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RESEARCH ARTICLE

ANATOMICAL STUDIES ON THE CRANIAL NERVES AND CRANIAL GANGLIA OF *ANGUILLA* *ANGUILLA* (LINNAEUS, 1758) EYE MUSCLE NERVES

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Abstract

The aim of this study is to analyze the ocular muscle nerves and the ciliary ganglion of the anguillid fish *Anguilla anguilla*. The ocular muscle nerves comprise the nervi oculomotorius, trochlearis and abducens. The oculomotor nerve leaves the cranial cavity together with the nervus abducens through a common foramen. It innervates four eye muscles; rectus superior, rectus inferior, rectus medialis and the obliquus inferior muscles. It carries pure somatic motor fibers and visceromotor (parasympathetic) ones. There is no ciliary ganglion but, there is one ciliary nerve arising from the nervus oculomotorius. The trochlear nerve has its own foramen and carries pure somatic motor fibers to the superior obliquemuscle. The abducens nerve has a single root. It leaves the cranial cavity through a common foramen together with the nervus oculomotorius. It carries pure somatic motor fibers to the rectus lateralis muscle.

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Introduction:-

Anguilliformes, also known as “true eels”, are an ecologically diverse group of predominantly marine fishes whose members are easily recognized by their extremely elongate bodies with reduced cross sectional areas and universal lack of pelvic fins (Nelson, 2006; Santini et al., 2013). Despite a conserved body plan, some anguilliforms exhibit high diversity in cranial morphology and prey capture mode (Mehta, 2009; Mehta and Wainwright, 2007).

The Anguillidae are a family of ray-finned fish that contains the freshwater eels. Eighteen of the 19 extant species and six subspecies in this family are in the genus *Anguilla* (Tesch, 2003); however this genus has 15 species (Silfvergrip, 2009) or about 20 species (Eschmeyer and Fong, 2011). They are elongated fish with snake-like bodies, their long dorsal, caudal and anal fins forming a continuous fringe (Nelson, 2006). They are catadromous fish, spending their adult lives in fresh water, but migrate to the ocean to spawn (Tesch, 2003; Briand et al., 2008).

The eels have a multi-stage life cycle. After spawning, the hatched leaf-like larvae, leptocephalus, drift with the oceanic currents towards their continental growth habitat. The larvae metamorphose to glass eels in the continental shelf and further develop into elvers when they reach the river estuaries (Jamandre, et al., 2007). During maturation, they become silver eels and return to their oceanic spawning grounds to reproduce and die (Tesch, 2003).

The European Eel *Anguilla anguilla*, is known to be particularly important commercially (FAO, 2009). In addition to being fished and used directly for consumption, wild juvenile eels or “glass eels” are also caught and used as

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“seed” in aquaculture production or farming (Briand et al., 2008). Populations of *Anguilla* species have declined considerably over the last 30 years (Casselmann and Cairns, 2009); this loss has been attributed to a number of factors, including catches for international trade.

European eels can survive, and even reproduce, at temperatures as low as 0°C. Optimum temperatures for gametogenesis in *Anguilla anguilla* are between 0°C and 30°C; warmer waters being preferred as long as oxygen is not low (Deelder, 1970; Coad, 2016). The lifespan of European eels is dependent on maturation time because once eels mature and spawn, they die. European eels can spawn as early as 7 years old. The maximum reported age of a European eel in the wild is 85 years (Dekker, van Os and van Willigen, 1998).

Behaviorally, European eels are essentially a solitary species, there is no evidence that any form of schooling is present (Suzuki et al., 2003). They migrate to various regions during different stages of their life (Deelder, 1970) and they are active mainly during the day (Deelder, 1970; Tsukamoto et al., 2003). European eels sense the environment using their sense of taste (Sola and Tongiorgi, 1998). There is little if any documentation of social communication between eels, although they have strong sense of olfaction, that is used most probably for homing purposes (Deelder, 1970).

European eels have completely different diets during different life stages, they are carnivore, insectivore, eats non-insect arthropods molluscivore, eats other marine invertebrates and scavenger (Sinha and Jones, 1975). European eels are reported to leap out of the water during the winter and feed on terrestrial invertebrates (Deelder, 1970).

Traditionally anguilliforms, the largest order of elopomorphs, comprise three suborders (Robins, 1989; Nelson, 2006): the Anguilloidei (freshwater eels); the Congroidei (short tail eels) and the Muraenoidei (false morays). Anguilliforms have traditionally been thought to be closely related to the Saccopharyngiformes (gulper eels and allies), a group formed by four families of deep-sea fishes (Nelson, 2006). Taxonomically, both morphological (Forey et al., 1996) and molecular studies of elopomorph interrelationships based on mitochondrial sequences (Wang et al., 2003; Inoue et al., 2004 & 2010) were done. The recently described Protanguillidae (Johnson et al., 2012) brings the total diversity of Anguilliformes to 937 species spread across 20 families (Wiley and Johnson, 2010; Froese and Pauly, 2012). Previous phylogenetic studies of anguilliform relationships based on morphological data alone (Forey, 1973; Nelson, 1973; Greenwood, 1977; Patterson and Rosen, 1977; Robins, 1989; Forey et al., 1996) have been unable to resolve the relationships among the three anguilliform suborders. These relationships are illustrated successfully through mitochondrial analyses (Wang et al., 2003; Lopez and Westneat, 2007; Inoue et al., 2010; Johnson et al., 2012).

More recently, Johnson et al. (2012) erected the new family Protanguillidae on the basis of the species *Protanguilla palau*, a recently discovered, enigmatic anguilliform. This species possesses a number of morphological traits that are absent in most living eels including collar-like gill openings, a pseudobranch, a premaxilla, unfused symplectic, and metapterygoid (Johnson et al., 2012).

Phylogenetically, it has been known that the Indo-Pacific region was the origin of the speciation of the freshwater eels of the genus *Anguilla* (Aoyama & Tsukamoto, 1997; Lin et al., 2001). The ancestors of both temperate and tropical eels originated from the Indo-Pacific region, particularly in the archipelagic area of Indonesia, Malaysia and the Philippines.

These sensory systems (receptors, their nerves as well as their centers) play a major and sometimes decisive role in many fish behavioral patterns (feeding, defense, spawning, schooling orientation, migration, etc.) (Romer, 1970). There is a growing base of information about sensory biology, sense organs and brain morphology in teleostes and in fishes in general (Meyer-Rochow and Klyne, 1982; Coombs and Montgomery, 1994; Eastman, 1988, 1993; Eastman and Lannoo, 1995, 1998, 2003a & b & 2008; Lannoo and Eastman, 1995, 2000; Montgomery, 1997; Montgomery and Macdonald, 1987; Montgomery et al., 1999; Meyer and Fanta, 1998).

Functionally, the extrinsic eye muscles are the effector organs for voluntary and reflexive movements of the eyes (Dakrory et al., 2018). Spencer and Porter (2006) stated that, the coordinating activity of the six extraocular muscles, must be accomplished with high precision as the fovea, subtends a very small angle of visual space. Extraocular muscles are innervated by motoneurons in the oculomotor, trochlear, and abducens nuclei (Spencer and Porter, 2006).

The disposition and innervation of the extraocular (extrinsic) muscles is a highly conserved and presumably ancient system among the vertebrates (Branson, 1966; Isomura, 1981; Young, 2008). They appear in the lower vertebrates in essentially the same form, as in man (Neal, 1918). Indeed their number and their nerve relations are the same in man as in the dogfish (Young, 2008).

There is a consistency among living and extant vertebrates, regarding to the innervation pattern by the three eye muscle nerves (Fritzsche et al. 1990). Although, of the homology in the innervation pattern of the ocular muscles among vertebrates; yet, the details of the eye muscle nerves (the nerve's origin, roots, intracranial pathway, location of exit from the cranium, extracranial course, anastomosis, relevant branches and to its innervations, ganglion (Ganglia) require further investigation (Dakrory et al., 2018).

Due to the absence of lens muscles, accommodation is not possible. Furthermore, the eel does not have a corpus chorioideae nor a musculus ciliaris (Stramke, 1972). Again, Biometric studies on the nucleus of the oculomotor nerve have shown that the yellow eel probably makes relatively little use of its eyes (Kirsche, 1966). All other species of fish studied, including the burbot (*Lota lota*) which is well known as a 'non-visual' animal- have a larger nucleus than the eel. Just before its spawning migration the eel has, in comparison with other fish, relatively small eyes (Wunder, 1936). This suggests a similarly reduced visual capacity just before the eel's marine period. With metamorphosis into a silver eel the diameter of the eye increases in size (Matschenis, 1965); this growth should be accompanied by an increase in the efficiency of the eye.

The cranial nerves are an important collection of nerves, where, they connect the brain with all the important centers of perception of the outer surface of the head, as well as the inner surface of the buccopharyngeal and other visceral regions. They travel directly to the brain rather than through the spinal cord. The cranial nerves have several functions vital for day-to-day life (Shaheen, 1987; Dakrory, 2000).

Of the first investigations done on the cranial nerves of Osteichthyes were those of Stannius (1849) and Goronowitsch (1888) on *Acipenser ruthenus*; these classical studies are still useful to investigators. Dakrory (2000) on *Ctenopharyngodon idellus*, Dakrory (2003) studied the ciliary ganglion and its anatomical relations in some bony fishes, Hussein (2010) on *Mugil cephalus*, Taha (2010) on *Hypophthalmichthys molitrix*, Mattar (2012) on *Gambusia affinis affinis*, Al-Harhi (2016) on *Liza aurata* and Almalki (2017) on *Oreochromis niloticus*, give details account on the morphological anatomy of the cranial nerves.

It is quite evident from the above historical reviews that there are numerous works on the cranial nerves of bony fishes, but few ones on Anguillid fishes which is an interesting group among teleosts. Thus, it was recommended that a detailed microscopic investigation on the eye muscle nerves in *Anguilla anguilla* belonging to family Anguillidae will be very fruitful. This investigation will highlight the nerves' origin, roots, intracranial pathway, exit from the cranium, the extracranial course and their innervation. In addition, the current study will give a concise and comprehensive explanation of the important characters of the nerves including their components, anastomosis, correlated ganglion (Ganglia), and relevant branches.

Material and Methods:-

The species chosen for this study is the European eel, *Anguilla anguilla* which is a fresh water bony fish belongs to the Family Anguillidae.

This family is characterized by the elongate body, numerous vertebrae, small elliptical scales which are difficult to see casually, a small and elliptical gill opening just in front of the pectoral fin base, very long dorsal and anal fins confluent with a reduced caudal fin, a terminal mouth with the lower jaw projecting a little, small teeth in several rows on the jaws and palate, the dorsal fin origin well behind the pectoral fin level but in front of the anus level, no pelvic fins, and by a suite of osteological characters (Deelder, 1970; Nelson, 1994; Coad, 2016).

The eel shape is characteristic along with the long and spineless dorsal and anal fins and the absence of pelvic fins, the scales are small, elliptical in shape and embedded in the skin, the lateral line is distinct (Nelson, 1994; Coad, 2016). Fish approaching sexual maturity develop very large eyes, the olfactory organs atrophy, the lateral line becomes more conspicuous, a tougher and thicker skin develops, and the colour changes (Coad, 2016). Colour is variable but the back is usually grey-brown, olive-brown, brownish-green, yellowish, or black and the belly is whitish to yellowish. The dorsal fin is dark, other fins are yellowish. The iris is yellow. This yellow or green eel

stage changes to the silver or bronze eel at maturity (Coad, 2016). The mature fish is turn green, yellow or brownish in color darker on the back, has silvery or bronze to coppery flanks and belly, a black pectoral fin and a clear contrasting black lateral line, as well as enlarged eyes and lose their ability to feed, (Van Ginniken and Van Den Thillhart, 2000; Coad, 2016).

Female eels are generally larger than males (Dekker, van Os and van Willigen, 1998). The maximum published length of a European eel was 133 cm (Dekker et al., 1998).

The geographic range of adult European eels includes the English Channel and coasts of the Mediterranean Sea and northern Atlantic Ocean from Iceland to Mauritania (Ringuet et al., 2002). Their range also encompasses the Baltic and North Seas, as well as all accessible continental or coastal hydrosystems (Ringuet et al., 2002). In the early spring months, European eels migrate to the Sargasso sea for breeding. Larvae are hatched from the Sargasso Sea and can also be found along the coast of Europe. Silver (juvenile) stage eels of *Anguilla anguilla* live in tributaries along the European coast (Ringuet et al., 2002; Ringuet et al., 2002; Tsukamoto et al., 1998). Depending on the life stage of the individual eel, European eels can be found in marine, freshwater, and brackish aquatic environments. Typically, the European eel is found in depths of 0-700 m, most often on the floor of the ocean or river in which it is living (Tsukamoto et al., 1998).

The 5 youngs of the chosen species will be collected from fish farm at **Ras El-Bar City, Damietta Governorate, Egypt** at July 2010. In the lab, the heads together with the branchial region of youngs were cut and immediately fixed in aqueous Bouin`s solution for 24 hours.

The specimens were washed several times to remove the excess Bouin`s solution. Decalcification is necessary before sectioning and staining for the specimens, this will be carried out by placing the heads in EDTA solution for about 40 days with changing the solution every 4 days.

After that, the heads will be prepared for blocking and sectioning. Two specimens were sectioned transversely at 10 micron by microtome. One of the two serial sections will be mounted on slides and stained with hematoxylin and eosin. The serial sections will be drawn by the aid of a projector microscope. From these drawings an accurate graphic reconstruction for the brain, eye and the eye muscle nerves will be made in a lateral view. Also, parts of certain sections will be photomicrographed to demonstrate the relation of these nerves with the other cranial structures.

Results:-

Nervus Oculomotorius

In the current study, the oculomotor nerve originates from the mid-lateral side of the mesencephalon by a single root (Figs. 1 &2, RO. III). It runs forwards, for a somewhat long distance, in a depression on the lateral side of the brain, at the level of Gasserian ganglion. After this forward course, the oculomotor nerve leaves the depression and runs within the cranial cavity, passing lateral to the brain, medial to the anterior end of Gasserian ganglion of the nervus trigeminus and ventromedial to the trochlear nerve.

Thereafter, it passes medial and dorsal to the cranial wall and lateral to the brain. It then shifts anteromedially extending ventral to the brain (cerebral hemisphere), dorsolateral to the nervus abducens and dorsal to the internal jugular vein.

More forwards, the nervus oculomotorius continues penetrating the meninx primitiva passing lateral to the nervus abducens and medial to the internal jugular vein. After this course, it leaves the cranial cavity through a common foramen together with the abducent nerve. This foramen (Fig. 3, COM. F) is located between the lateral edge of the parasphenoid bone medially and the basisphenoid bone laterally.

Extracranially, the nervus oculomotorius runs forwards passing ventrolateral to the cranial wall, dorsolateral to the nervus abducens, ventromedial to the internal jugular vein and medial to the maxillo-mandibular trunk of the nervus trigeminus. Shortly anterior, the nervus oculomotorius divides into a dorsal ramus superior (Figs. 1 &4, R.SP.III) and a ventral ramus inferior (Figs. 1 &4, R.IF.III).

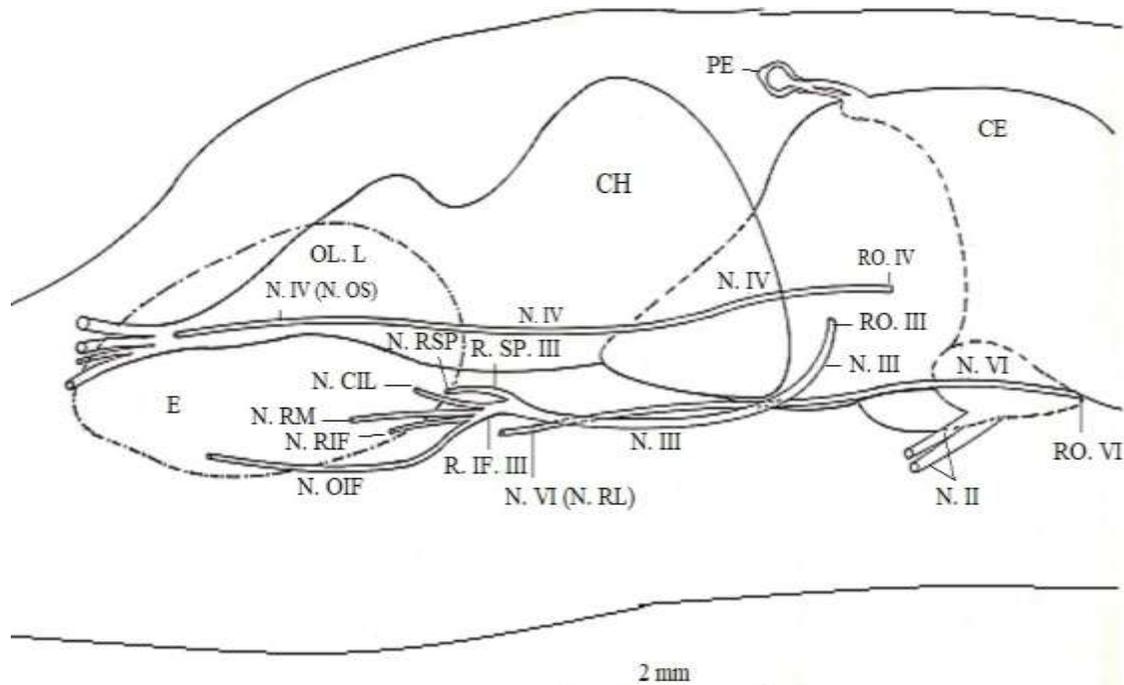


Fig. 1:- Reconstruction of the eye-muscle nerves of *Anguilla Anguilla* in a lateral view.

CE: Cerebellum; CH: Cerebral hemisphere; E: Eye; N. CIL: Ciliary nerve; N. II: Optic nerve; N. III: Nervus oculomotorius; N. IV: Nervus trochlearis; N. OIF: Nerve to the obliquus inferior muscle; N. OS: Nerve to the obliquus superior muscle; N. RIF: Nerve to the rectus inferior muscle; N. RL: Nerve to the rectus lateralis muscle; N. RM: Nerve to the rectus medialis muscle; N. RSP: Nerve to the rectus superior muscle; N. VI: Nervus abducens; OL. L: Olfactory lobe; PE: Pineal eye; R. IF. III: Ramus inferior of the nervus oculomotorius; R. SP. III: Ramus superior of the nervus oculomotorius; RO. III: Root of the nervus oculomotorius; RO. IV: Root of the nervus trochlearis; RO. VI: Root of the nervus abducens.

Ramus Superior

After its separation from the nervus oculomotorius, the ramus superior (Figs. 1 & 4, R.SP.III) extends anteriorly in the dorsolateral direction passing dorsal to the ramus inferior of the nervus oculomotorius and ventral to the rectus superior muscle. Shortly anterior, the ramus superior enters the latter muscle from its ventrolateral side, where it distributes and ends between its fibres (Figs. 1&5, R. SP. III).



Fig. 2:- Photomicrograph of part of transverse section of *Anguilla anguilla* passing through the postorbital region showing the root of the nervus oculomotorius from the brain. X 100. B: Brain; G. GS: Gasserian ganglion; PSP: Parasphenoid Bone.

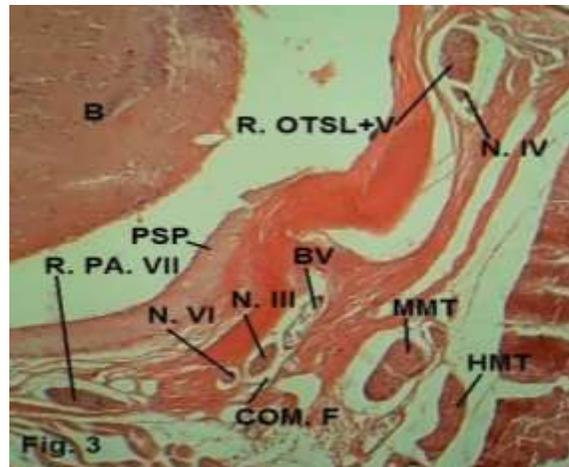


Fig. 3:- Photomicrograph of part of transverse section of *Anguilla anguilla* passing through the postorbital region demonstrating the common foramen of the nervi oculomotorius and abducens, the position of the nervus trochlearis. X 100. B: Brain; BV: Blood vessel; COM. F: Common foramen; HMT: Hyomandibular trunk; MMT: Maxillomandibular trunk; N. III: Nervus oculomotorius; N. IV: Nervus trochlearis; N. VI: Nervus abducens; PSP: Parasphenoid bone; R. OTSL+V: Ramus ophthalmicus superficialis lateralis and trigeminus; R. PA. VII: Ramus palatinus facialis.

Ramus Inferior

Immediately, after its separation from the nervus oculomotorius, the ramus inferior (Figs. 1 & 4, R.IF. III) extends anteriorly passing dorsal to the rectus lateralis muscle, dorsolateral to the nervus abducens and ventrolateral to the rectus superior muscle. Shortly anterior, the ramus inferior divides into three branches (Figs. 1 & 6). The dorsal branch runs anteriorly and directly divides into ventral and dorsal nerves (Fig. 1). The ventral nerve (Figs. 1 & 6, N. RM) extends anteriorly passing dorsolateral to the rectus inferior muscle, ventrolateral to both the rectus superior muscle and the ramus superior and dorsal to the rectus inferior muscle and the obliquus inferior muscle nerves. After a short distance in this position, it enters the rectus medialis muscle from its lateral side and branches to terminate between its fibres. The dorsal one (Figs. 1 & 6, N. CIL) extends anterolaterally passing dorsal to the rectus lateralis muscle and ventral to the ophthalmic vein. After a short course in this position, it enters the eyeball where it branches and distributes in the walls of its blood vessels, i.e., the ciliary nerve.

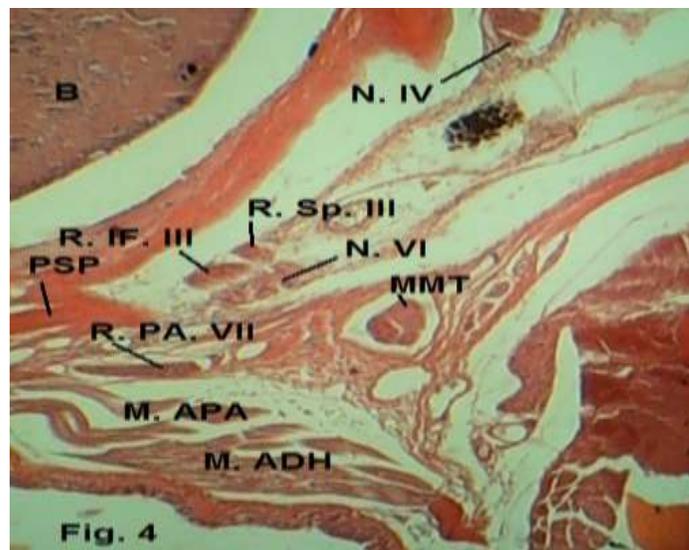


Fig. 4:- Photomicrograph of part of transverse section of *Anguilla anguilla* passing through the orbital region illustrating the division of the nervus oculomotorius into its rami; superior and inferior and the position of the nervi trochlearis and abducens. X100. B: Brain; M. APA: Arcus palatini muscle; M. ADH: Adductor hyomandibularis muscle; MMT: Maxillomandibular trunk; N. IV: Nervus trochlearis; N. VI: nervus abducens; PSP: Parasphenoid

bone; R. IF. III: Ramus inferior of the oculomotor nerve; R. PA. VII: Ramus palatinus of the nervus facialis; R. SP. III: Ramus superior of the oculomotor nerve.

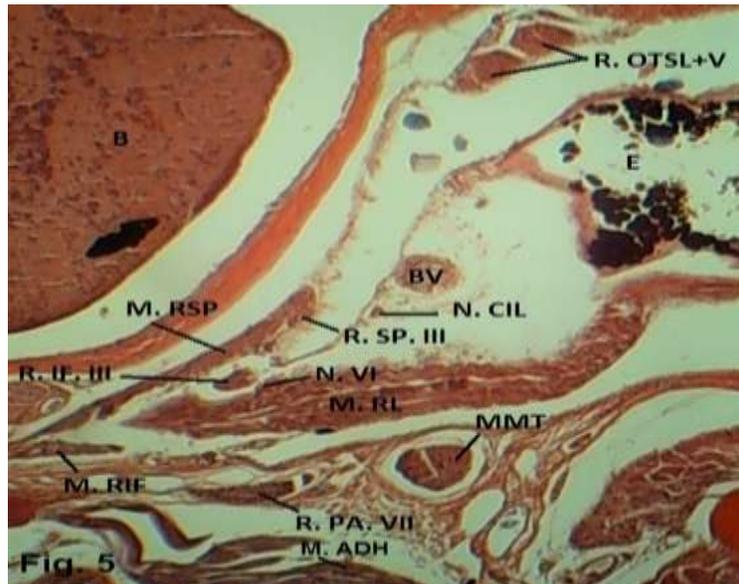


Fig. 5:- Photomicrograph of part of transverse section of *Anguilla anguilla* passing through the orbital region showing the ciliary nerve and the entrance of the ramus superior to the rectus superior muscle and the nervus abducens to the rectus lateralis muscle. X100. B: Brain; BV: Blood vessel; E: Eye; M. ADH: Adductor hyomandibularis muscle; M. RIF: Rectus inferior muscle; M. RL: Rectus lateralis muscle; M. RSP: Rectus superior muscle; MMT: Maxillomandibular trunk; N. CIL: Ciliary nerve; N. VI: Nervus abducens; R. IF. III: Ramus inferior of the nervus oculomotorius; R. PA. VII: Ramus palatinus of the nervus facialis; R. SP. III: Ramus superior of the nervus oculomotorius. The medial branch extends forwards in the ventrolateral direction, passing ventral to the rectus superior muscle and rectus medialis muscle nerve and dorsal to the rectus inferior muscle. After a short course in this position, it enters the latter muscle from its dorsolateral side where it branches and terminates between its fibres (Figs. 1 & 6, N. RIF).

The ventral branch of the ramus inferior (Figs. 1 & 6, N. OIF) runs forwards passing lateral and then ventral to the rectus inferior muscle and dorsal to the ramus palatinus of the nervus facialis. Thereafter, it continues ventromedial to the optic nerve and dorsomedial to the ramus palatinus of the nervus facialis. More forwards, it runs ventral to the rectus medialis muscle and lateral to the interorbital septum. After a long distance in this position, it penetrates the obliquus inferior muscle from its dorsomedial side where it achieves its final termination (Figs. 1 & 7, N. OIF).

Nervus Trochlearis

In *anguillid species studied*, the nervus trochlearis arises from the lateral side of the mid-brain just anterior to the origin of the nervus trigeminus by a single small root (Figs. 1 & 8, RO.IV). After its origin, this nerve extends anteriorly within the cerebral cavity passing lateral to the brain and dorsomedial to Gasserian ganglion. After a long forward course, it becomes dorsomedial to the ganglion of the nervus trigeminus, ventromedial to the anterodorsal lateral line nerve and lateral to the brain (Fig. 2, N.IV). Thereafter, in the orbitotemporal region it continues forwards running in the dorsolateral corner of the cerebral cavity. In the orbital region, it continues

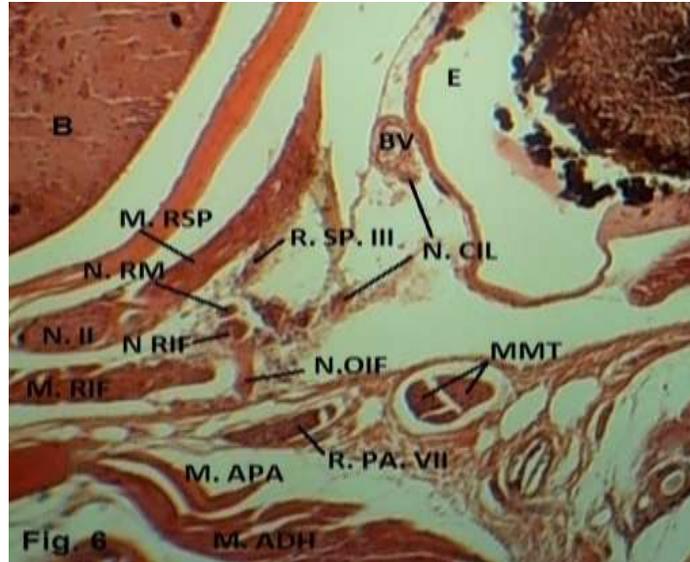


Fig. 6:- Photomicrograph of part of transverse section of *Anguilla anguilla* passing through the orbital region demonstrating the division of the ramus inferior into nervi to the recti medialis and inferior and obliquus inferior muscles and the ciliary nerve. X100. B: Brain; BV: Blood vessel;

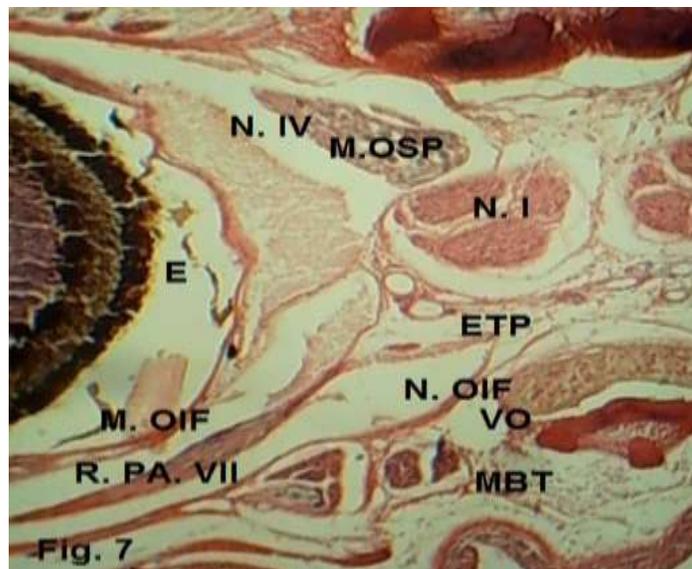


Fig. 7:- Photomicrograph of part of transverse section of *Anguilla anguilla* passing through the anterior orbital region illustrating the entrance of the nerve to the obliquus inferior muscle and nervus trochlearis to the obliquus superior muscle. X100.

E: Eye; ETP: Ethmoidal plate; M. OIF: Obliquus inferior muscle; M. OSP: Obliquus superior muscle; MBT: Maxillo-buccalis trunk ; N. I: Olfactory nerve; N. IV: Trochlear nerve; N. OIF: Nerve to the obliquus inferior muscle; R. PA. VII: Ramus palatinus facialis; VO: Vomer.

E: Eye; M. ADH: Adductor hyomandibularis muscle; M. APA: Arcus palatini muscle; M. RIF: Rectus inferior muscle; M. RSP: Rectus superior muscle; MMT: maxillomandibular trunk; N. CIL: Ciliary nerve; N. II: Optic nerve; N. OIF: Nerve to the obliquus inferior muscle; N. RIF: Nerve to the rectus inferior muscle; N. RM: Nerve to the rectus medialis muscle.

Forwards passing lateral to the brain and medial to the cranial wall. After a considerable course in the orbital region, it leaves the cranial cavity by penetrating the meninx primitiva through its own foramen (Fig. 9, F. IV). Extracranially, the

nervus trochlearis runs forwards passing lateral to the cranial wall and ventromedial to the ramus ophthalmicus lateralis and trigeminus and dorsomedial to the eyeball (Fig. 10, N. IV).

Reaching the mid-way of orbital region, the nervus trochlearis continues ventral to the supraorbital lateral line canal and the ramus ophthalmicus superficialis trigeminus and lateralis. Finally, the nervus trochlearis enters and ends between the fibres of the obliquus superior muscle (Figs. 1 & 7, N. IV).

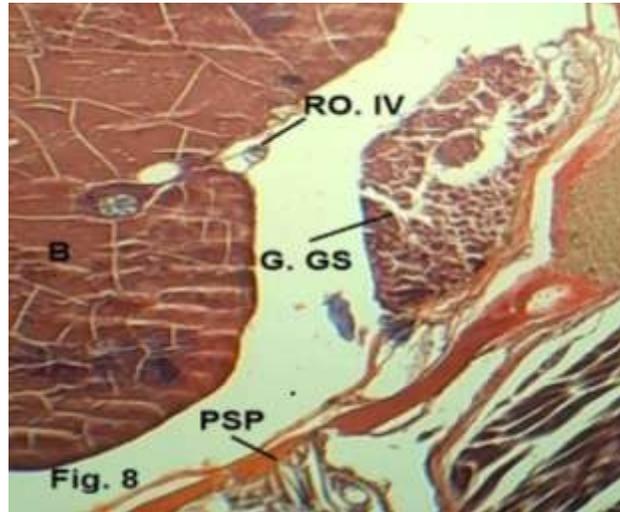


Fig. 8:- Photomicrograph of part of transverse section of *Anguilla anguilla* passing through the otic region showing the origin of the nervus trochlearis from the brain. X100. B: Brain; G. GS: Gasserian ganglion; PSP: Parasphenoid bone; RO. IV: Root of the nervus trochlearis.

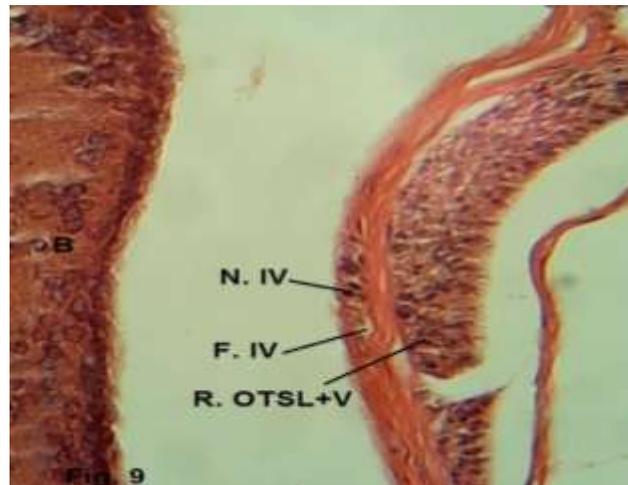


Fig. 9:- Photomicrograph of part of transverse section of *Anguilla anguilla* passing through the postorbital region demonstrating the passage of the nervus trochlearis through its foramen. X400. B: Brain; F. IV: Trochlear foramen; N. IV: Nervus trochlearis; R. OTSL+V: Ramus ophthalmicus superficialis lateralis and trigeminus.

Nervus Abducens

The nervus abducens of *Anguilla anguilla* studied, originates from the ventrolateral side of the medulla oblongata by a single root ventral to the origin of the nervus facialis (Figs. 1 & 11, RO.VI). After its origin, it runs forward passing ventrolateral to the brain and ventromedial to the geniculate ganglion of the nervus facialis (Figs. 2&8, N.VI). Shortly forward, this nerve continues ventral to the brain, medial to the geniculate ganglion of the nervus facialis. thereafter, it continues passing dorsomedial, dorsal and then lateral to the ramus palatinus of the facial nerve. After a considerable course in this position, the nervus abducens becomes ventral to the brain, lateral to the ramus palatinus of the nervus facialis and dorsal to the cranial wall. After a long anterior course in this position, the nervus

abducens becomes ventromedial and then medial to the nervus oculomotorius, lateral to the ramus palatinus of the nervus facialis and dorsal to the cranial wall. More and more cephalad, the nervus abducens leaves the cranial cavity by piercing the meninx primitiva together with the nervus oculomotorius through a common foramen (Fig. 3, COM. F). Extracranially, the nervus abducens extends anterolaterally for a short distance passing ventral to the nervus oculomotorius and dorsal and medial to the origin of the rectus lateralis muscle.

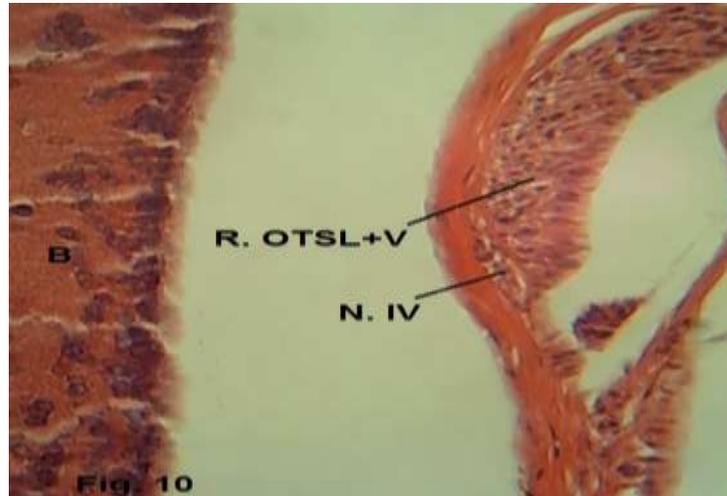


Fig. 10:- Photomicrograph of part of transverse section of *Anguilla anguilla* passing through the postorbital region illustrating the extracranial position of the nervus trochlearis. X400. B: Brain; N. IV: Nervus trochlearis; R. OTSL+V: Ramus ophthalmicus superficialis lateralis and trigeminus.

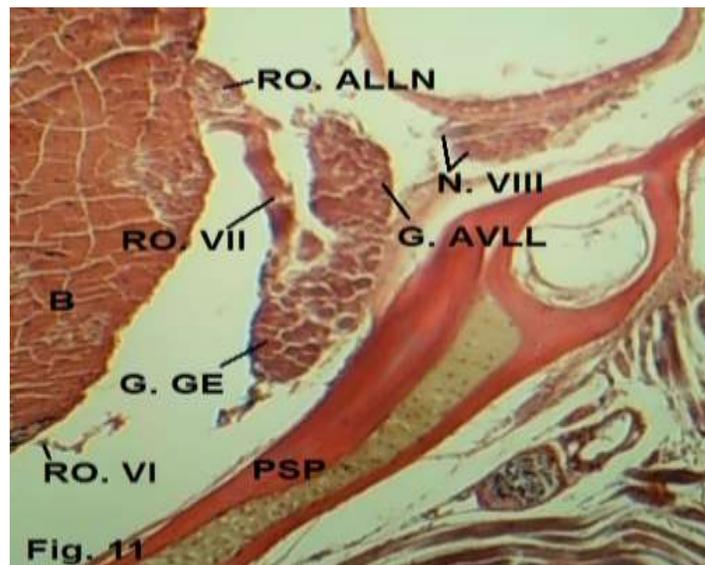


Fig. 11:- Photomicrograph of part of transverse section of *Anguilla anguilla* passing through the otic region showing the origin of the nervus abducens from the brain. X100. B: Brain; G. AVLL: Anteroventral lateral line ganglion; G. GE: Genuiculate ganglion; N. VIII: Nervus octavus; PSP: Parasphenoid bone; RO. VI: Root of the nervus abducens; RO. VII: Root of the nervus facialis.

Discussion:-

In the present study, the nervus oculomotorius shows no decussation near its origin inside the brain. Similar results are observed in *Liza ramada* (Ali, 2012), *Gambusia affinis affinis* (Mattar, 2012) and in *Liza aurata* (Al-Harthi, 2016). On the other hand, such decussation was reported in *Ctenopharyngodon idellus* (Dakrory, 2000), *Tilapia zillii* (Ali, 2005), *Mugil cephalus* (Hussein, 2010), *Hypophthalmichthys molitrix* (Taha, 2010) and in *Oreochromis niloticus* (Almalki, 2017).

In the present study, the oculomotor nerve gets its exit from the cranial cavity together with the nervus abducens through a common foramen. On the other hand, it leaves the latter cavity through its own foramen as shown in *Ailia* (Srinivasachar, 1956), *Amphipnous cuchia* (Saxena, 1967), *Trichiurus lepturus* (Harrison, 1981), *Ctenopharyngodon idellus* (Dakrory, 2000), *Tilapia zillii* (Ali, 2005), *Hypophthalmichthys molitrix* (Taha, 2010), *Gambusia affinis affinis* (Mattar, 2012; Dakrory et al., 2012), *Liza ramada* (Ali, 2012), *Liza aurata* (Al-Harhi, 2016) and in *Oreochromis niloticus* (Almalki, 2017). 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 29 mm in *Arius jella* and 16 mm in *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 *Gnathonemus petersii* (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; Mazhar, 1979; Dakrory, 2000).

In the present investigation, the oculomotor nerve gets its exit from the cranial cavity together with the abducens nerve through one and the same foramen, the common foramen. This foramen was found to be located between the parasphenoid bone and the basisphenoid bone. This foramen is located in the pleurosphenoid bone as reported by Dakrory (2000) in *Ctenopharyngodon idellus*, Taha (2010) in *Hypophthalmichthys molitrix* and by Ali (2012) in *Liza ramada*. Different localities for the oculomotor foramen were described in other fishes by some authors. It 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 surrounded by the pleurosphenoid bone in *Ctenopharyngodon idellus* (Dakrory, 2000) and in *Hypophthalmichthys molitrix* (Taha, 2010). 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*. This foramen is found between the prootic and the pleurosphenoid bones by Ali (2005) in *Tilapia zillii* and that of Mattar (2012) and Dakrory et al. (2012) in *Gambusia affinis affinis*.

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 be 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 a 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 work, 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), *Gambusia affinis affinis* (Mattar, 2012; Dakrory et al., 2012), *Liza aurata* (Al-Harhi, 2016) and in (Almalki, 2017). 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.

In the anguillid species of this study, there is no connection observed between the nervus oculomotorius and other cranial nerves. This result is the same in most fishes as shown in *Tilapia zillii* (Ali, 2005), *Alticus kirkii magnosi* (Ali and Dakrory, 2008), *Mugil cephalus* (Hussein, 2010), *Hypophthalmichthys molitrix* (Taha, 2010), *Gambusia affinis affinis* (Mattar, 2012; Dakrory *et al.*, 2012), *Liza ramada* (Ali, 2012; dakrory *et al.*, 2013), *Liza aurata* (Al-Harhi, 2016) and in *Oreochromis niloticus* (Almalki, 2017). In *Polypterus senegalus*, the oculomotor nerve joins the profundal 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). On the other hand, the connection between the nervus oculomotorius and the nervus trigeminus was recorded among some bony fishes. 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-lateralis complex. Earlier, an anastomosis between the nervus oculomotorius and the nervus trochlearis was found in *Pleuronectes* (Cole and Johnstone, 1901) and between the former 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 nervi trochlearis and abducens in *Pseudorhombus arsius*, *Ctenopharyngodon idellus*, *Tilapia zillii*, *Hypophthalmichthys molitrix* and *Gambusia affinis 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).

It is clear from the detailed anatomical study of the head serial sections of *Anguilla anguilla* that the nervus oculomotorius carries special somatic motor fibres and small components of general visceromotor ones.

The investigation of the serial sections of the anguillid species studied has not succeeded in demonstrating a ciliary ganglion; although, it elucidates the presence of a nerve arising from the nervus oculomotorius having the same characteristics of or homologous to the ciliary nerve. A completely lacking of the ciliary ganglion was, also mentioned 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 *Opisthroctus soleatus*, but he found a ganglion on the third cranial nerve. Therefore, this reflects the fact that the eye is not well developed in the studied fish and this fish not depends on vision during its feeding. So, it may be considered as bottom fish. A similar observation was found also by Young (1988), Ali (2005) in *Tilapia zillii*, Taha (2010) in *Hypophthalmichthys molitrix* and in *Gambusia affinis affinis* Mattar (2012) and Dakrory *et al.* (2012). Also, Stramke (1972) mentioned that, due to the absence of lens muscles, accommodation is not possible; furthermore, the eel does not have a corpus chorioideae nor a musculus ciliaris. Thus, the presence of this nerve appears to be controlling the smooth muscles of the choroid and the iris blood vessels. The same was mentioned by Radzimirska (2003) in the domestic turkey. Again, Biometric studies on the nucleus of the oculomotor nerve have shown that the yellow eel probably makes relatively little use of its eyes (Kirsche, 1966).

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*, by Ali and Dakrory (2008) in *Alticus kirkii magnosi*, by Ali (2012), Dakrory *et al.* (2013) in *Liza ramada* and Al-Harhi (2016) in *Liza aurata* and by Almalki (2017) in *Oreochromis niloticus*. However, there is 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* (Piotrowski and Northcutt, 1996), in both the batoid *Rhinobatus halavi* and in the cyprinoid *Ctenopharyngodon idellus* (Dakrory, 2000), in *Mugil cephalus* (Hussein, 2010) and in *Hypophthalmichthys molitrix* (Taha, 2010).

In the present study, the nervus trochlearis emerges from the cranial cavity through a special foramen; the trochlear foramen. This is the same 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), *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), *Gambusia affinis affinis* (Mattar, 2012; Dakrory *et al.*, 2012), *Liza ramada* (Ali, 2012; Dakrory *et al.*, 2013), *Liza aurata* (Al-Harhi, 2016) and in *Oreochromis niloticus* (Almalki, 2017). However, Srinivasachar (1959) showed that there is a large sphenoid fissure

for the emergence of the nervi opticus and facialis in the 29 mm larva of *Plotosus canis*. In *Clarias batrachus*, there is a common foramen for the exit of the nervi oculomotorius, 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 trigeminus 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 pterosphenoïd and basisphenoïd bones.

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 cyclostomate *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*.

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), *Gambusia affinis affinis* (Mattar, 2012; Dakrory et al., 2012), *Liza ramada* (Ali, 2012; Dakrory et al., 2013), *Liza aurata* (Al-Harathi, 2016) and in *Oreochromis niloticus* (Almalki, 2017). 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-lateralis 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).

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; Mattar, 2012; Almalki, 2017).

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

The nervus abducens of the studied anguillid 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), *Tetodon 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), *Hypophthalmichthys molitrix* (Dakrory et al., 2010), *Gambusia affinis affinis* (Mattar, 2012; Dakrory et al., 2013), *Liza ramada* (Ali, 2012; Dakrory et al., 2012), *Liza aurata* (Al-Harathi, 2016) and in *Oreochromis niloticus* (Almalki, 2017). 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 *Opsanus 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 present study shows that the abducens nerve leaves the cranial cavity by piercing the meninx primitiva together with the nervus oculomotorius through a common foramen. On the other hand, many studies 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*, Ali and Dakrory (2008) in *Alticus kirkii magnosi*, Dakrory et al. (2010) in *Hypophthalmichthys molitrix*, Ali (2012) and Dakrory et al. (2012) in *Liza ramada*, Al-Harathi (2016) in *Liza aurata* and by Almalki (2017) in *Oreochromis niloticus*. 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). In *Polypterus senegalus*, El-Toubi and Abdel-Aziz (1955) and Piotrowski and Northcutt (1996), 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*. Also, 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 this study, the nervus abducens shows no connection with other cranial nerves. This is the case 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; Issa and Mahgoub, 2013; Al-Harhi, 2016; Almalki, 2017). 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 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).

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; Mattar, 2012; Almalki, 2017). 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. Fritzsche *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 abducens nerve innervates one muscle (external rectus) in chondrichthyan and osteichthyan fishes but two muscles in the lamprey and in most tetrapods (Young, 2008).

In the present study, there is no posterior myodome (the eye muscle chamber). Some authors recorded the presence of this myodome as in *Ctenopharyngodon idellus* (Dakrory, 2000), *Tilapia zillii* (Ali, 2005; Issa and Mahgoub, 2013), *Gambusia affinis affinis* (Mattar, 2012), *Liza ramada* (Ali, 2012; Dakrory *et al.*, 2012), *Liza aurata* (Al-Harhi, 2016) and in *Oreochromis niloticus* (Almalki, 2017).

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

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