The Central Nervous System of Lethocerus indicum Lep. et Serv.

(Hemiptera-Heteroptera-Cryptocerata-Belostomatidae)

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Introduction

The morphology of the hemipteran nervous system has been described by Hamilton (1931), Presswala and George, (1936), Rawat (1939) and Ewen (1960, 62) in *Nepa cinerea, Sphaerodema rusticum, Naucoris cimicoides, Liocoris unctuosus* and *Adelphocoris lineolatus* respectively. Certain comparison of hemipteran nervous system has been made by Brandt (1878) and Pflugfelder (1937). Comparative study of the nervous system of hemipteran insects and other insects, chiefly by, Imms (1957) and Snodgrass (1935) have provided little information regarding the nervous system of Belostomatidae.

It is already mentioned above that the morphology of the hemipteran nervous system is inadequately described and so far no general pattern of nervous system has been established. The aim of the present study is to add this knowledge in the Group Cryptocerata by scrutinizing the nervous system of *Lethocerus indicum*. It must be recognized, however, that further detailed studies are needed before a typical scheme of nervous system for Hemiptera or indeed for Cryptocerata can be established.

A description of the gross anatomy of the nervous system of *Lethocerus indicum* is presented. It includes the anatomy, ganglia, and the nerve trunks. The important and main branches were traced and finer branches have been attempted. The terminology of the nervous system is based upon the terms applied by Snodgrass (1935) and Imms (1957).

Material and Method

The nervous system of *Lethocerus indicum* was studied in freshly killed specimens, because the nerves were more flexible than in preserved specimens and thus could be handled more safely without breaking. The animals were usually dissected in the Ringer's solution (Ephrushi & Beadle, 1936). Material fixed in Bouin's fluid was dissected in 70 % alcohol medium. The

common stain, methylene blue, was used for the early staining of the nerves. It was applied with a pipette or syringe to the area under examination, allowed to act for a few seconds only, then washed away. The stain shows the smaller nerves against the whitish tissue of the freshly killed insect. This technique was also used by Ewen (1960, 62) in describing the nervous system of *Liocoris unctuosus* and *Adelphocoris lineolatus*. All the observations and dissections were carried out under a stereoscopic binocular microscope.

The material for above mentioned work was collected from the suburb of Ajmer, especially from Anasagar and Foysagar Lakes in the month of August and September. Some specimens were preserved in formalin and other were kept alive in a pond.

Results

According to Imms (1957) the nervous system of Hemiptera exhibits considerable concentration, the abdominal ganglia being fused with the thoracic ganglia to a large extent. Even the thoracic ganglia are fused with each other or with the suboesophageal ganglia.

The present study has revealed only two ventral ganglia in *Lethocerus indicum*, the suboesophageal-prothoracic ganglion (Suboesophageal and prothoracic ganglia) and the thoraco-abdominal ganglion (Mesothoracic ganglion, Metathoracic ganglion and the abdminal ganglia.). Hamilton (1931) in *Nepa cinera*, Presswala and George (1936) in *Sphaerodema rusticum*, Rawat (1939) in *Nacuoris cimicoides* and Ewen (1962) in *Adelophocoris lineolatus* have also reported only two ventral ganglia. However, earlier Ewen (1960) has reported three ventral ganglia in *Liocoris uncutosus*. Imms (1957) has stated three ventral ganglia in *Lygaeus*, *Capsus*, *Notonecta* and *Aphrophora*. Further, Imms (1957) has stated a single ventral ganglionic mass in *Hydrometra* and Coccoidae, where it is formed by the coalescence of all the ventral ganglia. Ewen (1960) has stated the three ventral ganglia in *Liocoris unctuosus*, they are, the suboesophageal ganglion, prothoracic ganglion and the thoraco-abdminal ganglion. In *Nepa cinera*, *Sphaerodema rusticum*, *Nacuoris cimicoides*, *Adelphocoris lineolatus* and also in *Lethocerus indicum* the two ventral ganglia are suboesophgeal-prothoracic ganglion and the thoraco-abdminal ganglion. The following observations were made:

1. *The Brain*

The brain of *Lethocerus indicum* is a bilobed structure, placed in the posterior most region of the head between the two compound eyes. Like other insects (Imms; 1957, Snodgrass, 1935; Ewen, 1960, 62) the brain of *Lethocerus indicum* is primarily a connecting centre between the sensory organs of the head and the neurons of the cephalic, thoracic and abdominal motor centers. The major constitution of the brain is neuropile tissue mass, mainly made up of the proximal ends of the nerve roots and nerve tracts. These nerve roots and tracts are mainly from the structure like compound eyes, ocelli and sensory parts of the antenna (Imms, 1957; Snodgrass, 1935; Ewen, 1960 and 62).

The brain is generally divisible into three parts, the protocerebrum, the deutocerebrum and the tritocerebrum (Imms, 1957; Snodgrass, 1935). These three parts are not discernible externally in *Lethocerus indicum*. They can be differentiated from their nerve supply. The motor centers of brain are in deutocerebral and tritocerebral lober with motor connextion to antenna, labrum and muscles innervated from the symphathetic system. The three parts of brain are:

a. *Protocerebrum* (Fig. 1; B 1). — It is the largest and the most dorsal part of the neuropile mass. The protocerebrum is made up of lateral protocerebral lobes, the median pars intercerebralis and other internal structures. The large optic lobes are present on the lateral side of the brain. They are close to the protocerebral lobes, but they have distinct origin. The optic lobes are slightly narrow at their base and, therefore, the optic nerves are very short and stout.

b. *Deutocerebrum.* — The chief function of the deutocerebrum is to supply the sensory innervation to the antenna and motor innervation to the antennal musculature. The antennal nerves (3) are long, narrow stalked arising anteriorly and supplying short branches on the way to the antennal musculature.

c. *Tritocerebrum.* — The tritocerebrum give rise to the labrofrontal nerve anteriorly and this divides into two, the frontal ganglion connective (1) and labral nerve. The frontal ganglion connective runs anteriorly and medially to a frontal ganglion (FG), which lies beneath the main part of the brain. The labral nerve extends anteriorly to the labrum and innervates the labral muscles and lower parts of the anteclypeus. The frontal ganglion is also connected to the hypocerebral ganglion by a recurrent nerve (2).

Ventral or circumoesophageal connectives (12) join the tritocerebral lobes with suboesophageal-prothoracic ganglionic mass. In between these two connectives the esophagus passes. These are very short and thick structures and due to this the suboesophageal-prothoracic ganglionic mass is almost fused with the brain.

2. *The Suboesophageal-Prothoracic ganglion* (Fig. 1; SPG)

In *Lethocerus indicum* these two ganglia form a complex mass and morphologically there is no difference between these two ganglia. The fusion of these two ganglia has also been reported by Hamilton (1936) in *Nepa cinera*, Presswala and George (1936) in *Sphaerodema rusticum*, Rawat (1939) in *Nacuoris cimicoides* and Ewen (1962) in *Adelphocoris lineolatus*. Ewen in his early paper (1960) has reported these two ganglia as a separate ganglionic mass in *Liocoris unctuosus*.

The suboesophageal-prothoracic ganglion is elongated, dorso-ventrally flattened and a pear shaped body. It is situated in the cervical region of the head and great care should be taken during dissection because the head of the insect is delicately articulated with prothorax. The ganglion innervates the mandibular, maxillary, cephalic muscles, prothoracic muscles, the salivary gland and to the thoracic glands.

The nervus mandibular (5), nervus maxillaris (6), and nervus labialis (4) arise from the middle anterior portion of the ventral side of the ganglion. The nerves to the mandibular and maxillary bristles innervate

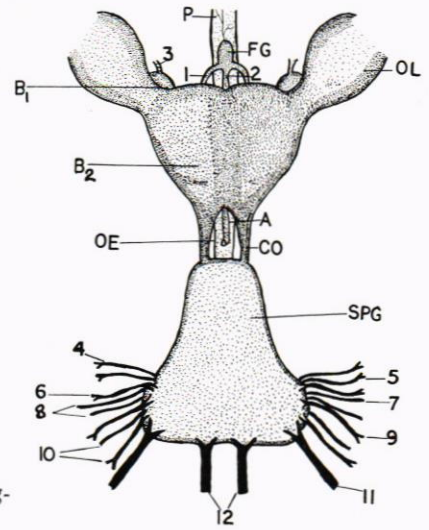

Fig. 1. Brain and Suboesophageal-prothoracic ganglia with their nerve supplies.

these mouth parts with sensory and motor branch to the labial muscles. The '*nerf laterale*' described by Cazal (1948) and Ewen (1962), was observed in *Lethocerus indicum*. Ewen (1960) has reported the absence of '*nerf laterale*' in *Liocoris unctuosus*.

Two pairs of cephalic nerves (8) arise just posterior to the nervus maxillaris, innervate the majority of the cephalic and thoracic muscles. A pair of salivary gland nerve (9) which innervate the salivary gland and duct, is observed in *Lethocerus indicum*. Just medial to the origin of the maxillary nerve a small nerve, the thoracic gland nerve, arise, which innervate the thoracic glands. Wells (1954) has reported that there is no thoracic gland nerve in heteroptera-homoptera. Ewen (1962) has reported the thoracic gland nerve in *Adelphocoris lineolatus*.

Two more main branches arise from the more posterior sector of the ganglion on the lateral surface. The first innervates (10) the cervical region muscles and the second (11) innervates the prothoracic leg. The latter is thick and stout.

From the posterior middle portion of the ganglion arise two ventral nerve cords (12) which connect the suboesophageal-prothoracic ganglion with the thoraco-abdominal ganglion. These two nerves are long and stout.

3. *The Thoraco-Abdominal Ganglion* (TAG)

In Hemiptera the thoracic and abdominal ganglia are always fused structures (Imms, 1957; Snodgrass, 1935; Hamilton, 1931; Preswala and George, 1936; Rawat, 1939 and Ewen, 1960, 1962) so as to form a complex, the thoraco-abdminal ganglion. It is situated in the posterior half of the mesothorax between the endosternites of mesothorax and metathorax, which support the ganglionic mass. To this ganglion Presswala and George (1936) have named as mesothoracic ganglion in *Sphaerodema rusticum*. Rawat

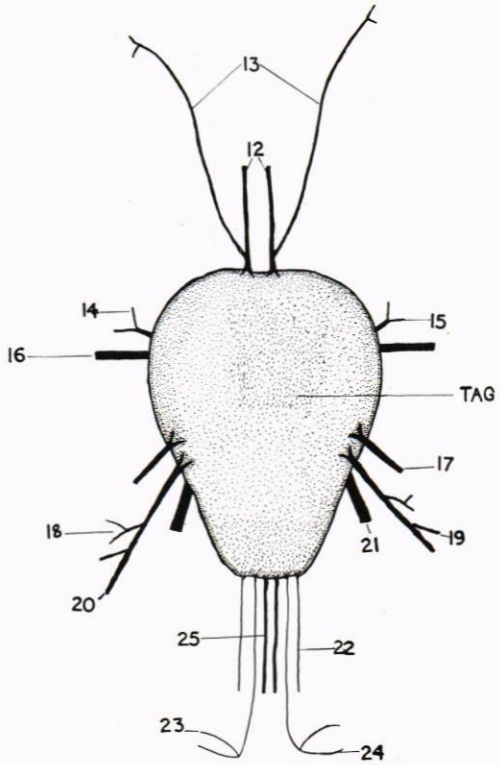

Fig. 2. Thoraco-abdominal ganglion and its nerves.

(1939) and Ewen (1960, 62) have named this ganglion as the thoraco-abdominal ganglion in *Nacuoris cimicoides*, *Liocoris unctuosus* and *Adelphocoris lineolatus* respectively.

The ganglionic mass is almost a pear shaped body, with slight bulge on the middle dorsal portion. Three distinct regions can be recognized externally according to their nerve supply. The anterior region, the middle region and the posterior region. The anterior region represents the mesothoracic ganglion becuase it supplies nerves to the mesothoracic areas. The middle portion represents the metathoracic ganglion because the nerve supplies to metathoracic parts are from this region. The posterior region represents the fused abdominal ganglia becuase the nerve supplies to all the abdominal segments take place from this portion.

From the antero-lateral region two nerves arise on the ventro-lateral side. The midanterior region gives rise to two long nerves just below the fusion of the nerve cord into the thoraco-abdominal ganglion, which innervates the hemelytra (13). The two divisions of the first one supply the anterior (14) and posterior (15) mesothoracic muscles. The second (16) innervate the muscles of mesothoracic legs. The mesothoracic leg nerve is stout and long.

The middle region gives out three nerves from dorso-lateral side. The first (17) innervates the anterior metathoracic muscles. The second runs posteri-

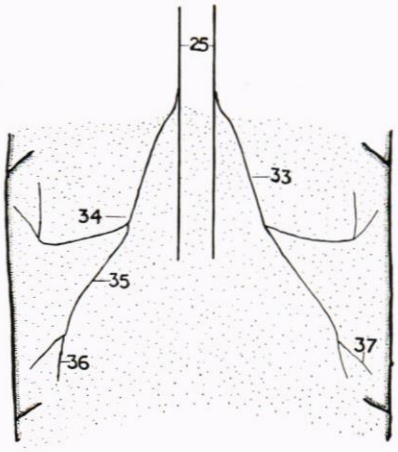

Fig. 3. A typical abdominal segment innervation from the main trunk.

orly and divides into three. The first (18) supplies the middle metathoracic muscles, the second (19) innervates the embolia and the third (20) to the posterior metathoracic muscles. The third (21) is thick and stout runs posteriorly to innertvate the metathoracic leg.

The posterior region send out three pairs of nerves. Presswala and George (1936) and Rawat (1939) have stated only two pairs of nerves in *Sphaerodema rusticum* and *Naucoris cimicoides* respectively. The first (22), the outer most, supplies the first abdominal segment. It is fine and thread like nerve. The second, middle one, runs posteriorly and divides into two and supplies to the second (23) and third (24) abdominal segments respectively. The third pair (25) consists of many nerves in a bundle so as to form a single nerve. They are the innermost and supply the remaining abdominal segments and to the genitalia.

From the main ventral cord (25) the divisions take place in each abdominal segments. The nerve first diverge in pair (33) from the main trunk. After running posteriorly each divides into two (34 and 35) which redivides again into two (36 and 37) to supply the longitudinal and transverse abdominal muscles. The innervation of the genitalia is different in *Lethocerus indicum*. Due to the pecularities develop in the genitalia the innervation change considerably in male and female.

In the male insect the VIII branch from the main trunk lies below the IX segment and supplies the muscles between eighth and ninth segments and then again curves upwards to supply the eighth segment. The ninth branch gives a fine nerve to the rectal pouch. Further, posteriorly it innervates the vasa defrentia and the ductus ejaculatoris. From here it divides into two branches- the external branch supplies the aedagial and parameral muscles and the inner one enters the ninth segment laterally and then continues posteriorly to innervate the last segment.

In the female insect the last branch from the main trunk (25), after innervating the VII segment, divides into two (26) main nerves which runs posteriorly side by side over the lateral common oviduct. The outer (27) of these two supplies the VIII segment (28) and the last segment (29) and then

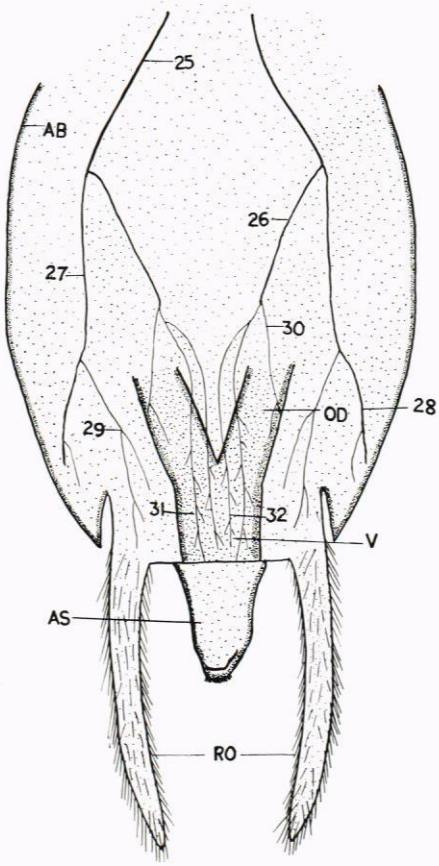

Fig. 4. Innervation of the female reproductive organs.

continues laterally as the nerve for the IX segment. The inner branch breaks up into three smaller branches. The inner most of these supplies the ovipositor muscles (30). The middle one supplies to the muscles of the third valvulae (31) and outer one ramifies over the vaginal wall (32).

Disscussion

The central nervous system of *Lethocerus indicum*, which is studied in detail here, is found to be one of the highly evolved nervous systems of insects. A series of extensive investigations are needed to establish a generalised pattern for the hemipteran nervous system. The present study has been made with this view point.

The fusion of the respective ganglia has been observed in *Lethocerus indicum*, as also observed in many hemipteran insects (Hamilton, 1931; Snodgrass, 1935; Presswala and George, 1936; Rawat, 1939; Imms, 1957 and Ewen, 1960 and 62). Imms (1957) has reported one ventral ganglia in *Hydrometra*, two in Nepidae and other and three ganglia in *Notonecta*. Ewen

(1960) has also reported three ventral ganglia in *Liocoris unctuosus* of family Miridae. Hamilton (1931), Presswala and George (1936), Rawat (1939) and Ewen (1962) have reported two ventral ganglia in *Nepa cinera*, *Sphaerodema rusticum*, *Naucoris cimicoides* and *Adelphocoris lineolatus* respectively. The present study also revealed only two ventral ganglia in *Lethocerus indicum* and agrees with the previous workers. In general it is observed that in all Cryptocerata (Aquatic bugs group) only two ventral ganglia occur.

From the above description it is clearly seen that the family Belonstomatidae has clear advancing position over family Miridae and Notonectidae, while on the other hand it is to noted that in *Hydrometra* and Coccidae only one ventral ganglon occurs. Due to the fusion of the ganglion, we can easily state that family Belostomatidae, indeed the whole group Cryptocerata, is much more evolved than the family Miridae and Notonectidae but less evolved than the family Hydrometidae and Coccidae.

It is interesting to note the presence of a single median ventral nerve cord in Miridae (Ewen, 1960 and 62) which supplies the remaining abdominal segments. Hamilton (1931), Presswala and George (1936) and Rawat (1939) have reported a paired ventral nerve cord in *Nepa cinera*, *Sphaerodema rusticum* and *Naucoris cimicoides* respectively. The present study has also revealed a paired ventral nerve cord in *Lethocerus indicum*.

The innervation the mesothoracic parts is different from the innervation of *Sphaerodema rusticum*. Presswala and George (1936) and Rawat (1939) have stated four mesothoracic nerves, which arise from the antero-lateral side of the thoraco-abdominal ganglia. In the present study, it is interesting to note that only two nerves arise from the antero-lateral side of the thoraco-abdominal ganglion for the innervation of the mesothorax.

The circumoesophageal connective in *Lethocerus indicum* is rather long and distinct than that of *Nepa cinera* (Hamilton, 1931), *Sphaerodema rusticum* (Presswala and George, 1936) and *Naucoris cimicoides* (Rawas, 1939). In the latter insects the suboesophageal-prothoracic ganglion is almost fused with the brain.

Summary

In the present paper the gross anatomy of the central nervous system of adult *Lethocerus indicum* is described and figured. The following are the noteworthy points.

1. Only two ventral ganglia are present.
2. The suboesophageal and prothoracic ganglia are fused in one to form a complex ganglionic mass.
3. The mouthparts and prothoracic legs are innervated from the suboesophageal-prothoracic ganglion.
4. The thoracic and abdominal ganglia are fused in a common center, the thoraco-abdominal ganglion.
5. The innervation of the mesothoracic, metathoracic and abdominal segments is from this center.
6. A long separate nerve has been observed for the first time, which innervates the elytra.
7. The innervation of male and female reproductive organs has been studied in detail.

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Abbreviations

A	Arota	OL	Optic lobe
AS	Anal segment	P	Pharynx
CO	Circumoesophageal connective	RO	Retractile organs
OD	Oviduct	V	Vagina
OE	Oesophagus		

References

BRANDT, E., 1878. Vergleichend-anatomisch untersuchungen über das nervous system der Hemipteran. Hor. Soc. Entomol. Ross. 14: 496—505.

CAZAL, P., 1948. Les glands endocrines rétrocérébrales des insects (étude morphologigue) Bull. Biol. Franch (suppl.) 32: 1—227.

COMSTOCK, J. H., 1924. An Introduction to Entomology. Comstock Publishing Company I.N.C. New York.

EPHRUSSI, B. and BEADLE, G. W., 1936. A techinque of transplantation for *Drosophila.* Ann. Naturilist. 70: 218—225.

EWEN, A. B., 1960. Gross anatomy of the nervous system and retrocerebral complex of adult *Liocoris unctuosus* Kelton (Hemiptera-Miridae) Cand. J. Zool. Vol. 38: 532—537.

— 1962. The cephalic nervous system of *Adelphocoris lineolatus* (Goeze) (Hemiptera-Miridae) Cand. J. Zool. Vol. 40: 1187—1193 Pl. I.

HAMILTON, M. A., 1931. The morphology of the water scorpion, *Nepa cinerea* Linn. Proc. Zool. Soc. Lond. pp. 1067—1136.

IMMS, A. D., 1957. A general text book of Entomology. 9th Edition Methunen London.

PFLUFELDER, O., 1937. Vergleichend-anatomisch, experimentelle und embryologische unter, suchungen über das Nerven system und die Sinnesorgane der Rhynchoten. Zoologica 34(93).

PRESSWALA, M. J. and GEORGE C. J., 1936. The morphology of *Sphaerodema rusticum.* Fabr. J. Uni. Bomb. Vol. IV, Part V: 1—40.

RAWAT, B. L., 1939. Notes on *Naucoris cimicoides* L. (Hemiptera-Heteroptera) L. Zool. Jb. Ant. 65: 535—600.

ROSS, H. H., 1948. A text book of Entomology. John Wiley & Sons I.N.C. New York.

SNODGRASS, R. E., 1935. Principles of Insect Morphology McGrew Hill Publication, New York.

WELLS, M. J., 1954. The thoracic glands of Hemiptera-Heteroptera. Quart. Joun. Micr. Sci. 95: 231—244.