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Anatomical Studies on The Cranial Nerves of *Mugil cephalus* (Family : Mugilidae) NERVUS VAGUS

Ahmed Imam Dakrory And Amar Khalifa Hussein

Department of Zoology, Faculty of Science, Cairo University.
Department of Zoology, Faculty of Science, Al-Fayoum University.

Abstract: This study deals with the nervus vagus of *Mugil cephalus.* The microscopic observations showed that, the nervus vagus arises from the brain by one root which leaves the cranial cavity through the jugular foramen.The intracranial dorsal vagal ramus arises from the vagal root and enters its own ganglion. It anastomoses with the posterior lateral line nerve.The vagus nerve divides into three branchial trunks and a truncus visceralis.Each branchial vagal trunk has an epibranchial ganglion. Distal to the ganglion each trunk branches into rami pharyngeus, anterior and posterior pretrematic and a posttrematic. The first branchial vagal trunk anastomoses with the vagal sympathetic ganglion.The nervus vagus carries general somatic sensory fibres to the skin, general viscerosensory fibres to the pharyngeal epithelium, special viscerosensory fibres to the gill rackers and the taste buds and visceromotor fibres to the levators and the adductor arcuales branchiales and the obliquus ventrales muscles of the second, third and fourth holobranchs and transversus dorsalis and ventralis muscles.In addition it also carries vegetative fibres (parasympathetic) for the blood vessels and the muscles of the gill filaments.

Key words: Nervus vagus- *Mugil cephalus*

INTRODUCTION

The study of the cranial nerves is important because their distribution is correlated with the habits and habitats of animals and also because they show an evolutionary trend among animals of the same group. The cranial nerves connect the brain with all the important centers of perception of the outer surface of the head, as well as the inner surface of the buccopharyngeal and other visceral regions, so that they seem to be important in determining the animal’s behaviour.

The life of fishes is entirely restricted to the aqueous environment, which is often devoid of light but rich in dissolved compounds. Therefore, they have to evolve highly developed chemosensory system, comprising the olfaction and tasting or gustation.

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

Although there are several classical sstudies on the cranial nerves of fishes, yet they are still useful to the investigators. The most valuable works from these early ones were that carried out by Allis (1897, 1903, 1909) and Herrick (1899, 1900, 1901).

Recently, several authors published their works on the cranial nerves of bony fishes. The most recent of them are the studies of Northcutt and Bemis (1993) and Piotrowski and Northcutt (1996) on *Latimeria chalumnae* and *Polypterus senegalus*, respectively and Dakrory (2000) on Ctenopharyngodon idellus. Other works on the nerve or group of nerves were performed. De Graaf (1990) studied the innervation of the gills in *Cyprinus carpio* by dissection. Also, Song and Northcutt (1991) gave a detailed description on the morphology, distribution and innervation of the lateral line receptors in the holostean, *Lepisosteus platyrhincus*. Dakrory (2003) studied the ciliary ganglion and its anatomical relations in some bony fishes.

It is quite evident from the above historical review that there are numerous works on the cranial nerves of fishes, but no study has been made concerning the cranial nerves of any species belonging to Mugilidae. Although the previously mentioned studies of different authors may throew light on the subject of the cranial nerves of fishes, yet it cannot be stated that the cranial nerves of a Mugilidae is similar to other fishes; and what are the differences if present? Thus it was suggested that a detailed microscopic study on the vagal nerve in *Mugil cephalus* will be very useful.

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

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

MATERIAL AND METHODS

Mugil cephalus is chosen for this study a diurnal fish inhabiting shallow areas. It feeds on deterius bottom algae and invertebrates. It is an economically important fish as a source of proteins. The fry of this species enter from Mediterranean Sea into lagoons and Nile tributaries during August, September and October.

The fully formed larvae of this species were collected from a fish farm at Balteem, Kafr El-Sheikh Govornorate, during August 2006. The heads of the fully formed larvae were fixed in aqueous Bouin for 24 hours. After that the heads washed several days with 70% alcohol.Decalcification was necessary before cutting and staining in toto for this bony species. This was carried out by placing the heads in EDTA solution for about 40 days, with changing the solution every 3 days.

The heads were sectioned transversely (10 microns in thickness), after embedding in paraffin. The serial sections were stained with Mallory's triple stain (Pantin, 1946). The serial sections were drawn with the help of the projector. From these sections, an accurate graphic reconstructions for the vagal nerve was made in a lateral views. In order to show the position of the nerve, and its relations to the other different structures of the head, several serial sections were photomicrographed.

RESULTS AND DISCUSIONS

In *Mugil cephalus*, the nervus vagus originates from the midlateral side of the medulla oblongata by a strong root (Figs. 1, 2 &8, RO.X). This root runs posterolaterally in a ventral direction within the cranial cavity. Reaching the meninx primitive, the vagal nerve leaves the cranial cavity through its own (Jugular) foramen found just posterior to the auditory capsule. This foramen is located between the prominentia sacularis ventrally and the prominentia utricularis dorsolaterally and the exoccipital bone posteriorlly (Figs. 2&8, F.JU). During its intracranial course, the nervus vagus gives off the intracranial dorsal vagal ramus (Fig. 1, R.IDV).

Intracranial Dorsal Vegal Ramus:

This ramus originates from the dorsolateral side of the nervus vagus and extends dorsally where it divides into an anterior and a posterior ramule (Fig. 1, R.IDV).The anterior ramulus runs forwards within the cranial cavity passing lateral to the medulla oblongata and dorsomedial to the posterior lateral line nerve. After a short course it carries few ganglionic cells (Fig. 1, G.C). At the position of these cells, it receives a fine branch from the posterior lateral line nerve (Fig. 1, R.CM.IDV+PLL). Anterior to this connection, this ganglion gives off two fine branches. These continue forwards till they end in the meninx primitive protecting the brain (Fig. 1, N.MP).

The posterior ramulus extends posterolaterally passing dorsal and dorsolateral to the posterior lateral line nerve. Here, it enters its own ganglion. This ganglion (Fig. 1, G.C) formed of an inverted C-shaped mass of ganglionic cells that lies around the posterior lateral line nerve. The anterior part of the ganglion lies intracranially whereas its posterior part lies in the jugular foramen.From the posterior end of this ganglion, the posterior ramulus arises as two branches (Fig. 1). These two branches leave the cranial cavity through a special foramen, found in the exocapital bone, together with the posterior lateral line nerve. Extracranially, one of these two branches runs anterolaterally and the second passes posterolaterally ventral to the posterior lateral line nerve.The anterior branch extends forwards passing to the lamina basotic and dorsal to the levator opercularis muscle. More forwards, it penetrates the latter muscle to end in skin covering it laterally.

The posterior branch extends posterolatrally passing ventral to the posterior lateral line nerve and dorsal to the epibranchial ganglion of the vagus nerve. It receives a branch from the ganglion of the posterior lateral line nerve (Fig. 1, R.CM.IDV+G.PLL). Thereafter, this branch runs laterally and then turns anteriorly running ventral to the dorsal spinal muscles and dorsal to the thymus gland. Lateral to the latter muscle, this branch gives off a large ramulus to the neuromast of the main lateral line canal (Fig. 1, N.NU). Following this ramulus, this branch gives off an anterior branch and a posterior one. The anterior branch runs forwards for a short distance and then ends in the skin lateral to the dorsal spinal muscle. The posterior branch extends backwards just under the skinand ends as fine ramification in the skin around the main lateral line canal.

During its exit from the jugular foramen, the main nervus vagus divides into an anterior division (Figs. 1 & 4, AN.DV.X) and a posterior one (Figs. 1 & 4, PO.DV.X). These two divisions divide in turn into an anterior and a posterior branchial trunks. Each branchial trunk enters its own epibranchial ganglion. The four ganglia (the three anterior epibranchial and the last visceral one) are located so much close to each other.

First Branchial Vagal Trunk:

Directly after its separation from the anterior division, the first branchial vagal trunk extends anteroventrally passing ventromedial to the third vagal trunk and dorsolateral to the head sympathetic chain and its vagal ganglion (Fig. 2, G.VA.SY). Shortly forwards, it enters its own ganglion; the first vagal epibranchial ganglion. This ganglion (Figs. 1& 5, G.EB.X_1) is oval shaped mass of cells. It is located dorsal to the anterior jugular vein (AJV), ventral to the basotic lamina, dorsolateral to the head sympathetic chain (SY.CH) and dorsomedial to the thymus gland. It connects with the latter chain (Fig. 1, R.CM.G.EB. X_1+ SY. CH). From the anteroventral end of the ganglion, the first branchial trunk arises and runs anteroventrally passing ventromedial to both the thymus gland and the second external and third levaor arcus branchialis muscles and lateral to the anterior jugular vein (Fig. 1, T.VB.X_1). Here, it gives off a medial branch for the second levator arcus branchialis muscle (Fig. 1, N. LB.II). Shortly anterior, the first vagal branchial trunk descends ventrally to enter the second holobranch. It passes dorsolateral to epibranchial bone and second efferent branchial vessel. While entering the holobranch, it divides into two divisions; one dorsomedial and the other ventrolateral. The dorsomedial division runs anteriorly for a short distance and divides into two rami; pharyngeus and anterior pretrematic.

Ramus Pharyngeus X:

This ramus (Fig.1 R.PH.X_1)separates from the pretrematic ramus of the first branchial trunk and runs anteromedially passing medial to the second epibranchial cartilage and lateral to the second efferent branchial vessel (Fig. 5, R.PH.X_1). Reaching the dorsolateral corner of the pharynx, this ramus distributes and ends as many fine branches in the epithelium lining the roof of the pharynx ventral to both the second efferent branchial vessel and the second levator arcus branchialis muscle.

Anterior Ramus Pretrematic X:

This ramus extends forwards running dorsomedial to the first holobranch (Fig. 1, R.APR.X_1). Shortly anterior this ramus enters the holobranch passing medial to the gill filament and lateral to the first epibranchial cartilage. Thereafter, it continues forwards passing lateral and then ventral to the first ceratobranchial and medial and then dorsal to the latter gill filament (Fig. 1). It gives off fine branches for the latter gill filament. After a long anterior course, this ramus ends as many fine branches in the epithelium and muscles of the filaments (Fig. 1, N.GF).

The ventrolateral division extends posteroventrally passing lateral to both the second efferent branchial vessel and the second epibranchial bone and medial to the gill filament of the second holobranch. Within the second holobranch and at its dorsal part, it gives off a medial motor branch for the second adductor branchialis muscle (Fig. 1, N.AB.II). The main division continues posteroventrally passing lateral and then ventral to the second epibranchial, ventral to the second efferent branchial vessel and lateral to the second adductor arcum branchialis muscle and then to the second ceratobranchial bone. In this position, it divides into a medial posterior pretrematic ramus (Fig. 1, R.PPR. X_1) and lateral to the posttrematic ramus (Fig. 1, R.PT. X_1).

The Posterior Pretrematic Ramus X:

Directly after its separation, the posterior pretrematic ramus runs posteromedially passing medial to the second ceratobranchial bone, ventral to the second adductor branchialis muscle and lateral to the pharyngeal epithelium and the gill rackers (Fig. 1, R.PPR.X_1). Here it gives off a fine nerve for both the epithelium and the rackers. Anterior to the origin of this branch, the ramus continues anteriorly running dorsomedial to the ceratobranchial and ventrolateral to the gill rackers and the pharyngeal lining. Here it gives rise to two branches one lateral to the other. The lateral branch ends in the dorsolateral gill rackers (Fig. 1, N.GR). The medial branch runs forwards, together with the main ramus for a long distance, giving many fine branches for the gill rackers (Fig. 1, N.GR). Thereafter, both the main ramus and its dorsal branch, continue anteriorly running dorsal to the ceratobranchial bone and ventral to the gill rackers. The dorsal branch ends as many fine nerves in the epithelium lining the gill rackers. The main ramus continues forwards giving rise many fine branches for the gill rackers (Fig. 1, N.GR). Finally, the posterior pretrematic ramus ends as fine nerves in the epithelium of the gill rackers.

Ramus Posttrematic X:

Posterior to its separation from the posterior pretrematic ramus, this ramus continues posteroventrally passing lateral to both the posterior pretrematic ramus and second adductor branchialis muscle, then to the ceratobranchial bone (Figs. 1, 5& 7, R.PT.X_1). Here, it joins the anterior pretrematic ramus of the second branchial vagal trunk (Fig. 1). Thereafter, the main ramus turns its course anteriorly giving off fine nerves for the lateral and ventrolateral gill filaments (Fig. 1, N.GF). At the beginning of its forward course, the ramus posttrematic extends ventrolateral to the ceratobranchial bone and dorsolateral to the second efferent branchial vessels. Here it gives off two fine nerves for the gill filaments (Fig. 1, N.GF). Thereafter, the main ramus continues forwards passing ventral to the lateral edge of the ceratobranchial and lateral to the efferent branchial vessels. After a long anterior course, the ramus posttrematic X_1 shifts medially passing dorsal to the efferent branchial vessels and ventral to the cerotobranchial bone (Fig.6, R.PT.X_1). More forwards, it continues passing ventral to the ceratobranchial bone and dorsomedial to the efferent branchial vessel. Here it gives off two fine nerves for the inner gill filament (Fig. 1, N.GF). More and more anteriorly, the ramus posttrematics continues passing ventromedial to the ceratobranchial bone and dorsomedial to the afferent branchial vessels. Reaching the point of attachment of the second holobranch with the isthmus. The posttrematic ramus X_1 leaves the holobranch and enters the isthmus. Shortly forwards, it extends ventromedial to both the second obliquus ventralis muscle and the second hypobranchial cartilage (Fig.6, R.PT.X_1). Here, it gives off a dorsal motor nerve for the latter muscle (Fig. 1, N.OV.II). Thereafter, it continues passing ventral to the hypobranchial bone, lateral to the thyroid gland. Here, it gives off a fine nerve for the latter gland (Fig. 1, N.TG). Finally, the ramus posttrematic ends as many fine nerves in the epithelium of the isthmus.

Second Branchial Vagal Trunk X:

Directly after its separation from the anterior division of the nervus vagus, the second branchial vagal trunk enters its own ganglion; the second epibranchial ganglion (Figs. 1 & 8, G.EB.X_2). This ganglion ventral to the prootic bone, dorsolateral to the head sympathetic chain, dorsal to the anterior jugular vein (Fig. 8, G.EB.X_2).

From the ventrolateral corner of the ganglion arises the second vagal branchial trunk (Fig. 1, T.VB.X_2). This trunk extends posteriorly in a ventral direction passing lateral to the anterior jugular vein and medial to the third levator arcus branchialis muscle. Just ventrolateral to the jugular vein, this trunk gives off a ventral anterior pretrematic ramus (Fig. 1, R.APR.X_2). Shortly posterior to this ramus, the trunk gives off two successive branches. These branches form the ramus pharyngeus of the second branchial vagal trunk (Fig. 1, R.PH.X_2). The main trunk extends more backwards passing ventral to the third levator arcus branchialis muscle and dorsolateral to the second epibranchial cartilage. As it enters, the third holobranch, it continues posteroventrally passing ventral to the third efferent branchial vessel and lateral to the third adductor branchialis muscle. Here, it gives off a motor branch for the latter muscle (Fig. 1, N.AB.III). Directly after that, it divides into a ventromedial posterior pretrematic ramus and a dorsolateral posttrematic ramus.

Ramus Pharyngeus X:

This ramus arises from the main trunk as two separate branches one dorsal to the other (Fig. 1, R.PH.X_2). These two branches run posteriorly passing ventromedial to the main trunk dorsal to the second epibranchial cartilage and lateral to the anterior jugular vein, reaching the dorsolateral corners of the pharynx, the ventral branch shifts posteromedially to passes dorsal to the pharyngeal epithelium, where it ramifies and distributes. The dorsal branch runs posteriorly in the same course, where it ends in the pharyngeal epithelium ventral to the third pharyngeobranchial bone.

Anterior Pretrematic Ramus X:

This ramus separates from the second branchial vagal trunk just anteroventral to the origin of the ramus pharyngeus X_2 (Fig. 1, R.APR.X_2). This ramus descends directly into the second holobranch. It passes lateral to both the second efferent branchial vessels and the second epibranchial cartilage. Shortly anterior, it joins the posttrematic ramus of the first vagal banchial trunk as previously mentioned.

Posterior Pretrematic Ramus X:

This ramus (Fig. 1, R.PPR.X_2) extends ventrally inside the third holobranch passing lateral to the third adductor branchialis muscle. Shortly posterior, it shifts medially passing dorsal to the latter muscle and ventral to the third epibranchial bone. Medial to the articulation between the epi- and ceratobranchial bones, it gives off a dorsal branch to the lateral pharyngeal epithelium. Directly after that, the pretrematic ramus turns its course anteriorly passing medial to the third ceratobranchial bone. Here, it gives off a ventral branch for the lateral gill rackers (Fig. 1, N.GR) and the epithelium. Shortly anterior this ramus gives off five or six branches for the rackers and epithelium of the holobranch (Fig. 1, N.GR). The main ramus gives off another ventral nerve for the ventral gill rackers. More and more forwards, the posterior pretrematic ramus extends dorsal to the ceratobranchial bone giving rise to three nerves for the gill rackers (Fig. 1, N.GR). Finally, it ends as many fine nerves in the epithelium and gill rackers of the third holobranch on its ventral side.

Ramus Posttrematic X:

After its separation from the posterior pretrematic ramus, the posttrematic one (Fig. 1, R.PT.X_2) runs posteroventrally, inside the third holobranch passing lateral to both the epibranchial bone and third adductor branchilis muscle. Here, it receives the anterior pretrematic ramus of the third vagal branchial trunk (Fig. 1). More backwords, it continues passing ventral to the third efferent branchial vessel and lateral to the ceratobranchial bone. Thereafter, it shifts its course ventrally and then anteriorly passing lateral to the latter bone and dorsal to the third afferent branchial vessels. During its anterior course, this ramus passes ventrolateral, ventral and ventromedial to the third ceratobranchial bone and dorsolateral, dorsal and then dorsomedial to the third efferent branchial vessel (Fig.6, R.PT.X_2). Here, it gives off many fine nerves for the gill filaments (Fig. 1, N.GF) of the third holobranch. At the attachment of the holobranch with the isthmus, the posttrematic ramus extends ventral to the ceratobranchial bone giving off a branch for the transversus ventralis muscle (Fig. 1, N.TV) and another motor branch for the third obliquus ventralis muscle (Fig. 1, N.OV.III). More forwards, the main ramus extends anteriorly and medially passing ventral to the third hypobranchial cartilage. Thereafter, it passes anterodorsally to end in the epithelium of the isthmus dorsal to the latter cartilage.

Third Branchial Vagal Trunk X:

During its passage through the jugular foramen, the posterior vagal division (Figs.1& 4, PO.VD.X), separates into an anterolateral third branchial vagal trunk (Figs. 1, T.VB.X_3) and a medial truncus visceralis (Fig. 1, T.VE). Directly, outside the cranial cavity, this trunk enters it own ganglion; the third epibranchial ganglion. This ganglion (Figs. 2 & 4, G.EB.X_3) is oval shaped mass of cells. It lies just ventral to the basiotic lamina, dorsal to the anterior jugular vein, dorsomedial to the fourth levator arcus branchialis muscle. The posterior part of the ganglion lies ventral to the ganglion of the truncus visceralis. From the posterior part of the ganglion arises the third branchial vagal trunk as two separate divisions (Fig. 1); the anterior one represents the rami pharyngeus and anterior pretrematic, the posterior one represents the posterior pretrematic and the posttrematic.

The anterior division extends posteroventrally passing medial to the thymus gland and lateral to the third levator arcus branchialis muscle, ventral to the latter muscle and dorsal to the third afferent branchial vessels, this division gives off the ramus pharyngeus X_3 medially (Fig. 1, R.PH.X_3) and the anterior pretrematic ramus ventrally and posteriorly (Fig. 1, R.APR.X_3).

Ramus Pharyngeus X:

After its separation, this ramus (Fig. 1, R.PH.X_3) extends posteriorly and medially to become dorsolateral to the pharynx, medial to the fourth levator arcus branchialis muscle and ventral to the tansversalis dorsalis muscle. Here, the ramus pharyngeus distributes in the epithelium of the roof of the pharynx.

Anterior Pretrematic Ramus X:

It runs posteroventrally to enter the third holobranch, posterior to the enterance of the third efferent branchial vessels. This ramus (Fig. 1, R.APR.X_3) extends within the holobranch passing lateral to the epibranchial cartilage and dorsal to the efferent branchial vessel. Thereafter, it runs anteriorly and joins the posttrematic ramus of the second branchial trunk (Fig. 1).

The posterior division originates from the caudal end of the ganglion and extends posteriorly passing ventrolateral to the ganglion of the truncus visceralis, medial to the fourth levator arcus branchialis muscle and dorsal to fourth epibranchial bone. Here it gives off a fine nerve for the lateral muscle (Fig. 1, N.LB.IV). Another nerve arises and enters the transversus dorsalis muscle (Fig. 1, N.TD). Thereafter, this division continues backwards passing medial to the thymus gland dorsal to the transversus dorsalis muscle and lateral to the truncus visceralis. After a long course, it enters the fourth holobranch passing lateral to the epibranchial bone and then to the fourth adductor branchialis muscle; here it gives off a branch for the latter muscle (Fig. 1, N.AB.IV). Shortly posterior to the origin of this branch it divides into the posterior pretrematic (Fig. 1, R.PPR.X_3) ramus and the posttrematic ramus (Fig. 1, R.PT.X_3).

Posterior Pretrematic Ramus X:

Directly after its origin, it continues posteroventrally inside the holobranch (Fig. 1, R.PPR.X_3). Then it shifts medially passing dorsal to the fourth adductor branchialis muscle and venrtral to the fourth epibranchial bone. Here, it gives off a branch for the gill rackers (Fig. 1, N.GR). Thereafter it changes its course ventrally then anteriorly passing dorsomedial to the ceratobranchial bone. This ramus runs forwards in this position for a long course giving rise to many fine nerves for the gill rackers and epithelium of the medial side of the holobranch (Fig. 1, N.GR).

Posttrematic Ramus X:

After its separation from the posterior pretrematic ramus, this ramus (Figs. 1, 2, 3& 4, R.PT.X_3) extends posteriorly and ventrally, passing lateral to both the fourth epibranchial bone and then the fourth adductor branchialis muscle and ventral to the fourth efferent branchial vessel. Shortly after that, this ramus turns its course anteriorly running ventrolateral to the ceratobranchial bone and dorsomedial to the fourth efferent branchial vessels. Here it gives off fine nerves for the epithelium of the gill filament (Figs. 1, N.GF). Thereafter, this ramus continues forwards passing ventral and then ventromedial to the ceratobranchial bone and dorsal to the efferent branchial vessels, till it reaches the anterior medial edge of the holobranch. Here, it gives off many fine nerves for the gill filaments (Figs. 1, N.GF). At the end of its anterior course it gives off a nerve for the fourth obliquus ventralis muscle (Fig. 1, N.OV.IV). The main ramus, then, passes ventral to the floor of the pharynx to end as fine nerves in the epithelium of the isthmus.

At the origin of the third trunk from its ganglion, few fibres pass directly from the root and don't enter any ganglion. This nerve passes to fourth levator arcus branchialis (Fig. 1, N.LB.IV).

Truncus Visceralis:

This trunk (Figs. 1& 9, T.VE) arises from the posterior division of the nervus vagus and enters directly its own ganglion (Figs. 1& 3, G.VE). From the posterior end of the ganglion arises the truncus visceralis.The posterior distribution of the trunk is out of our scope.

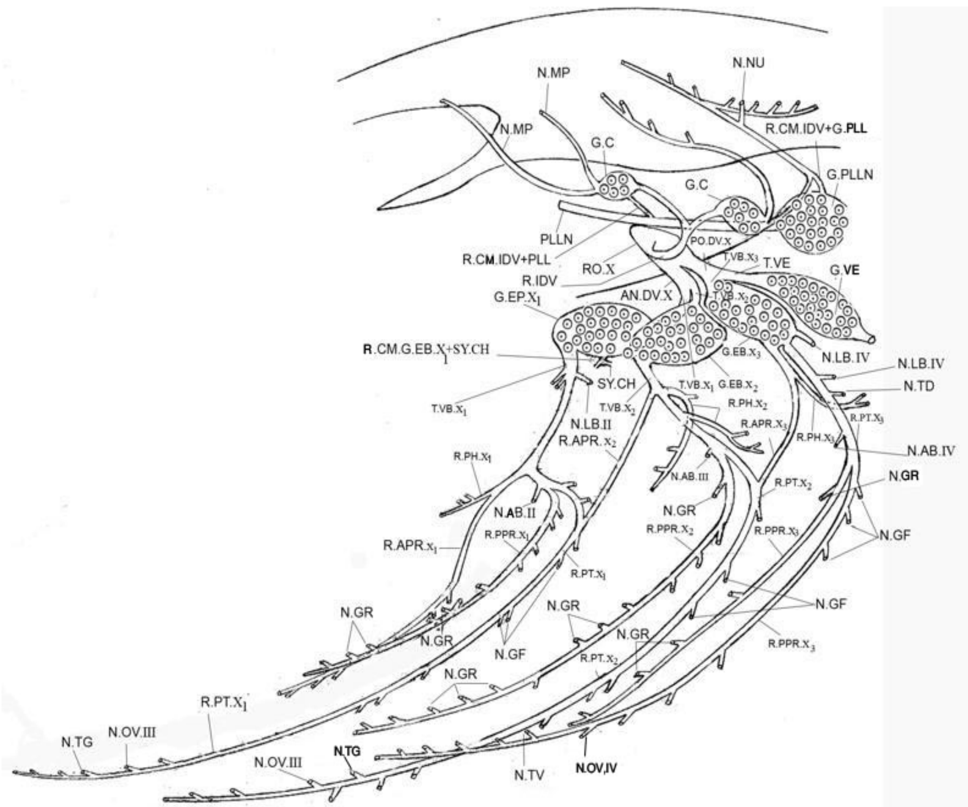

Fig. 1: Graphic reconstruction of the vagus nerve in a lateral view.

AN.DV.X	: Anterior division of the root of nervus vagus.
G.C	: Ganglionic cells.
G.CI	: Ciliary ganglion.
$G.EB.X_1$	: Epibranchial ganglion of the first vagal branchial trunk.
$G.EB.X_2$	: Epibranchial ganglion of the second vagal branchial trunk.
$G.EB.X_3$	: Epibranchial ganglion of the third vagal branchial trunk.
G.PLLN	: Ganglion of the posterior lateral line nerve
G.VA.SY	: Vagal sympathetic ganglion
G.VE	: Ganglion of truncus visceralis.
N.AB.II	: Nerve to the second adductor arcus branchialis muscle
N.AB.III	: Nerve to the third adductor arcus branchialis muscle
N.AB.IV	: Nerve to the fourth adductor arcus branchialis muscle
N.GF	: Nerve to the gill gilament.
N.GR	: Nerve to the gill rackers.
N.LB. II	: nerve to the second levator arcum branchialis muscle.
N.LB. III	: nerve to the third levator arcum branchialis muscle.
N.LB. IV	: nerve to the fourth levator arcum branchialis muscle.
N.MP	: Nerve to the oblique inferior muscle.
N.OV.II	: Nerve to the second obliquus ventralis muscle.
N.OV.III	: Nerve to the third obliquus ventralis muscle.
N.OV.IV	: Nerve to the fourth obliquus ventralis muscle.
N.TD	: Nerve to the transversus dorsalis muscle.
N.TG	: Nerve to the thyroid gland.
N.TV	: Nerve to the transversus ventralis muscle.

N.NU	: Nerves to the neuromast of the lateral line canal.
PLLN	: Posterior lateral line nerve.
PO.DV.X	: Posterior division of vagal nerve root.
R.APR.X_1	: Anterior pretrematic ramus of the first branchial vagal trunk.
R.APR.X_2	: Anterior pretrematic of the second branchial vagal trunk.
R.APR.X_3	: Anterior pretrematic of the third branchial vagal trunk.
R.CM.G.EB.X_1+ SY.CH	: Ramus communicans between the epibranchial ganglion of the first branchial vagal trunk and head sympathetic chain.
R.CM.IDV + G.PLL	: Ramus communicans between the intracranial dorsal vagal ramus and the : ganglion of the posterior lateral line nerve.
R.CM.IDV + PLL	: Ramus communicans between the intracranial dorsal vagal ramus and the posterior lateral line nerve.
R.IDV	: Intracranial dorsal vagal ramus.
R.PH.X_1	: Ramus pharyngeus of the first branchial vagal trunk.
R.PH.X_2	: Ramus pharyngeus of the second branchial vagal trunk.
R.PH.X_3	: Ramus pharyngeus of the third branchial vagal trunk.
R.PPR.X_1	: Posterior pretrematic ramus of the first branchial vagal trunk.
R.PPR.X_2	: Posterior pretrematic ramus of the second branchial vagal trunk.
R.PPR.X_3	: Posterior pretrematic ramus of the third branchial vagal trunk.
R.PT.X_1	: Posttrematic ramus of first branchial vagal trunk.
R.PT.X_1	: Posttrematic ramus of second branchial vagal trunk.
R.PT.X_1	: Posttrematic ramus of third branchial vagal trunk.
RO.X	: Root of nervus vagus.
SY.CH	: Head sympathetic chain.
T.VE	: Truncus visceralis.
T.VB.X_1	: First branchial vagal trunk.
T.VB.X_2	: Second branchial vagal trunk.
T.VB.X_3	: Third branchial vagal trunk.

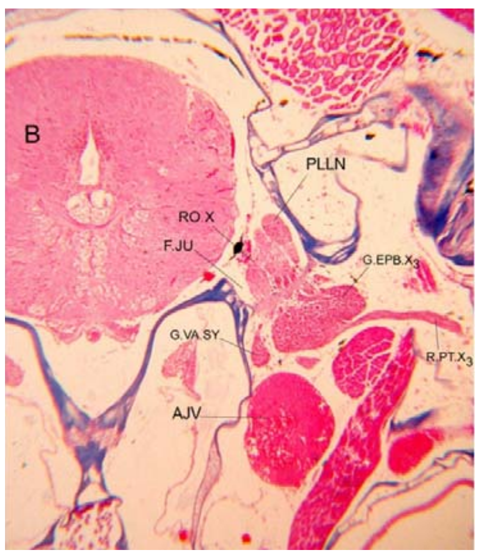

Fig. 2: Photomicrograph of a part of transverse section passing through the post otic region demonstrating the exit of both the vagal and posterior lateral line nerves through the jugular foramen. It also showing the posttrematic and the epibranchial ganglion of the third branchial vagal trunk. AJV, Anterior jugular vein; G.VA.SY, Vagal sympathatic ganglion; R.PT.X_3 Posttrematic ramus of the third vagal branchial trunk; F.JU, Jugular foramen; RO.X, Vagal root; G.EB.X_3, Ganglion of the third vagal branchial trunk, PLLN, Posterior lateral linenerve.

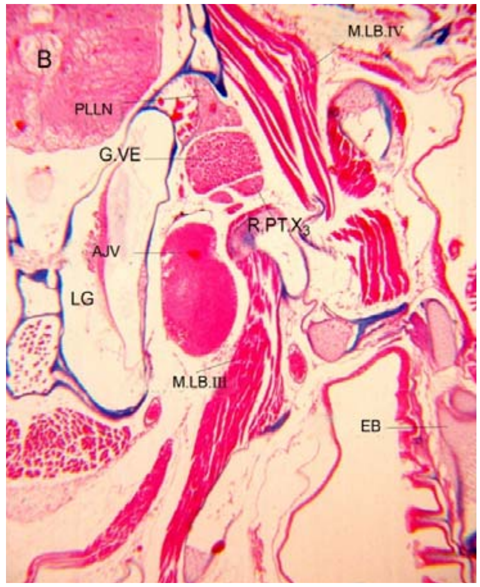

Fig. 3: Photomicrograph of a part of transverse section passing through the post otic region showing the division of the vagal root into its two divisions. It also illustrates the posttrematic and the epibranchial ganglion of the third branchial vagal trunk. R.PT.$X_{3,}$ Ramus posttrematic of the third vagal branchial trunk; LG, Lagena; EB, Epibranchial cartilage; M.LB.III, Third levator arcus branchialis muscle; G.VE, Vestibular ganglion; PLLN, Posterior lateral line nerve; AJV, Anterior jugular vein; M.LB.IV, Fourth levator arcus branchialis muscle; B, Brain.

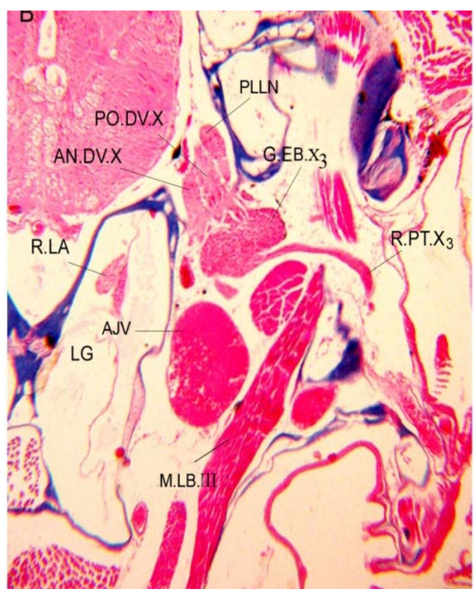

Fig. 4: Photomicrograph of a part of transverse section passing through thepost otic region showing the division of the vagal root into its two divisions. It also illustrates the posttrematic ramus and the epibranchial ganglion of the third branchial vagal trunk. R.PT.$X_{3,}$Ramus posttrematic of the third vagal branchial trunk; LG, Lagena; M.LB.III, Third levator arcus branchialis muscle; PLLN, Posterior lateral line nerve; AJV, Anterior jugular vein; B, Brain; PO.DV.X, Posterior division of vagal nerve root; AN.DV.X, Anterior division of vagal nerve root; R.LA, Lagenar ramus; G.EB.X_3, Epibranchial ganglion of the third vagal branchial trunk.

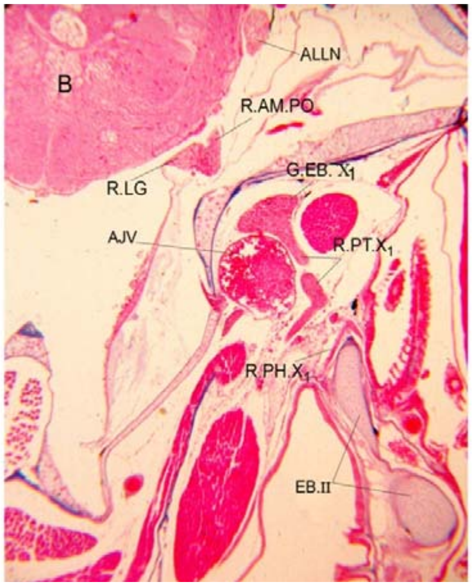

Fig. 5: Photomicrograph of a part of transverse section passing through the otic region showing the origin of the posterior lateral line nerve, the ramus ampullaris posterior, lagenar ramus the rami posttrematic, pharyngeus as well as the epibranchial ganglion of the first vagal branchial trunk.R.LG, Lagenar ramus; AJV, Anterior jugular vein; B, Brain; EB.II, Second epibranchial cartilage; R.PH.X_1. Ramus pharyngeus of the first branchial vagal trunk; R.PT.$X_{11,,}$ Ramus posttrematic of the first vagal branchial trunk, G.EB.X_1, Epibranchial ganglion of the first vagal branchial trunk; ALLN, Anterior lateral line nerve; R.AM.PO, Ramus ampularis posterior.

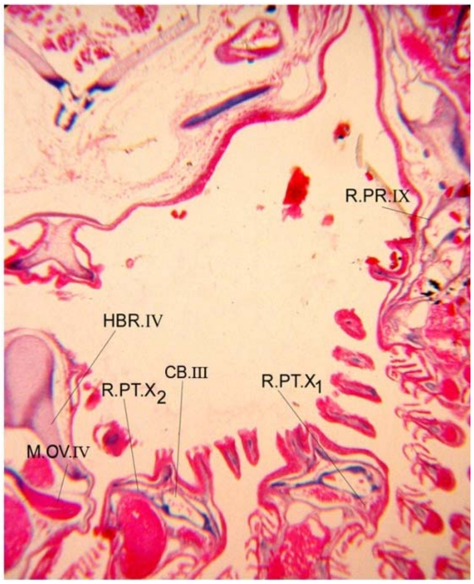

Fig. 6: Photomicrograph of a part of transverse section passing through the otic region showing the pretrematic ramus of the glossopharyngeal nerve and the posttrematic rami of the first and second branchial vagal trunks. R.PR.X_1, pretrematic ramus ofthe first branchial vagal trunk, R.PT.$X_{1,,}$ Ramus posttrematic of the first vagal branchial trunk,HBR.IV, Foutrh hypobranchial cartilage, CB.III; Third ceratobranchial cartilage; R.PT.X_2, Posttrematic ramus of thesecond branchial vagal trunk; M.OV.IV, Fourth obliquus ventralis muscle.

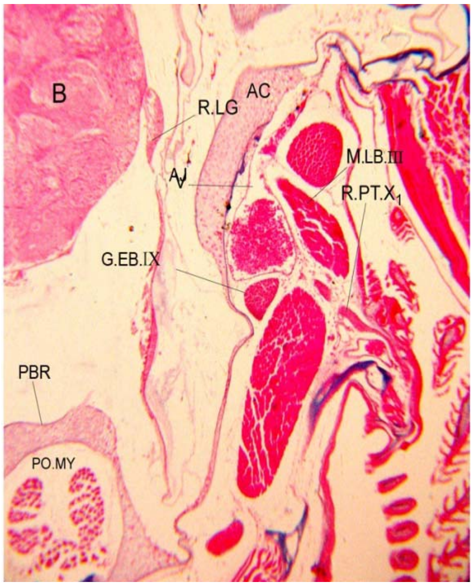

Fig. 7: Photomicrograph of a part of transversesection passing through the otic region showing the posttrematic ramus of the first branchial vagal trunk. PBR, Pseudobranch; PO.MY, Posterior myodome; G.EB.IX, Epibranchial ganglion of the nervus glossopharyngeus; B, Brain; R.LG, Lagenar ramus, AC, Auditory capsule; M.LB.III, Third levator arcus branchialis muscle; R.PT.X_1, posttrematic ramus of the first branchial vagal trunk.

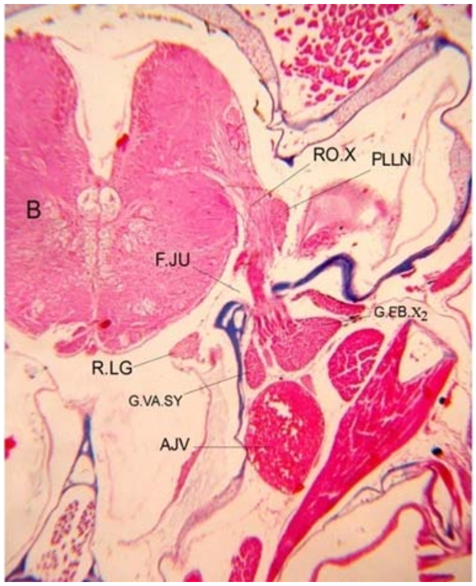

Fig. 8: Photomicrograph of a part of transverse passing in the postotic region showing the root of the nervus vagus, its foramen; jugular foramen, the epibranchial ganglion of the second branchial vagal trunk. G.EB.X_2, Epibranchial ganglion of the first vagal branchial trunk; B, Brain; R.LG, Lagenar ramus; AJV, anterior jugular vein; G.VA.SY, vagal sympathetic ganglion; F.JU, foramen jugular; RO.X, vagal root; PLLN, posterior lateral line nerve.

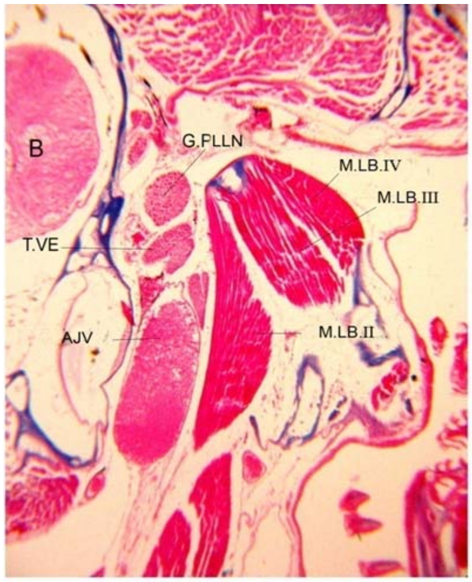

Fig. 9: Photomicrograph of a part of transverse passing gassing through the occipital region showing the ganglion of the posterior lateral line nerve & the truncus visceralis. B, Brain; M.LB.II, second levator arcus branchialis muscle; M.LB.III, Third levator arcus branchialis muscle; M.LB.IV, fourth levator arcus branchialis muscle; AJV, anterior jugular vein; T.VE, truncus visceralis; G.PLLN, ganglion of the posterior lateral line nerve.

Discussion:

In *Mugil cephalus*, the nervus vagus originates from the medulla oblongata by one strong root. It is distinctly separated from the root of the posterior lateral line nerve. The nervus vagus arises by a single strong root in *Menidia* (Herrick, 1899), *Parasilurus asotus* (Atoda, 1936), *Lampanyctus leucopsarus* (Ray, 1950), *Pseudorhombus arsius* (Marathe, 1955), *Mystus seenghala* (Mithel, 1964), *Ctenopharyngodon idellus* (Dakrory, 2000) and in *Tilapia zillii* (Ali, 2005; Dakrory and Ali, 2006). Three roots for the nervus vagus were described by Harrison (1981) in *Trichiurus lepturus*. In *Lepidotrigla* (Allis, 1909), the vagus nerve arises by three small anterior rootlets and a main posterior root. Four rootlets were found in *Polycentrus schomburgkii* (Freihofer, 1978), and five in *Latimeria chalumnae* (Northcutt *et al*., 1978) and *Gnathonemus petersii* (Lazar *et al*., 1992). The nerve in question arises by several rootlets in *Amia calva* and *Scomber scomber* (Allis, 1897 & 1909, respectively) and *Polypterus senegalus* (Piotrowski and Northcutt, 1996) and by twenty rootlets in *Polyodon* (Norris, 1925). In this respect, the multiplicity of rootlets appears to be of common occurrence and may be a general rule, among teleosts according to Stannius (1849).

Among cartilaginous fishes, in *Squalus acanthias*, Norris and Hughes (1920) stated that, there are thirty or more rootlets for the nervus vagus. Five rootlets for this nerve were found in the cartilaginous fishes studied by Gohar and Mazhar (1964). In the skate, *Raja eglanteria* (Sperry and Boord, 1992, 1993), the vagus nerve arises as a series of superficial rootlets. Edgeworth (1935) stated that the rootlets of the nervus vagus in cartilaginous fishes vary from two to thirty; the most anterior of which are sensory forming the posterior lateral line nerve, while the most posterior ones are exclusively motor.

Among amphibia, the nervus vagus arises by two roots as mentioned by Gaupp (1911), Soliman and Mostafa (1984) and Shaheen (1987). However, Wake *et al*. (1983) stated that the nervus vagus arises by three major and minor rootlets in the amphibians he studied.

In the species under investigation, the nervus vagus has a medial intracranial glanglion (the ganglion of the intracranial dorsal vagal ramus) and three lateral extracranial epibranchial ganglia and a ganglion for truncus visceralis. This ganglionic pattern occurs in most bony fishes. This was confirmed by Allis (1897, 1903, 1909) in *Amia calva*, *Scomber scomber* and *Lepidotrigla*, respectively, Atoda (1936) in *Parasilurus asotus*, Ray (1950) in *Polycentrus schomburgkii*, Northcutt and Bemis (1993) in *Latimeria chalumnae*, Piotrowski and

Northcutt (1996) in *Polypterus senegalus*, Dakrory (2000) in *Ctenopharyngodon idellus* and by Ali (2005) and Dakrory and Ali (2006) in *Tilapia zilli*.

Among cartilaginous fishes, there is no medial sensory ganglion for the nervus vagus (Norris and Hughes, 1920; Chandy, 1955; Sperry and Boord, 1993; Dakrory, 2000).

In Agnatha, no medial ganglion was reported in hagfish (Lindström, 1949). There is only one lateral (jugular or epibranchial) ganglion which is fragmented into several ganglia and scattered ganglion cells in *Eptotretus stoutii* and *Myxine glutinosa* (Braun, 1998). The same was found in lampreys by Johnston (1905 and 1908a), Wicht (1996) and Kuratani *et al*. (1997).

In *Mugil cephalus*, the medial ganglion is associated with the intracranial dorsal cutaneous vagal ramus, which carries general somatic sensory fibres to the skin covering the postotic region of the skull. The same was reported in *Menidia* (Herrick, 1899), *Scomber scomber* (Allis, 1903) and in *Ctenopharyngodon idellus* (Dakrory, 2000).

Among amphibia, a dorsal cutaneous vagal ramus is found in salamanders (Coghill, 1902; Northcutt, 1992).

The intracranial dorsal cutaneous vagal ramus in *Mugil cephalus* carries general "cutaneous" somatic sensory fibres. This is in agreement very well with the description of Allis (1897, 1903 & 1909) in *Amia calva*, *Scomber scomber* and *Lepidotrigla*, respectively, Herrick (1899) in *Menidia*, Norris (1925) in *Acipenser*, *Lepidosteus* and *Amia*, Freihofer (1963 & 1978) in *Atherinops affinis* and *Polycentrus schomburgkii*, respectively, Piotrowski and Northcutt (1996) in *Polypterus senegalus* and by Dakrory (2000) in *Ctenopharyngodon idellus*. On the other hand, this ramus was not found in *Protopterus annectens* (Pinkus, 1895), *Lampanyctus leucopsarus* (Ray, 1950) and *Latimeria chalumnae* (Northcutt and Bemis, 1993).

In the present study, the lateral vagal ganglion is divided into three epibranchial ganglia and visceralis one. Four epibranchial ganglia, in *Amia calva* (Allis, 1897), in *Menidia* (Herrick, 1899), in *Parasilurus asotus* (Atoda, 1936), in *Pseudorhombus arsius* (Marathe, 1955), in *Trichiurus lepturus* (Harrison, 1981), in *Cyprinus carpio* by de Graaf (1990), *Ctenopharyngodon idellus* (Dakrory, 2000) and in *Tilapia zilli* (Ali, 2005; Dakrory and Ali, 2006). Among bony fishes, three ganglia were described by Ray (1950) in *Lampanyctus leucopsarus* and Freihofer (1978) in *Polycentrus schomburgkii*. On the other hand, Herrick (1901) found that the lateral vagal (epibranchial) ganglion is divided into two parts only; one epibranchial and one intestinal (visceralis) in *Argyropelecus hemigymnus*. Also, Allis (1903) stated that, only the first epibranchial ganglion is separated, while the others are more or less fused in *Scomber scomber*. In *Cyclothone acclinidens* (Gierse, 1904), separate ganglia were described for the first two branchial trunks only. Also, *Polypterus senegalus* has only two lateral epibranchial vagal ganglia (Piotrowski and Northcutt, 1996).

Among cartilaginous fishes, there are four epibranchial ganglia and one visceral ganglion for the truncus visceralis. This was the case found in cartilaginous species studied by Shore (1889), Chandy (1955), Sperry and Boord (1993) and by Dakrory (2000).

In the present study, the first and second branchial vagal trunks arise from the nervus vagus as one division while the third one, and the visceral trunk originate from a second division. However, in *Ctenopharyngodon idellus*, Dakrory (2000) reported that the first and second branchial trunks arise as a common nerve, while the third and fourth ones, together with the visceral trunk originate at the same point from the main vagal nerve. In this respect, Atoda (1936), Dalela and Jain (1968) and de Graaf (1990) found that all the branchial vagal trunks arise at the same point in *Parasilurus asotus*, *Clarias batrachus* and *Cyprinus carpio*, respectively. In *Mastacembelus armatus* (Bhargava, 1959), there are two trunks arising from the vagal ganglion;one trunk innervating the viscera and the other splits into the four branchial nerves. However, two dorsal and three ventral trunks arise from the vagal mass in *Amphipnous cuchia* (Saxena, 1967).

The ramus opercularis vagi, which was mentioned by Herrick (1899) in *Menidia* and Freihofer (1978) in *Polycentrus schomburgkii*, is not represented in the mugilid fish of the present study. It is also not mentioned in *Lampanyctus leucopsarus* (Ray, 1950), *Trichiurus lepturus* (Harrison, 1981), *Polypterus senegalus* (Piotrowski and Northcutt, 1996) and *Ctenopharyngodon idellus* (Dakrory, 2000).

Typically, each of the branchial vagal trunks of fishes, as found in the present study, is divided into rami pharyngeus, pre-trematics and post-trematicus. On the other hand, in the bony fish, *Cyclothone acclinidens*(Gierse, 1904), the ramus pharyngeus is completely lacking. Among cartilaginous fishes, the last or fourth ramus post-trematic was found to be wanting in the batoid *Raja eglanteria* (Sperry and Boord, 1993).

In *Mugil cephalus*, the pretrematic rami of the branchial vagal trunks are two in number (anterior and posterior). This is also the case (but upper and lower) in *Acipenser*, *Lepidosteus* and *Amia* (Norris, 1925), *Lampanyctus leucopsarus* (Ray, 1950), *Cyprinus carpio* (de Graaf, 1990), *Polypterus senegalus* (Piotrowski and Northcutt, 1996) and in *Tilapia zillii* (Ali, 2005; Dakrory and Ali, 2006). On the other hand, one pretrematic ramus was found in the shark *Squalus acanthias* (Norris and Hughes, 1920), in the dipnoan *Protopterus annectens* (Pinkus, 1895), *Menidia* (Herrick, 1899), *Latimeria chalumnae* (Northcutt and Bemis, 1993) and *Ctenopharyngodon idellus* (Dakrory, 2000). In addition, one posttrematic ramus is present in *Mugil cephalus*. The same was described by Pinkus (1895) in the lungfish *Protopterus annectens*, Dakrory (2000) in *Ctenopharyngodon idellus*, and by Ali (2005) and Dakrory and Ali (2006). On the other hand, two rami are present in *Squalus acanthias* (Norris and Hughes, 1920) and in the bony fishes, *Menidia* (Herrick, 1899), *Acipenser*, *Lepidosteus* and *Amia* (Norris, 1925), *Cyprinus carpio* (de Grraf, 1990), *Latimeria chalumnae* (Northcutt and Bemis, 1993) and *Polypterus senegalus* (Piotrowski and Northcutt, 1996).

In the present study, the first epibranchial ganglion receives a sympathetic branches arising from the sympathetic vagal ganglion. In this respect, the post-trematic ramus of the first branchial vagal trunk receives a sympathetic branch arising from the sympathetic vagal ganglion in *Ctenopharyngodon idellus* (Dakrory, 2000). A connection between the nervus vagus and the sympathetic ganglion is present in *Pseudorhombus arsius* (Marathe, 1955) and *Takifugu niphobles* (Funakoshi *et al*., 1996 & 1997). Ray (1950) stated that the sympathetic trunk has a connection with one of the vagal nerves arising in the jugular foramen by a minute branch in *Lampanyctus leucopsarus*.

In this study, the nervus vagus carries special visceral sensory fibres for the taste buds and general visceral sensory fibres for the lining epithelium of the pharynx and visceral arches. In addition it carries, also, branchiomeric motor (visceromotor) fibres for the branchial muscles. In addition to these fibres, the nervus vagus carries also, general somatic sensory fibres to the skin covering the roof of the postotic region of the skull, and vegetative fibres (parasympathetic) for the blood vessels and the muscles of the gill filaments.

In this study, the somatic sensory fibres of the vagus nerve are included in a separate nerve which passes to the skin covering the postotic region of the skull.

The visceral sensory fibres are found in all the rami of the nervus vagus studied. The pharyngeal and pretrematic rami carry only visceral sensory, whereas, the posttrematic rami carry, in addition to the visceromotor fibres, visceral sensory ones. The visceral sensory fibres of the vaugs nerve and those of the nervus facialis innervate the oropharyngeal epithelium and their taste buds. This means that the gustatory fibres, in fishes, are carried by three cranial nerves; the facial, glossopharyngeal and vagal nerves. This was confirmed by Herrick (1944) and Kinnamon (1987) in fishes and tetrapods. In fishes, having external taste buds, these buds are innervated by rami derived from the facial nerve (Norris, 1925; Finger, 1983). Such external taste buds and their special facial rami are not observed in the present study. About the origin or source of the gustatory components of these three nerves, Landacre (1910) and Northcutt (1997) mentioned that these components have been thought to arise from a separate epibranchial neurogenic placode.

In lampreys, the gustatory fibres are carried by the nervi glossopharyngeus and vagus only. Such fibres are completely lacking from the facial nerve (Johnston, 1905 and 1908b; Finger and Morita, 1985; Finger, 1987; Braun, 1998).

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