Eye Muscle Nerves and the Ciliary Ganglion of *Coluber Rogersi* (Colubridae, Ophidia)

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Abstract: In *Coluber rogersi*, the nervus oculomotorius arises from the pars peduncularis mesencephalon. It fuses with the other eye muscle nerves and the ramus ophthalmicus profundus of the nervus trigeminus forming a stout trunk. This trunk leaves the cranial cavity through the foramen orbitale magnum. Through this foramen the trunk divides into its component nerves.The nervus oculomotorius hastwo rami; superior and inferior. The two rami innervate the rectus superior, rectus inferior, rectus medialis and obliquus inferior muscles. The nervus trochlearis fuses with the common trunk and passing to innervate the obliquus superior muscle. The nervus abducens arises from the medulla oblongata and passes through the vidian canal for a distance.It returns to the cranial cavity to fuse with the ramus ophthalmicus profundus andpassing to innervate the rectus lateralis muscle. The ciliary ganglion has a common root (mixedbranch) arises from the ramus nasalis of the nervus trigeminusanterior to its separation from the trunk. The ciliary ganglion consists of two types of neurons and gives off two ciliary nerves.
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1. Introduction

The snakes are highly specialized organisms, that consititute the members of the suborder Ophidia (Serpents) of the order Squamata.

The study of the anatomy of the cranial nerves is very important not only behaviorally but also systematically and phylogenetically. The neural characters are usefull for the taxonomic and phylogenetic studies.

Although, there are many studies in the subject of cranial nerves of reptiles generally, yet there are a few ones in Ophidia. These studies includethat ofHegazy (1976) on *Psammophis sibilans, Eryx jaculus* and *Cerastes vipera*, Mostafa (1990) on *Spalerosophis diadema*, Abdel-Kader *et al*. (2000) on *Naja haje*, El-Ghareeb *et al*. (2004 a & b) on *Natrix tessellata*, Abdel-Kader (2006)on *Telescopus dhara*.

These studies show many contradictions about the number of roots, nature and structure of the ciliary ganglion as well as the number of the ciliary nerves arising from the ganglion.

The present study deals with the eye-muscle nerves and the ciliary ganglion of the snake *Coluber rogersi* to analyze each of these nerves into its component fibres and to show the relations of these nerves to each other and to the other structures of the head as well as to show the nature and structure of the ciliary ganglion.

2.Material and Methods

The snake *Coluber rogersi* is a diurnal snake inhabiting a wide variety of desert habitats including both sandy and rocky areas. It is widely distributed in Egypt, Palastine, Jordan and western Iraq. In Egypt, it is found in Mediterranian Coastal Desert, Southward to Wadi El Natrun and eastward to northern Eastern Desert and Sinai.

Specimens of young snake *Coluber rogersi* were collected from Wadi El-Natrun. The young snakes were anesthetizedin diethyl ether and their heads were taken and fixed in aqueous Bouin solution for 24-48 hours, followed by washing several days with 70% ethyl alcohol. After that, the fixed heads were decalcified using EDTA solution for about six weeks, with changing solution every four days followed by washing with 70% ethyl alcohol. The the specimens heads were stained in *toto*with Grenscher's Borax Carmine for three days (according to Galigher & Kozloff, 1964). The excess stain was removed by washing with 1% acid alcohol for two hours. After that, the heads were dehydrated, cleared, mounted and embedded in paraffin wax and serially sectioned transversely at 12 µm thick. The serial sections were counterstained with Picroindigo-carmine. The serial sections were drawn with the help of projector. From these sections, an accurate graphic reconstruction for the eye muscle nerves and ciliary ganglion was made in a lateral view. In order to show the relation of these nerves with each other and with the other head structures, several serial sections are photomicrographed.

3. Results

III. Nervus Oculomotorius

In *Coluber regersi*, the nervus oculomotorius (N.III) originates from the ventral margin of the pars peduncularis mesencephalon of the midbrain by one stout root (Figs. 1&2, RO.III). Directly after its origin it penetrates the pia mater and extends anterolaterally passing dorsomedial to the nervi trochlearis, abducens and the ramus ophthalmicus profundus of the nervus trigeminus and ventrolateral to the brain (Fig. 3, N.III). The nervus oculomotorius continues its anterolateralcourse, within the cranial cavitytill it reaches andfuses with atrunk consisting of the nervi trochlearis, abducens and the ramus ophthalmicus profundus of the nervus trigeminus forming a common trunk (Fig. 4, CO.TR).

After a considerable anterior course within the cranial cavity, the common trunk leaves the cranial cavity through the foramen orbitale manum (Fig. 5, F.ORM). During its exits through this foramen, the common trunk separates into its nerve components. Moreover, the nervus oculomotorius separates from the trunk as its two rami; superior and inferior. The ramus superior separates from the dorsal side of the trunktogether with the nervus troclearis (Fig. 1, R.SPIII+N.IV). Shortly anteriorly, the ramus superior separates laterally and the nervus trochlearis separates medially (Figs. 1&5, R.SP+N.IV). The ramus inferior separates from the ventral side of the trunk together with the ramus nasalis of the nervus trigeminus (Figs, 1&5, R.IF.III+R.NA.). After that the two rami separate from one another (Fig. 1, R.IF).

Ramus Superior

Immediately after its separation from the nervus trochlearis (Fig. 5, R.SP.III), the ramus superior of the nervus oculomotoriusextendes anteriorly in a dorsal direction passing dorsal to the nervus abducens, the ramus nasalis of the nervus trigeminus and the ramus inferior of the nervus oculomotorius and medial to the rectus lateralis muscle and lateral to the nervus trochlearis. It continues its anterodorsal course running dorsal to the rectus lateralis muscle, the nervus abducens, the ramus nasalis of the nervus trigeminus and the ramus inferior of the nervus oculomotorius and ventrolateral to the rectus superior muscle (Fig. 6, R.SP.III). Shortly anterior, the ramus superior enters the latter muscle from its lateral side and distributes between its fibres.

Ramus Inferior

After its separation from the ramus nasalis of the nervus trigeminus (Fig. 6, R.IF.III), the ramus inferior of the nervus oculomotorius passes anteriorly in a position between the rectus superior muscle dorsally and the rectus lateralis muscle ventrally and the ramus nasalis of the nervus trigeminus dorsolaterally. After a considerable anterior distance, it passes dorsal to the rectus lateralis muscle, ventral to the ramus nasalis of the nervus trigeminus and lateral to the optic nerve.Here, it gives off a lateral branch. This branch (Fig. 1, N.RIF) extends anterolaterally passing dorsal to the rectus inferior muscle, lateral to the ramus inferior of the nervus oculomotorius and the optic nerve, ventral to the ramus nasalis of the nervus trigeminus, ventromedial to the ciliary nerves and medial to the dorsal part of the lacrimal gland. Shortly anterior, this branch enters the rectus inferior muscle from its dorsal side to terminate between its fibres. After that, the ramus inferior extends medially and then ventromedially to run ventrolateral to the optic nerve and dorsal to the rectus inferior muscle. Here, it gives off a second lateral branch to the same muscle (Fig. 1, N.RIF).Anterior to the origin of the second lateral branch, the ramus inferior extendes medially passing dorsal to the rectus inferior muscle, ventral to the optic nerve and medial to the second lateral branch. Shortly anterior, it runs dorsomediallypassing ventromedial to the optic nerve, dorsomedial to the rectus inferior muscle and dorsolateral to the trabecular cranii. Thereafter, the ramus inferior continues anteriorly in a dorsomedial direction passing dorsomedial to the lacrimal gland, ventromedial to the optic nerve and dorsolateral to the trabecular cranii. Here, it divides into two branches one dorsomedial and the other ventrolateral. The dorsomedial branch runs anterodorsally passing medial to the optic nerve,ventrolateral to the ramus nasalis of the nervus trigeminus and dorsal to both the ventrolateral branch and the lacrimal gland. After a short anterior distance, it becomes dorsal to the lacrimal gland, ventrolateral to the ramus nasalis of the nervus trigeminus, medial to the eyeball and lateral to the rectus medialis muscle. After a considerable distance in this position it entersand ends in the latter muscle (Fig. 1, N.RM).

The ventrolateral branch extends anteriorly in a ventrolateral directionpassing between the eyeball laterally and the lacrimal gland medially.After a considerable anterior distance in this position, the ventrolateral branch enters the obliquus inferior muscle, where it ramifies and distributes between its fibres (Fig. 1, N.OIF)

From the distribution of the nervus oculomotorius, it has been found that this nerve carries somatic motor fibres to four of the eye muscles in addition to general visceromotor fibres (parasympathetic) to the ciliary ganglion.

IV. Nervus Trochlearis

In *Coluber rogersi*, the nervus trochlearis (N.IV) arises from the ventrolateral side of the mesencephalon by single root (Fig. 1, RO.IV). It runs anteriorly in a lateral direction penetrating the pia mater,dorsolateral to the root of the nervus oculomotorius and dorsomedial to the ramus ophthalmicus profundus of the nervus trigeminus. This nerve extends anteroventrally within the cranial cavity passing dorsal to the ophthalmic ganglion and lateral to the root of the nervus oculomotorius (Fig. 2, N.IV).

After a considerable anteroventral course within the cranial cavity, the nervus trochlearisextendes dorsal to the ramus ophthalmicus profundus of the nervus trigeminus and lateral to the nervus oculomotorius. Shortly anterior, it fuseswitha nerve bundle formed of the nervus abducens and the ramus ophthalmicus profundus of the nervus trigeminus forming a nerve trunk. After a long anteroventral course, the nervus trochlearis separates from the common trunk together with the ramus superior of the nervus oculomotorius in the foramen orbitale magnum as previously mentioned. Sortly anterior, the nervus trochlearisseparates from the latter ramus and runs dorsomedially passing medial to the ramus superior of the nervus oculomotorius, dorsal to the ramus nasalis of the nervus trigeminus and dorsolateral to the ramus inferior of the nervus oculomotorius (Figs. 1&5, N.IV). It runs forwards in a dorsolateral direction passing medial to the rectus superior muscle and dorsolateral to the optic nerve. It continues its anterodorsal course to run dorsal to the ramus nasalis of the nervus trigeminus, medial to the eyeball and ventrolateral to the cranial wall. After short distance, this nerve extends lateral to the ramus nasalis of the nervus trigeminus and ventral to the obliquus superior muscle. At the end of its previous course, the nervus trochlearis enters and terminates between the fibres of the latter muscle.

From this study, the nervus trochlearis carries somatic motor fibres to the obliquus superior muscle.

VI. Nervus Abducens

In the species under investigation, the nervus abducens (N.VI) arises from the ventrolateral side of the medulla oblongata by a single fine root (Figs. 1&8, RO.VI). It passes forwards in a ventrolateral direction passing ventrolateral to the brain. After an intracranial distance, the nervus abducens passes through a vidian canal excavated in the anterolateral corner of the basal plate (Fig. 9, VC). After a considerable anterior distance, the nervus abducens leaves the vidian canal and returns into the cranial cavity to become medial to the constrictor-1-dorsalis nerve of the nervus trigeminus and ventromedial to the ophthalmic ganglion of the nervus trigeminus. Thereafter, it extends dorsolaterally to become dorsal tothe constrictor-1-dorsalis nerve and ventral to the ophthalmic ganglion. After a considerable forward distance,the nervus abducensjoins the ramus ophthalmicus profundus of the nervus trigeminus forming a nerve bundle,that will be fused with the nervi trochlearis and oculomotorius forming a large trunk as breviously mentioned. After a long anteriorcourse, the nervus abducens separates from the common trunk and runs anteriorly passing ventral to the ramus superior of the nervus oculomotorius. Shortly forwards, it passes dorsal to the lateral edge of the basal plate, lateral to the ramus nasalis of the nervus trigeminus, medial to the rectuslateralis muscle and ventral to the ramus superior of the nervus oculomotorius. Thereafter, it extendes dorsal and medial to the rectus lateralis muscle and lateral to the common branch released from the ramus nasalis of the nervus trigeminus and ventral to the ramus superior of the nervus oculomotorius.More forwards, it continues passing dorsal to the latter muscle, ventrolateral to the ciliary ganglion and lateral to the eyeball. Finally, it enters and ends in the rectus lateralis muscle.

From this study, the nervus abducens carries somatic motor fibres to the rectus lateralis muscle. Also, there is no retractor oculi or bursalis muscles, thus this nerve innervates only the rectus lateralis muscle of the eye.

Ciliary Ganglion

In *Coluber rogersi*, the ciliary ganglion (Fig. 7, G.CL) is a well-defined mass of ganglionic cells. It is located posteriorly in the orbital region dorsal to the rectus lateralis muscle, dorsomedial to the nervus abducens, dorsolateral to the ramus inferior of the nervus oculomotorius and lateral to the ramus nasalis of the nervus trigeminus, ventromedial to the sclera of the eye and ventral to both the rectus superior muscle and the ramus superior of the nervus oculomotorius (Fig. 6, G.CL).

The serial transverse sections examined showed that the ciliary ganglion (Fig. 7, G.CL) appears as triangular in shape consisting of two types of neurons, large neurons at the periphery and smaller ones in the center. This ganglion measures about 168 μm in length

The ciliary ganglion is connected with the ramus nasalis of the nervus trigeminus by a short common branch. This branchrepresented both the radix ciliaris brevis that transmitted the preganglionic parasympathetic fibres from the nervus oculomotorius to the ganglion and the radix ciliaris longathat carries general viscerosensory fibres from the eye. A relay takes place between preganglionic parasympathetic fibres and postganglionic neurons within the ciliary ganglion. The postganglionic fibres leave the ganglion and innervate the internal structures of the eye through the ciliary nerves.

In this study, the radix ciliaris brevis and the radix ciliaris longa reach the ciliary ganglion through a one mixed common branch arises from the ventro lateral side of the ramus nasalis of the nervus trigeminus after very short distance from its releases from the common trunk.

From the anterior part of the ciliary ganglion two ciliary nerves (Fig. 1, Nn.CL) arise at its lateral margin one after the other. These two nerves enter the eye ball through a foramen in the sclera and terminate in the muscles of the ciliary body.

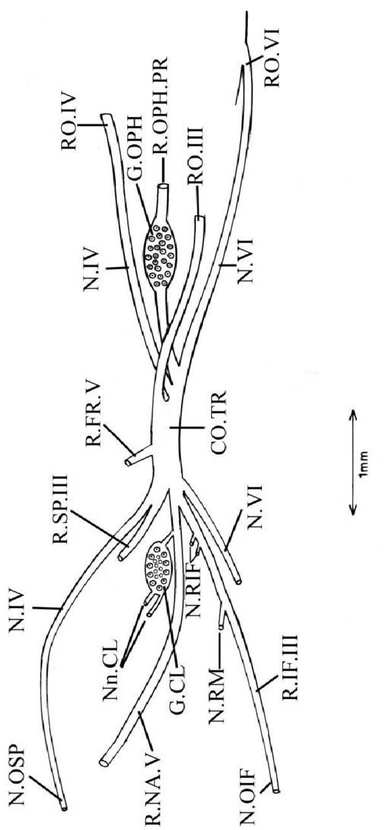

Fig. (1): Graphic reconstruction of the eye muscle nerves and the ciliary ganglion of *Coluber rogersi* in a lateral view.

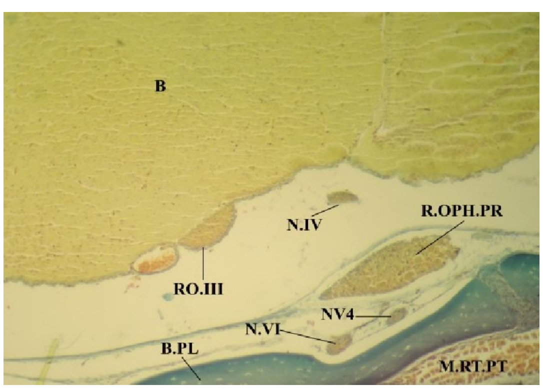

Fig. (2): Photomicrograph of a part of transverse section through the mesencephalon showing the roots of the nervi oculomotorius and trochlearis (X100).

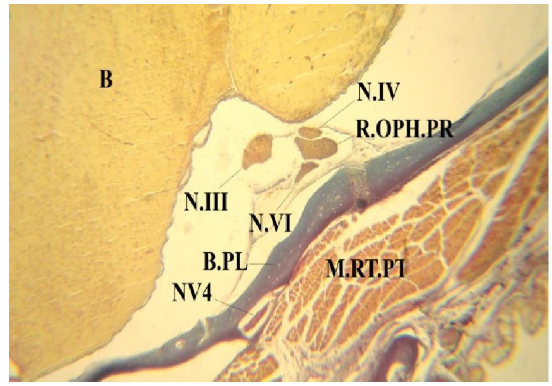

Fig. (3): Photomicrograph of a part of transverse section through the mesencephalon showing the nervi oculomotorius, trochlearis, abducens and the ramus ophthalmicus profundus just before forming the trunk (X100).

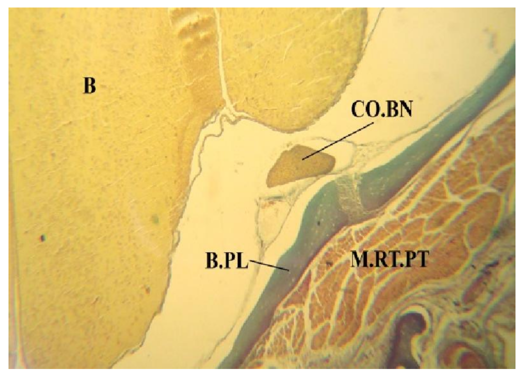

Fig. (4): Photomicrograph of a part of transverse section through the mesencephalon showing the common trunk forming of the threenervi oculomotorius, trochlearis, abducens and the ramus ophthalmicus profundus (X100).

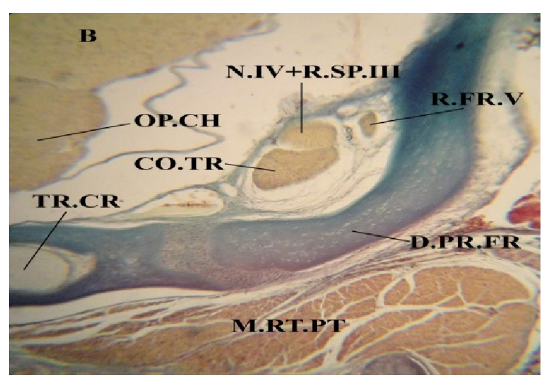

Fig. (5): Photomicrograph of a part of transverse section through the postorbital region showing the separation of the nervus trochlearis and the ramus superior from the trunk as one branch (X100).

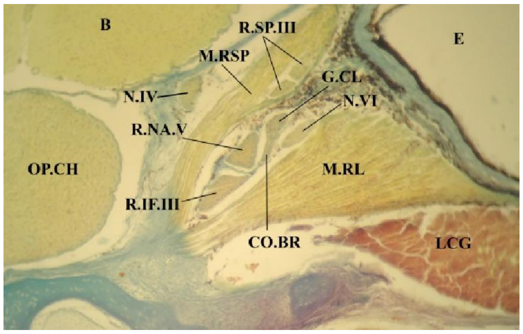

Fig. (6): Photomicrograph of a part of transverse section through the orbital region showing the separation of the common branch from the ramus nasalis and its entering to the ciliary ganglion (X100).

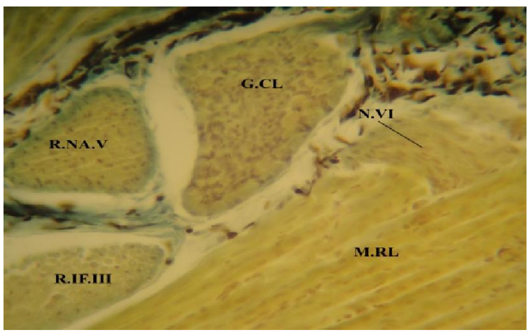

Fig. (7): Photomicrograph of a part of transverse section through the orbital region showing the structure of the ciliary ganglion (X400).

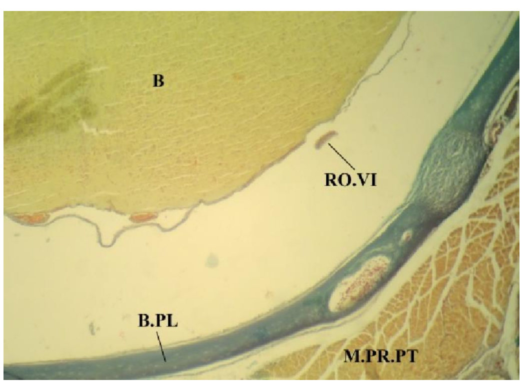

Fig. (8): Photomicrograph of a part of transverse section through the otic region showing the root of the nervus abducens (X100).

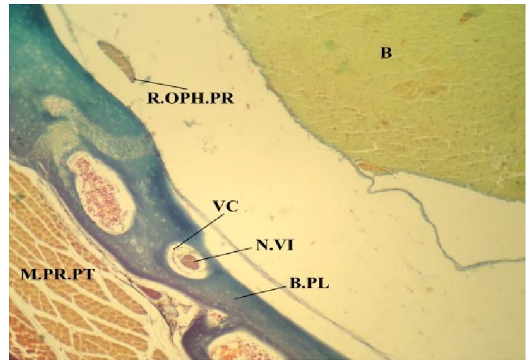

Fig. (9): Photomicrograph of a part of transverse section through the otic region showing the passage of the nervus abducens through the vidian canal (X100).

4. Analysis and Discussion

In *Coluber rogersi,* the nervus oculomotorius originates as a single root from the pars peduncularis mesencephali of the midbrain. The previous studies demonstrated that the emergence of the nervus oculomotorius from the ventral side of the mesencephalon is considered as a general character among Squamata (Ophidia & Lacertilia). On the other hand, this nerve arises from the crura cerebri in both *Eryx jaculus* and *Cerastes vipera* (Hegazy, 1976; Hammouda *et al*., 1976).

In the present study, there is no oculomotor or trochlear intracranial decussation On the other hand, in *Chamaeleon vulgaris* (Shanklin, 1930) and *Varanus monitor* (Shrivastava, 1964), the fibres of the nervus oculomotorius decussate near its origin from the nerve cells inside the brain. Shanklin (1930) reported that this decussation may have a role in the eye movement of *Chamaeleon vulgaris.* According to Shanklin (1930), such decussation is rare. On the other hand, the trochlear decussation is of a wide occurrence among reptiles. Among Ophidia, it was observed in the serpents *Psammophis sibilans* (Hegazy, 1976; Hammouda *et al*., 1976) and *Spalerosophis diadema* (Mostafa, 1990b). In Lacertilia, this decussation is described in the lizards *Chacides ocellatus* (Soliman and Hegazy, 1969), *Tarentola mauritanica* (Soliman and Mostafa, 1984), both *Agama pallida* and *Ptyodactylus hasselquistii* (Abdel-Kader, 1990),in the limbless blind *Diplometopon zarudnyi*(Dakrory, 1994).and in *Acanthodactylus boskianus* (El-Ghareeb, 1997).

Among Amphibia, such decussation was not mentioned (Mostafa and Soliman, 1984; Shaheen, 1987; Dakrory, 2002). Also, Edgeworth (1935) reported that the trochlear nerve undergoes a decussation with its follow above the midbrain (trochlear decussation) and innervates the obliquus superior muscle of the opposite side in nearly all vertebrates.

In the current study, the eye muscle nerves together with the ramus ophthalmicus profundus of the nervus trigeminus fused forming a common trunk. This common trunk pentrates the dura mater through the foramen orbitale magnum.Within the latter foramen, the trunk separates into its nerve components. In most ophidians studied by Hegazy (1976), Hammouda (1963), Hammouda *et al*. (1976) and El-Ghareeb *et al.* (2004b), the eye muscle nerves and the ramus ophthalmicus profundus of the nervus trigeminus leave the cranial cavity separately through the foramen orbitale magnum, i.e, it appears to be an ophidians character.

In some members of the suborder Lacertlia in the order Rhincocephalia, the nervi oculomotorius and trchlearis leave the cranial cavity through the metoptic fenestra. This condition was mentioned in *Sphenodon punctatum* (Howes and Swinnerton, 1901), *Lacerta agilis* (Gaupp, 1911), *Chacides ocellatus* (Soliman and Hegazy, 1969), *Tarentola mauritanica* (Soliman and Mostafa, 1984), *Ptyodactylus hasselquistii* (Abdel-Kader, 1990), *Acanthodactylus opheodurus* (Mostafa, 1990a), *Acanthodactylus boskianus* (El-Ghareeb, 1997) and in *Mabuya quinquetaniata* (Madboly, 2011).

Among chelonians, the nervi culomotorius and trochlearis in *Trionyx cartilaginous, Nanemys guttata* and *Clemmys decussate* emerge from the cranium through special separate foramina found in the membrano-cartilagenous lateral wall (Shiino, 1912). Recently, Paluh and Sheil (2013) confirmed this view. On the other hand, De Beer (1937) mentioned that the two nerves exit from the cranial cavity through incisura metoptica in *Emys lutaria;* while in *Chrysemys marginata,* he observed a separate foramen for each nerve.

In crocodilians, Shiino (1914) reported that the nervus oculomotorius leaves the cranial cavity through the metoptic fenestra, while the nervus trochlearis exits the cerebral cavity through its own foramen which is located on the posterior part of the taenia parietalis media.

In amphibians, the eye-muscle nerves leave the cerebral cavity through a special foramen for each nerve as demonstrated in previous studies. On the other hand, Haas and Richard (1998) found that the nervus trochlearis leaves the cranial cavity together with the optic nerve through the optic foramen.

In the majority of birds, a closed sphenoid fontanelle is found, through which the nervi opticus, oculomotorius and trochlearis emerge. This finding was confirmed by De Beer and Barrington (1934) in *Anas,*De Beer (1937) in *Anas* and *Struthio*, May (1961) in *Strix*, Müller (1961) in *Rhea* and by Til Macke (1969) in *Fulica*. However, such a sphenoid fontanelle is lacking, and each of the three nerves passes through a special foramen in the birds studied by Cords (1904) and Ábrahám and Stammer (1966). This was also the case described by Bellairs (1958) in *Pyromelana*, Soliman *et al*. (1986) in *Upupa, Passer* and *Steptopellia* and Abdel-Kader and Fathy (2000) in *Merops albicollis*.

In the examined ophidian species, the nervus abducens leaves the cranial cavity through a special canal excavated in the basal plate. This was described in *Tropidonotus natrix* (Gaupp, 1902; De Beer, 1937), *Viperaaspis* (Peyer, 1912), *Thamnophis rodinoides* (Auen and Langebartel, 1977) and in *Natrix tessellata* (El-Gareeb *et al.,* 2004b). However, this nerve passes into a depression and not canal in the snakes *Lamprophis inornatus, Desypeltis scaber, Causus rhombeatus* and *Hemachatus hemachatus* (Pringle, 1954), *Psammophis sibilans* (Hegazy, 1976; Hammouda *et al.,* 1976) and *Malpolon monspessulana* (El-Toubi*et al.,* 1973). *On* the other hand, there is neither a canal nor a depression in the ophidians *Eryx jaculus* (Hegazy, 1976) and *Cerastus vipera* (Hammouda *et al*., 1976) and in *Elaphe obsolete quadrivittata* (Auen & Langebartel, 1977).

An abducens tunnel was recorded in most lacertilian species. In was found in *Lacerta agilis* (Gaupp, 1902; De Beer 1937), *Anolis carolinensis* (Willard, 1915),*Platydactylus annularis* (Hafferl, 1921), *Ablepharus pannonicus* (Haas, 1930), in *Platydactylus maculosa* and *Lygodactylus capansis* (Brock, 1932), *Loposaura ventralis*(Brock, 1941), *Calotes versicolor* (Ramaswami, 1946), *Anniela pulchra* (Bellairs, 1950), *Hemidactylus turcica* (Kamal, 1961), *Chalcides ocellatus* (Soliman and Hegazy, 1969), *Agama pallida* (Soliman *et al.,* 1984) *Tarentola mauritanica* (Soliman & Mostafa, 1984). This canal was also mentioned in the amphisbaenian *Diplometopon zarudnyi* (Dakrory, 1994). However, an abducens depression was described in the lizard *Tropiocolotes tripolitanus* (Kamal, 1960).

Regarding other reptilian groups, the abducens tunnel was also found to be present in the Rhynchocephalian *Sphenodon punctatus*(Hows & Swinnerton, 1901), in the chelonians *Chrysemes marginata* and *Emys lutaria* (Kunkle, 1912) and in the crocodilian *Crocodilus biporcatus* (Shiino, 1914). This was also asserted by De Beer (1937). However, in the chelonians *Cyclanorbis* (Siebenrock, 1897) and both *Trionyx* and *Podocnemis* (Gaupp, 1911), the abducens tunnel is absent.

The presence of the abducens tunnel in birds was mentioned by Cords (1904), Müller (1961), Ábrahám and Stammer (1966) and Soliman *et al.* (1986). However, in *Streptopelia senegalensis*, an abducens tunnel is not represented (Soliman *et al.,* 1986). It appears from the cut strip references that the presence of a vidian canal and the passage of the nervus abducens through it, is a unique sauropsidan characters.

In the present study, there is a complete fusion between the ocular nerves and the ramus ophthalmicus profundus of the nervus trigeminus. An anastomosis between the eye muscle nerves and the nervus trigeminus seems to be widely spread among reptiles, birds and mammals. The connection of the nervi oculomotorius and trochlearis with the nervus trigeminus was mentioned in reptiles by many authors. For the nervus oculomotorius, an anastomosis between the ramus superior and the ramus nasalis was described in *Psammophis sibilans* and *Eryx jaculus* (Hegazy, 1976; Hammouda *et al.,* 1976). Among Lacertilia, this connection was found in *Chacides ocellatus* (Soliman and Hegazy, 1969). While in the gecko *Gymnodactylus kotschyi* (Evans and Minckler, 1938), it was found between the ramus superior and the radix ciliaris longa. On the other hand, Belogolowy (1910) and Soliman (1964), dealing with the chelonians *Emys lutaria* and *Chelone imbricate,* respectively, observed a connection between the nervus oculomotorius and the trigeminal ganglion. Such connection represents a shared primitive character.

Regarding the nervus trochlearis, an anstomosis with the ramus ophthalmicus was described in the snakes *Psammophis sibilans, Cerastes vipera* and *Eryx jaculus* (Hegazy, 1976; Hammouda *et al.,* 1976). Among Lacertilia, it was found in the gecko *Gymnodactylus kotschyi* and *Tarentola mauritanica* (Evans and Minkler, 1938; Soliman and Mostafa, 1984, respectively) and in the agamid *Agama pallida* (Soliman *et al.,* 1984). This connection was also found in the chelonians *Chelydra serpentine* and *Chelone imbricata* (Soliman, 1964). This represents an independent character.

On the contrary, the nervus abducens has no relation with the nervus trigeminus in reptiles. This condition seems to be a common unique character in reptiles. However, Vögt (1840) described a connection between the nervus abducens and the facial nerve in *Chelone mydas*. On the other hand, Hoffman (1886) and Ogushi (1913) mentioned that this connection was absent in Chelonia.

In Amphibia, Norris (1908) found two connections in *Amphiuma means*, one between the nervus oculomotorius and the Gasserian ganglion of the nervus trigeminus while the second one between the oculomotor nerve and the ramus ophthalmicus profundus. Mostafa and Soliman (1984) and Dakrory (2002) reported a connection between the nervus oculomotorius and the ramus ophthalmicus profundus in *Bufo viridis* and *Rana bedriage*, respectively. With respect to the nervus trochlearis, Herrick (1894) found a connection between this nerve and the ramus ophthalmicus profundus of the nervus trigeminus in *Amblystoma punctatus*. In *Amblystoma tigrinum*, Wiedersheim (1909) and Coghill (1902) reported a connection between the nervus abducens and the Gasserian ganglion.

In birds, there is no connection recorded between the nervi oculomotorius and trigeminus (Abdel-Kader, 1999; Soliman *et al*., 1986; Abdel-Kader and Fathy, 2000). With respect to the nervus trochlearis, there is no a connection between this nerve and the ramus ophthalmicus profundus in the hen (Cords, 1904), *Upupa epops* (Soliman *et al*., 1986) and *Merops albicollis* (Abdel-Kader and Fathy, 2000). In *Corvus cornix*, Bonsdorff (1852) mentioned the presence of a connection between the nervus abducens and both the radix ciliaris brevis of the ciliary ganglion and the ganglion itself. Cords (1904) reported the presence of the connection between the ciliary ganglion and the nervus abducens. In *Upupa epops* and *Passer domesticus*, Soliman *et al*. (1986) mentioned the presence of connection between the nervus abducens and both the ciliary ganglion and one of its ciliary nerves.Dakrory and Abdel-Kader (2011) stated that the radix ciliaris longa receives a branch from the nervus abducens in *Pterocles alchata*.

Regarding mammals, a connection between the main nervus oculomotorius and the ramus ophthalmicus profundus was described in the baboon embryo by Gasser and Hendrickx (1969). On the other hand, an anastomosis between the ramus inferior of the nervus oculomotorius and the ramus maxillaris was mentioned by many authors (Mobillio, 1912; Winckler, 1937; Godinho and Getty, 1971). A connection between the nervus trochlearis and the ramus frontalis of the nervus trigeminus was found by many investigators (Gasser and Hendrickx, 1969; Gasser and Wise, 1972). A connection between the nervus abducens and the nervus trigeminus was mentioned by Quiring (1950).

In *Coluber regersi*, there is an obvious ciliary ganglion. This ganglion located in the postorbital region of the head. Christensen (1935) and Godinho (1972) found an accessory ciliary ganglion, in addition to the main ciliary ganglion in cats and pig, respectively.This accessory ganglion is absent in the cloubrid species examined. This is the case found in the reptiles so far described.

In *Coluber regersi*, the ciliary ganglion consists of two types of neurons, large ganglionic cells at the periphery and small ones in the center. Similar finding was reported by El-Ghareeb *et al*. (2004b) in *Natrix tessellata*. Galvao (1917) described the ciliary ganglion of ophidians as formed of strictly unipolar cells. Hegazy (1976) found similar results in the serpents *Psammophis sibilans, Eryx jaculus* and *Cerastes vipera*.

In Lacerilia, the ciliary ganglion consists of either two types of neurons; large neurons and small ones, i.e, there are two differentiated regions, or only one type. A ciliary ganglion with two differentiated regions was described by Mostafa and Hegazy (1990) in *Agama siniata* and *Stenodactylus selvini* and Dakrory (2009) in *Uromastyx aegypticus* and *Sphenops sepsoides*. However, the ciliary ganglion consists of one type of neurons was recorded in *Anolis carolinensis* (Willard, 1915), *Chacides ocellatus*(Soliman and Hegazy, 1969; Santamaria-Arnaiz, 1959), *Ptyodactylus hasselquistii*, *Lacertaviridis*, *Acanthodactylus boskiana*, *Agama mutabilia* and *Mabuya quinquetaeniata* (Soliman, 1968), *Tarentola mauritanica* (Soliman and Mostafa, 1984), *Mabuya quinquetaeniata* (Abdel-Kader *et al*., 2007), *Tropiocolotes tripolitanus* (El-Bakry *et al*., 2007) and *Varanus griseus* (Dakrory, 2009).

In this respect, Haller von Hallerstein (1934) mentioned that the ciliary ganglion in reptiles and birds consists of two regions, one region contains large cells and the other one contains small cells. This finding was also recorded in Aves (Oehme, 1968; Soliman *et al*., 1976; Abdel-Kader & Fathy, 2000). Bullock *et al*. (1977) reported that the ciliary ganglion in hens consists of two types of cells: one type of these cells dominates on the unstriated muscles of the choroid, while the other type controls the muscle of both the ciliary body and the iris. Radzimirska (2003) recorded the same condition in *Meleagris domesticus*. This appears to be derived character.

In the current study, the microscopic examination of the serial transverse sections reveals that the ciliary ganglion is connected with the ramus nasalis after its releases from the common trunkthrough a mixed branch separates from. This branch carries two types of fibres; the parasympathetic fibres from the nervus oculomotorius and the viscerosensory fibres from the nervus trigeminus. The parasympathetic fibres (parasympathetic root of ciliary ganglion)that originated in the brain and leave it in the nervus oculomotorius transferred to the ramus nasalis of the nervus trigeminus at the fusion between them. These fibres are carried from the ramus nasalisto ciliary ganglion together with the sensory fibres originating in the Gasserian ganglion (radix ciliaris longa= sensory root of the ciliary ganglion) by one common mixed branch.

However, EL-Ghareeb *et al*. (2004b) demonstrated that the ciliary ganglion is connected with the ramus inferior of the nervus oculomotorius by the radix ciliaris brevis in *Natrix tessellata*. Onthe other hand, there is no radix ciliaris brevis and the ciliary ganglion is quite touching the ramus inferior of the nervus oculomotorius and the parasympathetic fibres are transmitted directly to the ganglion through the intermingling surface between them in the geckos *Tarentola mauritanica* (Soliman & Mostafa, 1984) and *Stenodactylus slevini* (Mostafa & Hegazy, 1990), in the amphisbaenian *Diplometopon zarudnyi* (Dakrory, 1994) and in the lizard *Acanthodactylus boskianus* (El-Ghareeb, 1997). In *Lacerta viridis* (Soliman, 1968), in addition to the presence of the radix ciliaris brevis which connects the ganglion with the ramus inferior of the nervus oculomotorius, there is another connection with the main nervus oculomotorius in front of the enterance of the radix ciliaris brevis to the ganglion. The radix ciliaris brevis however, is extremely short and the ganglion appears touching the main nerve in *Lacerta agilis* and *Lacerta muralis* (Lenhossék, 1912), in the gecko *Ptyodactylus hasselquistii* (Soliman, 1968; Abdel-Kader, 1990).

Among birds, the preganglionic parasympathetic fibres of the nervus oculomotorius are transmitted to the ciliary ganglion either through an anastomosing branch; the radix ciliaris brevis as in *Struthio* (Webb, 1957), *Upupaepops* and *Passer domesticus* (Soliman *etal*., 1976), *Merops albicollis* (Abdel-Kader & Fathy, 2000) and in *Halcyon smyrnensis* and *Pterocles alchata*(Dakrory& Abdel-Kader, 2011) or through the direct attachment of the ganglion to theramus inferior of the nervus oculomotorius as in the chick (Carpenter, 1906), *Streptopelia senegalensis* (Soliman *et al*., 1976), *Gallinula chloropus* (Abdel-Kader, 1999) and in *Bubulcus ibis* (Dakrory& Abdel-Kader, 2011).

Some studies mentioned that the radix ciliaris longa passes adjacent to the dorsal surface of the ciliary ganglion till it reaches the origin of the ciliary nerve and fuse with it. This condition was reported in *Eryx jaculus* (Hegazy, 1976). On the other hand, the radix ciliaris longa ends in the ciliary ganglion in each of *Psammophis sibilans* and *Cerastes vipera* (Hegazy, 1976), *Psammophis schokari* and *Spalerosophis diadema* (Mostafa, 1990), *Natrix tessellata* (El-Ghareeb *et al*., 2004b) and *Telescopus dhara* (Abdel-Kader, 2006).

Among Lacertlia, the radix ciliaris longa (transmits the sensory fibres) passes directly to the ciliary ganglion in *Varanus bivitatus* (Watkinson, 1906), *Anolis carolinensis* (Willard, 1915); *Lacerta viridis, Acanthodactylus boskiana, Agama mutabilis* and *Mabuya quinquetaeniata* (Soliman, 1968), *Agama pallida* (Soliman *et al*., 1984), *Agama sinaita, Stenodactylus slevini* and *Eumeces schneidri* (Mostafa and Hegazy, 1990) and in *Varanus griseus* (Dakrory, 2009).However, the radix ciliaris longa joins both the ciliary ganglion and the ciliary nerve distal to the ganglion in *Diplametepon zarudnyi* (Dakrory, 1994). This case is somewhat similar to that found in

Uromastyx aegyptius (Dakrory, 2009), where the radix ciliaris longa gives off a fine branch which enters the ganglion and the main nerve passes across the ganglion then turns to enter the ciliary nerve. Again, in the lizard *Chalcides ocellatus* (Soliman and Hegazy, 1969), the radix ciliaris longa passes across the dorsal side of the ciliary ganglion, then turns to enter the ciliary nerve. However, Santamaria-Arnaiz (1959), dealing with *Chalcides ocellatus*, stated that the radix ciliaris longa passes in contact with the ciliary ganglion but did not enter it. This case is homologous to that mentioned by Dakrory (2009) in *Sphenops sepesoides*.

In birds, it is obvious from the previous studies that there is no direct connection between the ciliary ganglion and each of the ramus ophthalmicus or ramus nasalis. But there is a connection between the ramus ophthalmicus and the ciliary nerves after their exit from the ganglion (Schwabe, 1879; Holtzmann, 1896; Soliman *et al.,* 1976; Dakrory& Abdel-Kader, 2011). In a few conditions, there is a direct connection between the ramus ophthalmicus and the ciliary ganglion (Jegorow, 1887; Webb, 1957; Soliman *et al.,* 1976; Abdel-Kader & Fathy, 2000). On the other hand, Bonsdroff (1852) described two branches from the nervus trigeminus in *Corvi cornices*.These two branches have the same character of the radix ciliaris longa so they are homologous.Dakrory and Abdel-Kader (2011) stated that the radix ciliaris longa transmits the sensory fibres from the ramus ophthalmicus profundus of the nervus trigeminus to bothciliary ganglion and ciliary nerve in *Bubulcus ibis*.

In mammals, the sensory fibres are carried to the ciliary ganglion through the ramus ophthalmicus of the nervus trigeminus in rhesus monkey (Christensen, 1933) and *Hemiechinus auritus* and *Rhosettus aegypticus* (Hegazy & Mostafa, 1990), and the sensory root connects the ciliary ganglion through a branch that joints the latter ganglion with the radix ciliaris longa of the ramus nasociliaris (Kuntz, 1933; Gasser & Wise, 1972, Godinho & Getty, 1971). In cats, there is a sensory root (Bast, 1933; Chrestensen, 1935). In many mammals, there is a connection between the ciliary ganglion and the ramus maxillaris of the nervus trigeminus (Mobillio, 1912; Gasser & Hendrickx, 1969; Godinho & Getty, 1971).

In the current study, there are two ciliary nerves arising from the ciliary ganglion. However, the number of the ciliary nerves varies from one to three in reptiles. One ciliary nerve was found in the snakes *Psammophis sibilans* and *Eryx jaculus* (Hegazy, 1976), *Coluber elegantissimus, Psammophis schokari* and *Spalerosophis diadema* (Mostafa, 1991). The same was found in the lizards *Chacides ocellatus* (Santamaria-Arnaiz, 1959; Soliman & Hegazy, 1969), *Ptyodactylus hasselquistii, Acanthodactylus boskiana* and *Lacerta viridis* (Soliman, 1968), *Acanthodactylus opheodurus*(Mostafa, 1990a),*Diplometopon zarudnyi* (Dakrory, 1994) and*Uromastyx aegypticus* (Mahgoub & Al-Fitouri, 2010). There are two nerves in *Cerastes vipera* (Hegazy, 1976), *Natrix tessellata* (El-Ghareeb *et al.,* 2004b) and *Telescopus dhara* (Abdel-Kader, 2006). In lizards, there are two ciliary nerves described in *Varanus bivittatus* (Watkinson, 1906), *Anolis carolenensis* (Willard, 1915), *Mabuya quinquetaeniata* (Soliman, 1968; Abdel-Kader *et al*., 2007), *Agamamutabilis* (Soliman, 1968), *Tarentolamauritanica* (Soliman & Mostafa, 1984), *Agama pallida* (Soliman *et al*., 1984), all lizards studied by Mostafa and Hegazy (1990) and *Tropiocolotus tripolitnus* (El-Bakry *et al*., 2007) and *Varanus griseus* (Dakrory, 2009). Soliman (1964) described two ciliary nerves in Chelonia. However, Evans & Minkler (1938) described three ciliary nerves in *Gymnodactylus kotschyi*.

In birds, the number of the ciliary nerves veries from one species to another. Schwalbe (1879) reported that the number of the ciliary nerves may vary from one (e.g., hen, owl and goose) to seven (e.g., parrots). One ciliary nerve was found in the chick (Carpenter, 1906) and also in *Merops albicollis* (Abdel-Kader & Fathy, 2000). However, Seto (1931) found five ciliary nerves in the chick. Two ciliary nerves were present in *Streptopelia senegalensis* (Soliman *et al*., 1976), three ciliary nerves were foundin *Passer domesticus* (Soliman *et al*., 1976) and in *Gallinula chloropus* (Abdel-Kader, 1999). Four ciliary nerves were found in the crow (Oehme, 1968) and in *Upupa epops* (Soliman *et al*., 1976) and five nerves were found in *Struthio* (Webb, 1957).

In mammals, there is obvious variation in the number of the ciliary nerves. Two ciliary nerves are present in the cat (Taylor & Weber, 1969) and in the baboon (Gasser& Wise, 1972). Three ciliary nerves were present in the hedgehog and four nerves in the bat (Hegazy & Mostafa, 1990). Four or five nerves were reported in the rhesus monkey (Kuntz, 1933; Bast, 1933). Twelve to fifteen ciliary nerves were present in humans (Cunningham, 1931).

In *Coluberrogersi*, there is no sympathetic connection with the ciliary ganglion or with the ciliary nerves. This agrees with the finding of Auen and Langebartel (1977) in the two colubrid snakes *Elapheobsolete* and *Thamnophis ordinoides*, Mostafa (1990b) in the snake *Spalerosophis diadema*, El-Ghareeb *et al*. (2004b) in *Natrix tessellata*. Among lizards, it is absent as mentioned by Soliman (1968) in the lizards *Acanthodactylus boskiana* and *Lacerta viridis*, Mostafa and Hegazy (1990) in the agamid *Agama sinaita*. Again it is not found in Chelonia as recorded by Soliman (1964) in the chelonians *Chelydra serpentine* and *Chelone imbricate*. However, a sympathetic connection is established with the ciliary nerves distal to the ganglion in the snakes *Psammophis sibilans* and *Cerastesvipera* (Hegazy, 1976). It is also mentioned in the lizard *agamamutabilis* (Soliman, 1968), *Chalcides ocellatus* (Soliman & Hegazy, 1969), *Agama pallida* (Soliman *et al*., 1984) and in the amphisbaenian *Diplometopon zarudnyi* (Dakrory, 1994).

In birds, there is no connection between the ciliary ganglion or the ciliary nerves and the internal carotid plexus. This was confirmed by several authors as Schwalbe (1879), Holtzmann(1896), Cords (1904), Carpenter (1906), Lenhossék (1912), Webb (1957), Àbrahàm and Stammer (1966), Abdel-Kader and Fathy (2000). Thus it can be stated that the absence of the sympathetic root is a common character among birds, so far described.

In mammals, Kurus (1956) reported that the sympathetic connection between the ciliary ganglion and the internal carotid sympathetic plexus was present in mammals. This connection was reported by Winckler (1937) in rhesus monkey, Taylor and Weber (1969) in cat and Hegazy and Mostafa (1990) in the hedgehog and the bat. On other hand, Lenhossék (1912) mentioned that the sympathetic root may be absent in humans. This connection was also absent in the ox (Schachtschabel, 1908) and in the goat, sheep and ox (Godinho & Getty, 1971). On the contrary, Cunningham (1931) and Kuntz (1934) reported that the sympathetic root of the ganglion in humans may or may not be carries by nasociliary nerve.

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List of Abbreviations

B	: Brain.
CO.TR	: Common trunk.
CO.BR	: Common branch.
D.PR.FR	: Descending process of the frontal.
E	: Eye.
G.CL	: Ciliary ganglion.
G.OPH	: Ophthalmic ganglion.
M.PR.PT	: Protractor pterygoideus muscle.
M.RT.PT	: Retractor pterygoideus muscle.
M.RL	: Rectus lateralis muscle.
N.III	: Nervus oculomotorius.
N.IV	: Nerus trochlearis.
N.OIF	: Nerve to the obliquus inferior muscle.
N.OSP	: Nerve to the obliquus superior muscle.
N.RIF	: Nerve to the rectus inferior muscle.
N.RM	: Nerve to the rectus medialis muscle.
N.VI	: Nervus abducens.
Nn.CL	: Ciliary nerves.
NV4	: Constrictordorsalis nerve.
OP.CH	: Optic chiasma.
R.FR.V	: Ramus frontalis of the nervus trigeminus.
R.IF.III	: Ramus inferior of the nervus oculomotorius.
R.NA.V	: Ramus nasalis of the nervus trigeminus.
R.OPH.PR	: Ramus ophthalmicus profundus.
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 abducence.
VC	: Vidian canal.

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