Comparative Anatomical Study On The Ciliary Ganglion Of Birds

Ahmed Imam Dakrory and Tharwat G. Abdel-Kader

Department of Zoology, Faculty of Science, Cairo University.
Department of Zoology and Entomology, Faculty of Science, Helwan University.

Abstract: This study deals with the ciliary ganglion of three species of birds belonging to three different orders and families. The fully formed embryos are collected from the fertilized eggs in lab. The heads were fixed, embedded in paraffin, then sectioned serially and stained. The ciliary ganglia were examined by the light microscope. The results can be summarized as follows: The ciliary ganglion was rounded shape in *Bublucus ibis* and oval shape in *Halcyon smyrnensis* and *Pterocles alchata*. The ganglion receives the parasympathetic fibres (root), carried by nervus oculomotorius, either through an obvious branch; the radix ciliaris brivis which is long and arises from ramus superior as in *Halcyon* or short and arises from ramus inferior as in *Pterocles* or through the intermingling surface between the ramus inferior and the ganglion as in *Bublucus*. The radix ciliaris longa "sensory root" originates from the ramus ophthalmicus profundus and is attached to either the ciliary nerves as in *Halcyon* and *Pterocles* or to the ganglion and the nerve as in *Bublucus*. There is no connection between the ganglion and the sympathetic carotid plexus, *i.e.,* there is no sympathetic root. The number of the ciliary nerves varies from species to another; there are three in *Halcyon*, four in *Pterocles* and seven in *Bublucus*. The ganglion consists of two types of neurons; large ciliary cells and small chorodial ones.

Key wards: Bublucus Ibis, Halcyon Smyrnensis, Pterocles Alchata, Ciliary Ganglion.

INTRODUCTION

The ciliary ganglion occupies an important position in the parasympathetic, sympathetic and sensory innervation of the ciliary muscles and the iris of the vertebrate eyes (Soliman *et al.*, 1976), as well as the sclera and choroidal blood vessels (Radzimirska, 2003).

The ciliary ganglion of birds (Webb, 1957; Ábráham and Stammer, 1966; Soliman *et al.*, 1976; Lee *et al.*, 2003 and Radzimirska, 2003). It is also invariably stated to be sympathetic in nature, although it differs from sympathetic ganglia in giving origin to medullated instead of nonmedullated fibres (Soliman *et al.*, 1976). It attracted the attention of several authors, a long time ago, because of its complicated and unknown structure.

The ganglion in question has received various names by different authors (ciliary, ophthalmic, lentecular, oculomotor). The ciliary ganglion has either three roots; Sympathetic, parasympathetic and sensory (Kurus, 1956 and Dakrory, 2009) or two roots parasympathetic and sensory and there is no sympathetic root (Lenhossek, 1912; Soliman *et al.*, 1976 and Abdel-Kader and Fathy, 2000). Again, there is a controversy in the opinions about the ciliary ganglion composition and the number of the ciliary nerves arising from the ganglion.

From the literature cited, it is clear that, there are many conflicting points of view among anatomists; regarding the origin of the ganglion, the nature of its cells and the numbers of its roots and nerves. This appears to be enough for studying the ciliary ganglion.

MATERIAL and METHODS

Three species of birds belonging to three different orders and three different families are selected for this study. These are the egret *Bublucus ibis* (Order: Pelecaniformes, Family: Ardeidae), the kingfisher *Halcyon smyrnensis* (Order: Coraciiformes, Family: Halcyonidae) and the pin-tailed sandgrouse *Pterocles alchata* (Order: Pteroclidiformes, Family: Pteroclididae).

The fertilized eggs of the three species were collected at May 2009 and brought to the lab. *Bublucus* and *Pterocles* eggs were collected from Kafr-ElShekh governorate, whereas, those of *Halcyon* from El-Menofyea governorate.

The eggs of *Bublucus* were pale bluish-white and oval-shaped. They measured about 45 X 53 mm, with the incubation period lasts around 23 days. The eggs of *Halcyon* were glossy-white and measured about 40 X 50 mm, while those of *Pterocles* is dirty white with pale irregular brown spots, and the mean measures were 31 X 47 mm.

The eggs were opened and the living healthy fully formed embryos were removed from the egg shells and quickly put in aqueous Bouin`s fluid for a time ranging between 24 – 48 hours according to the sizes of

Crossponding Author: Ahmed Imam Dakrory, Department of Zoology, Faculty of Science, Cairo University.
E-mail: dakrory2001@yahoo.com

embryos. Thereafter, the embryos were washed with 70% alcohol for several days to remove the excess of fixative. Thereafter, the heads of both *Bublucus* and *Pterocles* were cut and embedded in paraffin wax and then sectioned transversely at 15 µm thickness in *Bublucus* and 12 µm in *Pterocles*. The serial sections were stained with Mallory's Triple Stain (Pantin, 1946) in *Bublucus* and with haematoxylin and eosin in *Pterocles*. Whereas in *Halcyon*, the heads were stained with Borax carmine according to Grenacher's Borax carmine method (Galigher and Kozloff, 1964) and then the heads were sectioned transversely at 12 µm thickness after embedding in paraffin. The serial sections were counter stained in picroindigo carmine. The transverse sections were drawn with the help of a projector microscope. In order to illustrate the relations of the ganglia to other different parts of the head, several sections were photomicrographed.

RESULTS AND DISCUSSIONS

The ciliary ganglion of the three studied avian species appears as a more or less rounded mass of ganglionic cells, which is located in the posterior part of the orbital region of the head. This ganglion has a different shape and occupies different position from one species to another.

In *Bubulcus ibis*, the ciliary ganglion (Figs. 1, 4&7, G.CL) has a rounded shape and is located in a position surrounded by the rectus superior muscle dorsomedially, the eyeball (E) dorsolaterally and laterally and the rectus lateralis muscle ventrally.

In *Halcyon smyrnensis*, the ciliary ganglion (Figs. 2, 8&10, G.CL) is an oval shaped collection of ganglionic cells, which is located in a position medial to the eyeball (E), ventrolateral to the quadratus muscle (M.QU) and dorsolateral to the rectus lateralis muscle (M.RL).

In *Pterocles alchata*, such ganglion (Figs. 3, 12&14, G.CL) is an oval shaped mass of ganglionic cells, which is located medial to the eyeball (E), ventral to the ramus profundus of the nervus tigemenus (R.OPH), lateral to the both rami superior (R.SP) and inferior (R.IF) of the nervus oculomotorius and dorsolateral to the rectus lateralis muscle (M.RL).

The ciliary ganglion measures about 290 µm. in *Bubulcus ibis* and 360 µm. in both *Halcyon smyrnensis* and *Pterocles alchata*.

The ciliary ganglion is surrounded by a thick fibrous capsule (Fig. 13, FCA) which forms epineurium and perineurium.

In the present study, the ciliary ganglion is connected with the nervus oculomotorius by a thick nerve, the radix ciliaris brivis in both *Halcyon smyrnensis* (Figs. 2&10, RCB) and *Pterocles alchata* (Figs. 3&12, RCB). The radix ciliaris brivis arises from the lateral side of the ramus inferior of nervus oculomotorius in case of *Pterocles alchata* (Fig. 12, RCB) while in *Halcyon smyrnensis* (Fig. 10, RCB), it arises from the ventral side of the ramus superior (R.SP). On the other hand, in *Bubulcus ibis*, there is no radix ciliaris brivis, and the parasympathetic fibres are transmitted from the nervus oculomotorius to the ganglion through the intermengiling surface of the ramus inferior (Figs. 4&5, R.IF).

In the three avians investigated the sensory root of the ciliary ganglion, the radix ciliaris longa (Figs. 1, 2&3 RCL), originates from the ramus ophthalmicus profundus and joins the ciliary nerve in both *Halcyon smyrnensis* (Figs. 2&10, RCL) and *Pterocles alchata* (Figs. 3, 12&14 RCL), whereas in *Bubulcus ibis* (Figs. 1, 4&6 RCL) it connects both the ciliary ganglion and the ciliary nerve. In both *Halcyon smyrnensis* and *Pterocles alchata* the radix ciliaris longa arises from lateral or ventral aspect of the profundal ramus (Figs. 2&3 R.OPH) and extends anteroventrally to join the posterior ciliary nerve shortly after its origin from the ganglion (Figs. 2&3 Nn.CL). Again the anterior ciliary nerve is connected with other branch of the ramus profundus (radix ciliaris longa). In *Bubulcus ibis*, the sensory nerve (radix ciliaris longa) is connected with the ganglion as well as with ciliary branches (Fig. 1).

In the three birds examined, there are no connections between the ciliary ganglion and the internal sympathetic carotid plexus, *i.e.,* there is no sympathetic connection or sympathetic root in these birds.

In the three species studied, the ciliary nerves arise from the ciliary ganglion in variable numbers differing from one species to the other.

In *Bubulcus ibis* (Figs. 1& 4, Nn.CL), seven ciliary nerves originate from the ciliary ganglion. The most posterior one arises from the lateral side of the ganglion at its posterior end. Shortly after its origin, it turns poserolaterally receiving a branch of the radix ciliaris longa (Fig. 6, RCL). Shortly anterior, a large main radix ciliaris longa joins the ciliary ganglion from its ventrolateral side (Fig. 1, Nn.CL). The main posterior ciliary nerve originates from the lateral side of the ganglion and extends posterolaterally receiving a branch of the radix ciliaris longa. Shortly posterior, it gives off two nerves where they enter the sclera through different foramina (Fig. 7). Shortly dorsal to this nerve, three small ciliary nerves arise from the lateral side of the ganglion and fuse with the radix ciliaris longa and pass to the sclera, posterior to the exit of the optic nerve from the eyeball (Fig. 7). There are two dorsolateral nerves arise from the anterior part of the ganglion and fuse with a branch of the radix ciliaris longa and runs poserolaterally to enter the eyeball through a foramen in the sclera.
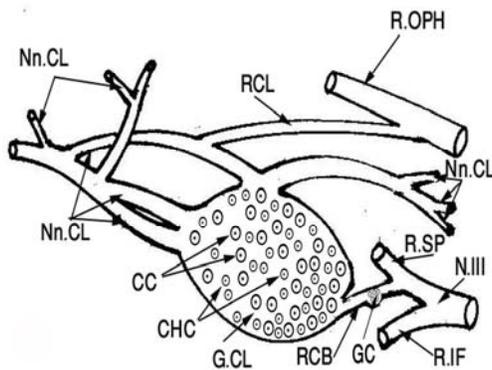
In *Halcyon smyrnensis*, three ciliary nerves originate from the ganglion (Fig. 2, Nn.CL). The main ciliary nerve arises from the lateral side of the ganglion and divides into a posterior and an anterior nerves (Fig. 2). The posterior nerve runs posteriorly for a distance and finally enters the eyeball through a foramen in the sclera and then ramifies with the choroid. The anterior nerve receives the radix ciliaris longa. Thereafter, it runs forwards to receive another branch from the most anterior ciliary nerve more forward, it divides into two nerves which enter the eyeball (Fig. 2). From the most anterior end of the ganglion, two ciliary nerves arise. They extend anteriorly for a distance; then they fuse together into one nerve (Fig. 2). This nerve gives off a connecting branch for the previously described anterior nerve. Anterior to this connection, this nerve enters the eyeball and divides into fine twigs.

In *Pterocles alchata*, four ciliary nerves originate from the ciliary ganglion (Fig. 3). The main ciliary nerve originates from the vetnrolateral aspect of the posterior half of the ganglion. At its origin, it receives a branch from the radix ciliaris longa (Figs. 3&14, RCL). The ciliary nerve runs posteriorly for a short distance and receives a second branch from the radix ciliaris longa (Fig. 3, RCL). Shortly after that, it divides into two ciliary nerves, one dorsal to the other. The dorsal nerve gives off an anterior branch which connects other ciliary nerves. The two posterior ciliary nerves enter the eyeball through separate foramina in the cartilaginous sclera, to end in the choroid wall. A third posterior ciliary nerve, separates off from the largest anterior nerve and runs backwards in the dorsal direction and divides into three nerves dorsal to each other (Fig. 3). The most ventral one anastomosis with one of the previous ciliary nerves and then enters the eyeball. The two dorsal nerves continue backwards and ramify then enter the eyeball by passing through the sclera (Fig. 12). The largest anterior ciliary nerve extends anteroventrally to enter the eyeball. From the most anterolateral end of the ganglion, it arises and extends anteriorly to divide into two nerves which enter the eyeball.

In *Pterocles alchata*, the radix ciliaris longa receives a branch from the nervus abducens (Fig. 3, R.CM.N.AB+RCL), this communication is not found in the other two species studied.
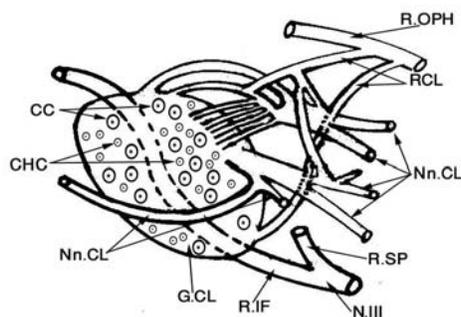

Fig. 1: Graphic reconstruction of the ciliary ganglion of *Bubulcus ibis* in a lateral view. **CC**, Ciliary cells, **CHC**, choroidal cells, **G.CL**, Ciliary ganglion, **N.III**, Nervus oculomotorius, **Nn.CL**, Ciliary nerves, **R.IF**, Ramus inferior, **R.OPH**, Ramus ophthalmicus profundus, **R.SP**, Ramus superior, **RCL**, Radix ciliaris longa.


Fig. 2: Graphic reconstruction of the ciliary ganglion of *Halcyon smyrnensis* in a lateral view. **CC**, Ciliary cells, **CHC**, choroidal cells, **G.CL**, Ciliary ganglion, **GC**, Ganglionic cells, **N.III**, Nervus oculomotorius, **Nn.CL**, Ciliary nerves, **R.IF**, Ramus inferior, **R.OPH**, Ramus ophthalmicus profundus, **R.SP**, Ramus superior, **RCB,** Radix ciliaris brivis, **RCL**, Radix ciliaris longa.
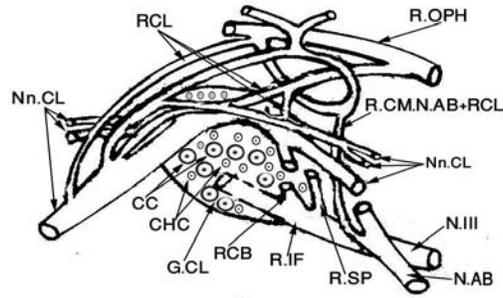
Fig. 3: Graphic reconstruction of the ciliary ganglion of *Pterocles alchata* in a lateral view. **CC**, Ciliary cells, **CHC**, choroidal cells, **G.CL**, Ciliary ganglion, **N.AB**, Nervus abducens, **N.III**, Nervus oculomotorius, **Nn.CL**, Ciliary nerve, **R.CM.N.AB+RCL,** Ramus comunicans between nervus abducens and radix ciliaris longa, **R.IF**, Ramus inferior, **R.OPH**, Ramus ophthalmicus profundus, **R.SP**, Ramus superior, **RCB,** Radix ciliaris brivis, **RCL**, Radix ciliaris longa.
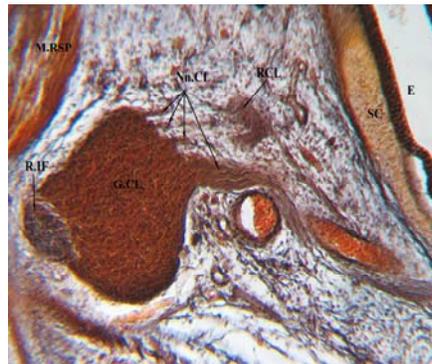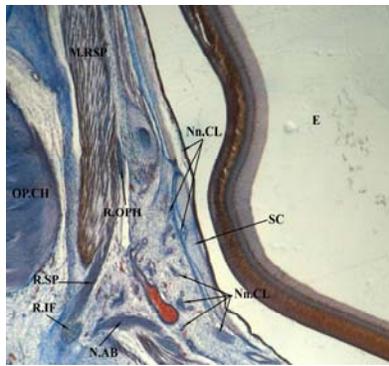

Fig. 4: A photomicrograph of a part of transverse section of *Bubulcus ibis* showing the position of the ciliary ganglion, the origin of the ciliary nerves, the radix ciliaris longa and the entermengling surface between the ganglion and the ramus inferior III. **E**, Eye, **G.CL**, Ciliary ganglion, **M.RSP**, Rectus superior muscle, **Nn.CL**, Ciliary nerves, **R.IF**, Ramus inferior, **RCL**, Radix ciliaris longa, **SC**, Sclera.
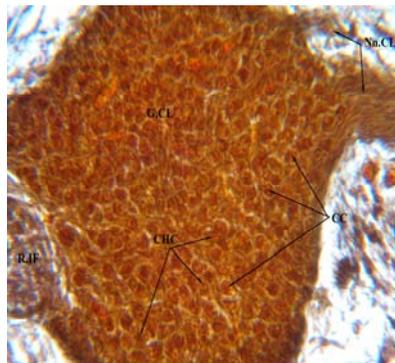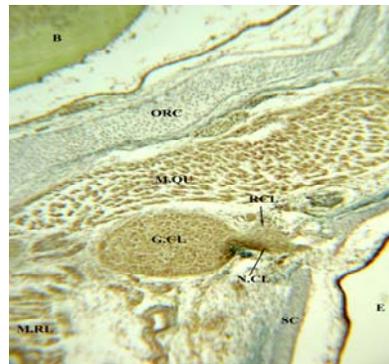

Fig. 5: A photomicrograph of a part of transverse section of *Bubulcus ibis* showing the types of neurons of the ciliary ganglion. **CC**, Ciliary cells, **CHC**, Choclear cells, **G.CL**, Ciliary ganglion, **Nn.CL**, Ciliary nerves, **R.IF**, Ramus inferior.
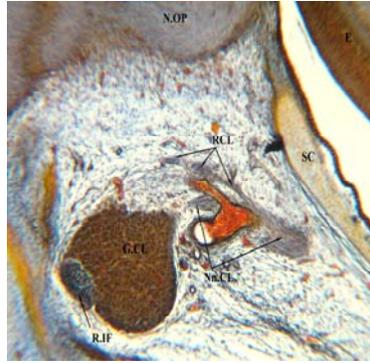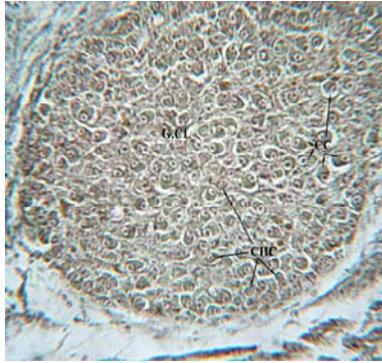
Fig. 6: A photomicrograph of a part of transverse section of *Bubulcus ibis* demonstrating the fusion of the radix ciliaris longa with the ciliary nerve and the entermengling surface between the ganglion and the ramus inferior III. **E**, Eye, **G.CL**, Ciliary ganglion, **N.OP**, Nervus opticus, **Nn.CL**, Ciliary nerves, **R.IF**, Ramus inferior, **RCL**, Radix ciliaris longa, **SC**, Sclera.
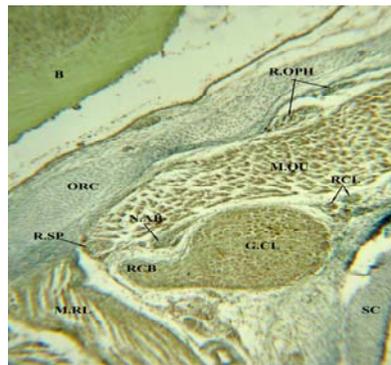

Fig. 7: A photomicrograph of a part of transverse section of *Bubulcus ibis* showing the ciliary nerves entering the eyeball. **E**, Eye, **M.RSP**, Rectus superior muscle, **N.AB**, Nervus abducens, **Nn.CL**, Ciliary nerves, **OP.CH**, Optic chiasma, **R.IF**, Ramus inferior, **R.OPH**, Ramus ophthalmicus profundus, **R.SP**, Ramus superior, **SC**, Sclera.
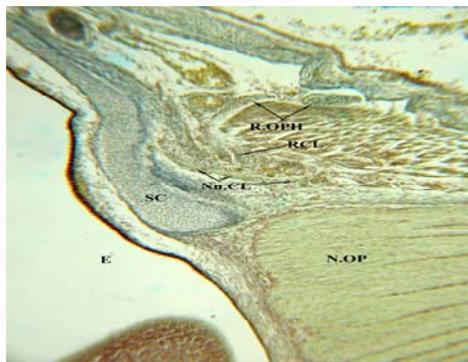

Fig. 8: A photomicrograph of a part of transverse section of *Halcyon smyrnensis* showing the position of the ciliary ganglion. **B,** Brain**, E**, Eye, **G.CL**, Ciliary ganglion, **M.QU**, Quadratus muscle, **M.RL**, Rectus lateralis muscle, **N.CL**, Ciliary nerve, **ORC**, Orbital cartilage, **RCL**, Radix ciliaris longa, **SC**, Sclera.
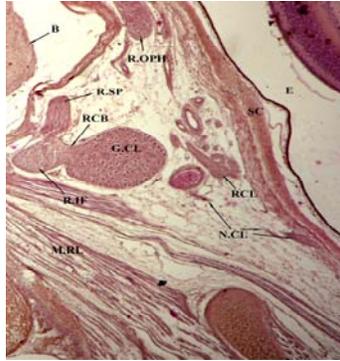
Fig. 9: A photomicrograph of a part of transverse section of *Halcyon smyrnensis* demonstrating the types of neurons of the ciliary ganglion. **CC**, Ciliary cells, **CHC**, Choclear cells, **G.CL**, Ciliary ganglion.

Fig. 10: A photomicrograph of a part of transverse section of *Halcyon smyrnensis* demonstrating the position of the ciliary ganglion and the entrance of radix ciliaris brivis into the ganglion. **B,** Brain, **G.CL**, Ciliary ganglion, **M.QU**, Quadratus muscle, **M.RL**, Rectus lateralis muscle, **N.AB**, Nervus abducens, **ORC**, Orbital cartilage, **R.OPH**, Ramus ophthalmicus profundus, **R.SP**, Ramus superior, **RCB,** Radix ciliaris brivis, **RCL**, Radix ciliaris longa, **SC**, Sclera.

Fig. 11: A photomicrograph of a part of transverse section of *Halcyon smyrnensis* showing the ciliary nerves entering the eyeball. **E**, Eye, **N.OP**, Nervus opticus, **Nn.CL**, Ciliary nerves, **R.OPH**, Ramus ophthalmicus profundus, **RCL**, Radix ciliaris longa, **SC**, Sclera.
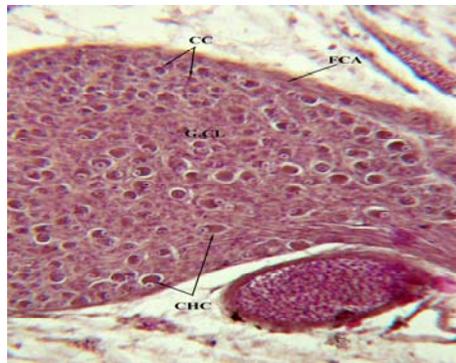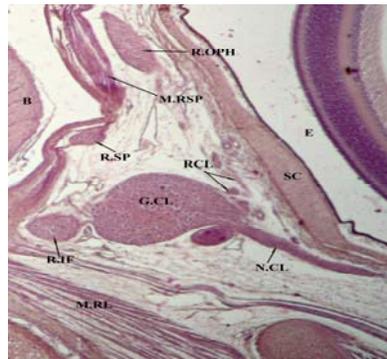
Fig. 12: A photomicrograph of a part of transverse section of *Pterocles alchata* showing the position of the ciliary ganglion and the entrance of radix ciliaris brivis into the ganglion. **B,** Brain, **E**, Eye, **G.CL**, Ciliary ganglion, **M.RL**, Rectus lateralis muscle, **N.CL**, Ciliary nerve, **R.IF**, Ramus inferior, **R.OPH**, Ramus ophthalmicus profundus, **R.SP**, Ramus superior, **RCB,** Radix ciliaris brivis, **RCL**, Radix ciliaris longa, **SC**, Sclera.

Fig. 13: A photomicrograph of a part of transverse section of *Pterocles alchata* showing the types of neurons of the ciliary ganglion. **CC**, Ciliary cells, **CHC**, Choclear cells, **FCA,** Fibrous capsule, **G.CL**, Ciliary ganglion.

Fig. 14: A photomicrograph of a part of transverse section of *Pterocles alchata* demonstrating the fusion of the radix ciliaris longa with the ciliary nerve and the ciliary nerves entering the eyeball. **B,** Brain, **E**, Eye, **G.CL**, Ciliary ganglion, **M.RL**, Rectus lateralis muscle, **M.RSP**, Rectus superior muscle, **N.CL**, Ciliary nerve, **R.IF**, Ramus inferior, **R.OPH**, Ramus ophthalmicus profundus, **R.SP**, Ramus superior, **RCL**, Radix ciliaris longa, **SC**, Sclera.

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 but it was not recorded in reptiles (Dakrory, 2009).

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 the three species studied. Same findings

were reported in avian species studied by Holtzmann (1896), Carpenter (1906), 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, as in the current study, 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 reptiles, the two cases are present; the ciliary ganglia which are composed of two types of neurons were found in *Agama sinaita* and *Stenodactylus slevini* (Mostafa and Hegazy, 1990), *Uromastyx aegyptius* and *Sphenops sepsoides* (Dakrory, 2009). The ganglia composed of only one type of neurons were found in *Ptyodactylus hasselquistii, Lacerta virides, Acanthodactylus boskiana, Agama mutabilis* and *Mabyua quinquetaeniata* (Soliman, 1968), *Tarentola mauritanica* (Soliman and Mostafa, 1984), *Acanthodactylus opheodurus* (Mostafa, 1990), *Mabuya quinquetaeniata* (Abdel-Kader *et al*., 2007), *Tropiocolotes tripolitanus* (El-Bakry *et al*., 2007) and *Varanus griseus* (Dakrory, 2009).

In the present study, the ciliary ganglion is connected with the nervus oculomotorius by a thick nerve, the radix ciliaris brivis in both *Halcyon smyrnensis* and *Pterocles alchata*. This was mentioned in *Struthio* (Webb, 1957), in *Upopa epops* and *Passer domesticus* (Soliman *et al*., 1976) and in *Merops albicollis* (Abdel-Kader and Fathy, 2000). The radix ciliaris brivis originates from the ramus superior in *Halcyon* studied. This result resembles the finging of Slonaker (1918), Stresemann (1927) and Soleman *et al.,* (1976) in *Passer domesticus*, where the radix ciliaris brivis originates from the ramus superior and not form the ramus inferior as usually found in other vertebrate studied. On the other hand, in *Bubulcus ibis* the ciliary ganglion is firmly attached to the ramus inferior of the nervus oculomotorius with the absence of the radix ciliaris brevis and the parasympathetic fibres are transmitted through the intermengiling surface of the ramus inferior. That was mentioned in the goose, *Falco palumbarius, Aquila ieucocephala, Meleagris gallopavo, Ardea einerea, Vanellus cristatus* and *Gallinula pusilla* (Gadow and Selenka, 1891), in *Gallus domesticus* (Holtzmann, 1896), 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 (1981) and Siéssere *et al.,* (2008) 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 reptiles, the radix ciliaris brivis is described to be well-distinct branch by Abdel-Kader *et al*. (2007) in *Mabuya quinquetaeniata* and by Dakrory (2009) in *Uromastyx aegyptius, Sphenops sepsoides* and *Varanus griseus*. However, 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 *Tropiocotes tripolitanus* (El-Bakry *et al*., 2007) and in the amphisbaenian *Diplometopon zarudnyi* (Dakrory, 1994).

In the present study, the radix ciliaris longa transmits the sensory fibres from the ramus ophthalmicus profundus of the nervus trigeminus to the ciliary nerves in both *Halcyon smyrnensis* and *Pterocles alchata* and to both ciliary ganglion and ciliary nerve in *Bubulcus ibis*. In this respect, it seems to be a common character in birds, as described by Soliman *et al*. (1976), that there is no direct connection between the ciliary ganglion and the ramus ophthalmicus and this connection, however, is carried out between the latter ramus and the ciliary nerves distal to the ganglion. However, a direct connection between the ramus ophthalmicus and the ciliary ganglion were described 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 trigeminus, 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 monky (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).

In case of reptiles, the radix ciliaris longa passes directly to the ciliary ganglion in the lizards *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). The same condition was also recorded in the snakes *Psammophis sibilians* and *Cerastes vipera* (Hegazy, 1976), *Coluber elegantissimus, Psammophis schokari* and *Spalecosophis diadema* (Mostafa, 1991), *Natrix tessellate* (El-Ghareeb *et al*., 2004) and in *Telescopus dhara* (Abdel-Kader, 2006).

However, the radix ciliaris longa joins both the ciliary ganglion and the ciliary nerve distal to the ganglion in the amphisbaenian *Diplametepon zarudnyi* (Dakrory, 1994) and in the lizard *Uromastyx aegyptius* (Dakrory, 2009). Again, in the lizard *Chalcides ocellaus* (Soliman and Hegazy, 1969) and the snake *Eryx jaculus* (Hegazy, 1976), the radix ciliaris longa passes across the dorsal side of the ciliary ganglion, then turns to enter the ciliary nerve. The same case was reported in the lizard *Sphenops sepsoides* (Dakrory, 2009).

In the present study, there is no connection between the ciliary ganglion or the ciliary nerves and the internal sympathetic carotid plexus. This was confirmed by several authors; Cords (1904), Carpenter (1906), Lenhossek (1912), Webb (1957), Abraham and Stammer (1966), 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 ciliry ganglion and the carotid plexus is, generally, present in mammals. The sympathetic root of the ganglion was described by Taylor and Weber (1969) in the cat and by Hegazy and Mostafa (1990) in the hedgehog and the bat. However, Lenhossék (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, steep 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.

Among reptiles, this condition is variable. The sympathetic connection with the ciliary ganglion or with the ciliary nerves was not found in *Acanthodactylus boskiana* and *Lacerta viridis* (Soliman, 1968), *Acanthodactylus opheodurus* (Mostafa, 1990), *Agama sinaita, Stenodactylus slevini* (Mostafa and Hegazy, 1990), in *Mabuya quinquetaenata* (Abdel-Kader *et al*., 2007) and *Tropiocolates tripolitanus* (El-Bakry *et al*., 2007). It is also absent in the serpents *Spalerosophis diadema* (Mostafa, 1990) and *Natrix tessellate* (El-Ghareeb *et al*., 2004). However, the sympathetic root connects the ganglion in *Ptyodactylus hasselquistii* and *Mabuya quinquetaeniata* (Soliman, 1968), *Tarentola mauritanica* (Soliman and Mostafa, 1984), *Eumeces schneidri* (Mostafa and Hegazy, 1990) and *Sphenops sepsoides* (Dakrory, 2009). In Ophidia it is found in the serpent *Eryx jaculus* (Hegazy, 1976). On the other hand, a connection between the carotid plexus and the ciliary nerve found in the lizars *Agama mutabilis* (Soliman, 1968), *Chalcides ocellaus* (Soliman and Hegazy, 1969), *Agama pallida* (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 amphisbaenian *Diplometopon zarudmyi* (Dakrory, 1994).

In this study, there are seven nerves arising from the ciliary ganglion in *Bubulcus ibis*, four in *Pterocles alchata* and three in *Halcyon smyrnensis*. 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 *Streptopelia 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).

Among reptiles, the number of ciliary neves ranges from one to three. One ciliary nerve was found in *Chalcides ocellatus* (Santamaria-Arnaiz, 1959; Soliman and Hegazy, 1969), *Ptydactylus hasselquistii, Acanthodactylus boskiana* and *Lacerto viridis* (Soliman, 1968), *Acanthodactylus opheodurus* (Mostafa, 1990), *Diplometopon zarudnyi* (Dakrory, 1994), in both *Uromastyx aegypius* and *Sphenops sepsoides* (Dakrory, 2009) and in all serpents studied by Mostafa (1991). There are two nerves in *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), *Tropiacolotes tripolitanus* (El-Bakry *et al.*, 2007), *Varanus griseus* (Dakrory, 2009) and also in the snakes *Cerastes vipera* (Hegazy, 1976), *Natrix tessellate* (El-Ghareeb *et al.*, 2004) and *Telscopus dhara* (Abdel-Kader, 2006). Three ciliary nerves were present in the gecko *Gymnodactylus kotschyi* (Evans and Minckler, 1938).

Regarding the development of the ciliary ganglion 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 placoidal origin.

This view of the author is evident from his observation on the avians studied, 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.

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.

Concerning reptoles, 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). Lenhossék (1912), on the other hand, dealing with *Lacerta agilis* and *Lacerta muralis,* agreed with the finding of Beranéck (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 kotschyi*. The author supports Santamaria-Arnaiz (1959).

From the aforementioned discussion, it is clear that, there are differences in the ciliary ganglion of the studied avian species, concerning the morphology, structure and relations and even the number of ciliary nerves. In addition, the three avian species are homologous in several aspects, as presence of only two roots and the absence of the internal carotid plexus connection. Thus we can conclude that, although there is a specific variation regarding the ciliary ganglion yet it is at an intermediate rank between reptiles from one side and the mammals from the other side.

REFERENCES

Abdel-Kader, I.Y., 1990. Anatomical studies on the cranial nerves of the lizards *Agama pallida* and *Ptyodactulus hasselquistii*. Ph.D. Thesis, Fac. Sci., Cairo Univ., Egypt.

Abdel-Kader, I.Y., 1999. The cranial nervus of *Gallinula chloropus*. The eye muscle nerves and ciliary ganglion. J. Union Arab Biol., 12(A): 197-216.

Abdel-Kader, I.Y., 2006. The cranial nerves of the cat snake *Telescopus dhara* (Colubridae, Ophidia): I. The eye muscle nerves and the ciliary ganglion. J Egypt Ger Soc Zool., 50(B): 1-16.

Abdel-Kader, I.Y., S.M. Fathy, 2000. The cranial nerves of the bee eater, *Merops albicollis* (Meropidae, Coraciiformes). The eye muscle nerves and the ciliary ganglion. J Egypt Ger Soc Zool., 34: 141-163.

Abdel-Kader,T.G., A.A. Shamakh, A.I. Dakrory, 2007. The cranial nerves of *Mabuya quinquetaeniata*. I. The eye muscle nerves and the ciliary ganglion. Egypt J Zool., 49: 193-209.

Abraham, A., A. Stammer, 1966. Über die Struktur und die Innervierung der Augenmuskeln der Vögel unter Berucksichtigung des Ganglion Ciliare. Acta. Biol. Univ. Szeged., 12: 87-118.

Bast, T.H., 1933. The anatomy of the rhesus monkey (*Macaca mulatta*): The eye and the ear. Hafner publishing Co., New York.

Béraneck, E., 1884. Recherches sur le development des nerfs craniens chez les lézards. Recueil Zool Suisse, Sér 1, Tom, 1(4): 519-603.

Bonsdorff, E.J., 1952. Symbolae ad anatomiam compartum nervorum animalium vertebratorum. 1- Nervi cerebrales *Corvi cornices*. 2- Nervi cerebrales *Gruis cinereae*. Acata Soc Sci Fenn-Helsingforsiae, 3: 505-569, 591-624.

Bullock, T.H., R. Orkand, A. Grinnell, 1977. Introduction to the Nervous System. W.H. Freeman and Company, USA.

Carpenter, F.W., 1906. The development of the oculomotor nerve, the ciliary ganglion, and the abducens nerve in the chick. Bull Mus Comp Zool., 48: 139-230.

Christensen, K., 1933. The anatomy of the rhesus monkey (*Macaca mulatta*): The cranial nerves. Hafner publishing Co. New York.

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

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

Cunningham, J., 1931. Textbook of anatomy. Oxford Univ. Press, Oxford.

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

Dakrory, A.I., 2009. Comparative anatomical study on the ciliary ganglion of lizrds (Reptilia – Squamata – Lacertilia). Aust J Basic & Appl Sci., 3(3): 2064-2077.

Deery, E.M., 1931. Observations on the development of the ciliary ganglion. Bull Neurol Inst New York, 1(3): 563-578.

Dupas, J.H.L., 1924. "Contribution a L'tude et histologique du ganglion ophthalmique chez L'homme et divers animaux". These, Faculte de Medecine et de Pharmacie Universte de Bordeaux, French.

El-Bakry, A.M., A.A. Shamakh, A.I. Dakrory, 2007. The cranial nerves of the gecko *Tropiocolotes tripolitanus*. I. the eye muscle nerves and the ciliary ganglion. Egypt J Zool., 49: 361-379.

El-Ghareeb, A.A., I.Y. Abdel-Kader, A.F. Mahgoub, 2004. The cranial nerves of the snake *Natrix tessellata* (Ophidia, Colubridae). The eye muscle nerves, and the ciliary ganglion. J Union Arab Biol Cairo, 22(A): 305-330.

Evans, L.T., J. Minkler, 1938. The ciliary ganglion and associated structure in the gecko, Gymnodactylus kotschyi. J Comp Neurol., 69: 303-314.

Gadow, H., E. Selenaka, 1891. Bronns Kiassen und Ordnungen des Their-Reichs. Vögel. 1. Anat. Theil, 6. Leipzig.

Galigher, A.E., E.N. Kozloff, 1964. Essentials of practical microtecnique. Lea and Febiger, Philadelphia.

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

Godinho, H.P., 1972. Gross anatomy of the parasympathetic ganglia of the head in domestic Artiodactyla. Arq Esc Vet Univ Fed Minas Gerais, 22: 129-139.

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

Goodrich, E.S., 1986. Studies on the Structure and Development of Vertebrates. Maxmillan and Co. London.

Haller von Hallerstein, V., 1934. Anatomie der Wirbeltiere 2/1, herausgegeben von Bolk, Göppert, Kallius, Lubosch. Berlin und Wien.

Hara, H., S. kobavashi, K. Sugita, S. Tsukahara, 1982. Innervation of the dog ciliary ganglion. Histochemistry, 76(3): 295-301.

Hegazy, M.A., 1976. Comparative Anatomical studies on the cranial nerves of Ophidia. Ph.D. Thesis, Fac Sci, Cairo Univ, Egypt.

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

His, W., 1880. Anatomie menschlicher Embryonen. I- Embryonen den ersten Monats. Leipzig.

His, W., 1888. Zur Geschichte des Gehirns sowie der centralen und peripherischen Nervenbahnen beim Menschlichen Embryo. Abh. Sachs. Gesell. Wiss., math.-phys. Cl Leipzig, 14(7): 339-392.

Hoffman, C.K., 1886. Weitere Untersuchungen zur Entwicklun-gsgeschichte der Reptilien. J Morphol II(2): 176-219.

Holtzmann, H., 1896. Untersuchungen Über Ciliarganglion und Ciliarnerven. Morphol Arbeit., 6: 114-142.

Kuntz, A., 1913. The development of the cranial sympathetic ganglion in the pig. J Comp Neurol., 23: 71-96.

Kuntz, A., 1933. Autonomic nervous system. Lea and Febiger, Philadelphia.

Kuntz, A., 1934. Nerve fibres of spinal and vagus origin associated with the cephalic sympathetic nerves. Ann Otol Rhinol Laryng., 43: 50-66.

Kurus, E., 1956. Über die Morphologie des Ganglion Ciliare. Klin Monatasble Augenheilk, 129-145.

Lee, V.M., J.W. Sechrist, S. Luetolf, M. Bronner-Fraser, 2003. Both neural crest and placode contribute to the ciliary ganglion and oculomotor nerve. Dev. Biol., 263(2): 176-190.

Lenhossék, M.V., 1912. Das Ciliarganglion der Reptilian. Anat Anz., 40: 74-80.

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

Mostafa, R.H., 1991. On the ciliary ganglion of Ophidia (Squamata: Reptilia). Proc Egypt Acad Sci., 41: 131-142.

Mostafa, R.H., M.A. Hegazy, 1990. Comparative study on the ciliary ganglion of some lizards. Proc Egypt Acad Sci., 40: 139-146.

Nowak, E., T. Kuder, A. Szczurkowski, G. Kushinka, 2004. Anatomical and histological data on the ciliary ganglion in the Egyptian spiny mouse (Acomys cahirinus Desmarest). Folia Morphol. (warsz), 63(3): 267-272.

Oehme, H., 1968. Das ganglion Ciliare der Rabenvogel (Corvidae). Anat Anz., 123: 261-277.

Pantin, C.F.A., 1946. Notes on microscopical technique for Zoologists. Cambridge, England: Cambridge, University Press.

Radzimirska, H., 2003. The motphology, topography and cytoarchitectonics of the ciliary ganglion and the domestic turkey (*Meleagris gallopavo domesticus*). Fola Morphol. (Warsz), 62(4): 389-391.

Reuter, K., 1897. Über die Entwicklung der Augenmuskulatur beim Schwein. Anat Hefte, 9: 365-387.

Rex, H., 1900. Zur Entwicklung der Augenmuskeln der Ente. Arch F Mikr Anat., 57: 229-271.

Santamaria-Arnaiz, P., 1959. Le ganglion Ciliare chez *Chalcides ocellatus*. (Contribution âL'etude de. L'anatomie comparée du system nerveux). J Morphol., 101(2): 263-278.

Schachtschabel, A., 1908. Der Nervus Facialis und Trigeminus des Rindes. Inaugural-Dissertation. Anatomischen Institut der Konigi. Tierartlichen Hochschule, Leipzig.

Schwalbe, G., 1879. Das Ganglion oculomotorii. Ein Beitrag zur vergleichenden Anatomie der Kopfnerven. J Natur W., 13: 173-268.

Seto, H., 1931. Anatomish-histologishe Studien Über des Ganglion Ciliare der Vögel nebst séinen ein und austretenden Nerven. I. Bei den erwachsenen Hühnern. J Oriental Med., 15: 123-124.

Siessere, S, M. Vitti, L.G. Sousa, M. Semprini, M.M. Iyomasa, S.C.H. Regulo, 2008. Anatomical variation of cranial parasympathetic ganglion. Braz Oral Res., 22(2): 101-105.

Sinnreich, Z., H. Nathan, 1981. The ciliary ganglion in man (anatomical observation. Anat Anz., 150(3): 287-297.

Slonaker, L.J., 1918. A physiological study of the anatomy of the eye and its accessory parts of the English sparrow (Passer domesticus). J Morph., 31: 351-434.

Soliman, M.A., 1968. Studies on the ciliary ganglion of Lacertilia. Bull Fac Sci Cairo Univ., 42: 117-130.

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

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

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

Soliman, M.A., R.H. Mostafa, I.Y. Abdel-Kader, 1984. Anatomical studies on the cranial nerves of *Agama pallida* (Reuss). I. The eye-muscle nerves and Ciliary ganglion. Egypt J Anat., 8: 135-158.

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

Stewart, F.W., 1920. The development of the cranial sympathetic ganglia in the rat. J Comp Neurol., 31: 163-217.

Streeter, G.L., 1912. The development of the nervous system. Human Embryology, Keibel & Mall., 2: 1-56.

Stresemann, E., 1927. Aves. In Kükenthal's Handbuch der Zoologie–Berlin-Leiptzig.

Taylor, W.T., R.J. Weber, 1969. Functional mammalian anatomy (with special reference to the cat). D. van Nostrand Company, Inc. Toronto, New York, London.

Watanabe, T., 1972. The fine structure of the ciliary ganglion of the guinea pig. Arch Histol Jap., 34: 261-276.

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