial nerves of some members of bony fishes. These works include the studies of Northcutt and Bemis (1993), Piotrowski and Northcutt (1996) and Dakrory (2000) on *Latimeria chalumnae*, *Polypterus senegalus* and *Ctenopharyngodon idellus,* respectively. The most recent works are those of Hussein (2010) on *Mugil cephalus* and Mattar (2012) on *Gambusia affinis affins.*

From the fish literature available there is little information about the origin, branching, ends and the analysis of the eye muscle nerves. Again, the structure, nature and the relations of the ciliary ganglion of fishes seem to be completely neglected. Regarding the structure, the ganglion, consisting of either one (Dakrory, 2003; Ali & Dakrory, 2008) or two types of neurons (Dakrory, 2000 & 2003; Dakrory *et al*., 2010).

Regarding the types and number of the ciliary ganglion roots in fishes,there are many conflicting points of view among investigators. Friehofer (1978) and Dakrory (2000) described three roots for the ganglion. On the other hand, Harrison (1981) mentioned nothing about its sensory root, while Piotrowski and Northcutt (1996) mentioned nothing about its sympathetic root.

Again, there is very little information concerning the relationships of the ciliary ganglion with other cranial structures, specially the cranial nerves.

Moreover, the presence of the ciliary ganglion or its absence, as well as the degree of its development in relation to its function and to both the habit and habitat of the fish, have not been studied yet as it should be.

It is quite evident from the literatures that there is a great shortage in information about the structure, nature and the relationships of the ciliary ganglion of fishes. Thus, such shortage seems to be a sufficient reason for the study of this subject.

2. Material and Method

Tilapia zillii is a diurnal fish inhabiting shallow areas with vegetation. It feeds on aquatic weeds and epiphytic diatoms. It is an economically important fish as a source of proteins. It is not a water breader and builds nests for egg incubation.

The fully formed larvae of this species were collected from a Nile tributary near Abu-Rawash. The heads of the fully formed larvae were fixed in aqueous Bouin for 24 hours. After washing several days with 70% alcohol, the heads were decalcified by placing the heads in EDTA solution for four weeks with changing the solution every four days. Thereafter the specimens stained with Borax carmine in *toto* according to

Grenacher's Borax carmine method (Galigher and Kozloff, 1964) which is highly satisfactory for nerve cells and fibres.

The heads were sectioned transversely (10 microns in thickness), after embedding in paraffin. The serial sections were counter stained in picroindigo carmine. The serial sections were drawn with the help of the projector. From these sections, an accurate graphic reconstructions for the eye muscle nerves was made in a lateral views. In order to show the position of the nerves, and their relations to the other different structures of the head, several serial sections are photomicrographed.

3.Results

III. Nervus Oculomotorius

In the present study, the nervus oculomotorius (Fig. 1, N.III) arises from the midlateral side of the mesencephalon by one root. Directly after they emerge from their bodies, the root fibres collect into right and left rootlet. The two rootlets, deccussate inside brain (Fig. 2, DE.III) and emerge laterally from the mesencephalon as the nervus oculomotorius (Figs. 1& 2, RO.III).

Immediately after its emergence, the nervus oculomotorius runs anteroventrally within the cranial cavity, passing lateral to the brain, ventral and then ventromedial to the nervus trochlearis and medial to the Gasserian ganglion of the nervus trigeminus. Thereafter, it passes medial to the ramus palatinus of the nervus facialis and lateral to the brain. It continues anteroventrally running ventral to the brain, medial to the pleurosphenoid bone and dorsal to the internal jugular vein. Shortly after that, the nervus oculomotorius leaves the cranial cavity and enters the posterior myodome (Fig. 3, PO.MY) by penetrating the meninx primitiva through the foramen oculomotorium (Fig. 3, F.OC). This foramen is located between the lateral edge of the prootic bone (PRO) medially and the pleurosphenoid bone (PLS) laterally. During its exit from the cranial cavity, the nervus oculomotorius divides into a dorsal ramus superior (Figs. 1&4, R.SP) and a ventral ramus inferior (Figs. 1&4, R.IF).

Ramus Superior

Immediately after its separation from the nervus oculomotorius, the ramus superior (Figs. 1&4, R.SP) extends anteriorly in the ventromedial direction, running dorsal to both the ramus inferior of the nervus oculomotorius and the rectus lateralis muscle and ventral to the lateral edge of the prootic bone. Shortly forwards, it runs dorsomedial and then medial to the ramus inferior of the nervus oculomotorius and dorsolateral to the rectus superior muscle. At this position, it divides into three fine branches, one ventral to the others. These branches enter the rectus superior muscle from its lateral side where they end between its fibres (Figs. 4 & 7, R.SP&N.RSP).

Ramus Inferior

Directly after its separation from the nervus oculomotorius, the ramus inferior (Figs. 1&4, R.IF) extends forwards in the ventromedial direction passing ventromedial to the ramus superior, dorsal to the rectus lateralis muscle and dorsolateral to the rectus superior muscle. Thereafter, it shifts ventrally passing lateral to the rectus superior muscle and medial to the rectus lateralis muscle, where it gives off a lateral branch which is the radix ciliaris brevis (Figs. 1, 5 & 6, RD.CB). This branch enters the ciliary ganglion from its dorsomedial side (Fig.6).

Shortly, anterior to the origin of the radix ciliaris brevis, the ramus inferior gives off a ventral branch (Figs. 1 & 6, N.OIF). This branch runs anteriorly in a ventromedial direction passing medial to the ciliary ganglion (G.CIL) and then to the rectus lateralis muscle (M.RL) and lateral to the rectus superior muscle (M.RSP). Shortly forwards, it becomes ventral to the ramus inferior and the ciliary ganglion, ventromedial to the rectus lateralis muscle and ventrolateral to the rectus superior and the rectus inferior muscles. Thereafter, it shifts medially in an anterior direction being ventral to the rectus inferior muscle, lateral to the rectus medialis muscle and dorsal to the adductor arcus palatini muscle. This ventral branch continues its course surrounded by the rectus medialis muscle dorsomedially, the rectus inferior muscle dorsolaterally and the adductor arcus palatine muscle ventrally. Then, it becomes ventral to the rectus medialis muscle and medial to the rectus inferior muscle. More forwards, this branch (Fig. 1, N.OIF) becomes dorsomedial to the rectus inferior muscle, medial to the eyeball, and ventral to the rectus medialis muscle. After a long anterior course, this branch becomes medial to the eyeball, ventromedial to the rectus medialis muscle. More forwards, it becomes lateral to the trabecula communis, dorsal to the obliquus inferior muscle and ventrolateral to the rectus medialis muscle and divides into three fine nerves which enter the obliquus inferior muscle from its dorsomedial edge and terminate between its fibres (Fig. 1, N.OIF).

Shortly, anterior to the origin of the previous branch, the ramus inferior (Fig. 1, R.IF) extends more forwards running medial to the ciliary ganglion (G.CIL) and lateral to the rectus superior muscle (M.RSP) where it divides into two branches, one lateral and the other medial. The lateral branch (Figs. 1 & 6, N.RIF) extends anteriorly in the ventromedial direction, passing lateral and then ventral to the medial branch and medial to the ciliary nerve. Thereafter, it continues running anteriorly passing ventromedial to the ciliary nerve, ventral to the medial branch and lateral to the rectus inferior muscle. Finally, the lateral branch enters the latter muscle and terminates between its fibres.

The medial branch (Fig. 1, N.RM) runs forwards in a dorsomedial direction extending medial and then dorsal to the lateral branch and lateral to the rectus superior muscle. Shortly anterior, it passes dorsomedial to the ciliary nerve, ventrolateral to the rectus superior muscle, lateral to the rectus inferior muscle and dorsal to the lateral branch. After that, the medial branch shifts dorsomedially passing ventral to the rectus superior muscle and dorsal to the rectus inferior muscle. Directly after that, it reaches the dorsolateral side of the rectus medialis muscle where, it ends between its fibres (Fig. 1).

Ciliary Ganglion

In *Tilapia zillii*, the ciliary ganglion (Figs. 1, 5, 6 & 7, G.CIL) is a rounded structure, consists of a collection of ganglionic cells. It lies in the posterior part of the orbital region. The ganglion (Fig. 6, G.CIL) is located in a position between the rectus lateralis muscle (M.RL) laterally and the ramus inferior of the nervus oculomotorius medially (R.IF).

The ciliary ganglion measures about 120 µm in length. The microscopic examination indicated that the ciliary ganglion (Figs. 6&7, G.CIL) consists of peripheral large neurons (LN) and central small ones (SN). The ganglion is connected to the ramus inferior of the nervus oculomotorius by a stout connecting branch, which is the radix ciliaries brevis (Figs. 1 &6, RD.CB). This branch transmits the preganglionic parasympathetic fibres from the ramus inferior of the nervus oculomotorius to the ciliary ganglion and constitutes the parasympathetic root of the ganglion. It originates from the lateral side of the ramus inferior (Fig. 1 & 6, RD.CB) of the nervus oculomotrius and enters directly the ciliary ganglion from the dorsomedial side of its posterior end (Fig.6).

Regarding the sensory and sympathetic roots of the ciliary ganglion, the microscopic study elucidated that the sensory or the radix ciliaris longa (Fig. 1, RD.CL) and the sympathetic roots (Fig. 1, N. CSY) fuse and enter the ganglion as one common nerve. The sensory root arises from the nervus profundus and fuses with the sympathetic root originating from the trigeminal sympathetic ganglion to form a common root (Figs. 1, 5 & 7, CO.RO). This runs forwards in a ventromedial direction, till it enters the ciliary ganglion from its dorsolateral side.

There is a single ciliary nerve (Figs. 1& 8, N.CIL) arising from the anterior end of the ciliary ganglion. The ciliary nerve extends forwards in a lateral direction, passing lateral to the rectus superior muscle and the ramus inferior of the nervus oculomotorius and then to the rectus inferior muscle and medial to the eyeball. Then, it shifts and becomes dorsolateral to the latter muscle, lateral to the rectus medialis muscle, ventrolateral to the optic nerve and medial to the eyeball. Finally, it enters the eyeball just posteroventral to the optic nerve.

IV. Nervus Trochlearis

In *Tilapia zillii*, the nervus trochlearis arises from the lateral side of the mid brain just anterior and dorsal to the origin of the nervus trigeminus, by a single small root (Figs. 1 & 9, RO.IV). This root extends anteriorly within the cranial cavity in a ventrolateral direction passing ventral and lateral to the brain and dorsomedial to the trigeminal nerve (Fig. 2, N.IV). Shortly forwards, it becomes dorsal to the ganglion of the anterodorsal lateral line nerve and medial to the membranous labyrinth (anterior semicircular canal). Thereafter, the nervus trochlearis continues forward, running ventrolateral to the brain and dorsomedial to the auditory capsule. Reaching the postorbital region, the nervus trochlearis extends medial to the supraorbital cartilage and lateral to the brain. After a considerable course in the orbital region, it leaves the cranial cavity by penetrating the meninx primitiva through its own foramen (Fig. 10, F.TR). Extracranially, the nervus tochlearis runs forwards passing dorsal to the eyeball, ventromedial to the supraorbital cartilage and lateral to the cranial wall. Thereafter, it continues its course extending dorsomedial to the rectus superior muscle and ventrolateral to the cranial wall. Thereafter, it becomes dorsal and then medial to the latter muscle. On reaching the mid-way of orbital region, the nervus trochlearis continues in a dorsolateral direction being dorsal to the obliquus superior muscle and ventromedial to the supraorbital lateral line canal and the ramus ophthalmicus superficialis trigeminus and lateralis. More forwards, the nervus trochlearis continues its course passing dorsomedial to the obliquus superior muscle and venterolateral to the taenia marginalis posterior. Finally, it enters and ends between the fibres of the latter muscle.

VI. Nervus Abducens

In the species under investigation, the nervus abducens originates from the ventral side of the medulla oblongata by a single fine root just medial to the origin of the nervus octavus (Figs. 1 & 11, RO.VI). Directly after its origin, it passes ventrolaterally running medial to the nervus ocatvus and lagenar nerve. Shortly forwards, this nerve continues passing medial to the lagena, dorsal to the lateral margin of the prootic bridge, which forms roof of the posterior myodome (posterior eye muscle chamber) (Figs. 11 & 12, N.VI). After a considerable course, the nervus abducens leaves the cranial cavity by piercing the meninx primitiva through a foramen abducens (Fig. 12, F.AB) in the lateral margin of the prootic bridge (Fig. 12, PR.B) and enters the posterior myodome, which lodges the recti lateralis and medialis muscles. Within the myodome, the nervus abducens ramifies and enters the rectus lateralis muscle (M.RL) where it ends to innervate its fibres.

4. Discussion

In the present work, the nervus oculomotorius is divided into its two rami superior and inferior extracranially. This case is generally found in the vertebrates (Hussein, 2010; Mattar, 2012; Dakrory *et al*., 2012). However, in the teleost *Gnathonemus petersii* (Szabo *et al*., 1987), the nervus oculomotorius is divided intracranially into a posterior branch to the rectus superior muscle and an anterior branch to the other three muscles. In *Lampanyctus leucopsarus* (Ray, 1950), the division of the nervus oculomotorius into its two rami takes place in the oculomotor foramen.

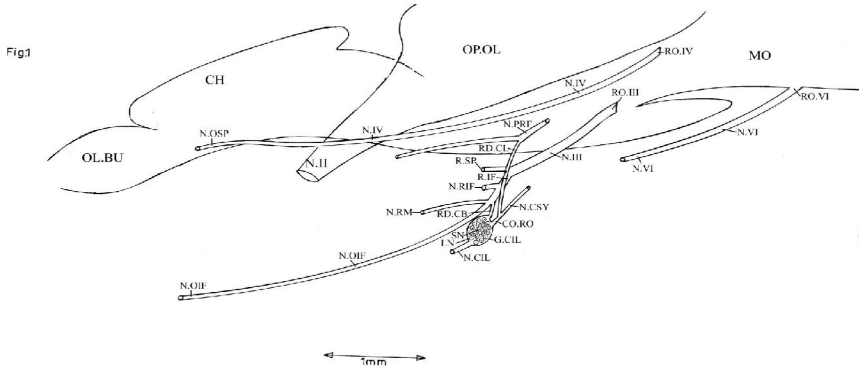
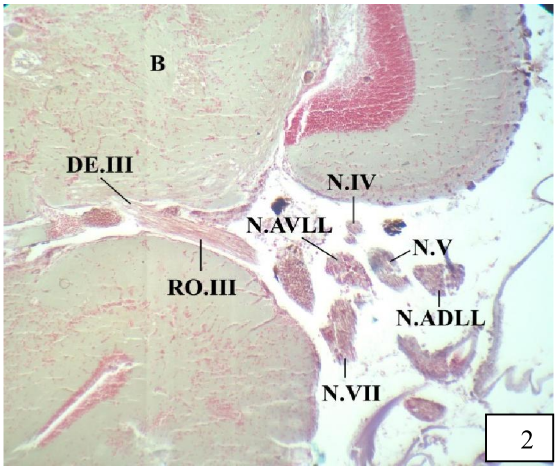
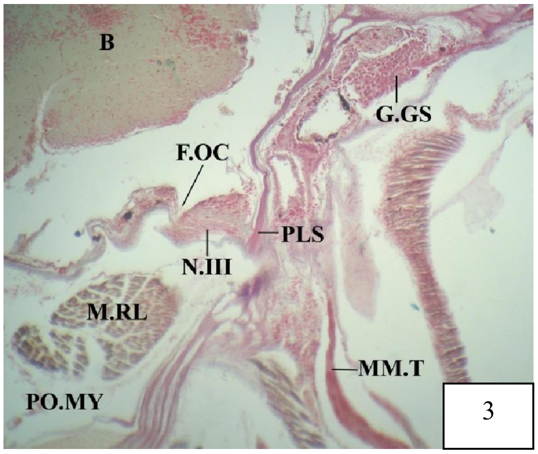
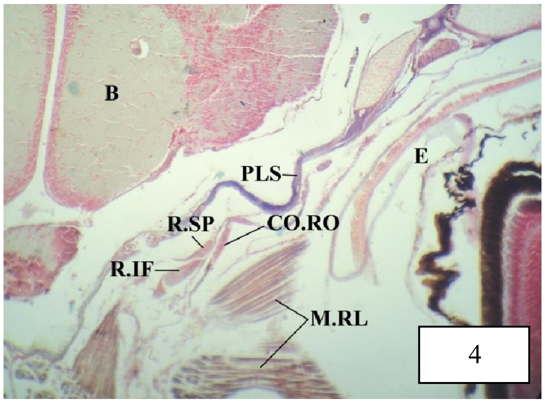
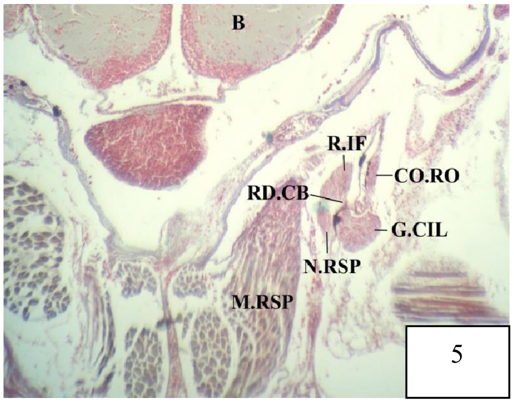


Fig. 1: Graphic reconstruction of eye muscle nerves and the ciliary ganglion of *Tilapia zillii* in a lateral view.









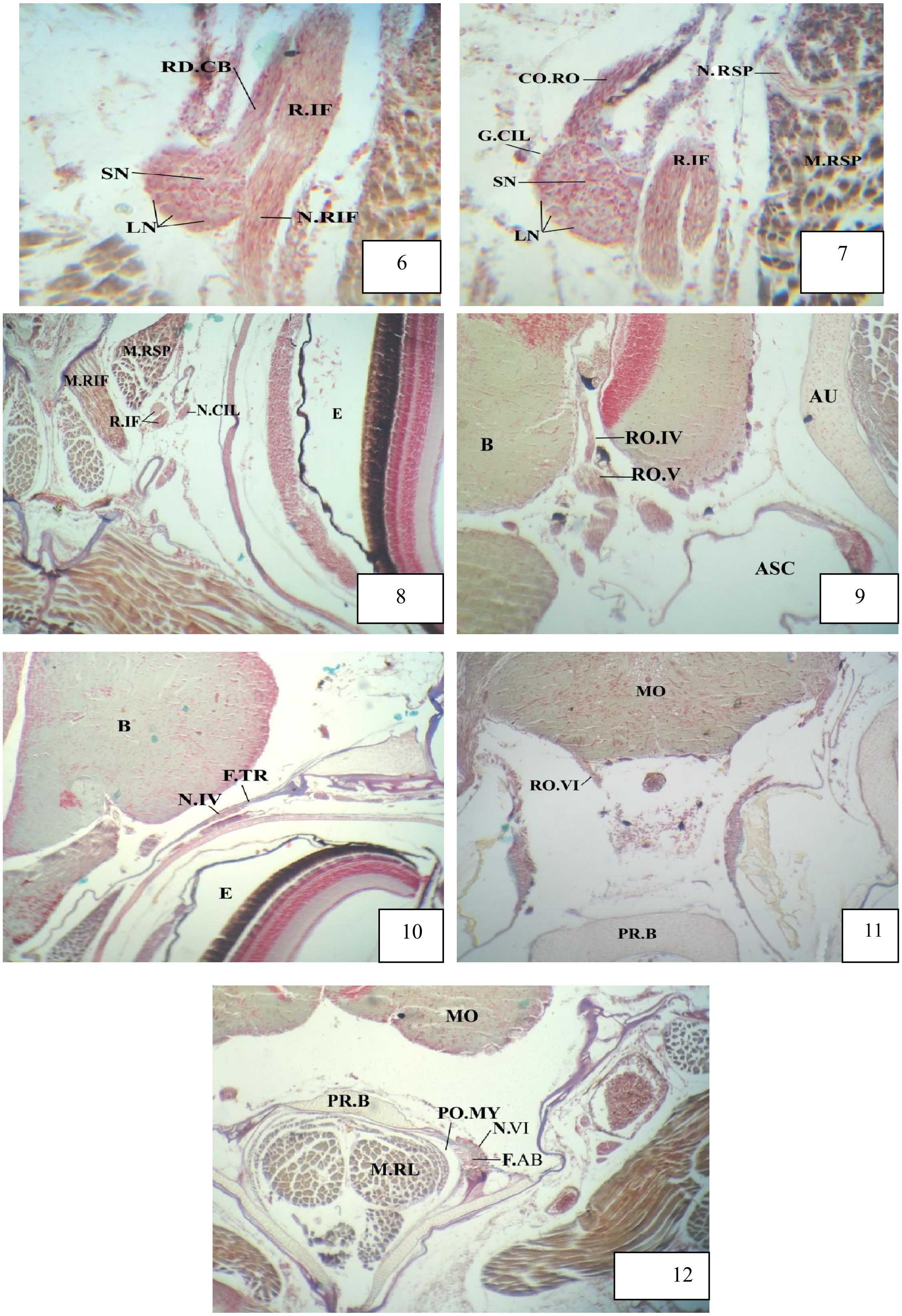


Fig. 2: Part of transverse section passing through the otic region showing the root and decussation of the nervus oculomotorius.

Fig. 3: Part of transverse section passing through the postorbital region showing the oculomotor foramen and the passage of the nervus oculomotorius into the posterior myodome.

Fig. 4: Part of transverse section passing through the postorbital region demonstrating the division of the nervus oculomotorius into its two rami superior and inferior.

Fig. 5: Part of transverse section passing through the orbital region illustrating the position of the ciliary ganglion.

Fig. 6: Part of transverse section passing through the orbital region elucidating the entrance of the radix ciliaris brevis into the ciliary ganglion and the structure of this ganglion.

Fig. 7: Part of transverse section passing through the orbital region showing the structure of the ciliary ganglion, the entrance of the common root into this ganglion and the entrance of the ramus superior into the rectus superior muscle.

Fig. 8: Part of transverse section passing through the orbital region illustrating the ciliary nerves and the branches of the ramus inferior of the nervus oculomotorius.

Fig. 9: Part of transverse section passing through the otic region demonstrating the root of the nervus trochlearis.

Fig. 10: Part of transverse section passing through the orbital region elucidating the position of the trochlear foramen and the exit of the nervus trochlearis from the cranial cavity.

Fig. 11: Part of transverse section passing through the otic region illustrating the root of the nervus abducens.

Fig. 12: Part of transverse section passing through the postorbital region demonstrating the abducens foramen.

In the present work, there is no connection between nervus oculomotorius and other cranial nerves. This is agree with that mentioned by Hussein (2010) on *Mugil cephalus* and Mattar (2012) and Dakrory *et al*. (2012) on *Gambusia affinis affins*. However, the connection between the nervus oculomotorius and the nervus trigeminus was recorded among bony fishes. In *Polypterus senegalus* (Lehn, 1918; de Beer, 1926; El-Toubi and Abdel-Aziz, 1955), this nerve joins the profundus nerve. In the same species however, two connections between these two nerves were found by Piotrowski and Northcutt (1996). However, these connections were denied by Allis (1922) in *Polypterus senegalus*. In *Gnathonemus petersii* (Szabo *et al*., 1987), the oculomotor nerve anastomoses with the ophthalmic branch of the trigemino-lateral line complex. An anastomosis between the nervus oculomotorius and the nervus trochlearis is found in *Pleuronectes* (Cole and Johnstone, 1901) and between this nerve and the nervus abducens in *Cyclothone acclinidens* (Gierse, 1904). The latter two connections are lacking in *Pseudorhombus arsius* (Marathe, 1955) and in *Ctenopharyngodon idellus* (Dakrory, 2000).

An anastomosis between the nervus oculomotorius and the other cranial nerves seems to be widely spread among tetrapods. Concerning the matter in Amphibia, the nervus oculomotorius is connected with both the Gasserian ganglion and the ramus ophthalmicus profundus in *Amphiuma means* (Norris, 1908). In *Xenopus leavis, Bufo viridis* and *Bufo regularis*, this connection was noted by Paterson (1939), Soliman and Mostafa (1984) and Shaheen (1987), respectively.

In *Tilapia zillii,* under investigation, the ciliary ganglion is found in the postorbital region. Among bony fishes, a distinct ciliary ganglion was mentioned in the perciform, *Uranoscopus* (Young, 1931), *Lampanyctus leucopsarus* (Ray, 1950), *Pseudorhombus arsius* (Marathe, 1955), *Polycentrus schomburgkii* (Freihofer, 1978), *Trichiurus lepturus* (Harrison, 1981), in the cladistian, *Polypterus senegalus* (Piotrowski and Northcutt, 1996), in *Ctenopharyngodon idellus* (Dakrory, 2000), in *Gambusia, Tilapia* and *Mugil* (Dakrory (2003), in *Mugil cephalus* (Hussein, 2010) and in *Gambusia affinis affinis*(Mattar, 2012; Dakrory *et al*., 2012).

In cartilaginous fishes, a ciliary ganglion was mentioned by Young (1988) in the dog fish *Mustelus* and in skates and rays. However, the ciliary complex was found to be completely lacking in *Salmo* and *Cyclothone acclinidens*, (Gierse, 1904), in Dipnoi (Jenkin, 1928) and in the ray *Dasyatis rafinesque* (Chandy, 1955). Again, Burr (1933) denied the presence of the ciliary complex in *Opistroproctus soleatus*, but he found a ganglion on the third cranial nerve.

In Amphibia, the ciliary ganglion seems to be absent or transitory. It was found to be absent in *Amblystoma punctatum* (Herrick, 1894), *Amphiuma means* (Norris, 1908), *Necturus* (McKibben 1913) and *Xenopus leavis* (Paterson, 1939) while it was only transitional and non-functional in *Amblystoma tigrinum* (Coghill, 1902; Kuntz, 1914). In *Rana bedriagie*, the ciliary ganglion is poorly developed (Dakrory, 2002). However, Mostafa and Soliman (1984) described a ciliary gangion of two parts in *Bufo viridis*.

In this work, the ciliary ganglion consists of small neurons at the center and large ones at the periphery. Such case was reported in both the batoid *Rhinobatus halavi* and the cyprinid *Ctenopharyngodon idellus* (Dakrory, 2000) and in *Gambusia affinis affinis* (Dakrory, 2003; Dakrory *et al*., 2012, Mattar, 2012).

In *Tilapia zillii*, there is a well-developed motor root, the radix ciliaris brevis. Similar findings were reported in *Lampanyctus leucopserus* (Ray, 1950), *Pseudorhombus arsius* (Marathe, 1955) and in *Polyptorus senegalus* (Piotrowski and Northcutt, 1996). On the other hand, among bony fishes, it has been found that the ciliary ganglion has no radix ciliaris brevis in both *Gambusia offinis offinis*

(Dakrory, 2003; Dakrory *et al*., 2012; Mattar, 2012) and *Mugil cephalus* (Dakrory, 2003 and Hussein, 2010). Among cartilagenous fishes, Young (1988) and Dakrory (2000) mentioned that a motor root from the oculomotor nerve joins a sensory one from the trigeminal nerve then enters the ganglion.

It appears that in fishes the parasympathetic fibres of the nervus oculomotorius may or may not form a separate branch, radix ciliaris brevis, which enters the ganglion, or the latter is found on the ramus inferior without any communicating branch.

In the present work, the sensory root (radix ciliaris longa) originates from the nervus profundus distal to profundal ganglion.The same resut recorded in *Mugil cephalus* (Hussein, 2010) and in *Gambusia offinis offinis* (Mattar, 2012; dakrory *et al*., 2012). Dakrory (2003), on the other hand, reported that this root in *Gambusia affinis affinis* arises from the Gasserian ganglion of nervus trigeminus. A similar case was mentioned by Dakrory (2000) in both the batoid *Rhinobatus halavi* and the cyprinid *Ctenopharyngodon idellus*. The radix ciliaris longa was found to be arising from either the truncus ciliaris profundus as in *Lampanyctus leucopsarus* (Ray, 1950) or from the profundal ganglion as in *Polypterus senegalus* (Piotrowski and Northcutt, 1996) and in *Mugil cephalus* (Dakrory, 2003).

In the present study, the sensory root (radix ciliaris longa) fuses with the sympathetic one and enters the ciliary ganglion as one common root. This is typically the case found in *Lampanyctus leucopsarus* (Ray, 1950), *Trichiurus lepturus* (Harrison, 1981), *Ctenopharyngodon idellus* (Dakrory, 2000) and in *Gambusia affinis affinis* (Dakrory, 2003; Dakrory *et al*., 2012; Matter, 2012) and *Mugil cephalus* (Dakrory, 2003& Hussein, 2010).

In the present work, the sympathetic root originates from the trigeminal sympathetic ganglion. This appears to be a common character among the bony fishes so far described (Ray, 1950; Harrison, 1981; Dakrory, 2000& 2003). However, in *Uranoscopus* (Young, 1931) and *Polycentrus schomburgkii* (Freihofer, 1978), the sympathetic fibres pass from the trigeminal sympathetic ganglion and fuse with the ciliary nerve distal to the ciliary ganglion. On the other hand, such sympathetic root or connection was not mentioned in the dipnoian *Lepidosiren paradoxa* (Jenkin, 1928), *Pseudorhombus arsius* (Marathe, 1955) and in *Polypterus senegalus* (Piotrowski and Northcutt, 1996). Also, the cartilaginous fishes lack the head sympathetic system (Chandy, 1955; Walker, 1987; Young, 1988; Dakrory, 2000). Again, cyclostomes lack such system (Walker, 1987).

In Amphibia, there is no mention of this connection in the literature cited (Mostafa and Soliman, 1984; Shaheen, 1987; Dakrory, 2002).

In *Tilapia zillii*, there is, in addition to the ciliary nerve, a truncus ciliaris which enters the eyeball through a foramen excavated in the dorsal side of the sclera just ventral to the obliquus superior muscle. This is the same case found by Young (1988), Piotrowski and Northcutt (1996), (Hussein, 2010) and (Mattar, 2012) that described two ciliary nerves in the cartilaginous fishes, *Polypterus senegalus*, *Mugil cephalus* and in *Gambusia affinis affinis, respectively*.

The presence of one ciliary nerve appears to be a common charcter among bony fishes (Marathe, 1955; Freihofer, 1978; Harrison, 1981; Dakrory, 2003). In *Menidia,* however, Herrick (1899) mentioned many ciliary nerves.

On the other hand, there is one ciliary nerve arising from the ophthalmicus profundus nerve and not from the ciliary ganglion in the ray *Dasyatis refinesque* (Chandy, 1955). Kent (1978) stated that the postganglionic fibres penetrate the sclera and pass to the sphincter pupillae and the ciliary muscle of the iris diaphragm in cartilaginous fishes. He added that the bony fishes lack ciliary muscles, but there is a special compound (Campanula Halleri) which draws the lens backwards for accommodation. Young (1988) concluded that the campanula Halleri or retractor lentis muscle is innervated through the oculomotor nerve and the ciliary ganglion.

Among Amphibia, there are two ciliary nerves in *Bufo viridis* (Mostafa and Soliman, 1984) and *Rana bedriagie* (Dakrory, 2002).

On the other hand, there is no ciliary ganglion and, consequently, no ciliary nerve in many amphibians (Norris, 1908; McKibben, 1913; Paterson, 1939; Shaheen, 1987).

In this study, there is no decussation of the right and the left trochlear nerves. However, there is a complete trobchlear decussation found by Szabo *et al*. (1987), in *Gnathonemus petersii* by Piotrowski and Northcutt (1996) in *Polypterus senegalus* and by Dakrory (2000) in *Ctenopharyngodon idellus* and *Rhinobatus halavi*.

In this respect, Kent (1978) mentioned that the trochlear nerve is one of the few nerves with motor fibres that decussate before emerging from the brain. In the jawless fishes, Edgeworth (1935) mentioned a trochlear decussation in *Petromyzon*, a case that was denied by Jollie (1968) in Cyclostomata.

In the present study, the nervus trochlearis emerges from the cranial cavity through a special trochlear foramen in the pleurosphenoid bone. This is the case found also in *Parasilurus asotus* (Atoda, 1936), *Lampanyctus leucopsarus* (Ray, 1950), *Polypterus senegalus* (El-Toubi and Abdel-Aziz, 1955; Piotrowski and Northcutt, 1996), *Amphipnous cuchia* (Saxena, 1967) and in *Trichiurus lepturus* (Harrison, 1981). However, Srinivasachar (1959) mentioned that there is a large sphenoid fissure for the emergence of the nervi II-VII in the 29 mm larva of *Arius jella* and the 16 mm larva of *Plotosus canis*. In *Clarias batrachus*, there is a common foramen for the exit of the nervi oculomotorius, trochlearis, abducens and trigemino-facial complex (Dalela and Jain, 1968).

Among cartilaginous fishes, the nervus trochlearis leaves the cerebral cavity through its own trochlear foramen (Chandy, 1955; El-Toubi and Hamdy, 1959, 1968; Hamdy and Hassan, 1973; Khalil, 1978, 1979a, b; Mazhar, 1979; El-Satti, 1982; Dakrory, 2000).

In the agnathan *Petromyzon,* the nervus trochlearis leaves the cranial cavity together with the optic, oculomotor and abducens nerves through the optic fenestra (Johnels, 1948). On the other hand, Jollie (1968) mentioned a special foramen for this nerve in lampreys.

In most Amphibia, the nervus trochlearis exits from the cerebral cavity through a special foramen (Herrick, 1894; Norris, 1908; Stadtmüller, 1925; Aoyama, 1930; de Beer, 1937; Paterson, 1939; Sokol, 1975 & 1981; Mostafa and Soliman, 1984; Shaheen, 1987; Trueb and Hanken, 1992; Haas, 1995; Dakrory, 2002). In most cases, this foramen is found in the orbital cartilage. However, van Eeden (1951) mentioned that the trochlear foramen, in *Ascophus truei*, does not pierce the orbital cartilage at all; but the nervus trochlearis passes over its margin. He added that *Ascaphus truei* shares this feature with some Urodela. Sokol (1977), in his work on the anuran *Pipa carvalhoi*, gave the following statement: “I cannot locate the trochlear foramen which is undoubtedly very small, and presumably lies above the oculomotor foramen as in other tadpoles”. In this respect, the trochlear foramen in *Amblystoma punctatum* (Herrick, 1894) and *Necturus* (McKibben, 1913) was found to be located in the parital bone. Sheil (1999), dealing with *Pyxicephalus adspersus*, stated that the trochlear foramen is located ventral to the lamina prependicularis of the frontoparietal bone or it pierces it. On the other hand, a large optic-prootic foramen, for the exit of the nervi II-VII, was described by Trueb and Cannatella (1982) in *Rhinophrynus dorsalis* and *Pipa pipa*. Haas and Richard (1998) mentioned that the nervi opticus and trochlearis leave the cranial cavity together through a large foramen opticum in *Boophis*.

In *Tilapia zillii*, there is no connection between the nervus trochlearis and the other cranial nerves. It is in agreement with the results recorded in *Ctenopharyngodon idellus* and *Rhinobatus halavi* (Dakrory, 2000), *Mugil cephalus* (Hussein, 2010) and in *Gambusia affinis affinis* (Matter, 2012; Dakrory *et al*., 2012).The nerve in question, however, was found to be connected with the nervus oculomotorius in *Pleuronects* (Cole and Johnstone, 1901). An anastomosis between the nervus trochlearis and the nervus trigeminus is widely found among fishes. Such anastomosis was mentioned with the mandibular branch of the trigeminal-lateral line complex in *Gnathonemus petersii* (Szabo *et al*., 1987) and with the profundus nerve in *Polypterus senegalus* (Piotrowski and Northcutt, 1996). The connection between the trochlear nerve and the trigemino-facial ganglion was observed by Atoda (1936) in *Parasilurus asotus*. A connection between the nervus trochlearis and the ramus lateralis accessorius was recorded by Herrick (1899) in *Menidia*.

Among Amphibia, the nervus trochlearis was found to anastomose with the ramus ophthalmicus profundus of the nervus trigeminus in *Amblystoma punctatum* (Herrick, 1894), *Xenopus laevis* (Paterson, 1939) and in *Bufo regularis* (Shaheen, 1987). However, such a connection is not found in *Amblystoma tigrinum* (Coghill, 1902) and in *Bufo viridis* (Mostafa and Soliman, 1984).

n the present study, the nervus abducens arises from the medulla oblongata by a single root. The presence of a single root was found in *Argyropelecus hemigymnus* (Handrick, 1901), *Scomber scomber* and *Scorpaena scrofa* (Allis, 1903 & 1909), *Cyclothone acclinidens* (Gierse, 1904), *Tetrodon oblongus* (Bal, 1937), *Lampanyctus leucopsarus* (Ray, 1950), *Polypterus senegalus* (El-Toubi and Abdel-Aziz, 1955), in *Nadus nadus* (Saxena, 1969), *Ctenopharyngodon idellus* (Dakrory, 2000), *Mugil cephalus* (Hussein, 2010), *Hypophthalmichthys molitrix* (Dakrory *et al*., 2010) and in *Gambusia affinis affinis* (Mattar, 2012; Dakrory *et al*., 2012). On the other hand, the nervus abducens arises by two roots, as it was found by Stannius (1849) in *Cottis* and *Trigla*, Herrick (1899, 1901) in *Menidia* and *Ameiurus melas*, respectively, Allis (1909) in both *Lepidotrigla* and adult *Scorpaena scrofa*, Pankratz (1930) in *Opsunus tau*, Atoda (1936) in *Parasilurus asotus* and by Harrison (1981) in *Trichiurus lepturus*. In this respect, Harder (1975) stated that a double root is considered to be standard for teleosts. However, multiple roots were described for the nervus abducens in *Amia calva*, *Palydon spathula, Scphirynchus platorhynchus* and *Lepidosteus platostomus* (Norris, 1925), in the dipnoan *Latimeria chalumnae* (Northcutt *et al*., 1978) and in *Polypterus senegalus* (Piotrowski and Northcutt, 1996). Among the cartilaginous fishes, the nervus abducens arises by a single root in *Dasyatis rafinesque* (Chandy, 1955), *Hydrolagus* (Jollie, 1968) and *Rhinobatus halavi* (Dakrory, 2000). However, in the shark *Squalus acanthias* (Norris and Hughes, 1920; Jollie, 1968) this nerve arises by two roots.

In Amphibia, the nervus abducens arises by one root (Mostafa and Soliman, 1984; Shaheen, 1987; Dakrory, 2002).

In the present study, the nervus abducens emerges from the cranial cavity through a foramen in the lateral margin of the prootic bridge. However, among bony fishes, the exit of the nervus abducens from the cranial cavity is through a special foramen. This was observed in *Trichiurus lepturus* (Harrison, 1981), *Ctenopharyngodon idellus* (Dakrory, 2000) and in *Hypophthalmichthys molitrix* (Dakrory *et al*., 2010).

On the other hand, El-Toubi and Abdel-Aziz (1955) and Piotrowski and Northcutt (1996), dealing with *Polypterus senegalus*, stated that the nervus abducens emerges from the cranial cavity, together with the nervus trigeminus, through the foramen trigeminal.

In *Clarias batrachus*, the nervus abducens issues from the cranial cavity, together with the trigeminofacial complex, through the foramen prooticum (Dalela and Jain, 1968). Saxena (1967) mentioned that the nervus abducens runs out of the cranial cavity, together with the nervus opticus, through one foramen located in the lateral ethmoid bone in *Amphipnous cuchia*.

The condition found in *Tilapia zillii* is in agreement with that mentioned in the cartilaginous fishes, *Chlamydoselachus anguineus* (Allis, 1923), *Rhinobatus halavi, Rhynchobatus djiddensis* and *Trygon kuhlii* (El-Toubi and Hamdy, 1959), *Rhinoptera bonasus* (Hamdy, 1960), *Aetamylus milvus* (Hamdy and Khalil, 1970), *Torpedo ocellata* (Hamdy and Hassan, 1973), *Trygon postinaca* (Khalil, 1979b), *Squatina oculata* and *Rhinoptera jayakari* (El-Satti, 1982) and *Rhinobatus halavi* (Dakrory, 2000).

In the jawless fishes, the nervus abducens emerges from the cerebral cavity, together with the optic, oculomotor and trochlear nerves, through the optic fenestra (Johnels, 1948). On the other hand, Jollie (1968) mentioned that in lampreys the nervus abducens passes out the cranial cavity together with the nervi trochlearis and trigeminus, through a large opening in the lateral side of the skull. However, Kent (1978) stated that the lampreys seem to lack an abducens nerve but some authorities think that it is represented by a small bundle emerging from the hindbrain, on the anterior surface of the trigeminal nerve.

Regarding the emergence of the nervus abducens from the cranial cavity in Amphibia, it was found that this nerve passes, together with the nervus trigeminus, through the foramen prooticum (Sokol, 1977 & 1981; Mostafa and Soliman, 1984; Shaheen, 1987; Reiss, 1997; Dakrory, 2002). However, Haas (1995) observed that the nervus abducens in *Colostethus nubicola, Colostethus subpunctatus, Epipedobates tricolor* and *Phyllobates bicolor,* leaves the cranial cavity through a fissura prootica. On the other hand, Trueb and Cannatella (1982) described a single foramen “optic-prootic foramen” for the exit of the optic, oculomotor, trochlear, trigeminal, abducens and facial nerves in *Rhinophrynus dorsalis* and *Pipa pipa*.

In the present study, the nervus abducens shows no connections with other cranial nerves. This is the case, recorded in many fishes (Allis, 1903; Bal, 1937; Ray, 1950; El-Toubi and Abdel-Aziz, 1955; Chandy, 1955; Saxena, 1967& 1969; Harrison, 1981; Dakrory, 2000). In *Cyclothone acclinidens* (Gierse, 1904), however, the nervus abducens anastomoses with the nervus oculomotorius and the ramus palatinus facialis. Two connections between the nervus abducens and the profundus nerve are recorded by Piotrowski and Northcutt (1996) in *Polypterus senegalus*.

In Amphibia, the nervus abducens passes through the Gasserian ganglion without any interchange of fibres. It leaves this ganglion with the ramus ophthalmicus profunds with which it is merged (Herrick, 1894; Coghill, 1902; Norris, 1908; Wiedersheim, 1909; Paterson, 1939; Mostafa and Soliman, 1984; Shaheen, 1987).

In the species under investigation, the nervus abducens, as in all vertebrates, innervates the rectus externus muscle. In many Tetrapoda, it innervates the rectus externus and the retractor oculi muscles. In Cyclostomata, Edgeworth (1935) stated that the nervus abducens innervates the rectus externus and the rectus externus inferior muscles. Fritzsch *et al.* (1990) found that two of the six ocular muscles are innervated by the nervus abducens in *Petromyzon marinus*. This finding is confirmed by Pombal *et al*. (1994).

List of Abbreviations

ASC	: Anterior semicircular canal.
AU	: Auditory capsule.
B	: Brain.
CH	: Cerebral hemisphere.
CO.RO	: Common root.
DE.III	: Deccussation of nervus oculomototrius.
E	: Eye.
F.AB	: Foramen abducens.
F.OC	: Foramen oculomotorius.
F.TR	: Foramen trochlearis.
G.CIL	: Ciliary ganglion.
G.GS	: Gasserian ganglion.
LN	: Large neuron.
M.RIF	: Rectus inferior muscle.
M.RL	: Rectus lateralis muscle.
M.RSP	: Rectus superior muscle.

MM.T : Maxillo-mandibular trunk.
MO : Medulla oblongata.
N.II : Nervus opticus.
N.III : Nervus oculomotorius.
N.IV : Nervus trochlearis.
N.V : Nervus trigeminus.
N.VI : Nervus abducens.
N.VII : Nervus facialis.
N.ADLL: Anterodorsal lateral line nerve.
N.AVLL: Anteroventral lateral line nerve.
N.CIL : Ciliary nerves.
N.CSY : Cranial sympathetic nerve.
N.OIF : Nerve to the obliquus inferior muscle.
N.OSP : Nerve to the obliquus superior muscle.
N.PRF : Nervus profundus.
N.RM : Nerve to the rectus medialis muscle.
N.RSP : Nerve to the rectus superior muscle.
OL.BU : Olfactory bulb.
OP.LO : Optic lobe.
PLS : Pleurosphenoid bone.
PO.MY: Posterior myodome.
PR.B : Prootic bone.
R.IF : Ramus inferior of the nervusoculomotorius.
R.SP : Ramus superior of the nervusoculomotorius.
RD.CB : Radix ciliaris brevis.
RD.CL : Radix ciliaris longa.
RO.III : Root of the nervusoculomotorius.
RO.IV : Root of the nervus trochlearis.
RO.V : Root of the nervus trigeminus.
RO.VI : Root of the nervus abducens.
SN : Small neuron.

References

1. **Ali, R.S. AND Dakrory, A.I.** (2008): Anatomical studies on the cranial nerves of *Alticus kirkii magnosi*. I. The eye muscle nerves and the ciliary ganglion. Egypt. J. Zool., 51: 221-239.
2. **Allis, E.P. Jr. (1897):** The cranial muscles and cranial and first spinal nerves in *Amia calva*. *J. Morph.*, **12**: 487-808.
3. **Allis, E.P. Jr. (1903):** The skull, and the cranial and first spinal muscles and nerves in *Scomber scomber*. *J. Morph.*, **18**: 45-310.
4. **Allis, E.P. Jr. (1909):** The cranial anatomy of the mail-cheeked fishes. *Zool.* (Stuttgart), **22**: 1-219.
5. **Allis, E.P. Jr. (1922):** The cranial anatomy of polypterus, with special reference to *Polypterus bichir*. *J. Anat.*, **56**: 189-294.
6. **Allis, E.P. Jr. (1923):** The cranial anatomy of *Chlamydoselachus anguineus*. *Acta. Zool. Stockh.*, **4**: 123-221.
7. **Aoyama, F. (1930):** Die Entwicklungsgeschichte des Kopfskelettes des *Cryptobranchus japonicus*. *Z.f. Anat. U. Entw. Gesch.*, **93**: 107.
8. **Atoda, K. (1936):** The innervation of the cranial nerves of the cat-fish, *Parasilurus asotus* L. *Sci. Rep. Tohoku Univ.*, **11**: 91-115.
9. **Bal, D.W. (1937):** Studies on Indian puffers or globe fishes. III. The nervous system of *Tetrodon oblongus*. *J. Univ. Bombay*, **5** (5): 44-57.
10. **Burr, H.S. (1933):** The extra-ocular mechanism of *Opisthoproctus soleatus*. *Anat. Rec.*, **55** (4): 47.
11. **Chandy, M. (1955):** The nervous system of the Indian sting-ray *Dasyatis rafinesque* (Trygon cuvier). *J. Zool. Sci. India*, **7** (1): 1-12.
12. **Coghill, G.E. (1902):** The cranial nerves of *Amblystoma tigrinum*. *J. Comp. Neurol.*, **12**: 205-289.
13. **Cole, F.J. (1898):** Observation on the structure and morphology of the cranial nerves and lateral sense organs of fishes; with special reference to the genus *Gadus*. *Trans. Linn. Soc. London*, **7**: 17-221.
14. **Cole, F.J. and Johnstone, J. (1901):** Pleuronectes. L.M.B.C. Memoirs, VIII. London.
15. **Dakrory, A.I. (2000):** Comparative anatomical studies on the cranial nerves of *Rhinobatus halavi* (Class: Chondrichthyes) and *Ctenopharyngodon idellus* (Class : Osteichthyes). Ph.D. Thesis, Fac. Sci., Cairo Univ., Egypt.
16. **Dakrory, A.I. (2002) :** The cranial nerves of *Rana bedriagie* (Amphibia, Anura, Ranidae). I. The eye-muscle nerves and the ciliary ganglion. Egypt. J. Zool., 39: 395-409.
17. **Dakrory, A.I. (2003) :** The ciliary ganglion and its anatomical relations in some bony fishes. Egypt. J. Zool., 41: 1-13.
18. **Dakrory, A. I.; El-Shershaby, A. M.; Shamakh, A. A. and Taha, F. K. (2010)**: Anatomical studies on the cranial nerves of *Hypophthalmichthys molitrix* (Osteichthys: Actinopterygii: Cyprinidae). 1- The eye-muscle nerves and ciliary ganglion.J. Egypt. Ger. Soc. Zool. 61(B): 87-105.
19. **Dakrory, A. I. GABRY, M. S.; Abdel-Kader, T. G. and Mattar, S.F.(2012):** Anatomical Studies on the Cranial Nerves of Fully Formed Embryonic Stage of Gambusia affinis affinis (Baird & Girard, 1853) I. The eye muscle nerves and ciliary ganglion. J. Amer. Sci., 8(12):230-242.
20. **Dalela, R.C. and Jain, D.K. (1968):** Studies on the cranial nerves of *Clarias batrachus* (Linn.). *J. Agra Univ. Res.*, **17**: 107-114.
21. **De Beer, G.R. (1926):** Studies of the vertebrate head. II The orbitotemporal region of the skull. *Q.J. Micr. Sci.*, **70**: 263-370.
22. **De Beer, G.R. (1937):** The development of the vertebrate skull. Clarendon Press, Oxford.
23. **Edgeworth, F.H. (1935):** The cranial muscles of the vertebrates. Cambridge Univ. Press.
24. **El-Satti, F.M. (1982):** Studies on the head skeleton of Selachii. *Ph.D. Thesis. Fac. Home economic, Helwan Univ. Egypt.*
25. **El-Toubi, M.R. and Abdel-Aziz, I. (1955):** On the chondrocranium and cranial nerves of larval polypterus. *Bull. Fac. Sci. Cairo Univ.*, **33**: 1-44.
26. **El-Toubi, M.R. and Hamdy, A.R. (1959):** Studies on the head skeleton of *Rhinobatus halavi,*

Rhynchobatus djiddensis and *Trygon kuhlii*. *Publ. Mar. Biol. Sta. Gharadqa, Red Sea*, **10**: 1-44.

27. **El-Toubi, M.R. and Hamdy, A.R. (1968):** The neurocranium of *Dasyatis uarnak*. *Bull. Fac. Sci., Cairo Univ.*, **42**: 141-152.
28. **Freihofer, W.C. (1978):** Cranial nerves of a percoid fish, *Polycentrus schomburgkii* (Family: Nandidae), a contribution to the morphology and classification of the order Perciformes. *Occ. Pap. Calf. Acad. Sci.*, **128**: 1-75.
29. **Fritzsch, B.; Sonntag, R.; Dubuc, R.; Ohta, Y. and Grillner, S. (1990):** Organization of the six motor nuclei innervating the ocular muscles in lamprey. *J. Comp. Neurol.*, **294**: 491-506.
30. **Galigher, A.E. and Kozloff, E.N. (1964):** Essentials of practical microtecnique. Philadelphia, Lea and Febiger.
31. **Gierse, A.F. (1904):** Untersuchungen über das Gehirn und die Kopfnerven von *Cyclothone acclinidens*. *J. Morph.*, **32**: 602-688.
32. **Haas, A. (1995):** Cranial features of dendrobatid larvae (Amphibia: Anura: Dendrobatidae). *J. Morph.*, **224**: 241-264.
33. **Haas, A. and Richard, S.G. (1998):** Correlations of cranial morphology, ecology and evolution in Australian suctorial tadpoles of the genera *Litoria* and *Nyctimystes* (Amphibia: Anura: Hylidae: Pelodryadinae). *J. Morph.*, **238**: 109-141.
34. **Hamdy, A.R. (1960):** The head skeleton of *Rhinoptera bonasus* (Mitchill). *Proc. Egypt, Acad. Sci.*, **14**: 74-81.
35. **Hamdy, A.R. and Hassan, S.H. (1973):** On the neurocranium of *Torpedo ocellata*. *Bull. Fac. Sci. Cairo Univ.*, **46**: 127-136.
36. **Hamdy, A.R. and Khalil, M.S. (1970):** The neurocranium of *Aetomylus milvus*. *Proc. Egypt, Acad. Sci.*, **17**.
37. **Handrick, K. (1901):** Zur Kenntnis des Nervensystems und der Leuchtorgane des *Argyropelecus hemigymnus*. *Zoologica*, **32**: 1-68.
38. **Harder, W. (1975):** Anatomy of fishes, 1,2. (2nd eds.) Stuttgart: E. Schweitzerbart' Sche Verlagsbuchhandlung.
39. **Harrison, G. (1981):** The cranial nerves of the teleost *Trichiurus lepturus*. *J. Morph.*, **167**: 119-134.
40. **Herrick, C.J. (1894):** The cranial nerves of *Amblystoma punctatum*. *J. Comp. Neurol.*, **4**: 193-207.
41. **Herrick, C.J. (1899):** The cranial and first spinal nerves of *Menidia*: a contribution upon the nerve components of the bony fishes. *J. Comp. Neurol.*, **9**: 153-455.
42. **Herrick, C.J. (1901):** Cranial nerves and cutaneous sense organs of North American siluroid fishes. *J. Comp. Neurol.*, **11**: 177-272.
43. **Herrick, C.J. (1904):** The organ and sense of taste in fishes. *Bull. U.S. Fish Comm.*, **22**: 237-272.
44. **Hussein, A.K. (2010)**: Anatomical studies on the cranial nerves of Mugil cephalus (Family: Mugilidae). M.sc. Thesis, Fac. Sci., Cairo Uni., Egypt.
45. **Jenkin, P.M. (1928)**: Note on the sympathetic nervous system of Lepidosiren paradoxa. Proc Roy Soc London, 7: 56-69.
46. **Johnels, A.G. (1948):** On the development and morphology of the skeleton of the head of *Petromyzon*. *Acta Zool.*, **29**: 139-279.
47. **Johnston, J.B. (1898):** Hind brain and cranial nerves of *Acipenser*. *Anat. Anz.*, **14**: 580-602.
48. **Jollie, M.T. (1968):** Chordate morphology. New York, Reinholt.
49. **Kent, G.C. (1978):** Comparative anatomy of the vertebrates. The C.V. MOSBY Co., Saint Louis.
50. **Khalil. M.S. (1978):** The head skeleton of *Zygaena malleus*. Part I. The neurocranium. *Proc. Zool. Soc. A.R.E.*, **5**: 59-67.
51. **Khalil. M.S. (1979a):** The neurocranium of *Galeocerdo cuvier*. *Proc. Zool. Soc. A.R.E.*, **6**: 289-301.
52. **Khalil. M.S. (1979b):** The head skeleton of *Trygon pastinaca*. *Proc. Zool. Soc. A.R.E.*, **6**: 303-320.
53. **Kuntz, A. (1914):** Further studies on the development of cranial sympathetic ganglia. *J. Comp. Neurol.*, **24**: 235-267.
54. **Lehn, C. (1918):** Beiträge zur Kenntnis des primordial-schödels von *Polypterus*. *Zeitsch. F. angewandte Anst. U. Konstitutions lehre*, **2**: 349-408.
55. **Marathe, V.B. (1955):** The nervous system of *Pseudorhombus arsius* (H.B.). *J. Bombay Univ.*, **23**, B3: 60-73.
56. **Mattar, S. F. (2012):** Anatomical Studies on the Cranial Nerves of Fully Formed Embryonic Stage of Gambusia affinis affinis (Baird & Girard, 1853). M.sc. Thesis, Fac. Sci., Helwan Uni., Egypt.
57. **Mazhar, F.M. (1979):** The elasmobranchs of the Mediterranean. V. The ray *Pteroplatea altavela* (Linn.). *Proc. Zool. Soc. A.R.E.*, **6**: 117-131.
58. **McKibben, P.S. (1913):** The eye-muscle nerves in *Necturus*. *J. Comp. Neurol.*, **23**: 153-172.
59. **Mostafa, R.H. and Soliman, M.A. (1984):** The cranial nerves of *Bufo viridis* (Laur.). The eye muscle nerves. *Bull. Fac. Sci. Cairo Univ.*, **52**: 401-424.
60. **Norris, H.W. (1908):** The cranial nerves of *Amphiuma means*. *J. Comp. Neurol.*, **18**: 527-568.
61. **Norris, H.W. (1925):** Observation upon the peripheral distribution of the cranial nerves of certain ganoid fishes (*Amia, Lepidosteus, Polyodon, Scaphirhynchus* and *Acipenser*). *J. Comp. Neurol.*, **39**: 345-432.
62. **Norris, H.W. and Hughes, S.P. (1920):** The cranial, occipital and anterior spinal nerves of the dogfish, *Squalus acanthias*. *J. Comp. Neurol.*, **31**: 292-402.
63. **Northcutt, R.G. and Bemis, W.E. (1993):** Cranial nerves of coelacanth, *Latimeria chalumnae* (Osteichthyes: Sarcoptergii: Actinistia), and Comparisons with other Craniata. *Brain Behav. Evol.*, **42** (Suppl. 1): 1-76.

64. **Northcutt, R.G.; Neary, T.J. and Senn, D.G. (1978):** Observations on the Brain of the Coelacanth *Latimeria chalumnae*: External Anatomy and Quantitative Analysis. *J. Morph.*, **155**: 181-192.
65. **Pankratz, D.S. (1930):** The cranial nerve components of the toad fish (*Opsanus tau*). *J. Comp. Neurol.*, **50** (3): 247-288.
66. **Paterson, N.F. (1939):** The head of *Xenopus laevis*. *Q.J. Micr. Sci.*, **81** (II): 161-234.
67. **Piotrowski, T. and Northcutt, R.G. (1996):** The cranial nerves of the senegal bichir, *Polypterus senegalus* (Osteichthyes: Actinopterygii: Cladistia). *Brain Behav. Evol.*, **47**: 55-102.
68. **Pombal, A.M.; Rodicio, M.C. and Anadon, R. (1994):** Development and organization of the ocular motor nuclei in the larval sea lamprey, *Petromyzon marinus* L.: An HRP study. *J. Comp. Neurol.*, **341**: 393-406.
69. **Ray, D.L. (1950):** The peripheral nervous system of *Lampanyctus leucopsarus*. *J. Morph.*, **87**: 61-178.
70. **Reiss, J.O. (1997):** Early development of the chondrocranium in the tailed frog *Ascaphus truei* (Amphibia: Anura): implications for anuran palatoquadrate homologies. *J. Morph.*, **231**: 63-100.
71. **Saxena, P.K. (1967):** The cranial nerves of the mud eel *Amphipnous cuchia*. *Acta. Anat.*, **67**: 306-320.
72. **Saxena, P.K. (1969):** The cranial nerves of *Nandus nandus* (Ham.) and *Xenetoden cancile* (Ham.). *Anat. Anz.*, **124**: 142-155.
73. **Shaheen, A.A. (1987):** Anatomical studies on the cranial nerves of *Bufo regularis* Reuss. *M.Sc. Thesis, Faculty of Science, El-Minia University, Egypt*.
74. **Sheil, C.A. (1999):** Osteology and skeletal development of *Pyxicephalus adspersus* (Anura: Ranidae: Raninae). *J. Morph.*, **240**: 49-75.
75. **Sokol, O.M. (1975):** The phylogony of anuran larvae: a new look. Copeia, 1-23.
76. **Sokol, O.M. (1977):** The free swimming *Pipa* larva, with a review of pipid larvae. *J. Morph.*, **154**: 357-426.
77. **Sokol, O.M. (1981):** The larval chondrocranium of *Pelodytes punctatus*, with a review of tadpole chondrocrania. *J. Morph.*, **169**: 161-183.
78. **Soliman, M.A. and Mostafa, R.H. (1984):** The cranial nerves of *Bufo viridis* (LAUR). The nervus trigeminus. *Bull. Fac. Sci. Cairo Univ.*, **52**: 425-457.
79. **Srinivasachar, H.R. (1959):** Development of the skull in catfishes: Part IV: development of the chondrocranium in *Arius jella* Day (Ariidae) and *Plotosus canius* Ham: (Plotosidae) with an account of their interrelationships. Gegenbauers *J. Morph.*, **100**: 986-1016.
80. **Stadtmüller, F. (1925):** Studien am Urodelenschadel. 1. Zur Entwicklungs geschichte des Kopfskeletts der *Salamandra maculosa*. *Z. F. Anat. U. Entw. Gesch.*, **75**: 149.
81. **Stannius, H. (1849):** Das peripherische Nervensystem der Fische, anatomisch und physiologisch untersucht. Rostock.
82. **Szabo, T.; Lazer, G.; Libouban, S.; Toth, P. and Ravaille, M. (1987):** Oculomotor system of the weakly electric fish *Gnathonemus petersii*. *J. Comp. Neurol.*, **264**: 480-493.
83. **Trueb, L. and Cannatella, D.C. (1982):** The cranial osteology and hyolaryngeal apparatus of *Rhinophrynus dorsalis* (Anura: Rhinophrynidae) with comparisons to recent pipid frogs. *J. Morph.*, **171**: 11-40.
84. **Trueb, L. and Hanken, J. (1992):** Skeletal development in *Xenopus laevis* (Anura: Pipidae). *J. Morph.*, **214**: 1-41.
85. **Van-Eeden, J.A. (1951):** The development of the chondrocranium of *Ascaphus truei* Stejneger with special reference to the relations of the palatoquadrate to the neurocranium. *Acta Zool.* (Skockh.), **32**: 41-176.
86. **Walker, W.F.Jr. (1987):** Functional anatomy of the vertebrates. An erolutionary percepective. Saunders Coll. Publ. Philadelphia.
87. **Wiedersheim, R. (1909):** Vergleichende Anatomie der Wirbeltiere. Fisher, Jena.
88. **Young, J.Z. (1931):** On the autonomic nervous system of the teleostean fish *Uranoscopus scaber*. *Q. J. Microsc. Sci.* **74**: 491-535.
89. **Young, J.Z. (1988):** The life of vertebrates. 2nd ed. Oxford Univ.Pres. New York and Oxford.

9/12/2013