Comparative Anatomical Study on The Ciliarly Ganglion of Lizards  
(Reptilia - Squamata - Lacertilia)

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Abstract: The ciliary ganglion is a well-defined ovate ganglionic mass in the three species studied Uromastix aegyptius, Sphenops sepsoides and Varanus griseus. The ganglion consists of bipolar neurons in the three species studied. In both Uromastix and Sphenops the neurons are of two sizes large and small, while in Varanus they are of one and the same size. In the three species studied, the ciliary ganglion has three roots, parasympathetic (motor), sympathetic and sensory roots. The parasympathetic root is represented by the radix ciliaris brevis which arises from the ramus inferior of the nervus oculomotorius. The sympathetic root arises from the internal carotid plexus and joins the ganglion in both Sphenops and Varanus while it joins the ciliary nerve in Uromastix. The sensory root is formed of the radix ciliaris longa which connects the ramus nasalis of the nervus trigeminus and the ciliary ganglion in Varanus and the ciliary nerve in Sphenops and both in Uromastix. The ciliary ganglion gives off one ciliary nerve in both Uromastix and Sphenops whereas, it gives rise to two nerves in Varanus.

Key words: Ciliary ganglion - Lacertilia - Uromastys aegyptius - Sphenops sepsoides Varanus griseus.

INTRODUCTION

The ciliary ganglion is a cranial parasympathetic ganglion that is located in the postorbital region of the head in the majority of vertebrates. Such ganglion is well represented in reptiles, birds and mammals. However, it seems to be transitory or absent to large extent in Amphibia (Norris, 1908; Kuntz, 1914; Paterson, 1939; Dakrory, 2002). Among fishes, the ciliary ganglion is either present and well developed (Freihofer, 1978; Piotrowski and Northcutt, 1996; Dakrory, 2000 & 2003; Ali and Dakrory, 2008) or totally absent (Jenkin, 1928; Chandy, 1955). In reptiles, the ciliary ganglion together with the ocular muscles and their nerves are vestigial in the blind snake Leptotyphlops cairi (Abdel-Kader, 2005).

Functionally, the ciliary ganglion plays a major role in both the accommodation of the eye and animal behavior (Evans and Minckler, 1938; Bullock et al., 1977; Guyton and Hall, 1996). Dakrory (2003) observed a close relation of the ciliary ganglion development and habit of the fishes. The ganglion is well developed in the diurnal and surface feeding fishes and is poorly developed in the fishes living in turbid lightless water, nocturnal fishes and bottom feeding fishes.

The nature of the ciliary ganglion and its relation in reptiles has attracted the attention of anatomists a long time ago; Haller von Hallerstein (1934), Evans and Minckler (1938), Santamaria-Arnaiz (1959), Soliman (1968), Mostafa and Hegazy (1990), Mostafa (1991) and Abdel-Kader et al. (2007). There was an obvious contradiction between the observation of Haller von Hallerstein (1934) and that of Santamaria-Arnaiz (1959) on the formation of the ganglion. So, this point needs further investigation.

The ciliary ganglion possesses two roots; radix ciliaris brevis and radix ciliaris longa in lacertilian species (Soliman, 1968) and in Agama sinaia and Stenodactylus slevini (Mostafa and Hegazy, 1990), where as in Eumeces schneideri extra-sympathetic root from the carotid plexus is observed.

The sympathetic connection with the ganglion in reptiles has not yet been well-defined (Soliman, 1968; Mostafa and Hegazy, 1990; Mostafa, 1991; Dakrory, 1994; Abdel-Kader, 2006; El-Bakry et al., 2007; Abdel-Kader et al., 2007). The number of the ciliary nerves arising from the ganglion varies from one to three among reptiles.

There are conflicting points of view among investigators, not only regarding the origin of the ciliary ganglion, but also in regard to the nature of its cells, the number of ganglion roots, its sympathetic connection.
and the number of ciliary nerves. This wide diversity in the opinions about the ciliary ganglion and its relationships seems to be a sufficient reason for the study of this subject.

From the present point of view, this study may anticipate for a new anatomical evidence from lacertilian to support ideas in the reptilian evolution. Also, it may help us to understand the phylogenetic relation between Lacertilia and other reptiles.

**MATERIAL AND METHODS**

Three lacertilian species belonging to three different families were chosen for this study; *Uromastyx aegyptius* (Family: Agamidae), *Sphenops sepsoides* (Family: Scincidae) and *Varanus griseus griseus* (Family: Varanidae).

*Uromastyx aegyptius* is also known as spiny-tailed lizard or dabb lizard. This species inhabits hard sand and gravel desert, preferring flat areas with light vegetation. It is primarily herbivorous, but occasionally eat young insects. It digs deep burrows in the hard soil usually with single entrance. It is diurnal species that spends most of its walking hours basking in the sun near the burrow entrance especially at morning time. This species is adapted to the arid habitat. It is found throughout North Africa, Middle east across south-central Asia and into India. Female dobb lizard can lay from 5 to 40 eggs. The eggs are laid (at July to August) approximately 30 days after copulation with an incubation time of 70-80 days. The specimens are collected from Gabal Al-Maghara, South of El-Arish City, Northern Sinai, Egypt.

The embryos of *Uromastyx* were collected during the last days of the incubation period. After careful removing of the embryos from the shells, they were fixed immediately in an aqueous Bouin's fluid for 24 hours.

*Sphenops sepsoides* is a sand dwelling fossorial species with extremely reduced limbs for sand locomotion. It is found in a wide variety of habitats; ranging from depressions of Western desert to the sand spots in the rock wadies of Eastern desert and Sinai. It appears to be nocturnal and feeds entirely on fossorial insects (i.e., insectivore), this species is ooviviparous.

The embryos of *Sphenops sepsoides* are collected from two pregnant females in the lab. The fully formed embryos were fixed immediately in aqueous Bouin's fluid for 24 hours.

*Varanus griseus griseus* is a large diurnal lizard. It feeds on lizards, snakes, and rodents. This species lives in sandy areas throughout the Western and Eastern desert and Northern of Sinai. It is found in North Africa and Western Asia. The desert monitor lizards move in groups on searching for food.

Ten youngs (newly hatched) *Varanus* were collected from Romana tritories at El-Arish city, Northern of Sinai. These youngs, after being anaesthetized, were fixed in aqueous Bouin's fluid for 36 hours.

After fixation, the specimens of both *Uromastyx* and *Varanus* were passed into decalcificating EDTA solution for about 30 to 50 days. Then washed in distilled water and transferred to 70% ethyl alcohol for 48 hours. The embryos were embedded in paraffin wax then transversely serially sectioned at 10 μm thickness in *Uromastyx* and 15 μm in both *Sphenops* and *Varanus*. The serial sections were then stained in Mallory's triple stain for *Uromastyx* and *Varanus* and in haematoxylin and then counter stained with eosin for *Sphenops*. The serial sections were drawn by the projector and graphic reconstructions of the ciliary ganglion were made. Photomicrographs for parts of the transverse sections were made to elucidate the position and relations of the ganglion to the other structures of the head.

**RESULTS AND DISCUSSIONS**

*Results:*

The ciliary ganglion in the three species studied appears as a well-defined ovate ganglionic mass, which is located posteriorly in the orbital region. The ciliary ganglion occupies a different position from one species to another.

In *Uromastyx aegyptius*, the ciliary ganglion (Fig. 5, G.C) located medial to both the eyeball (E) and the ciliary nerve (N.C), dorsal to the rectus lateralis muscle (M.RL), ventrolateral to the rectus superior muscle (N.RS), and ventromedial to the ramus nasalis of the nervus trigeminus (R.N.A.V).

In *Sphenops sepsoides*, such ganglion (Figs. 6 & 7, G.C) lies between the arms of the oblique U-shaped rectus lateralis muscle (M.RL). This muscle surrounds the ganglion dorsally, laterally and ventrally, it is surrounded medially by the optic nerve (OP.N).

In *Varanus griseus griseus*, this ganglion (Figs. 8 & 9, G.C) is situated ventrolateral to both the rectus superior muscle (M.RS) and the ramus superior of the nervus oculomotorius (R.S.P.III), ventromedial to both
the ramus nasalis of the nervus trigeminus (R.NA.V) and the retractor occuli muscle (M.REO), dorsomedial to the bursalis muscle (M.BU) and dorsal and dorsolateral to the rectus lateralis muscle (M.RL).

The ciliary ganglion measure about 250 μm in *Uromastyx aegyptius*, 132 μm in *Sphenops sepsoides* and 526 μm in *Varanus griseus griseus*.

In the three studied lacertilian species, light microscopic investigation reveals that the ciliary ganglion consists mainly of bipolar neurons. These cells are distinct and have the same size in *Varanus* (Figs. 1 & 9), while in both *Uromastyx* (Figs. 1 & 4) and *Sphenops* (Figs. 3 & 7) the ganglion consists of large (LN) and small (SN) cells.

In the three species investigated, the ciliary ganglion is connected with the ramus inferior of the nervus oculomotorius via the radix ciliaris brevis. The latter is large and stout in both *Uromastyx* and *Varanus* and it is small in *Sphenops*. It carries the preganglionic parasympathetic fibres of the nervus oculomotorius to the ganglion, i.e., it is the parasympathetic (motor) root of the ganglion.

In *Uromastyx aegyptius* (Fig. 1, RCB), the radix ciliaris brevis arises from the dorsolateral side of the inferior oculomotor ramus just ventral to the origin of the rectus superior muscle. It runs forwards for a short distance, where it receives a fine branch from the radix ciliaris longa (Fig. 1) and continues to enter the ganglion. In *Sphenops sepsoides* (Fig. 3, RCB) the radix ciliaris brevis separates from the dorsolateral side of the inferior ramus of the nervus oculomotorius medial to the rectus lateralis muscle. It runs anteriorly for a short distance to enter the ganglion. In *Varanus griseus griseus* (Figs. 2 & 8, RCB), radix ciliaris brevis originates from the lateral side of the inferior ramus of the oculomotor nerve. It extends anterolaterally, passing dorsal to the rectus lateralis muscle, medial to the retractor oculi muscle, ventromedial to the radix ciliaris longa, ventral to the ramus superior of the oculomotor nerve and ventromedial to the origin of the rectus superior muscle. Anteriorly, the radix ciliaris brevis fuses with the radix ciliaris longa just, at the posterior extremity of the ciliary ganglion (Fig. 8).

In the present study, the light microscopic examination elucidated that, there is a connection between the ramus nasalis of the ophthalmic ramus of the nervus trigeminus and the ciliary ganglion, through the radix ciliaris longa. It transmits the sensory fibres of the ramus nasalis to the ganglion; i.e., it represents the sensory root of the ganglion.

In *Uromastyx aegyptius* (Fig. 1, RCL), the radix ciliaris longa arises from the ventromedial side of the ramus nasalis of the ophthalmic ramus of the trigeminal nerve. It runs anteriorly in a ventromedial direction passing ventral to the ramus superior of the oculomotor nerve and dorsal to the rectus lateralis muscle. Thereafter, it continues forwards, running ventromedial to both the rami nasalis of the nervus trigeminus and superior of the nervus oculomotorius, ventral to the rectus superior muscle and lateral to the radix ciliaris brevis where a fine medial branch originates. This fine branch fuses with the radix ciliaris brevis, as previously mentioned (Fig. 1). Shortly anterior to this fusion, the ganglion is located. The main radix ciliaris longa, continues anteriorly passing lateral to the ganglion, dorsomedial to the rectus lateralis muscle and ventral to the rectus superior muscle. Thereafter, it becomes dorsolateral and then lateral to the ganglion; where it incorporates within the connective tissue sheath of the ganglion (Fig. 4, RCL) without intermingling with its neurons, till it leaves the ganglion with the ciliary nerve (Figs. 1 & 4).

In *Sphenops sepsoides*, the radix ciliaris longa separates from the medial side of the ramus nasalis of the ophthalmic ramus of the trigeminal nerve (Fig. 3, RCL). It runs anteriorly and then shifts ventrally passing dorsal and then medial to the rectus lateralis muscle. Thereafter, it runs laterally touching the ciliary ganglion from its dorsal side (Figs. 1 & 7, RCL), i.e., it has no synaptic relation with the ganglionic cells. Finally, it enters the ciliary nerve together with the postganglionic nerve fibres.

In *Varanus griseus griseus* (Figs. 2 & 8, RCL), the radix ciliaris longa originates from the medial side of the ramus nasalis of the ophthalmic ramus of the nervus trigeminus. It runs forwards in a ventromedial direction extending ventromedial to the ramus superior of the oculomotor nerve, dorsolateral to the ramus inferior of the oculomotor nerve and dorsomedial to the retractor oculi muscle (Fig. 8). Shortly anterior, it shifts ventrally and laterally to fuse with the radix ciliaris brevis. Shortly anterior to this fusion the ciliary ganglion is found (Figs. 2 & 8).

In the present study, the light microscopic investigation demonstrates that there is a sympathetic connection between the ciliary ganglion and the sympathetic carotid plexus in both *Varanus griseus griseus* (Figs. 2 & 9, R.SY), and *Sphenops sepsoides* (Figs. 3 & 7, R.SY), while in *Uromastyx aegyptius*, this connection is with the ciliary nerve after its origin from the ganglion (Figs. 1 & 5, R.SY).

In both *Uromastyx aegyptius* and *Sphenops sepsoides* there is only one ciliary nerve originating from the ganglion, while in *Varanus griseus griseus* two ciliary nerves are found.
Fig. (1): Reconstruction of the ciliary ganglion of *Uromastyx aegyptius* in a lateral view; Fig. (2): Reconstruction of the ciliary ganglion of *Varanus griseus griseus* in a lateral view; Fig. (3): Reconstruction of the ciliary ganglion of *Sphenops sepsoideus* in a lateral view. G.C, Ciliary ganglion; LN, Large neurons; N.C, Ciliary nerve; N.III, Oculomotor nerve; Nn.C, Ciliary nerves; R.IF.III, Ramus inferior of the nervus oculomotorius; R.NA.V, Ramus nasalis of the nervus trigeminus; R.SP.III, Ramus superior of the nervus oculomotorius; R.SY, Sympathetic ramus connecting the ciliary ganglion with the internal carotid plexus; RCB, Radix ciliaris brevis; RCL, Radix ciliaris longa; SN, Small neurons.
Fig. (4): A photomicrograph of a part of a transverse section of *Uromastyx aegyptius* passing in the postorbital region showing the shape, position and types of neurons of the ciliary ganglion. X100 (Scale bar 2 mm); Fig. (5): A photomicrograph of a part of a transverse section of *Uromastyx aegyptius* showing the position of the ganglion, the sympathetic ramus and the origin of the ciliary nerve. X40 (Scale bar 1 mm); Fig. (6): A photomicrograph of a part of a transverse section of *Sphenops sepsoides* demonstrating the position of the ciliary ganglion. X40 (Scale bar 1 mm); B, Brain; E, Eyeball; G.C, Ciliary ganglion; IOR.S, Interorbital septum; LN, Large neurons; M.RIF, Rectus inferior muscle; M.RL, Rectus lateralis muscle; M.RS, Rectus superior muscle; N.C, Ciliary nerve; OP.N, Optic nerve; R.IF.III, Ramus inferior of the nervus oculomotorius; R.NA.V, Ramus nasalis of the nervus trigeminus; R.SY, Sympathetic ramus connecting the ciliary ganglion with the internal carotid plexus, RCL, Radix ciliaris longa; SN, Small neurons; TCO, Trabecula communis.
FIG. (7): A photomicrograph of a part of a transverse section of *Sphenops sepsoides* passing in the postorbital region demonstrating the two types of neurons of the ganglion and the radix ciliaris longa touching the dorsal side of the ciliary ganglion. X100 (Scale bar 2 mm); Fig. (8): A photomicrograph of a part of a transverse section of *Varanus griseus griseus* showing both the origin of the radix ciliaris longa from the ramus nasalis, the radix ciliaris brevis and their fusion. X40 (Scale bar 1 mm); Fig. (9): A photomicrograph of a part of a transverse section of *Varanus griseus griseus* illustrating both the position and structure of the ciliary ganglion as well as its sympathetic root. X100 (Scale bar 2 mm); B, Brain; G.C, Ciliary ganglion; LN, Large neurons; M.BU, Bursalis muscle; M.REO, Retractor oculi muscle; M.RL, Rectus lateralis muscle; M.RS, Rectus superior muscle; OP.N, Optic nerve; R.NA.V, Ramus nasalis of the nervus trigeminus; R.SP.III, Ramus superior of the nervus oculomotorius; R.SY, Sympathetic ramus connecting the ciliary ganglion with the internal carotid plexus, RCB, Radix ciliaris brevis; RCL, Radix ciliaris longa; SN, Small neurons.
In *Uromastyx aegyptiuis* (Figs. 1 & 5, N.C), one large ciliary nerve arises from the dorsolateral side of the ganglion. It receives a fine branch from the carotid plexus, directly after its origin as previously mentioned (Fig. 1). After this anastomosis the ciliary nerve extends posteriorly and laterally to enter the eyeball through a foramen in the cartilaginous sclera of the eyeball (Fig. 5, N.C). Within the choroid of the eyeball, the ciliary nerve runs ventrally in the anterolateral direction till it reaches the iris and the ciliary body where it terminates. In *Sphenops sepsoides* (Fig. 3, N.C), one ciliary nerve arises from the anterolateral side of the ganglion. It extends anterolaterally being lateral to the optic nerve penetrating the rectus lateralis muscle. This nerve enters the eyeball through its own foramen in the cartilaginous sclera, posterior to the entrance of the optic nerve. Within the eyeball the ciliary nerve runs anterolaterally in the choroid giving fine branches for its blood vessels, till they reach the iris and ciliary muscles where it ends.

In *Varanus griseus griseus*, two ciliary nerves, one lateral and the other medial, originate from the anterior end of the ganglion (Fig. 1, Nn.CL). These nerves run ventral to both the ramus nasalis of the nervus trigeminius and the rectus superior muscle and dorsal to the rectus lateralis muscle. Thereafter, the ciliary nerves continue running ventrolateral to the optic nerve, dorsal to the rectus lateralis muscle and medial to the eyeball. More forwards, the two nerves fuse together and continue till they reach the medial side of the eyeball. Here they give off a fine branch for the blood vessels. The fused ciliary nerves, then pass laterally ventral to the eyeball. After a considerable forward course, the ciliary nerves enter the eyeball through a foramen excavated in the cartilaginous sclera. Within the eyeball, the ciliary nerves run anterolaterally in the choroid giving fine branches for its blood vessels, till they reach the iris and ciliary muscles where they end.

**Discussion:**

A distinct ciliary ganglion is found in the posterior orbital region of the three examined species. In addition, an accessory ciliary ganglion was described by Christensen (1935) in the cat and by Godinho (1972) in the pig. From the description cited in the reptilian literature, the present author is inclined to record the absence of such an accessory ciliary ganglion in reptiles.

According to the observed structure of the ciliary ganglion, two types of neurons are recognized; large neurons and small ones, that are equally distributed in the ganglion of both *Uromastyx* and *Sphenops*, whereas the ciliary of *Varanus* composed of only one type of neurons. Similar result that found in both *Uromastyx* and *Sphenops* was described by Mostafa and Hegazy (1990) in both *Agama* and *Stenodactylus*. However, in *Agama pallida* (Soliman et al., 1984), *Eumeces schneideri* (Mostafa and Hegazy, 1990) in the amphibious *Diplometapon zaruanyi* (Dakrory, 1994) and in the serpent *Natrix tesselata* (El-Ghareeb et al., 2004), the ciliary ganglion is divided into two distinct regions, large neurons at the periphery and small ones at the centre. On the other hand, the ciliary ganglion of the studied *Varanus griseus* is undivided and the neurons are homologous all over the ganglion. Similar pattern structure was found in *Anolis carolinensis* (Willard, 1915), *Chalcides ocellatus* (Santamaria-Arnaiz, 1959; Soliman and Hegazy, 1969), *Ptyodactylus hasselquistii*, *Lacerta viridis*, *Acanthodactylus boskiana*, *Agama mutabilis* and *Mabuya quinquetaeniata* (Soliman, 1968), *Tarentola mauritanica* (Soliman and Mostafa, 1984), *Acanthodactylus opheodurus* (Mostafa, 1990), *Mabuya quinquetaeniata* (Abdel-Kader et al., 2007) and *Tropiocolotes tripolitanus* (El-Bakry et al., 2007). The same finding was also observed in the ophidian studied by Galvao (1917), Hegazy (1976) and Mostafa (1990 & 1991). In this respect, Haller von Hallerstein (1934) described the ciliary ganglion of reptiles and birds confirming the existence of two parts; the first is composed of small neurons, while the second is formed of large ones. This finding was mentioned in birds by Oehme (1968), Soliman et al. (1976) and Abdel-Kader and Fathy (2000). In this context, Bullock et al. (1977), stated that, the ciliary ganglion of chick is composed of two cell populations, one controlling the smooth muscles in the choroid and the other for the iris and ciliary body. The same was mentioned by Radzimirska (2003) in the domestic turkey, *Meleagris gallopavo domesticus*.

In mammals, the ciliary ganglion is undivided into two regions in any case. These pattern structure was observed in cat (Taylor and Weber, 1969), guinea pig (Watanabe, 1972), in man (Stefani, 1972) and in both the hedgehog and bat (Hegazy and Mostafa, 1990).

In the three species studied, the ciliary ganglion is connected with the ramus inferior of the nervus oculomotorius by a well-distinct branch; the radix ciliaris brevis. This was mentioned by Willard (1915) in *Anolis carolinensis* and by Abdel-Kader et al. (2007) in *Mabuya quinquetaeniata*. However, in *Lacerta viridis*, the ciliary ganglion receives another branch from the nervus oculomotorius, a little anterior to the entrance of the radix ciliaris brevis (Soliman, 1968). On the other hand, the radix ciliaris brevis is very extremely short so that the ganglion appears touching the nervus oculomotorius in *Lacerta agilis* and *Lacerta muralis* (Lenhosséck, 1912) and *Ptyodactylus hasselquistii* (Soliman, 1968; Abdel-Kader, 1990). In contrast, the ciliary
ganglion is firmly attached to the ramus inferior of the nervus oculomotorius, i.e., the radix ciliaris brevis is lacking and the preganglionic parasympathetic fibres are transmitted directly to the ganglion through the intermingling surface in the geckos Tarentola mauritanica (Soliman and Mostafa, 1984), Stenodactylus slevini (Mostafa and Hegazy, 1990) and Tropidocotyes tripolitanus (El-Bakry et al., 2007) and in the amphibiaenian Diplometopon zarudnyi (Dakrory, 1994).

Among birds, the preganglionic parasympathetic fibres, carried by the nervus oculomotorius are transmitted to the ciliary ganglion either through an anastomosing branch; the radix ciliaris brevis or through the direct attachment of the ganglion to the ramus inferior of the nervus oculomotorius. The radix ciliaris brevis is mentioned in Struthio (Webb, 1957), in Upopa epops and Passer domesticus (Soliman et al., 1976) and in Merops albicollis (Abdel-Kader and Fathy, 2000). On the other hand, the ciliary ganglion is firmly attached to the ramus inferior of the nervus oculomotorius with the absence of the radix ciliaris brevis in the chick (Carpenter, 1906), in Streptopelia senegalensis (Soliman et al., 1976) and in Gallinula chloropus (Abdel-Kader, 1999).

Concerning mammals, Schwalbe (1879) reported that not all the higher vertebrates possess a short root, as it is the case in many mammals (sheep, calf, dog, rabbit), and the ganglion is situated directly on the trunk of the nervus oculomotorius. The same condition was described by Christensen (1935) in the cat, Godinho (1972) in the ruminants, Watanabe (1972) in the guinea pig, Hegazy and Mostafa (1990) in both the hedgehog and bat, Sinnreich and Nathan (2003) in the man and by Nowak et al. (2004) in the Egyptian spiny mouse, Acomys cahirinus. In the baboon Papio cenocephalus, on the other hand, the ciliary ganglion receives two branches from the ramus inferior (Gasser and Wise, 1972).

Among fishes, the preganglionic parasympathetic fibres of the nervus oculomotorius are transmitted to the ciliary ganglion by branch, i.e., the radix ciliaris brevis in Lampsanycus teucropsorus (Ray, 1950), Pseudorhombus aruus (Marathe, 1955) Polypeterus senegulus (Piotrowski and Northcutt, 1996) and in Filapia zillii (Dakrory, 2003; Ali, 2005). On the other hand, such fibres are transmitted directly to the ganglion through the intermingling surface between them, i.e., no radix ciliaris brevis in Polycentrus schomburgki (Freihofer, 1978), Trichiusus lepatus (Harrison, 1981), Ctenopharyngodon idellus (Dakrory, 2000) and in both Mugil cephalus and Gambusia affinis affinis (Dakrory, 2003).

In the present study, the radix ciliaris longa transmits the sensory fibres from the ramus nasalis (branch of the ramus ophthalmicus) of the nervus trigeminius to the ciliary ganglion or ciliary nerves or both. In this respect, the case in Squamata is variable. The radix ciliaris longa passes directly to the ciliary ganglion in different snakes and lizards belonging to different families. This was found in the lizards Varanus bivittatus (Watkinson, 1906), Anolis carolinensis (Willard, 1915); Lacerta viridis, Acanthodactylus boskiana, Agama mutabilis and Mahuya quinquetaeniata (Soliman, 1968), Agama pallida (Soliman et al., 1984), Agama sinaia, Stenodactylus slevini and Eumeces schneidri (Mostafa and Hegazy, 1990). The same condition was also recorded in the snakes Psammophis sibilans and Cerastes viperas (Hegazy, 1976), Coluber elegantissimus, Psammophis schokari and Spalerosophis diadema (Mostafa, 1991), Natrix tessellate (El-Ghareeb et al., 2004) and in Telecsopus dhara (Abdel-Kader, 2006). This is the case found in the Varanus griseus of the present study.

In the gecko Gymnodactylus kotschyi (Evans and Minckler, 1938) and in the amphibiaenian Diplometopon zarudnyi (Dakrory, 1994), however, the radix ciliaris longa joins both the ciliary ganglion and the ciliary nerve distal to the ganglion a case which is somewhat similar to that found in Uromastyx aegyptius studied, 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) and the snake Eryx jactus (Hegazy, 1976), 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; a case which is homologous to that found in Sphenops sepesoides studied. Also, Osawa (1898) found that the radix ciliaris longa did not enter the ganglion, but it joined the ciliary nerves in Hatteria punctata.

In birds, no direct connection appears to exist between the ciliary ganglion and the ramus ophthalmicus. Such connection, however, is carried out between the latter ramus and the ciliary nerves distal to the ganglion. This appears to be common in birds; as described by Soliman et al. (1976). However, a direct connection between the ramus ophthalmicus and the ciliary ganglion were described. It was mentioned in Struthio (Webb, 1957), Upopa epops (Soliman et al., 1976) and in Merops albicollis (Abdel-Kader and Fathy, 2000). On the other hand, Bonsdroff (1952) described, for the crona, two rami from the nervus trigeminius, which have the typical relations of the long root (radix ciliaris longa) of the ganglion.
In mammals, the sensory fibres are carried to the ciliary ganglion through the ramus ophthalmicus of the trigeminal nerve. In the rhesus monkey (Christensen, 1933), and in both the hedgehog Hemiechinus auritus and in the bat Rhosettus aegyptiacus (Hegazy and Mostafa, 1990), the ganglion receives sensory fibres constituting its sensory root via a branch which connects it with the long ciliary nerve of the nasociliary branch. The communicating branch, i.e., the sensory root, however, is directly given off from the nasociliary branch in the rhesus monkey (Kuntz, 1933), in domestic ruminants (Godinho and Getty, 1971) and in the baboon (Gasser and Wise, 1972). However, there is no direct connection between the ciliary ganglion and the nasociliary branch in the cat (Dupas, 1924; Christensen, 1935) and in the rhesus monkey (Bast, 1933) and hence the so-called sensory root of the ganglion is not found. In such species, the connection, however, is carried out between the long ciliary nerve of the nasociliary branch and one of the short ciliary nerves arising from the ganglion. At the point of union between the long and the short ciliary nerves distal to the ganglion, accessory ciliary ganglia are usually found, as stated by Christensen (1935).

A connecting branch between the ciliary ganglion and the ramus maxillaries of the trigeminal nerve was recorded in several mammalian species. It was described in the ox by Mobillio (1912), in the baboon by Gasser and Hendricks (1969) and in the goat, sheep and ox by Godinho and Getty (1971). Only, Mobillio (1912) considered such a branch as a sensory root entering the ciliary ganglion, in addition to another root originating from the nasociliary branch.

Schawlbé (1879) did not find any connection between the ciliary ganglion (ganglion oculomotorius) and the nervus trigeminus in several vertebrate species. Jegorow (1887), however, asserted that such a connection is constant and necessary for the existence of the ganglion, throughout the vertebrate series. On the other hand, Holtzmann (1896) found that the ciliary ganglion in amphibians birds and mammals is more intimately connected with the nervus oculomotorius than with the trigeminal one.

From the above discussion, it is thoroughly evident that both roots; radix ciliaris brevis and radix ciliaris longa, communicate, for the most part, with the ganglion separately. This was also the case found in the bony fish Tilapia zilli (Dakrory, 2003). This is in contrast to the condition found in Varanus griseus of this study, where both the radix ciliaris brevis and radix ciliaris longa are fused just posterior to the ganglion. This is the case found in the cyprinid fish Ctenopharyngodon idelus (Dakrory, 2000).

In the present study, there is a sympathetic connection (sympathetic root) between the carotid plexus and the ciliary ganglion in Sphenops seposoides and between both the ganglion and its nerves distal to the ganglion in Varanus griseus and between the plexus and the ciliary nerve distal to the ganglion in Uromastyx aegyptius. Among reptiles, this condition is variable. Similar condition to that found in Sphenops and Varanus, i.e., the sympathetic root connects the ganglion was recorded in the gecko Gymnodactylus kotschi (Evans and Minckler, 1938), in Priodactylus hasselquistii and Mabuya quinquetenata (Soliman, 1968), Tarentola mauritanica (Soliman and Mostafa, 1984) and Eumeces schneideri (Mostafa and Hegazy, 1990). In Ophidia it is found in the serpent Eryx jacoius (Hegazy, 1976) and in the chelonian Trionyx japonicus (Ogushi, 1913). On the other hand, a connection between the carotid plexus and the ciliary nerve found in Uromastyx aegyptius studied was, also described in the lizards Agama mutabilis (Soliman, 1968), Chalcides ocellatus (Soliman and Hegazy, 1969), Agama pullida (Soliman et al., 1984). The same results was mentioned by Hegazy (1976) in the snakes Psammophis sibilans and Cerastes vipera, in the snakes studied by Mostafa (1991) and in the snake Telescopus dhara by Abdel-Kader (2006). It is also found in the amphibiaenian Diplometopon zarudymyi (Dakrory, 1994).

However, the sympathetic connection with the ciliary ganglion or with the ciliary nerves was not found in Lacerta viridis and Lacerta ocellatus (Weber, 1877), Lacerta muralis (Lenhossek, 1912), Acanthodactylus boskiana and Lacerta viridis (Soliman, 1968), Acanthodactylus ophiourus (Mostafa, 1990) and in Agama sinaita, Stenodactylus slevini (Mostafa and Hegazy, 1990), in Mabuya quinquetenata (Abdel-Kader et al., 2007) and Tropiocolotes trilopiatus (El-Bakry et al., 2007). It is also absent in the serpents Spalerosophis diadema (Mostafa, 1990) and Natrix tessellate (El-Ghareeb et al., 2004). Such connection was found to be also lacking in the chelonian Chelydra serpentina and Chelone imbricata (Soliman, 1964).

Among fishes, such connection, i.e., sympathetic root, appears to be found in most bony fishes (Dakrory, 2003; Ali, 2005).

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 Webb (1957), Oehme (1968), Soliman et al. (1976) and 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 this respect, the condition observed in birds is quite different from that in mammals. Kurus (1956) stated that, the sympathetic connection (Sympathetic root) between the ciliary ganglion and the carotid plexus is, generally, present in mammals. The sympathetic root of the ganglion was described by Winkler (1932) in
the rhesus monkey, Taylor and Weber (1969) in the cat and by Hegazy and Mostafa (1990) in the hedgehog and the bat. However, Lenhossek (1912) mentioned that the sympathetic root may be absent in human being. This root was found to be absent in the ox (Schachtschabel, 1908) and in the goat, sheep and ox (Godinho and Getty, 1971). On the other hand, Cunningham (1931) and Kuntz (1934) mentioned that the sympathetic root of the ganglion in man may or may not be incorporated with the nasociliary branch.

In this study, there is only one ciliary nerve arising from the ciliary ganglion in both Uromastyx aegyptius and Sphenops seposoids and two nerves in Varanus griseus griseus. Among reptiles, the number of ciliary nerves ranges from one to three. One ciliary nerve was found in Chalcides ocellatus (Santamaria-Arnaiz, 1959; Soliman and Hegazy, 1969), Pydactylus hasselquistii, Acanthodactylus boskiana and Lacerto viridis (Soliman, 1968), Acanthodactylus opheodurus (Mostafa, 1990) and Diplometopon zarudnyi (Dakrory, 1994). The same was present in the snakes Psammophis sibilans and Eryx jaculus (Hegazy, 1976), in all serpents studied by Mostafa (1991). There are two nerves in Varanus bivittatus (Watkinson, 1906), Anolis carolinensis (Willard, 1915), Mabuya quinquetaeniata (Soliman, 1968; Abdel-Kader et al., 2007), Agama mutabilis (Soliman, 1968), Tarentola mauritanica (Soliman and Mostafa, 1984), Agama pellida (Soliman et al., 1984) in all the lizards studied by Mostafa and Hegazy (1990), and in Tropiacolotes tripolitanus (El-Bakry et al., 2007). There are also two in the snakes Cerastes vipera (Hegazy, 1976), Natrix tessellate (El-Ghareeb et al., 2004) and Tlescopus dhara (Abdel-Kader, 2006). Also two ciliary nerves were found in the chelonians Chelydra serpentine and Chelone imbricata (Soliman, 1964). Three ciliary nerves were present in the gecko Gymnodactylus kotchyi (Evans and Minckler, 1938).

Among birds, the number of the ciliary nerves varies from species to another. Schwalbe (1879) mentioned 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 detected in the chick (Carpenter, 1906) and also in Merops albicollis (Abdel-Kader and Fathy, 2000). However, Seto (1931) found five ciliary nerves in the chick. Two ciliary nerves were present in Striptopelia senegalensis (Soliman et al., 1976) and in Meleagris gallopavo domesticus (Radzimirska, 2003) three ciliary nerves were found in 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).

The number of the ciliary nerves arising from the ciliary ganglion is also variable among mammals. Two ciliary nerves were found in the cat by Taylor and Weber (1969) and in the baboon by Gasser and Wise (1972). Three ciliary nerves were found in Hemiechinus auritus and four ones in Rhosettus aegypticus arising from the ciliary ganglion as mentioned by Hegazy and Mostafa (1990). Four to five ciliary nerves were present in the rhesus monkey (Bast, 1933; Kuntz, 1933). Twelve to fifteen ciliary nerves were found in man by Cunningham (1931).

Concerning the development of the ciliary ganglion, Béraneck (1884), dealing with Lacerta agilis, related the origin of the ganglion to the nervus oculomotorius. The description given by Hoffmann (1886) of the development of this ganglion is quite different from that of Béraneck (1884), although both authors dealt with the same species. Hoffmann (1886) stated that the cells of the ciliary ganglion separate from the ophthalmic ganglion (nervus trigeminus). Lenhossek (1912), on the other hand, dealing with Lacerta agilis and Lacerta muralis, agreed with the finding of Beranèck (1884), but he mentioned that the ciliary ganglion, in the two species, is principally formed from cells arising in the central nervous system. Also Santamaria-Arnaiz (1959), dealing with Chalcides ocellatus, mentioned that there is no reason to think that the ciliary ramus of the ophthalmic ganglion forms a part of the ganglion. However, Haller von Hallerstein (1934) reported that both the nervi oculomotorius and trigeminus share in the formation of the ciliary ganglion in reptiles and birds. The same finding was also mentioned by Evans and Minckler (1938) in the gecko Gymnodactylus kotchyi. The author supports Santamaria-Arnaiz (1959). This view of the author is evident from his observation on both the Uromastyx aegyptius and Sphenops seposoids, where the sensory fibres of the radix ciliary longa pass directly to the ciliary nerves without any relations to the ganglionic cells of the ganglion.

Regarding the matter in birds, Rex (1900) found that the ciliary ganglion in the duck makes its appearance as a distinct thickening in the course of the nervus oculomotorius. But he did not follow the origin of the ganglion cells. Carpenter (1906) offered a complete account of the development of the ciliary ganglion in birds. He stated that the ciliary ganglion of the chick appears as a collection of actively dividing “accompanying” cells near to the distal extremity of the nervus oculomotorius. Carpenter regarded these “accompanying” cells as medullary cells which have migrated into the nerve from the neural tube. He further mentioned that a small number of the ophthalmic ganglion cells migrate to the ciliary ganglion, passing along a communicating ramus from the ophthalmic branch of the nervus trigeminus. Recently, Lee et al. (2003) suggested that the ciliary ganglion of the chick has a dual, neural crest and placodal origin.
Among mammals, the illustration given by Reuter (1897) and Kuntz (1913) of the development of the ciliary ganglion in the pig embryos is quite different. Reuter (1897) related the ganglion to the oculomotor nerve. Kuntz (1913), however, believed that it arose from cells migrating from the neural tube along the oculomotor nerve and from others migrating from the semilunar ganglion along the ophthalmic branch of the trigeminal nerve. From the reviews of Deery (1931) and Goodrich (1986), it seems that both the oculomotor nerve and the ophthalmic branch contribute to the formation of the ganglion. On the other hand, Stewart (1920), stated that the rat neuroblasts, giving rise to the ciliary ganglion, reach their place through the ophthalmic branch. In man, there are generally two different points of view on this subject. In this regard, His (1880 & 1888) and Streeter (1912), assigned the ciliary ganglion to cells arising from the semilunar ganglion, which is a direct descendant of the neural crest. However, Kuntz (1933) concluded that the ganglion appears to be derived from both the oculomotor nerve and the trigeminal ganglion. Hara et al. (1982) concluded that the ciliary ganglion in dogs is composed of the oculomotor trigeminal and sympathetic nerves.

From the above mentioned discussion, it is obvious that, there are differences in the ciliary ganglion of the studied species, concerning the structural relations and even the number of ciliary neves. Again, it also shows similarities in number of ciliary roots and unity of the cellular (neurons) structure; hence all formed of bipolar neurons. Though, there is only one ciliary nerve in Uromastyx and Sphenops yet this nerve is large and stout in the former species. Thus we can conclude that, although there is a specific variations regarding the ciliary ganglion yet it is at an intermediate rank between Amphibia and fishes from one side and the birds and mammals from the other side.

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