Anatomical studies on the cranial nerves of fully formed embryonic stage of *Liza ramada* (Risso, 1827). I. The eye muscle nerves and the ciliary ganglion

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Abstract: This study deals with the eye muscle nerves and the ciliary ganglion of the bony fish *Liza ramada*. The eye muscle nerves include the nervi oculomotorius, trochlearis and abducens. The oculomotor nerve leaves the cranial cavity through its own foramen. It innervates the rectus superior, rectus inferior, rectus medialis and the obliquus inferior muscles. It carries pure somatic motor fibres and visceromotor (parasympathetic) ones. The ciliary ganglion is small and there is only one ciliary nerve arising from it. The radix ciliaris longa originates from the truncus ciliaris. 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 to the obliquus inferior muscle. The nervus abducens leaves the cranial cavity through its own foramen. It enters the posterior eye muscle canal (myodome) and it has no connection with the other cranial nerves. It carries pure somatic motor fibres to the rectus lateralis muscle.

Key Words: *Liza ramada* -oculomotor-trochlear-abducens-ciliary ganglion.

1. Introduction:

The sensory system of fishes (receptors, their nerves as well as their centers) play a major and sometimes a decisive role in many fish behavioral patterns (feeding, defense, spawning, schooling orientation, migration, etc.).

The study of the cranial nerves is important because their distribution is correlated to the habits and habitats of animals and also because they show an evolutionary trend among the animals of the same group.

Of the very early works done on the cranial nerves of bony fishes were those of Stannius (1849) and Goronowitsch (1888); these classical studies are still useful to investigators. Similar work on the morphology and structure of the cranial nerves in the genus *Pleuronectes* was done by Cole and Johnston (1901). The most valuable works of these early ones were those carried out by Allis (1903, 1909 & 1922) and Herrick (1899 & 1901).

Northcutt and Bemis (1993) on *Latimeria chalumnae*, Piotrowski and Northcutt (1996) on *Polypterus senegalus*, Dakrory (2000) on *Ctenopharyngodon idellus,* Ali (2005) on *Tilapia zilli*, Hussein (2010) on *Mugil cephalus* and Taha (2010) on *Hypophthalmichthys molitrix* have presented detailed works on the morphology of the cranial nerves.

It is quite evident from the above historical review that there are numerous works on the cranial nerves of fishes, but few studies has been made concerning the cranial nerves of species belonging to mugillid fishes which is an interesting group among teleosts. Thus it was suggested that a detailed microscopic study on the eye muscle nerves in *Liza ramada* belonging to family Mugillidae will be very useful.

The main and fine branches of these cranial nerves, their distribution, their relations with other nerves and with the other structures of the head, their analysis and the organs they innervate are studied thoroughly, hoping that they may add some knowledge on this important subject and also to the behavior and phylogeny of this group of fishes.

2. Materials and Methods

The thinlip mullet is found in the eastern Atlantic Ocean from Cape Verde and Senegal north to the Baltic Sea. It is also found in the Mediterranean Sea and Black Sea .

The fully formed larvae were collected from fish farm in Kafr El-Sheikh Governorate, Egypt. The heads of the fully formed larvae were separated and fixed in aqueous Bouin's solution for 24 hours. This was followed by several washing with 70% ethyl alcohol for 3-4 days to get rid of excess Bouin's solution and its yellow colour from the specimens. Decalcification of bones was necessary before sectioning and staining the specimens, this was carried out by placing the heads in EDTA solution for about 40 days with changing the solution every 4

days. Thereafter, the embryonic heads were washed several times with 70% ethyl alcohol.

The heads were made ready for blocking and this was followed by sectioning the heads transversely at 10 micron in thickness by the microtome. The serial sections were stained in Mallory triple stain. The serial sections were drawn by the aid of a projector microscope. From these drawings an accurate graphic reconstruction for the nervi oculomotorius, trochlearis and abducens and also the ciliary ganglion and the eye was made in a lateral view. In order to avoid confusion of lines, few rami were slightly displaced from their normal position. Also, parts of certain sections were photomicrographed to demonstrate the relation of the nerves with other cranial structures.

3. Results
III. Nervus Oculomotorius

In Liza ramada, the oculomotor nerve arises from the midlateral side of the mesencephalon by one stout root (Figs. 1 & 2, RO.III). Immediately after its emergence, it runs anteroventrally within the cranial cavity, passing lateral, dorsolateral and ventral to the brain, ventromedial to the nervus trochlearis and medial to the geniculate ganglion. It continues anteroventrally running ventromedial to the trochlear nerve, dorsolateral to the brain and medial to the profundus ganglion. Thereafter, the nervus oculomotorius containues passing ventral and lateral to the brain and ventromedial to the prootic foramen and the nervus trigeminus.

Shortly after that, the nervus oculomotorius leaves the cranial cavity by penetrating the meninx primitive through its own foramen; the foramen oculomotorius (Fig. 3, F.OC). This foramen is located in the pleurosphenoid bone. At this position, the nervus oculomotorius divides into a dorsal ramus superior (Figs. 1 & 3, R.SP) and a ventral ramus inferior (Figs. 1 & 3, R.IF).

Ramus Superior

Immediately after its separation from the nervus oculomotorius, the ramus superior (Figs. 1 & 3, R.SP), extends anteriorly in the ventromedial direction passing dorsal to the ramus inferior, the vena capitis lateralis and medial to the medial edge of the prootic bone.

Shortly forwards, it continues passing dorsolateral to both the ramus inferior of the nervus oculomotorius and the rectus superior muscle dorsal to the vena capitis lateralis and medial to head sympthatic nerve. At this position, it divides into two branches; one medial to the other. Both branches enter the rectus superior muscle (M.RS) from its dorsolateral side and terminate between its fibres Figs. 3 & 4, R.SP).

Ramus Inferior

Directly after its separation from the nervus oculomotorius, the ramus inferior (Figs. 1 & 3, R.IF) extends forwards in a ventromedial direction passing ventral to the ramus superior, dorsomedial to both the vena capites lateralis and the rectus lateralis muscle and ventrolateral to the rectus superior muscle.

Here, the ramus inferior gives off a ventromedial branch (Figs. 1 & 3, R.IF). This branch runs anteroventrally passing medial to both the vena capitis lateralis and the rectus lateralis muscle and lateral to the rectus superior muscle. Thereafter, this branch extends forwards passing ventral to the rectus superior muscle, ventromedial the main ramus inferior, ciliary ganglion and the rectus lateralis muscle, dorsal to both the ramus palatines faciles and the adductor hyomandibularies muscle and lateral to the rectus medialis muscle. More forwards, this branch containues passing ventral, then ventromedial to the rectus inferior muscle, ventrolateral to the rectus medial muscle and dorsal to the adductor hyomandibulures muscle. More and more forwards it passes ventral and then ventromedial to the rectus medialis muscle. Thereafter, the two branches of the opposite sides continue forwards side by side along the mid line and medial to the rectus medialis muscles. After a considerable forward course in this position this branch enters and ends between the fibres of the obliquues inferior muscle (Figs. 1 & 4, N.OIF).

Shortly, anterior to the origin of the previous branch, the ramus inferior receives a branch from the common nerve formed of the the radix ciliaris longa and the cranial sympathetic nerve (Fig. 1, CO.N). Then it extends more forwards running dorsal and dorsomedial to the vena capitis lateralis, ventromedial to the ramus superior and lateral to the rectus superior muscle. Here, it gives off a fine branch; the radix ciliaris brevis to the ciliary ganglion (Figs. 1 & 4, RCB).

Shortly anterior, the ramus inferior divides into a ventromedial branch and a dorsolateral one. The two branches runs anteromedially passing dorsomedial to both the vena capitis lateralis and the ciliary nerve and ventrolateral to the rectus superior muscle. Thereafter, the ventromedial branch continues anteriorly passing medial to the ciliary nerve, ventral to the rectus superior muscle and lateral to the rectus inferior muscle. Here, it enters the lateral muscle from its lateral side where it achieves its final distribution (Fig. 1, N.RIF).

The dorsolateral branch runs forwards passing ventral to the rectus superior muscle and dorsal to both the ciliary nerve and the vena capitis lateralis. After a considerable course, this branch continues passing ventromedial to the rectus superior

muscle, dorsolateral to the rectus inferior muscle and dorsal to the ciliary nerve. Shortly after that, this branch runs medially passing dorsal to the rectus inferior muscle to enter the rectus medialis muscle where it terminates (Fig. 1, N.RM).

Ciliary Ganglion

In Liza ramada, the ciliary ganglion ((Figs. 1 & 4, G.CL) is rounded shaped structure, consisting of a collection of ganglionic cells. It is located in the posterior part of the orbital region, in a position surrounded by the rectus lateralis muscle ventrolaterally (M.RL), the vena capitis lateralis laterally, the ramus inferior of the nervus oculomotorius (R.IF) dorsolaterally and the rectus superior muscle dorsomedially (R.SP). It measures about 96 μm in length.

The ciliary ganglion is commonly described as possessing three roots; a motor (parasympathetic), a sensory and a sympathetic roots. The first root carries preganglionic parasympathetic (viscero-motor) fibres which arise in the midbrain. These fibres, as it has long been known, constitute the tectal portion of the cranial outflow of the parasympathetic system. The preganglionic parasympathetic fibres are transmitted to the ciliary ganglion by way of the nervus oculomotorius, with or without a special root; the radix ciliaris brevis. They terminate in the ganglion in synaptic relationship with the postganglionic cell bodies. The sensory root of the ganglion consists of sensory components of the ramus ophthalmicus of the nervus trigeminus. These fibres enter the ganglion by means of a long branch; the radix ciliaris longa. The sympathetic root is composed of the postganglionic sympathetic fibres which originate in the superior cervical sympathetic ganglion and extend cephalad via the internal carotid plexus. Such fibres are carried to the ciliary ganglion by a fine branch; the sympathetic root. Both the sensory and postganglionic sympathetic fibres usually pass through the ganglion without interruption and become incorporated in the ciliary nerves arising from it.

In the present study, the ciliary ganglion receives a very short branch from the ramus inferior of the nervus oculomotorius; the radix ciliaris brevis (Figs. 1 & 4, RCB). The microscopic investigation reveals that the preganglionic parasympathetic fibres leave the ramus inferior as a short branch. Such branch constitutes the parasympathetic (general motor) root of the ganglion.

In this study, the radix ciliaris longa (Figs. 1 & 4, RCL), carrying the sympathetic fibers, devides into two branches; one dorsal to the other. The dorsal branch runs anteromedially to fuse with the ramus inferior of the nervus oculomotorius. The ventral branch extends anteriorly in the ventromedial

direction passing along the ventrolateral wall of the vena capitis lateralis till it reaches and joins the ciliary nerve shortly after its origin from the ganglion (Fig. 1).

In this work, there is a single ciliary nerve (Fig. 1, N.CL) arising from the anterior end of the ciliary ganglion. This nerve extends forwards in a lateral direction, being ventrolateral to the rectus superior muscle, ventral to the ramus inferior of the nervus oculomotorius and ventromedial to the vena capitis lateralis. Thereafter, it runs lateral to the rectus inferior muscle and medial to the eyeball. Shotly anterior, it shifts and becomes dorsal to the latter muscle, ventrolateral to both the rectus medialis muscle and the optic nerve and medial to the eyeball. Finally, it enters the eyeball just posteroventral to the optic nerve.

IV. Nervus Trochlearis

In Liza ramada, the nervus trochlearis (Fig. 1, N.IV) arises from the lateral side of the midbrain just anterior and dorsomedial to the origin of the nervus trigeminus, by a single small root (Figs. 1 & 5, RO.IV). This root extends anteriorly within the cranial cavity in a ventrolateral direction passing ventral and medial to the trigeminal nerve, common geniculate and the anteroventral lateral line ganglion and lateral to the brain. After a long forward course, it becomes medial to both the nervus trigeminus and the ganglion of the anterodorsal lateral line nerve, ventral and lateral to the brain and dorsal to the nervus oculomotorius. On reaching the postorbital region, it stills intracranially extending ventral and lateral to the brain. After a long anterior interacranial course in the orbital region, it leaves the cranial cavity by penetrating the meninx primitiva through its own foramen (Fig. 6, F.TR).

Extracranially, the nervus trochlearis runs forwards passing dorsomedial to the rectus superior muscle, ventromedial to the supraorbital cartilage and lateral to the cranial wall. Thereafter, it continues its forwards course running dorsomedial to the rectus superior muscle and ventrolateral to the cranial wall. Thereafter, it becomes dorsomedial to the eyeball and lateral to the cranial wall. On reaching the mid way of the orbital region, it continues running in a dorsolateral direction being dorsal to the medaial edge of the obliquus superior muscle and ventromedial to the supraorbital lateral line canal. Finally, it enters and ends between the fibres of the latter muscle.

VI. Nervus Abducens

In Liza ramada, the nervus abducens originates from the ventrolateral corner of the medulla oblongata by a single fine root just ventromedial to the origin of the nervus octavus (Figs. 1 & 7, RO.VI). Directly after its origin, it runs

forwards in a ventrolateral direction passing ventromedial to the root of the nervus octavus. Shortly forwards, this nerve continues passing medial to the lagena and its lagenar branch and dorsal to the lateral margin of the prootic bridge. This bridge forms the roof of the posterior myodome (posterior eye muscle chamber (Fig. 7, PM).

After a considerable anterior course, the nervus abducens leaves the cranial cavity by piercing the meninx primitiva through a foramen in the lateral margin of the prootic bridge, abducens foramen (Fig. 8, FO.A). Extracranially, the nervus abducens enters the posterior myodome (Fig. 8, PM), which lodges the recti lateralis and medialis muscles. Within the myodome, it ramifies and enters the rectus lateralis muscle where it terminates.
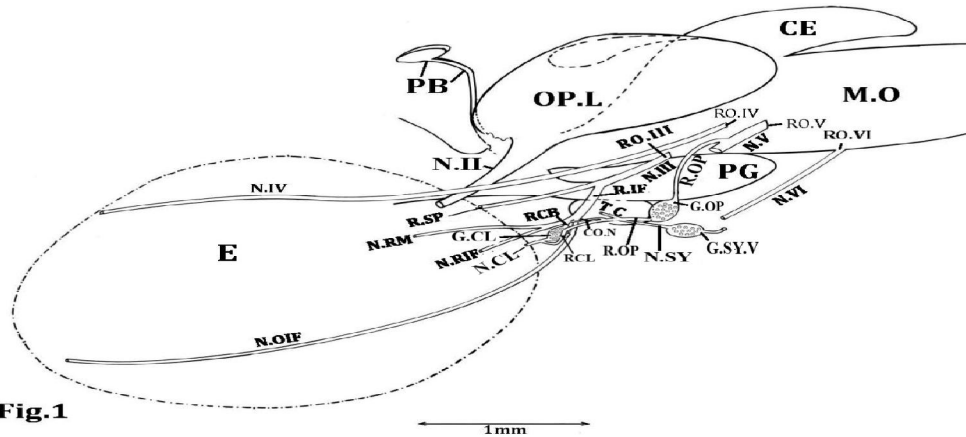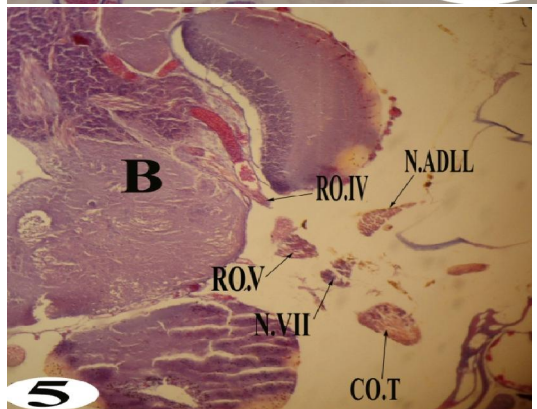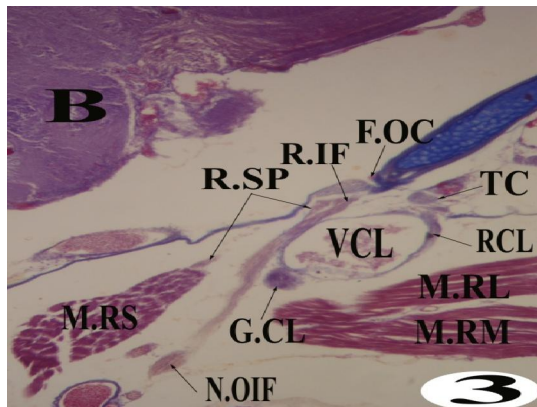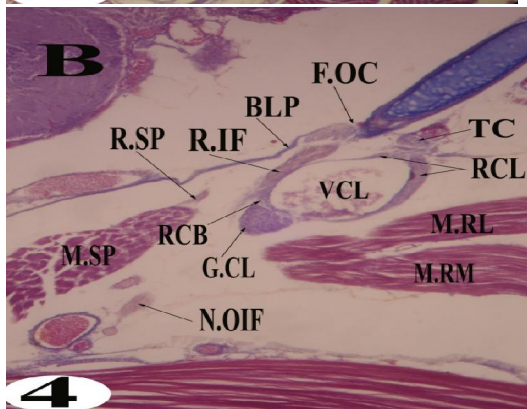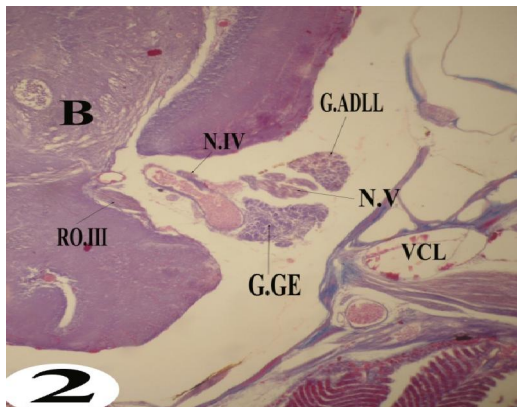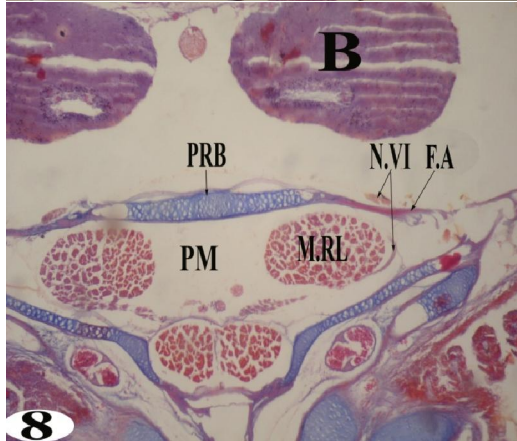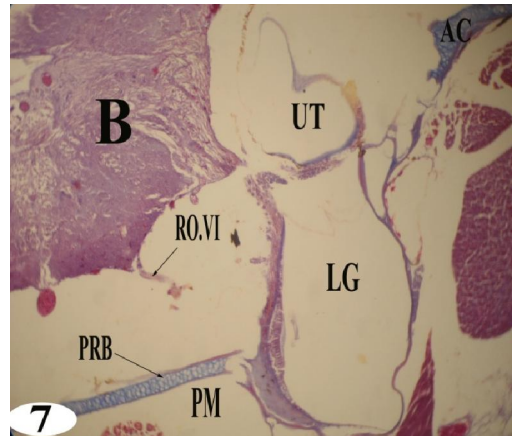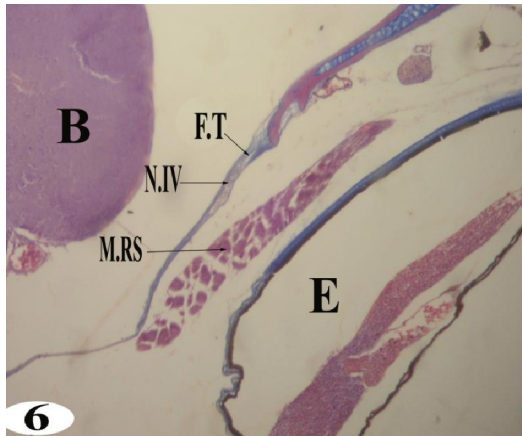

Fig.1

Fig.1: Lateral view of a graphic reconstruction of the brain, the nervi oculomotorius, trochlearis and abducens and the eye of *Liza ramada*.

Fig.2: A photomicrograph of part of transverse section passing through the orbital region of *Liza ramada* illustrating the oculomotor root, the nervus trochlearis, the geniculate ganglion, the nervus trigeminus and the anterior dorsal lateral line ganglion.

Fig.3: A photomicrograph of part of transverse section passing through the postorbital region of *Liza ramada* illustrating the ciliary ganglion, the oculomotor foramen, ramus superior, ramus inferior, truncus ciliaris and radix ciliaris longa.

Fig.4: A photomicrograph of part of transverse section passing through the postorbital region of *Liza ramada* illustrating the ciliary ganglion, the oculomotor foramen, ramus superior, ramus inferior, radix ciliaris longa and radix ciliaris brivis.

Fig.5: A photomicrograph of part of transverse section passing through the anterior otic region of *Liza ramada* illustrating the trochlear root, the trigeminal root, the facial nerve, anterior dorsal lateral line nerve and the common trunk.

Fig.6: A photomicrograph of part of transverse section passing through the orbital region of *Liza ramada* illustrating the trochlear foramen and the trochlear nerve.

Fig.7: A photomicrograph of part of transverse section passing through the otic region of *Liza ramada* illustrating the abducens root, the utricle and the lagina.

Fig.8: A photomicrograph of part of transverse section passing through the postorbital region of *Liza ramada* illustrating the abducens foramen and the abducens nerve entering the posterior myodome.

4. Discussion

In the present study, the nervus oculomotorius shows no decussation in the brain while complete decussation near its origin in the brain was observed by Dakrory (2000) in *Ctenopharyngodon idellus*, Ali (2005) in *Tilapia zillii*, Hussein (2010) in *Mugil cephalus* and Taha (2010) in *Hypophthalmichthys molitrix*.

The nervus oculomotorius gets its exit from the cranial cavity through its own foramen, the foramen oculomotorius.Among bony fishes, the nervus oculomotorius waweras found to issue from

the cranial cavity through its own foramen as in *Ailia* (Srinivasachar, 1956), *Amphipnous cuchia* (Saxena, 1967), *Trichiurus lepturus* (Harrison, 1981), *Ctenopharyngodon idellus* (Dakrory, 2000), *Tilapia zillii* (Ali, 2005), *Hypophthalmichthys molitrix* (Taha, 2010)and in *Gambosia affinis affinis (*Mattar, 2012; Dakrory *et al.,* 2012). However, the nervus oculomotorius was found to leave the cerebral cavity together with the nervi opticus, trigeminus, abducens and facialis through a large sphenoid fissure in 29 mm *Arius jella* and 16 mm *Plotosus canius* (Srinivasachar, 1959). In *Clarias batrachus* (Dalela and Jain, 1968), the nerve in question was found to emerge from the cavum cranii together with the nervi trochlearis, trigeminus, abducens and facialis through the foramen prooticum. In *Polypterus senegalus*, the nervus oculomotorius leaves the cranium, together with the profundus nerve through a single foramen. This finding may be related to the absence of the true pila prootica (El-Toubi and Abdel-Aziz, 1955; Piotrowski and Northcutt, 1996). On the other hand, in *Gnathonemuspetersii* (Szabo *et al.,* 1987), the oculomotor nerve is divided within the cranial cavity into two branches, which enter the orbit separately, *i.e.,* there are two foramina for the nervus oculomotorius.

In cartilaginous fishes, the nervus oculomotorius gets its exit from the cranial cavity through its own foramen (Chandy, 1955; Hamdy, 1959; El-Toubi and Hamdy, 1959 &1968; Gohar and Mazhar, 1964; Hamdy and Khalil, 1970; Hamdy and Hassan, 1973; Khalil, 1978 & 1979a &b; Mazhar, 1979; Dakrory, 2000).

In the present work, the oculomotor foramen was found to be located in the pleurosphenoid bone. This result is similar to the finding of Dakrory (2000) in *Ctenopharyngodon idellus* and Taha (2010) in *Hypophthalmichthys molitrix*. Different localities for the oculomotor foramen were described in other fishes by some authors. This foramen was found in the lateral ethmoid bone in *Amphipnous cuchia* (Saxena, 1967), in the basisphenoid bone in *Trichiurus lepturus* (Harrison, 1981), in the orbitosphenoid bone in *Polypterus senegalus* (Piotrowski and Northcutt, 1996) or surrouned by the pleurosphenoid bone in *Ctenopharyngodon idellus* (Dakrory, 2000) and in *Hypophthalmichthys molitrix* (Taha, 2010). Ali (2005) in *Tilapia zillii* and Mattar (2012) and Dakrory *et al*. (2012) in *Gambosia affinis affinis* recorded an oculomotor foramen between the prootic bone and the pleurosphenoid bone. However, Ray (1950) described a special oculomotor foramen in the membranous cranial wall of the orbitotemporal region in *Lampanyctus leucopsarus*, while Srinivasachar (1956) described this foramen in the preoptic root of the orbital cartilage in

Ailia.

In the jawless fishes, Johnels (1948) described an optic fenestra through which emerge the optic and the three eye muscle nerves from the cranial cavity in *Petromyzon*. However, Jollie (1968) described a separate oculomotor foramen in lampreys. The author added that this may confluent with a large optic foramen located anterior to it. On the other hand, the three eye muscle nerves along with their muscles are lacking in the hagfishes (Jollie, 1968; Northcutt, 1985; Wicht, 1996). Fernholm and Holmberg (1975) stated that the hagfishes have relatively small eyes and there was tendency toward eye reduction. Parallel with these results, Wicht (1996) recorded that the external eye muscles as well as the accompanying nerves are entirely lacking in all species of hagfishes even in that retained relatively large and differentiated eyes as in *Eptatretidae*.

In Amphibia, the oculomotor nerve has its own foramen as described by many authors (Sokol, 1977 & 1981; Mostafa and Soliman, 1984; Shaheen, 1987). However, in *Rhyacotriton olympicus* (Srinivasachar, 1962), the optic and the oculomotor nerves pass together through a common foramen.

In the present investigation, the nervus oculomotorius is divided extracranially into two rami, the ramus superior and the ramus inferior. This case was agreed with what was generally found in most fishes such as *Ctenopharyngodon idellus* (Dakrory, 2000), *Tilapia zillii* (Ali, 2005), *Hypophthalmichthys molitrix* (Taha, 2010) and in *Gambosia affinis affinis* (Mattar, 2012; Dakrory *et al.,* 2012). However, in the teleosts *Gnathonemus petersii* (Szabo *et al.*, 1987) and *Alticus kirkii magnosi* (Ali and Dakrory, 2008) 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 is in the oculomotor foramen.

The studied species showed no connection between the nervus oculomotorius and other cranial nerves. This observation was similar to that found in *Tilapia zillii* (Ali, 2005), *Alticus kirkii magnosi* (Ali and Dakrory, 2008), *Mugil cephalus* (Hussein, 2010), *Hypophthalmichthys molitrix* (Taha, 2010) and in *Gambosia affinis affinis* (Mattar, 2012; Dakrory *et al.,* 2012). However, the connection between the nervus oculomotorius and the nervus trigeminus was recorded among bony fishes. In *Polypterus senegalus*, this nerve joins the profundus nerve (El-Toubi and Abdel-Aziz, 1955). In the same species, however, two connections between these two nerves were found by Piotrowski and Northcutt (1996). In *Ctenopharyngodon idellus* (Dakrory, 2000) the nervus oculomotorius is connected to the trigeminal ganglion through a fine anastomosing

branch. In *Gnathonemus petersii* (Szabo *et al.,* 1987), the oculomotor nerve anastomoses with the ophthalmic branch of the trigemino-lateral line complex. Earlier, an anastomosis between the nervus oculomotorius and the nervus trochlearis was found in *Pleuronectes* (Cole and Johnstone, 1901) and between this nerve and the nervus abducens in *Cyclothone acclinidens* (Gierse,1904). However, Marathe (1955), Dakrory (2000), Ali (2005), Taha (2010) and Mattar (2012) revealed no connections between the nervus oculomotorius and both the nervi trochlearis and abducens in *Pseudorhombus arsius*, *Ctenopharyngodon idellus*, *Tilapia zillii*, *Hypophthalmichthys molitrix* and *Gambosia affinis*, respectively.

An anastomosis between the nervus oculomotorius and other cranial nerves seems to be widely spread among Amphibia, reptiles, Aves and mammals. With respect to amphibians, the nervus oculomotorius is connected with both Gasserian ganglion and the ramus ophthalmicus profundus as in *Bufo viridis* and *Bufo regularis* (Paterson, 1939; Soliman and Mostafa, 1984b; Shaheen, 1987).

The connection of the nervus oculomotorius, or its branches, with the nervus trigeminus, or its branches, was mentioned in reptiles by many authors. In birds, no mention of an anastomosis between the nervi oculomotorius and trigeminus had never been recorded (Soliman *et al.*, 1986a). Regarding mammalia, a connection between the main nervus oculomotorius and the ramus ophthalmicus was described in the baboon embryo and Gasser and Hendrichx (1969). Also an anastomosis between the ramus inferior and the ramus maxillaris of the nervus trigeminus was mentioned by many authors (Mobilio, 1912; Whitteridge, 1955; Godinho and Getty, 1971).

It is clear from the detailed anatomical study of the head serial sections of *Liza ramada* that the nervus oculomotorius carries special somatic motor fibres and small components of general visceromotor fibres for the ciliary ganglion.

The ciliary ganglion of the fish *Liza ramada* is found in the postorbital region of the head, this finding was also reported by Dakrory (2000) in *Ctenopharyngodon idellus* and in *Gambusia affinis affinis*, *Tilapia* and *Mugil cephalus* (Dakrory, 2003), *Tilapia zillii* (Ali, 2005), *Alticus kirkii magnosi* (Ali and Dakrory, 2008), *Mugil cephalus* (Hussein, 2010), *Hypophthalmichthys molitrix* (Taha, 2010) and in *Gambusia affinis affinis* (Matter*,* 2012*; Dakrory et al.,* 2012*)*. Among bony fishes, a distinct ciliary ganglion was also described in the perciform, *Pseudorhombus arsius* (Marathe, 1955), *polycentrus schomburgkii* (Freihofer, 1978), *Trichiurus lepturus* (Harrison, 1981) and in the cladistian, *Polypterus senegalus* (Piotrowski and Northcutt, 1996).

In cartilaginous fishes, the ciliary ganglion was observed by Young (1988) in dog fish *Mustelus* and in skates and rays and by Dakrory (2000) in *Rhinobatus halavi*. However, the ciliary ganglion was completely lacking in *Salmo* and *Cyclothone acclinidens* (Gierse, 1904) in *Dipnoi* (Jenkin, 1928) and in the ray fish *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) 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 ganglion of two parts in *Bufo viridis*.

Among Reptilia, a well distinct ciliary ganglion was recorded in reptiles so far described. Dakrory (2009) described this ganglion in *Uromastyx aegyptius*, *Sphenops sepsoides* and *Varanus griseus griseus*. Also in birds, it was occurred widely. In mammals, in addition to the ciliary ganglion, an accessory ganglion was described by Christensen (1935) and Kuchiiwa *et al*., (1994) in cat and by Godinho (1972) in the pig.

In the current study, the ciliary ganglion consists of two types of neurons, large neurons at the periphery and small ones at the central region. Such case was recorded in both the batoid *Rhinobatus halavi* and the cyprinid *Ctenopharyngodon idellus* (Dakrory, 2000), *Gambusia affinis affinis* (Dakrory, 2003; Matter*,* 2012; Dakrory *et al.,* 2012), *Tilapia zillii* (Ali, 2005) and in *Hypophthalmichthys molitrix* (Taha, 2010). The same structure was also recorded in many reptiles by many authors such as Dakrory (2009) reported in *Uromastyx aegyptius* and *Sphenops sepsoides* and Omar (2009) in *Agama sinaita* and in birds (Oehme, 1968; Soliman *et al.,* 1976). In Mammalia, the ganglion is formed of one type of neurons (Stefani, 1972; Hegazy and Mostafa, 1990). Also, the ganglion of the bony fishes *Mugil cephalus* (Dakrory, 2003 & Hussein, 2010) and *Alticus kirkii magnosi* (Ali and Dakrory, 2008) showed no regional differentiation, *i.e.* it consists of one type of neurons. However, in the birds studied by Soliman *et al.,* (1976) and Abdel-Kader and Fathy (2002), the ciliary ganglion consists of two parts; the first is composed of small neurons and the second is composed of large ones.

In general, the ciliary ganglion has three roots; sensory, sympathetic and parasympathetic (motor) roots. The sensory root of the ganglion consists of sensory components of the ramus ophthalmicus profundus of the nervus trigeminus and these fibres

enter the ganglion by the way of the radix ciliaris longa. The sympathetic root is formed of the postganglionic fibres that arise from the facial sympathetic ganglion and they are transmitted to the ciliary ganglion via the sympathetic root. The motor (parasympathetic) root of the ganglion is composed of the preganglionic fibres that originate in the brain and transmitted to the ciliary ganglion by the way of the nervus oculomotorius through the radix ciliaris brevis.

In the present study, the sensory root, the radix ciliaris longa, originates from the nervus profundus distal to its ganglion. A similar finding was reported in *Lampanyctus leucopsarus* (Ray, 1950), *Tilapia zillii* (Ali, 2005), *Alticus kirkii magnosi* (Ali and Dakrory, 2008) and *Hypophthalmichthys molitrix* (Taha, 2010). The radix ciliaris longa originates from the profundal ganglion in *Polypterus senegalus* (Piotrowski and Northcutt, 1996), *Mugil cephalus* (Dakrory, 2003 & Hussein, 2010) and in *Gambusia affinis affinis* Mattar (2012) and Dakrory *et al.* (2012).On the other hand, it was reported in the batoid *Rhinobatus halavi* and the cyprinid *Ctenopharyngodon idellus* (Dakrory, 2000) that the radix ciliaris longa originates from the Gasserian ganglion of the nervus trigeminus.

In the present investigation, there is very short radix ciliaris brevis which carries the motor component of the nervus oculomotorius to the ciliary ganglion from the ramus inferior. A well developed motor root, the radix ciliaris brevis, was observed in *Lampanyctus leucopsarus* (Ray, 1950*), Polypterus senegalus* (Piotrowski and Northcutt, 1996) and in *Tilapia zillii* (Ali, 2005). On the other hand, there is no radix ciliaris brevis and the motor fibre stransmitted directly to the ganglion in the cyprinid, *Ctenopharyngodon idellus* and in *Mugil cephalus* (Dakrory, 2000 & 2003, respectively), in *Alticus kirkii magnosi* (Ali and Dakrory, 2008) and by Taha (2010) in *Hypophthalmichthys molitrix.*

Among Chondrichthyes, Young (1988) and Dakrory (2000) reported that, the motor root from the oculomotor nerve joins a sensory one from the trigeminal nerve then it enters the ganglion. A radix ciliaris brevis was found in some reptiles (Soliman and Hegazy, 1969; Abdel-Kader, 1990; Omar, 2009), in some birds (Soliman *et al.*, 1976) and in some mammals (Godinho, 1972; Hegazy and Mostafa, 1990).

From the above mentioned observation, it appears that the parasympathetic fibres (the motor root) of the nervus oculomotorius may or may not form a separate branch, radix ciliaris brevis, which enters the ganglion or the latter ganglion, is found on the ramus inferior without any communicating branch.

In the present study, one ciliary nerve arises from the ciliary ganglion. The number of ciliary nerves is variable in vertebrates. The presence of one ciliary nerve appear to be a common character among bony fishes as in *Trichiurus lepturus* (Harrison, 1981), in *Polypterus senegalus* (Piotrowski and Northcutt, 1996), in the cyprinid, *Ctenopharyngodon idellus* (Dakrory, 2000), in *Mugil cephalus* (Dakrory, 2003), in *Alticus kirkii magnosi* (Ali and Dakrory, 2008), in *Hypophthalmichthys molitrix* (Taha, 2010) and in *Gambusia affinis affinis* (Mattar, 2012; and Dakrory *et al.*, 2012). On the other hand, there is one ciliary nerve arising from the ophthalmicus profundus nerve and not from the ciliary ganglion as in the ray *Dasyatis refinesque* (Chandy, 1955).

In the current study, the poeciliid fish *Liza ramada* shows that in addition to the ciliary nerve, a truncus ciliaris profundus enters the eyeball through a foramen excavated in the dorsal side of the sclera just ventral to the obliquus superior muscle. This finding shows that the eye is accommodated by both the ciliary nerve and the truncus ciliaris. Therefore, this reflects the fact that the eye is well developed in the studied fish and this fish depends on vision during its feeding. So, it is considered as a diurnal animal. A similar observation was found also by Young (1988) in *Mustelus*, Ali (2005) in *Tilapia zillii*, Taha (2010) in *Hypophthalmichthys molitrix* and by Mattar (2012) and Dakrory *et al.* (2012) in *Gambusia affinis affinis*. In *Polypterus senegalus*, Piotrowski and Northcutt (1996) described two ciliary nerves.

In cartilaginous fishes, Kent (1978) stated that the postganglionic fibres penetrate the sclera and pass to the sphincter pupillae and the ciliary muscle of the iris diaphragm. The author added that the bony fish lack the ciliary muscles but there is a special compound, Campanula Halleri, was found which draw 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 was present in some other amphibians (Norris, 1908; McKibben, 1913; Paterson, 1939; Shaheen, 1987).

In the present study, the nervus trochlearis emerges from the cranial cavity through a special foramen; the trochlear foramen. This is the case found in some fishes such as *Parasilurus asotus* (Atoda, 1936), *Lampanyctus leucopsarus* (Ray, 1950), *Polypterus senegalus* (El-Toubi and Abdel-Aziz, 1955; Piotrowski and Northcutt, 1996), *Amphipnous cuchia* (Saxena, 1967), *Trichiurus lepturus* (Harrison, 1981), in the cyprinid fish, *Ctenopharyngodon idellus* (Dakrory, 2000), *Tilapia zillii* (Ali, 2005), *Alticus kirkii magnosi* (Ali and Dakrory, 2008), *Hypophthalmichthys*

molitrix (Taha, 2010), *Mugil cephalus* (Dakrory, 2003 & Hussein, 2010) and in *Gambusia affinis affinis* (Mattar, 2012; Dakrory *et al.*, 2012). However, Srinivasachar (1959) showed that there is a large sphenoid fissure for the emergence of the nervioptius and facialis in the 29 mm larva of *Plotosus canis*. In *Clarias batrachus*, there is a common foramen for the exit of the nervioculomotorius, trochlearis, abducens and the trigemino-facial complex (Dalela and Jain, 1968). In the Goldfish, *Carassius auratus*, the nervus trochlearis leaves the braincase together with the ramus ophthalmicus superficialis through an opening on the optic tectum (Puzdrowski, 1987). Nakae and Sasaki (2006) reported that the trochlear nerve in *Mola mola* emerges from the cranium through the anterior part of the suture between the pterosphenoid and basisphenoid.

Among cartilaginous fishes, the nervus trochlearis leaves the cerebral cavity through its own foramen, the trochlear foramen (Chandy, 1955; El-Toubi and Hamdy, 1959 & 1968; Hamdy and Hassan, 1973; Mazhar, 1979; El-Satti, 1982; Dakrory, 2000). In the cyclostomates *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) reported a special foramen for the trochlear nerve in lampreys.

In most amphibians, the trochlear nerve exits from the cerebral cavity through a special foramen (Herrick, 1894; Norris, 1908; Stadtmüller, 1925; Aoyama, 1930; De Beer, 1937; Paterson, 1939; Sokol, 1977 & 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 *Ascaphus truei*, does not pierce the orbital cartilage at all; but the nervus trochlearis passes over its margin. This author added that *Ascaphus truei* shares this feature with some Urodela. Sokol (1977) reported that the trochlear foramen in the anuran *Pipa cadvalhoi* is very small and presumably lies above the oculomotor foramen as in other tadpoles. In this respect, the trochlear foramen *Amblystoma punctatum* (Herrick, 1894) and *Necturus* (McKibben, 1913) was found to be located in the parietal bone. Sheil (1999), dealing with *Pyxicephalus adspersus*, stated that the trochlear foramen is located ventral to the lamina perpendicular to the frontoparietal bone or pierces it. On the other hand, a large optic-prootic foramen, for the exit of the nervi opticus and facialis was described by Trueb and Cannatella (1982) in *Rhinophrynus dorsalis* and *Pipa pipa*. Haas and Richard (1998) revealed that the nervi opticus and trochlearis leave the cranial cavity together through a large foramen opticum in Boophis.

In Reptilia, the emergence of the nervus trochlearis from the cranial cavity shows a wide variety. In *Sphenodon punctatus*, this nerve passes out of the cerebral cavity together with the nervus oculomotorius through the fenestra metoptica (Howes and Swinnerton, 1901). A fenestra metoptica, for the exit of the nervi trochlearis and oculomotorius, was described in most lacertilians (Soliman and Hagazy, 1969; Soliman and Mostafa, 1984a; Mostafa, 1990c). However, in some species of lacertilian, there is no metoptic fenestra, and these nerves leave the cerebral cavity through the membranous cranial wall or metoptic membrane (Willard, 1915; Oelrich, 1956; Dakrory, 1994). In ophidian, the nervus trochlearis, together with the nervi opticus, oculomotorius and abducens, issue from the cranium through the foramen orbitale magnum (Gaupp, 1902; Hegazy, 1976). In Celonia, the nervus trochlearis leaves the cranial cavity either with the nervus oculomotorius through the incisura metoptica (De Beer, 1937). In Crocodiles, a special foramen for the nervus trochlearis is located in the posterior part of the taenia parietalis media (Shiino, 1914).

Among birds, the nervus trochlearis passes out of the cranial cavity either together with the nervi opticus and oculomotorius through a closed splenoid fontanelle (De Beer, 1937; May, 1961; Müller, 1961; TilMacke, 1969) or through a special foramen, *i.e.* no sphenoid fontanelle is present (Cords, 1904; Bellaris, 1958; Soliman *et al.,* 1986b).

In the present study, there is no decussation of the left and right trochlear nerves inside the brain. This finding was in agreement with that reported by Ali (2005) in *Tilapia zillii* and by Ali and Dakrory (2008) in *Alticus kirkii magnosi*. However, there a complete trochlear decussation of the left and right trochlear nerves inside the brain as reported in *Gnathonemus petersii* (Szabo *et al.,* 1987), *Polypterus senegalus* (Piortrowski and Northcutt, 1996), in both the batoid *Rhinobatus halavi* and in the cyprinid *Ctenopharyngodon idellus* (Dakrory, 2000), in *Mugil cephalus* (Hussein, 2010) and in *Hypophthalmichthys molitrix* (Taha, 2010).

The present investigation shows no connection between the nervus trochlearis and the other cranial nerves. This observation was in agreement with the result recorded in *Rhinobatus halavi* and *Ctenopharyngodon idellus* (Dakrory, 2000), *Tilapia zillii* (Ali, 2005), *Alticus kirkii magnosi* (Ali and Dakrory, 2008), *Hypophthalmichthys molitrix* (Taha, 2010), *Mugil cephalus* (Dakrory, 2003; Hussein, 2010) and in *Gambusia affinis affinis* (Mattar, 2012; Dakrory *et al.*, 2012). 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 previously 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 amphibians, 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). An anastomosis between the nervus trochlearis and the ramus ophthalmicus of the nervus trigeminus was described in some reptiles such as the geckos (Evans and Minckler, 1938; Soliman and Mostafa, 1984a), in some snakes (Hegazy, 1976; Mostafa, 1990a & b) and in *Chelonia (Soliman,* 1964). However, such connection was not recorded by Soliman and Hegazy (1969) in *Chalcides ocellatus* and by Dakrory (1994) in *Diplometopon zarudnyi*.

Concerning birds, a connection between the nervus trochlearis and the ramus profundus was mentioned by Cords (1904), and asserted by Soliman *et al.*, (1986a). Regarding mammals, an anastomosis between the nervus trochlearis and the ramus frontalis of the nervus trigeminus was found in many mammals (Owen, 1868; Dixon, 1896; Gasser and Hendrickx, 1969; Gasser and Wise, 1972).

Generally and as present in the current study, the nervus trochlearis innervates the obliquus superior muscle; a finding which was reported also by many authors (Kassem *et al.*, 1988; Bauchot *et al.,* 1989; Dakrory, 2000; Ali, 2005; Nakae and Sasaki, 2006; Taha, 2010).

It is clear from the detailed anatomical studies of the head serial sections of *Liza ramada* that the nervus trochlearis carries special somatic motor fibres.

In this work, the nervus abducens of the studied mugillid fish arises from the medulla oblongata by a single root. This is the same condition observed 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), *Dasyatis rafinesque* (Chandy, 1955), *Polypterus senegalus* (El-Toubi and Abdel-Aziz, 1955), in *Nadus nadus* (Saxena, 1969), *Ctenopharyngodon idellus* (Dakrory, 2000),*Tilapia zillii* (Ali, 2005), *Alticus kirkii magnosi* (Ali and Dakrory, 2008), *Mugil cephalus* (Hussien, 2010) and in *Gambusia affinis affinis (*Mattar, 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*, Harrison (1981) in *Trichiurus lepturus* and by Bauchot*et al.,* (1989) in*Chaetodon trifasciatus*. In the fish *Tridentiger trigonocephalus*, Kassem*et al.,* (1988) stated that the abducens nerve has only one root, but further down the nerve divides into two distinct fascicles, which innervate two distant regions of the lateral rectus muscle. In this respect, Harder (1975) concluded 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, it has been found by some authors that the nervus abducens arises by a single root as in *Dasyatis Rafinesque* (Chandy, 1955), in *Hydrolagus* (Jollie, 1968) and in *Rhinobatus halavi* (Dakrory, 2000). However, in the shark *Squalus acanthias* this nerve arises by two roots (Norris and Hughes, 1920; Jollie, 1968). In Amphibia, the nervus abducens arises by one root (Mostafa and Soliman, 1984; Shaheen, 1987; Dakrory, 2002). The same was found in the reptiles (Soliman and Hegazy, 1969; Soliman and Mostafa, 1984a; Dakrory, 1994; El-Mahgoub, 2004). This is also the condition found in birds (Soliman *et al.,* 1986a)

The present study shows that the nervus abducens emerges from the cranial cavity through a foramen in the lateral margin of the prootic bridge .It was reported that the nervus abducens emerges from the cranial cavity through a foramen in the lateral margin of the prootic bridge by Ali (2005) in *Tilapia zillii* and Ali and Dakrory (2008) in *Alticus kirkii magnosi*. The latter case was also found in agreement with that observed in the cartilaginous fishes such as *Chlamydoselachus anguineus* (Allis, 1923), *Rhinobatus halavi*, *Rhynchobatus djiddensis* and *Trygon kuhlii* (El-Toubi and Hamdy, 1959), *Rhinoptera bonus's* (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). It was also found that the nervus abducens leaves the cranial cavity through a foramen excavated between the prootic bridge and the prootic cartilage in *Hypophthalmichthys molitrix* (Taha, 2010). However, among bony fishes, the exit of the nervus abducens from the cranium was observed through a special foramen as in *Trichiurus lepturus* (Harrison, 1981) and in *Ctenopharyngodon idellus*

(Dakrory, 2000). On the other hand, El-Toubi and Abdel-Aziz (1955) and Piotrowski and Northcutt (1996), dealing with *Polypterus senegalus*, revealed that the nervus abducens emerges from the cranial cavity together with the nervus trigeminus through the trigeminal foramen. In *Clarias batrachus*, the nervus abducens issues from the cerebral cavity together with the trigemino-facial complex, through the foramen prooticum (Dalela and Jain, 1968). In addition, Saxena (1967) showed 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*.Again, the nervus abducens emerges from the cranial cavity together with the truncus hyomandibularis of the nervus facialis through the facial foramen in *Gambusia affinis affinis (*Mattar, 2012*)*.

In 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) reported that in lampreys the nervus abducens passes out the cranium together with the trochlear and trigeminal nerves through a large opening in the lateral side of the skull. However, Kent (1978) stated that lampreys seem to lack an abducens nerve or may be represented by small bundle emerging from the hind brain on the anterior surface of the trigeminal nerve.

Regarding the emergence of the nervus abducens from the cerebral cavity in Amphibia, it was found that this nerve passes with the nervus trigeminus, through the foramen prooticum (Sokol, 1977 & 1981; Mostafa and Soliman, 1984; Shaheen, 1987; Reiss, 1997; Dakrory, 2002). However, Haas (1995) showed that the nervus abducens in *Colostethus nubicola*, *Colostethus subpunctatus*, *Epipedobates tricolor* and *Phyllobates bicolor*, leaves the cranial cavity through a fissure 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 reptiles, the nervus abducens was found by some authors to pass from the cerebral cavity to the orbit through a special canal or tunnel (Willard, 1915; de Berr, 1937; Pringle, 1954; Soliman and Hegazy, 1969; Soliman and Mostafa, 1984a; Dakrory, 1994; Abdel-Kader *et al.*, 2007; Dakrory and Abdel-Kader, 2009; Mahgoub and Al-Fietori, 2010). Among birds, an abducens tunnel was recorded by Cords (1904), Müller (1961) and Soliman *et al.*, (1986a). However, such tunnel is absent in *Streptopelia senegalensis* (Soliman *et al.*, 1986a).

In this study, the nervus abducens shows no connection with other cranial nerves. This is the case, which was mentioned in many fishes (Allis, 1903; Bal, 1937; Ray, 1950; El-Toubi and Abdel-Aziz, 1955; Chandy, 1955; Saxena, 1967 & 1969; Harrison, 1981; Dakrory, 2000; Ali, 2005; Ali and Dakrory, 2008; Taha, 2010; Hussien, 2010; Mattar, 2012). However, two connections between the nervus abducens and the profundus nerve were 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 profundus with which it is merged (Herrick, 1894; Coghill, 1902; Norris, 1908; Wiedersheim, 1909; Paterson, 1939; Mostafa and Soliman, 1984; Shaheen, 1987).

In Reptilia, the nervus abducens has no relation with other cranial nerves (Soliman and Hegazy, 1969; Soliman and Mostafa, 1984a; Dakrory, 1994). On the other hand, Vögt (1840) recorded a connection between the nervi abducens and facialis in *Chelone mydas*.

Concerning birds, an anastomosis was found between the nervus abducens and the ramus ciliaris trigeminus in *Corvus carnix*, while in *Gruis cinereae* the nervus abducens is connected to both the ramus ciliaris internus of the ciliary ganglion and the ganglion itself (Bonsdorff, 1852). In *Upupa epops* and *Passer domesticus*, Soliman *et al.*, (1986a) observed an anastomosis between the nervus abducens and the ciliary ganglion and with one of the ciliary nerves arising from the ganglion. Such connection was also described by Cords (1904) in hen and by Webb (1957) in *Struthio*.

Regarding mammalian, a connection between the nervus abducens and the nervus trigeminus was mentioned by Quiring (1950), Weichert (1958) and Gasser and Hendrickx (1969).

Generally and in the present work, the nervus abducens, as in all vertebrates, innervates the rectus lateralis muscle. This condition was reported by many authors in some fishes (Bauchot *et al.*, 1989; Dakrory, 2000; Ali, 2005; Nakae and Sasaki, 2006; Ali and Dakrory, 2008; Taha, 2010). In *Tridentiger trigonocephalus*, Kassem *et al.*, (1988) stated that the rectus lateralis muscle consists of two kinds of fibres and is innervated by two distinct nerve bundles. However, in *Latimeria chalumnae* (Northcutt and Bemis, 1993) and in many tetrapoda, the abducens nerve innervates the rectus lateralis and the retractor oculi muscles. In Cyclostomata, Edgeworth (1935) stated that the nervus abducens innervates the rectus lateralis 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*. Pombal *et al.,* (1994) confirmed this finding.

The rectus lateralis muscle is located within

the posterior myodome (the eye muscle chamber). Some authors recorded the presence of this myodome in *Ctenopharyngodon idellus* (Dakrory, 2000), *Tilapia zillii* (Ali, 2005) and in *Gambusia affinis affinis (*Mattar, 2012*).

It is clear from the detailed anatomical study of the head serial sections of *Liza ramada* that the nervus abducens carries special somatic motor fibres.

List of Abbreviations

AC	: Auditory capsule.
B	: Brain.
BLP	: Pleurosphenoid bone.
CE	: Cerebellum.
CO.N	: Common nerve.
CO.T	: Common trunk.
E	: Eye.
F.A	: Abducens foramen.
F.OC	: Oculomotor foramen.
F.T	: Trochlear foramen.
G.ADLL	: Anterodorsal lateral line nerve ganglion.
G.CL	: Ciliary ganglion.
G.GE	: Geniculate ganglion.
G.OP	: Ophthalmic ganglion.
G.SY.V	: Trigeminal sympathetic ganglion.
LG	: Lagina.
M.RL	: Rectus lateralis muscle.
M.RM	: Rectus medialis muscle.
M.RS	: Rectus suprior muscle.
MO	: Medulla oblongata.
N.ADLL	: Anterodorsal lateral line nerve.
N.CL	: Ciliary nerve.
N.II	: Nervus opticus.
N.III	: Nervus oculomotorius.
N.IV	: Nervus trochlearis.
N.OIF	: Nerve for obliquus inferior muscle.
N.RIF	: Nerve for rectus inferior muscle.
N.RM	: Nerve for obliquus medialis muscle.
N.SY	: Sympathetic cranial nerve.
N.V	: Nervus trigeminus.
N.VI	: Nervus abducens.
N.VII	: Nervus facialis.
OP.L	: Optic lobe.
PB	: Pineal body.
PG	: Pitutary gland.
PM	: Posterior myodome.
PRB	: Prootic bone.
R.IF	: Ramus inferior.
R.OP	: Ramus ophthalmic profundus.
R.SP	: Ramus superior.
RCB	: Radix ciliaris brivis.
RCL	: Radix ciliaris longa.
RO.III	: Oculomotor root.
RO.IV	: Trochlear root.
RO.V	: Trigeminal root.
RO.VI	: Abducens root.
TC	: Truncua ciliaris.
UT	: Utricle.
VCL	: Vina capitis lateralis.

References

1. **Abdel-Kader, I.Y. (1990):** Anatomical studies on the cranial nerves of the lizards *Agama pallida* and *Ptyodactlus hasselquistii*. Ph.D. Thesis, Fac. Sci. Cairo Univ. Egypt.
2. **Abdel-Kader, I.Y. and Fathy, S.M. (2002):** The cranial nerves of the bee eater white throated *Merops albicollis* (Meropidae, Coraciiformes): the nervusTrigeminus. J. Egypt. Soc. Zool., **38:** 21-29.
3. **Abdel-Kader, I.Y.; Shamakh, A.A. and Dakrory, A.I. (2007):** The cranial nerves of *Mabuya quinquetaeniata*. I. The eye muscle nerves and the ciliary ganglion. Egypt. J. Zool., **49:** 193-209.
4. **Ali, R.S. (2005):** Comparative anatomical studies on the cranial nerves of the embryo of *Tilapia zillii*. Ph.D. Thesis, Fac. Sci., Helwan Univ., Egypt.
5. **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.
6. **Allis, E.P.Jr. (1903):** The skull and the cranial and the first spinal muscles and nerves in *Scomber scomber*. J. Morph., **18:** 45-310.
7. **Allis, E.P.Jr. (1909):** The cranial anatomy of the mail-cheeked fishes. Zool. (Stuttgart), **22:** 1-219.
8. **Allis, E.P.Jr. (1922):** The cranial anatomy of *Polypterus*, with special reference to *Polypterus bichir*. J. Anat., **56:** 189-294.
9. **Allis, E.P.Jr. (1923):** The cranial anatomy of *Chlamydoselachus anguineus*. Acta. Zool. Stockh., **4**:123-221.Ann Univ. Stellenbosch, **46:** 1-146.
10. **Aoyama, F. (1930):** Die Entwicklungsgeschichte des Kopfskelettes des *Cryptobranchus japonicus*. Z.f. Anat. U. Entw. Gesch., **93:** 107.
11. **Atoda, K. (1936):** The innervation of the cranial nerves of the cat-fish, *Parasilurus asotus* L. Sci. Rep. Tohoku Univ., **11:** 91-115.
12. **Bal, D.W. (1937):** Studies on Indian puffers or globefishes. III. The nervous system of *Tetrodon oblongus*. J. Univ. Bombay, **5(5):** 44-57.
13. **Bauchot, R.; Thomot, A. and Bauchot, M.L. (1989):** The eye muscles and their innervation in *Chaetodon trifasciatus* (Pisces, Teleostei, Chaetodontidae). Enviro. Biol. Of fishes., **25(1-3):** 221-233.
14. **Bonsdorff, E.J. (1852):** Symbolae ad anatomiam compratum nervorum animalium vertebratorum. I. Nervi cerebrales *Corvi cornicis*. 2. Nervi cerebrales *Gruis cinereae*. Acta Soc. Sci. *Fenn-Helsingforsiae*, **3:** 505-569, 591-624.

15. **Burr, H.S. (1933):** The extra-ocular mechanism of *Opisthoproctus soleatus*. Anat. Rec., **55 (4):** 47.

16. **Chandy, M. (1955):** The nervous system of the Indian sting-ray *Dasyatia Rafinesque* (Trygoncuvier). J. Zool. Sci. India, **7(1):** 1-12.

17. **Christensen, K. (1935):** Sympathetic and parasympathetic nerves in the orbit of the cat. J. Anat., **70:** 225-234.

18. **Coghill, G.E. (1902):** The cranial nerves of *Amblystoma tigrinum*. J. Comp. Neurol., **12:** 205-289.

19. **Cole, F.J. and Johnstone, J. (1901):** Pleuronectes. L. M. B. C. Memoirs, VIII. London.

20. **Cords, E. (1904):** Beiträge zur Lehre vom Kopfnerven-System der Vögel. Anat. Hefte., **26:** 49-100.

21. **Dakrory, A.I. (1994):** Anatomical studies on the cranial nerves of Amphisbaenian (*Diplometopon zarudnyi*). M.Sci. Thesis. Fac. Sci. Cairo Univ. Egypt.

22. **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.

23. **Dakrory, A.I. (2002):** The cranial nerves of *Rana bedriagie* (Amphibia: Anura: Ranidae). 1. The eye-muscle nerves and the ciliary ganglion. Egypt. J. Zool., **39:** 395-409.

24. **Dakrory, A.I. (2003):** The ciliary ganglion and its anatomical relations in some bony fishes. Egypt. J. Zool., **41:** 1-13.

25. **Dakrory, A.I. (2009):** Comparative anatomical studies on the ciliary ganglion in some lizards (Reptilia- Squamata- Lacertilia). Aust. J. Basic & Appl. Sci., **3(3):** 2064-2077.

26. **Dakrory, A.I. and Abdel-Kader, T.G. (2009):** The cranial nerves of *Chamaeleon africanus*. I. The eye muscle nerves and the ciliary ganglion. Egypt. J. Zool., **53:**57-75.

27. **Dakrory, A.I; GABRY, M.S; Abdel-Kader, T.G. and Mattar, S.F.E. (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 Am Sci; 8(12):230-242.

28. **Dalela, R.C. and Jain, D.K. (1968):** Studies on the cranial nerves of *Clarias batrachus* (Linn). J. Agra Univ. Res., **17:**107-114. Das Cranium der Cyprinoiden. J. Morph., **17:**489-595.

29. **De Beer, G.R. (1937):** The development of vertebrate skull. Clarendon Press, Oxford.

30. **Dixon, A.F. (1896):** On the development of the branches of the fifth cranial nerves in man. Roy. Dublin Soc. Sci. Tr., **6:** 19-76.

31. **Edgeworth, F.H. (1935):** The cranial muscles of vertebrates. Cambridge Univ. Press.

32. **El-Mahgoub, A.F. (2004):** Anatomical studies on cranial nerves of the snake *Natrix tessellata*. Ph.D. Thesis, Fac. Sci., Cairo Univ.

33. **El-Satti, F.M. (1982):** Studies on the head skeleton of Selachii. Ph.D. Thesis, Fac. Home economic, Helwan Univ. Egypt.

34. **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.

35. **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. Gharadaqa, Redsea, **10:** 1-44.

36. **El-Toubi, M.R. and Hamdy, A.R. (1968):** The neurocranium of *Dasyatis uarnak*. Bull. Fac. Sci., Cairo Univ., **42:** 141-152.

37. **Evans, L.T. and Minckler, J. (1938):** The ciliary ganglion and associated structures in the gecko, *Gymnodactylus kotschyi*. J. Comp. Neurol., **69:** 303-314.

38. **Fernholm, B. and Holmbera, K. (1975):** The eyes in three genera of hagfish (*Eptatretus*, *Paramyxine* and *Myxine*), a case of degenerative evolution. Vision Res., **15:** 253-259.

39. **Freihofer, W.C. (1978):** Cranial nerves of a percoid fish, *Polycentrus schomburgkii* (family: Nandidae), a contribution to the morphology and classification of other perciformes. Occ. Pap. Calf. Acad. Sci., **128:** 1-75.

40. **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.

41. **Gasser, R.F. and Hendrickx, A.G. (1969):** The development of the trigeminal nerve in baboon embryos *(Papio* sp.). J. Comp. Neurol., **136:** 159-182.

42. **Gasser, R.F. and Wise, D.M. (1972):** The trigeminal nerve in baboon. Anat. Rec., **172:** 511-522.

43. **Gaupp, E. (1902):** Über die Ala temporalis des Säugerschädels und die Regio orbitalis einiger anderen Wirbeltierschädel. Anat. Hefte., **19:** 155-230.

44. **Gierse, A.F. (1904):** Untersuchungen über das Gehirn und die Kopfnerven von *Cyclothone acclinidens*. J. Morph., **32:** 602-688.

45. **Godinho, H.P. (1972):** Gross anatomy of parasympathetic ganglia of the head in domestic Artiodactyla. ARQESCVET. Univ. Fed. Minas Gerais, **22:** 129-139.

46. **Godinho, H.P. and Getty, R. (1971):** The branches of the ophthalmic and maxillary nerves to the orbit of goat, sheep and ox. Arq. Esc. Vet., **23:** 229-241.

47. **Gohar, H.A.F. and Mazhar, F.M. (1964):** The internal anatomy of Selachii from the North-Western Red sea. Bubl. Mar. Biol. Sta. Ghardaqa, Red sea, **13:** 145-240.

48. **Goronowitsch, N. (1888):** Das Gehirn und die Cranial nerven von *Acipenser ruthenus*. J. Morph., **13:** 427-474.

49. **Haas, A. (1995):** Cranial features of the dendrobatid larvae (Amphibia: Anura: Dendrobatidae). J. Morph., **224:** 241-264.

50. **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.

51. **Hamdy, A.R. (1959):** The development of the neurocranium of *Rhinobatus halavi*. Proc. Egypt, Acad. Sci., **13:** 1-18.

52. **Hamdy, A.R. (1960):** The head skeleton of *Rhinoptera bonasus* (Mitchill). Proc. Egypt, Acad. Sci., **14:** 74-81.

53. **Hamdy, A.R. and Hassan, S.H. (1973):** On the neurocranium of *Torpedo ocellata*. Bull. Fac. Sci. Cairo Univ., **46:** 127-136.

54. **Hamdy, A.R. and Khalil, M.S. (1970):** The neurocranium of *Aetomylis milvus*. Proc. Egypt, Acad. Sci., **17:** 30-45.

55. **Handrick, K. (1901**): Zur Kenntnis des Nerven systems und der Leuchtorgane des Argyropelecus hemigymnus. Zoologica, **32:** 1-68.

56. **Harder, W. (1975):** Anatomy of fishes, 1, 2. (2nd eds.). Stuttgart: E. Schweitzerbart` Sche Verlagsbuchhandlung.

57. **Harrison, G. (1981):** The cranial nerves of the teleost *Trichiurus lepturus*. J. Morph., **167:** 119-134.

58. **Hegazy, M.A. (1976):** Comparative anatomical studies on the cranial nerves of Ophidia. Ph.D. Thesis, Fac. Sci., Cairo Univ. Egypt.

59. **Hegazy, M.A. and Mostafa, R.H. (1990):** Studies on the ciliary ganglion and its anatomical relationships in the Hedgehog *Hemiechinus auritus* (Insectivora) and the Bat *Rhosettus aegyptiacus* (Chiroptera). Proc. Zool. Soc. A.R.E., **19:** 51-70.

60. **Herrick, C.J. (1894):** The cranial nerves of *Amblystoma punctatum*. J. Comp. Neurol., **4:** 193-207.

61. **Herrick, C.J. (1899):** The cranial and first spinal nerves of Menidia: a contribution upon the nervous components of the bony fishes. J. Comp. Neurol., **9:** 153-455.

62. **Herrick, C.J. (1901):** Cranial nerves and cutaneous sense organs of North American Siluroid fishes. J. Comp. Neurol., **11:** 177-272.

63. **Howes, G.B. and Swinnerton, H.H. (1901):** *Sphenedon,* development of chondrocranium. Trans. Zool. Soc., London, **16**.

64. **Hussein, A.K. (2010):** Anatomical studies on the cranial nerves of *Mugil cephalus* (Family: Mugilidae). M.sc. Thesis, Fac. Sci., Cairo Uni., Egypt.

65. **Jenkin, P.M. (1928):** Note on the sympathetic nervous system of *Lepidosiren paradoxa*. Proc Roy Soc London, **7:** 56-69.

66. **Johnels, A.G. (1948):** On the development and morphology of the skeleton of the head of *Petromyzon*. Acta Zool., **29:** 139-279.

67. **Jollie, M.T. (1968):** Chordate morphology. New York, Reinholt.

68. **Kassem, M.A.; Thomot, A. and Bauchot, R. (1988):** The eye muscles and their innervations in the Gobiid fish *Tridentiger trigonocephalus*. Jap. J. Ichthyol., **35(3):** 341-350.

69. **Kent, G.C. (1978):** Comparative anatomy of the vertebrates. The C.V. MOSBYCo., Saint Louis.

70. **Khalil, M.S. (1978):** The head skeleton of *Zygaena malleus*. Part I. The neurocranium. Proc. Zool. Soc. A.R.E., **5:** 59-67.

71. **Khalil, M.S. (1979a):** The neurocranium of *Galeocerdo cuvier*. Proc Zool. Soc. A.R.E., **6:** 289-301.

72. **Khalil, M.S. (1979b):** The head skeleton of *Trygon pastinaca*. Proc Zool. Soc. A.R.E., **6:** 303-320.

73. **Kuchiiwa, S.; Kuchiiwa, T. and Nakagawa, S. (1994):** Localization of preganglionic neurons of the accessory ciliary ganglion in the midbrain, HPR and WGA. HPR studies in the cat. Comp. Neurol., **340:** 577-591.

74. **Kuntz, A. (1914):** Further studies on the development of cranial sympathetic ganglia. J. Comp. Neurol., **24:** 235-267.

75. **Mahgoub, A.F. and Al-Fietori, Z.R. (2010):** the eye muscle nerves and the ciliary ganglion of *Uromastyx aegyptius*. Egypt. J. Zool., **55:** (In Press)

76. **Marathe, V.B. (1955):** The nervous system of *Psendorhombus arsius* (H.B). J. Bombay Univ., **23, B3:** 60-73.

77. **Matter, S.F.E. (2012):** Anatomical studies on the cranial nerves of fully formed embryonic stage of *Gambusia affinis affinis* (Baird & Girard, 1853). M.Sci. Thesis. Fac. Sci. Helwan Univ. Egypt.

78. **May, W. (1961):** Die Morphologie des Chondrocranium und Osteocranium eines Waldkauz embryos (*Strix aluco* L.). Z. F. W. Zool., **166:** 137-202.

79. **Mazhar, F.M. (1979):** The elasmobranch of Mediterranean. V. the ray *Pteroplatea altavela* (Linn.). Proc. Zool. Sci. A.R.E., **6:** 117-131.

80. **McKibben, P.S. (1913):** The eye-muscle nerves in *Necturus. J. Comp. Neurol.*, **23:** 153-172.

81. **Mobilio, C. (1912):** Ricerche anatomo-comparate Sull innervazione del musculo piccolo obliqus dell'occhio ed apunti *Sulle radicie* del ganglio oftalmico nei mammiferi: innervazione del musculo accessorio del grande obliquo nell'asino. *Monit. Zool. Ital.*, **23:** 80-106.

82. **Mostafa, R.H. (1990a):** The cranial nerves of serpent, *Spalerosophis diadema*. I. Muscle nerves of the eye and ciliary ganglion. Egypt J. Anat., **13(2):** 59-73.

83. **Mostafa, R.H. (1990b):** The cranial nerves of serpent, *Spalerosophis diadema*. II. The nervus trigeminus. Egypt J. Anat., **13 (2):** 75-105.

84. **Mostafa, R.H. (1990c):** The cranial nerves of *Acanthodactylus opheodurus*. I. The eye muscle nerves and ciliary ganglion. Egypt J. Anat., **13 (1):** 49-66.

85. **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.

86. **Müller, H.J. (1961):** Die Morphologie und Entwicklung des Cranium von *Rhea americana* Linne. I. Das knorpellige Neurocranium. Z. F. W. Zool., **165 (3-4):** 221-319.

87. **Nakae, M. and Sasaki, K. (2006):** Peripheral nervous system of the ocean sunfish *Molamola* (Tetraodontiformes: Moidae). Ichthyol. Res., **53:** 233-246.

88. **Norris, H.W. (1908):** The cranial nerve of *Amphium ameans*. J. Comp. Neurol., **18:** 527-568.

89. **Norris, H.W. (1925):** Observation upon the peripheral distribution of the cranial nerves of certain ganoid fishes (*Amia, Lepidosteus, Polyodon, Scaphirhynchus* and *Acipenser*). J. CompNeurol., **39:** 345-432.

90. **Norris, H.W. and Hughes, S.P. (1920):** The cranial, occipital and anterior spinal nerves of the dogfish and *Squalus acanthias*. J. Comp. Neurol., **31:** 292-402.

91. **Northcutt, R.G. (1985):** The brain and sense organs of the earlist vertebrates: reconstruction of a morphotype. In Evolutionary Biology of primitive fishes (Eds. By Foreman, R.E.; Dodd, J.M. and Olsson, R). Plenum. Publ. (O). New York, **pp.** 81-112.

92. **Northcutt, R.G. and Bemis, W.E. (1993):** Cranial nerves of the coelacanth, *Latimeria chalumnae* (Osteichthyes: Sarcopterygii: Actinista), and comparisons with other craniate. Brain Behav. Evol., **42(1):** 1-76.

93. **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.

94. **Oehme, H. (1968):** Das Ganglion Ciliare der Rabenvogel (Corridae). Anat. Anz., **123:** 261-277.

95. **Oelrich, T.H. (1956):** The anatomy of the head of *Ctenosaura pectinata* (Iguanidae). Misc. Publ. Mus. Zool. Michigan, **94:** 9-122.

96. **Omar, A.R. (2009):** Comparative anatomical studies on the cranial nerves of *Agama sinaita*. M.Sc. Thesis, Fac. Sci. Cairo Univ. Egypt.

97. **Owen, R. (1868):** On the anatomy of vertebrates. Vol. III: mammals, Longmans, Green and Co. London.

98. **Pankratz, D.S. (1930):** The cranial nerve components of the toad fish (*Opsanus tau*). J. Comp. Neurol., **50 (3):** 247-288.

99. **Paterson, N.F. (1939):** The head of *Xenopus laevis*. Q. J. Micro. Sci., **81(II):** 161-234.

100. **Piotrowski, T. and Northcutt, R.G. (1996):** The cranial nerves of Senegal bichir, *Polypterus senegalus* (Osteichthyes: Actinopterygii: Cladistia). Brain Behav. Evol., **47:** 55-102.

101. **Pombal, A.M.; Rodicio, M.C. and Anadon, R. (1994):** Development and organization of the oculomotor nuclei in the larval sea Lamprey, *Petromyzon marinus* L.: An HRP study. J. Comp. Neurol., **341:** 393 - 406.

102. **Pringle, J.A. (1954):** The cranial development of certain South African snakes and the relationship of this group. Proc. Zool. Soc. London, **123:** 813-865.

103. **Puzdrowski, R.L. (1987):** The peripheral distribution and central projection of the sensory rami of the facial nerve in Goldfish, *Carassius auratus*. J. Comp. Neurol., **259:** 382-392.

104. **Quiring, D.P. (1950):** Functional Anatomy of the Vertebrates. 1st Ed. New York, Toronto, London. Mc. Graw-Hill Book Company, Inc. **pp.** 239-249.

105. **Ray, D.L. (1950):** The peripheral nervous system of *Lampanyctus leucopsarus*. J. Morph., **87:** 61-178.

106. **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.

107. **Saxena, P.K. (1967):** The cranial nerves of the mudeel *Amphipnous cuchia*. Acta. Anat., **67:** 306-320.

108. **Saxena, P.K. (1969):** The cranial nerves of *Nandus nandus* (Ham.) and *Xenetoden cancile* (Ham.). Anat. Anz., **124:** 142-155.

109. **Shaheen, A.A. (1987):** Anatomical studies on the cranial nerves of *Bufo regularis* Reuss. M.Sc. Thesis, Fac. Sci. El-Minia Univ., Egypt.

110. **Sheil, C.A. (1999):** Osteology and skeletal development of *Pyxicephalus adspersus* (Anura: Ranidae: Raninae). J. Morph., **240:** 49-75.

111. **Shiino, K. (1914):** Studien zur Kenntnis der Wirbeltierkopfes. I. Das Chondrocranium von *Crocodilus* mit Berücksichtigung der Gehirnnerven und der Kopfgefässe. Anat. Hefte., **50:** 253-382.

112. **Sokol, O.M. (1977):** The free swimming pipa larva, with are view of pipid larvae. J. Morph., **154:** 357-426.

113. **Sokol, O.M. (1981):** The larval chondrocranium of *Pelodytes punctatus*, with are view of tadpole chondrocrania. J. Morph., **169:** 161-183.

114. **Soliman, M.A. (1964):** Die Kopfnerven der Schildkröten. Z. F. W. Zool., **169:** 215-312.

115. **Soliman, M.A. and Hegazy, M.A. (1969):** The cranial nerves of *Chalcides ocellatus*. I. The eye muscle nerves. Bull. Fac. Sci. Cairo Univ., **43:** 49-62.

116. **Soliman, M.A. and Mostafa, R.H. (1984a):** A detailed study on the cranial nerves of the gecko *Tarentola mauritanica*. I. The ciliary ganglion and the eye muscle nerves. Proc. Zool. Soc., **52:** 289-309.

117. **Soliman, M.A. and Mostafa, R.H. (1984b):** The cranial nerves of *Bufo viridis* (LAUR). The nervus trigeminus. Bull. Fac. Sci. Cairo Univ., **52:** 425-457.

118. **Soliman, M.A.; Hegazy, M.A. and Mostafa, R.H. (1986a):** The cranial nerves of Birds. II. The main special sensory nerves, the nervus olfactorius, nervus opticus and nervus octavus. Proc. Zool. Soc. A.R. E., **10:** 211-232.

119. **Soliman, M.A.; Hegazy, M.A. and Mostafa, R.H. (1986b):** The cranial nerves of Birds. III. The nervus trigeminus. Proc. Zool. Soc. A.R.E., **11:** 375-406.

120. **Soliman, M.A.; Mahgoub, A.S.; Hegazy, M.A. and Mostafa, R.H. (1976):** The ciliary ganglion and its relations in birds. Bull. Fac. Sci. Cairo Univ., **48:** 171-186.

121. **Srinivasachar, H.R. (1956):** Development of the skull in catfishes: part I: development of the chondrocranium in *Silonia*, *Pangasisus* and *Ailia* (schilbeidae). J. Morph., **22B(6):** 335-365.

122. **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.

123. **Srinivasachar, H.R. (1962):** Development and morphology of the skull of *Rhacotritono lympicus olympicus* Gaige (Amphibia: Urodela: Ambystomidae). J. Morph., **103:** 263-302.

124. **Stadtmüller, F. (1925):** Studien am Urodelenschadel. 1. Zur Entwicklungs geschichte des Kopfskeletts der *Salamandra maculosa*.Z.F. Anat. U.Entw. Gesch.,**75:** 149.

125. **Stannius, H. (1849):** Das peripherische Nervensystem der Fische, anatomisch und physiologisch untersucht. Rostock.

126. **Stefani, F.H. (1972):** Further studies on "aberrant" ganglion cells in the human oculomotor nerve. Ophthal. Res., **3:** 46-54.

127. **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.

128. **Taha, F.K. (2010):** Anatomical studies on the cranial nerves of the fish *Hypophthalmichthys molitrix*. M. Sci. Thesis. Fac. Sci. Cairo Univ.

Egypt.

129. **Til Macke (1969):** Die Entwicklung des Cranium von *Fulica atra*. J. Morph., **113, 2:** 229-294.

130. **Trueb, L. and Cannatella, D.C. (1982):** The cranial osteology and hyolaryngeal apparatus of *Rhinophrynus dorsalis* (anura: Rhinophrynidae) with comparisons to recent Pipid frog. J. Morph., **171:** 11-40.

131. **Trueb, L. and Hanken, J. (1992):** Skeletal development in *Xenopus laevis* (Anura: Pipidae). J. Morph., **214:** 1-41.

132. **Van-Eeden, J.A. (1951):** The development of the chondrocranium of *Ascaphus truei* Stejneger with special reference to the relation of the palatoquadrate to the neurocranium. Acta Zool. (Skockh.)., **32:** 41-176.

133. **Vögt, C. (1840):** Beiträge zur Neurologie der Reptilien. Neue Denkschr. *d. allg. Schweiz.Gesellsch. F.d. Gesamt-Naturwiss.*, **4:** 1-60.

134. **Webb, M. (1957):** The ontogony of the cranial bones, cranial peripheral and cranial parasympathetic nerves, together with a study of the visceral muscles of *Struthio*. Acta Zool., **38:** 81-203.

135. **Weichert, C.K. (1958):** Anatomy of chordates. McGraw-Hill, New York, Toronto and London.

136. **Whitteridge, D. (1955):** A separate afferent nerve supply from the extraocular muscle of goats. Q. J. Exp. Physiol., **40:** 331-336.

137. **Wicht, H. (1996):** The brains of Lampreys and Hagfishes: Characteristics, Characters and Comparisons. Brain Behav. Evol., **48:** 248-261.

138. **Wiedersheim, R. (1909):** Vergleichende Anatomie der Wirbeltiere. Fisher, Jena.

139. **Willard, W.A. (1915):** The cranial nerves of *Anolis carolinensis*. Bull. Mus. Comp. Zool., **59:** 17-116.

140. **Young, J.Z. (1988):** The life of the vertebrates. 2nd eds. Oxford Univ. New York.

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