



Research Article

Description of Digestive Tract of *Notonecta glauca* Linn., the Indian Backswimmer

Jaivir Singh^{1*}, Mohammad Shoeb², Harish Chandra³, Yogesh Kumar Gupta¹, Sher Singh¹, and H.N. Sharma⁴

¹P.G. Department of Zoology, Ganjundwara P.G. College, Ganjundwara, Etah 207242, India.

²Department of Zoology, Gandhi Faiz-e-Aam College, Shahjahanpur 242001, India.

³K.B.A. Degree College, Barnahal, Mainpuri 205261, India.

⁴Department of Environmental Toxicology, Dr. B.R. Ambedkar University, Agra 282002, India.

Abstract: The backswimmer, *Notonecta glauca* Linnaeus for the morphological and bioecological investigations were collected during, the months of July to November from various ponds, ditches, and canals of Mathura and its nearby areas. These bugs were easily recognised due to their oblong, convex body; large eye; short four jointed antennae; four jointed rostrum; large triangular scutellum; anterior legs inserted at the posterior margin of the pronotum; moderate long pronotum; last joint of antennae being must shorter than the penultimate one and posterior tarsi being without unguiculi. These insects are commonly known as water boatman and backswimmer as they swim on their backs with the help of their long oar-like hind legs. They are extremely predaceous and are very common around the edges of freshwater reservoirs such as ponds, lakes, and streams throughout India and the way be easily taken with a net. In the present study, a detailed description of the digestive tract of the aforesaid insect has been noted.

Keywords: Water boatman, Hypopharyngeal complex, Food pump, Foregut, Midgut, Oesophageal Valve.

1. Introduction

Notonecta glauca Linnaeus is the most commonly distributed insects of family Notonectidae Leach (1815) in India. These are most interesting and fascinating of all aquatic Hemiptera of the tropics and subtropics and are commonly known as backswimmer as they swim on their backs with long oar-like hind legs. These are medium sized, about 14 to 17mm long aquatic insects and are at once distinguished from the all other water bugs. When seen in the water: because they swim "Upside down" i.e. on their backs. The body is linear, developed wide posteriorly; wings well developed. Hemelytra with corium and clavus well-defined membrane short without anal vein. The forelegs are relatively short and raptorial. Middle legs are somewhat shorter and used for killing the prey. Hind legs are very long, oar-like with swimming hair, extended towards the head when at rest, without claws. First tarsal segment on the forelegs are so small that it is often overlooked. Scutellum well developed. Abdomen with medium keel, and carry air for respiration under the

water. Backswimmer *Notonecta glauca* Linnaeus is very common around the edges of freshwater ponds, lakes, and streams and may be easily taken with a net. They are predator hunters and feed upon many kinds of small animals including tadpoles, crustaceans, insects and their larvae etc. They sometimes even trouble bathers by infinite painful bite, when handled. They fly freely at night, leaping out of the water to take wings. Very little is known about the bionomics of these insects. The eggs are glued or inserted into the tissues of aquatic plants.

2. Materials and Methods

These bugs were killed by chloroform vapours and fixed in different fixatives. Small punctures were made by microneedles to the abdominal before putting them into fixative in order to ensure proper fixation. The fixatives use were;

- (1) Bouin's fluid,
- (2) Alcoholic Bouin's and
- (3) Zenker's fluid.

*Corresponding author:
E-mail: drhnsharma2015@gmail.com.

After keeping in fixative for about in 24 hours, they were washed thoroughly through several changes of 70% alcohol mixed with a few drops of glycerine. The specimens were later washed, upgraded and preserved in glycerine and mounted in Canada balsam. Dissections of the specimens were made in a small dish with the help of micro-scalpels, forceps, and microneedles under the high power of binocular microscope. The studies on the musculature were made in the insects fixed in alcoholic Bouin's solution. The fresh specimens dissected for the musculature did not yield satisfactory results because the muscles of freshly killed specimens were extremely soft. The insects were embedded in wax and dissected from different angles for the study of various muscles. Some sections were also cut by a sharp razor blade to study the musculature of the Labium, the antennae, the legs and the genitalia. Few dissections were stained by one or two drops of Mann's Methyl blue-eosin or Borax carmine. The organs of support and locomotion of the backswimmer, *Notonecta glauca* Linnaeus were thus studied.

The study of the digestive system was made by dissecting the freshly killed and Bouin's fixed material. The dissections of freshly killed specimens yielded good results. The diagrams of gross anatomy were sketched directly from the dissections. For the histological studies of the alimentary canal, the different regions were immediately fixed after the dissections in the alcoholic Bouin's solution. Later the material was washed, dehydrated in usual manner, cleared and embedded in paraffin wax for microtomy. The sections of 6 to 8 μ thickness were cut, stained with Haematoxylin, Eosin, Mann's Methyl blue-eosin and Mallory's triple. A triple embedding technique was found most satisfactory for the purpose.

3. Results and Discussion

3.1 Mouthparts

Backswimmer, *Notonecta glauca* Linnaeus is carnivorous in its feeding habit and its mouth part is adapted for piercing and sucking fluids from various aquatic animals etc. upon which they predate. For the study of the mouthparts, the cephalic capsule is separated from the body, boiled for five minutes in 5% KOH, left overnight and the various mouth appendages dissected and studied under bull lens and a binocular microscope. Sagittal sections of the head were also repaired and studied. Mouthparts consist of Labrum, Hypopharynx, sucking pump and a beak.

The labrum (LBR) is a short, subtriangular sclerite, apically inserted into the dorsal basal region of the first rostral segment. It is distinctly defined basally from the apical margin of the clypeus (CLP). Its inner surface is continuous with that of the clypeus and forms epipharyngeal wall which is heavily chitinised in the form of the anteclypeus. The epipharynx (EPH) arises from the clypeal region and is basally continuous with the food pump. It is apically inserted beneath the

labrum into the second rostral segment. It is significant to mention that the backswimmer, *Notonecta glauca* Linnaeus possesses remarkably prolonged epipharynx.

The mandibular plate is well separated from the maxillary plate by a transverse suture. The basal margin of the mandibular plate possesses a mush elongate, subtriangular lever which is connected with the mandibular style. The mandibular stylets (MNST) are a pair of needle-like structures found and on each side. Each stylet is thick at its base and is provided with a flat triangular plate-like a lever. Each mandibular stylet (MNST) is rectangularly curved at its base behind the basal margin of the lever for the attachment of the muscles. The tips of the mandibular stylets resemble cart screw and are acutely pointed.



Photograph of backswimmer in water



Diagram showing ventral segmentation of backswimmer

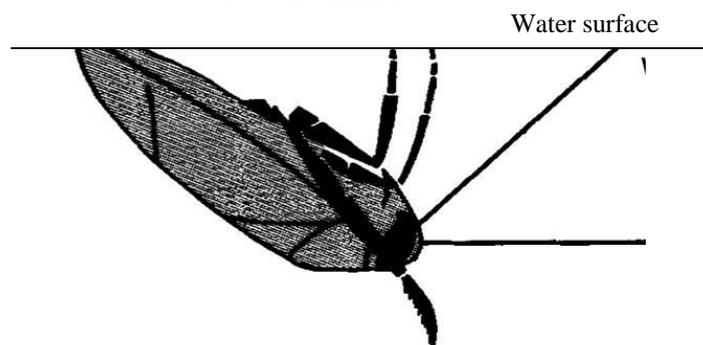


Diagram showing position of backswimmer in water

The maxillary plate does not bear the maxillary lever. The maxillary stylet (MXST) ensheath basally the seattle pouch which extends a little beyond the middle of the mesothoracic. The maxillary stylets are also needle like with thick base and are found behind an internal to the mandibular stylets. The maxillary stylets are supported by tendon rod, which arises from the lateral angle of the foramen magnum. The greatly prolonged maxillary stylet and the tendon rod represent the posterior tentorium. The anterior tentorium is absent in *Notonecta glauca* Linnaeus. The tips of maxillary stylets are serrated and blade like. The Maxillary stylet of one side, when locked with that of the other side forms a Maxillary tube. The salivary syringe is well sclerotized with a piston that arises from the posterior end. The food pump is supported ventrally by a single, distinct, well sclerotized long plate which is homologous with the hypopharyngeal wing found in some groups of Hemiptera. The rostrum is three segmented and placed on the ventral surface of the head during the rest. It extends up to the posterior margin of prosternum. It is labial in origin; the basal two segments represent the postmentum and pre mentum and the apical segment, the ligula.

3.2 Endoskeleton of the head capsule

The endoskeleton of the head capsule of the backswimmer, *Notonecta glauca* Linnaeus consist of food pump and hypopharyngeal complex. The anterior tentorium is absent in it. The rod arising from the lateral angle of the foramen magnum provides support to the maxillary stylets and regarded as the posterior tentorium. Similar observations have also been reported by Ekblom (1926) in *Nepa apiculata* Uhler, *Nepa hoffmanni* Esaki, and *Ranatra linearis* Linn. The food pump includes epipharynx and hypopharynx. The hypopharyngeal complex consists of three regions viz., hypopharyngeal lobe, hypopharyngeal wing, suspensory plate and salivary apparatus.

3.3 Food pump

The food pump or the cibarium is an elongated tube situated within the head capsule in the region of the fronton clypeus medially in between the hypopharyngeal Wing (HPW). It is anteriorly continuous with the food meatus and posteriorly with the pharynx (PH). Snodgrass (1936) and others regarded the food pump to include both of the structures, the cibarium as well as pharynx. Louis and Kumar (1973) found that the food pump exhibit no distinction between the pharynx and the cibarium in Halix denture. A frontal ganglion is located about in the middle of the pump demarcates the limit between the pharynx and cibarium (Snodgrass, 1934). Griffith (1945) observed that the food pump of *Notonecta* and *Ramphocorixa* include both the cibarium and the pharynx. Marks (1958) pointed out that, the food pump of Anisops shows little if any distinction between the cibarial and the pharyngeal portion of the pump, either

in the musculature or in the skeletal apparatus. The present study of the food pump of the backswimmer, *Notonecta glauca* Linnaeus clearly shows a marked distinction between the cibarial and pharyngeal portions. The dilator muscles of the anterior cibarial portions are different from those of the posterior pharyngeal portion in shape and the surface of their attachment. A pair of sclerotized bars is situated in the roof of the pump, just posterior to the opening of the salivary syringe of lateral bars as the hypopharyngeal suspensorium. The food pumps are consisting of a dorsal membranous epipharynx and a well sclerotized ventral hypopharynx. The epipharynx and hypopharynx have fused along their lateral margin behind of their mandibular plate and enclosed a narrow cavity which remains separated anteriorly. The epipharynx after its separation from the hypopharynx has become attached laterally to the anterolateral edges of the clypeus and labrum to form labro-anteclypeal epipharyngeal cavity. The hypopharynx after being separated from the epipharynx forms a grooved hypopharyngeal lobe. The lateral edges of hypopharyngeal lobe form the precibarial part of the food pump. The thin membranous epipharynx which lies dorsally to the hypopharynx raise upon the contraction of dilator muscles as a result of which the food pump begins the sucking action. The epipharynx is a hard chitinous structure and forms the floor of the food pump. The hypopharynx is heavily sclerotized and form hypopharyngeal lobe, which has been termed variable by different authors such as the hypopharynx proper by Marlatle (1895), Spoon-shaped, acute hypopharynx by Snodgrass (1944), Beak like projection by Quadri (1949).

3.4 Hypopharyngeal complex

The hypopharyngeal complex in backswimmer, *Notonecta glauca* Linnaeus consist of a pair of hypopharyngeal wing, hypopharyngeal lobe, suspensory plate and salivary apparatus.

3.4.1 Hypopharyngeal wings and suspensory plate: The hypopharyngeal wings in backswimmer, *Notonecta glauca* Linnaeus are highly sclerotized flap like processes, located lateral to the medium body of hypopharynx and salivary syringe. The hypopharyngeal wings have folded along their longitudinal axis and form a trough-shaped structure having a dorsal vertical and a ventral flat plate which extends from the anterior region of the head in front to the occipital foramen behind.

The dorsal vertical plate of each hypopharyngeal wing anteriorly forms the vertical wall on each side of the efferent duct of the salivary pump. The ventral plate is fused anteriorly along the ventral margins in the form of a wide flat plate; the suspensory plate posteriorly extends as a semimembranous process up to the occipital foramen. The suspensory plate lies below the precibarial portion of the food pump and genal sac. The distal margin of the suspensory plate is fused with the

proximal margin of the labium. The posterolateral margin of the suspensory plate is attached to the inner surface of the maxillary plate.

3.4.2 Salivary apparatus: The salivary apparatus of backswimmer, *Notonecta glauca* Linnaeus is situated below the hypopharynx in between the hypopharyngeal wings. It consists of a piston, piston roll, afferent duct, efferent duct and a two layered salivary pump. The salivary pump is a cylindrical vesicle-like structure, consisting of an outer and inner. The outer layer folded on its inner side and forms the piston which is attached with a short piston rod. A pair of muscles arises from the hypopharyngeal wing and become inserted in the piston. A pair of afferent ducts, extending one on each salivary duct opens into the cavity of salivary pump. The alternate contraction and relaxation of the piston bring about the action of the salivary syringe. The pressure inside the pump decreases due to the withdrawal of the piston. It results in the collapse of the membranous roof of the efferent duct due to which the flow of the saliva in the backward direction is prevented. The salivary secretion is drawn into the pump through the afferent opening due to the lowering of the pressure at this time.

3.5 Main Salivary glands

The main salivary gland (MSG) consists of a pair of a long glandular mulberry like elongated structure, found one on each side of the foregut in the region of the thorax and the first two abdominal segments. It is bounded by numerous highly branched tracheas with the anterior region of the alimentary canal. Each gland consists of a large number of small rounded lobes or acini (AC) which are arranged around a central axis. The acini are smaller towards the proximal and distal ends, but larger in the middle, giving a mulberry fruit like appearance to the gland. Each acini is a hollow flask-shaped structure that opens into the central canal of the gland by a short duct.

3.5.1 Accessory salivary gland: The accessory salivary gland (ASG) closely resembles the main salivary gland (MSG) in its shape and structure except for the relatively smaller size. Like the main salivary gland (MSG) it also bears a large number of similar lobes or acini (AC). A few of the anterior acini open directly into the central duct. The duct of the accessory salivary gland (DASG) joins with the central canal of the main salivary gland (DMSG) in between the two salivary vesicles (SV). The Accessory salivary is relatively much smaller in size than the main glands (MSG) and bears similar type of acini or lobes around the central axis. The acini give of very minute cuticular canals, which open into the lumen of the central duct. The ezine of the accessory salivary glands possesses a thick layer of syncytial epithelium (AP) with a few oval nuclei and granular cytoplasm. The epithelium forming the inner lining of the duct of the accessory salivary

gland is produced into numerous distinct longitudinal folds.

3.5.2 Salivary Vesicle: The central canal (CC) after emerging from the main salivary gland anteriorly receives two small ducts from a pair of small, thin-walled, glistening white, bulbous structure, the salivary vesicles (SV). The salivary vesicles are situated just in front of the main salivary gland (MSG) and may be regarded highly specialized enlarged anterior most can of the gland proper. The epithelial layer of the salivary vesicles exhibits secretory epithelia layer that of acini. The lumen of the salivary vesicles is seen filled with milkish white blue. A well develops valve is present at the opening of the salivary vesicles into the small duct which opens into the central canal of the main gland. The presence of milky white secretion in the vesicle and value to regulate the flow of secretion at its opening into the small duct suggest that these vesicles provide some special type of secretion that mixes with the saliva.

The histological studies of salivary vesicles of backswimmer *Notonecta glauca* Linnaeus reveal that it consists of a thin layer of syncytial epithelium (EP) which is produced into numerous small spherical localized vesicles like structure which have been attributed secretory epithelium. The cytoplasm is richly granulated with several small, haphazardly distributed minute nuclei. The central canal of the main salivary gland receives a pair of duct (DSV) from the salivary vesicles a duct (DASG) from the accessory salivary gland and a duct (DSR) from the salivary reservoir and then extends as the main duct (MSGD) of the salivary gland which extends anteriorly and opens into a salivary syringe. The main salivary duct consists of a layer of multinucleated syncytial epithelium having granular cytoplasm with scattered distinct nuclei. The basement membrane and initial lining are quite thick.

3.5.3 Salivary Reservoir: The backswimmer *Notonecta glauca* Linnaeus possess a pair of salivary reservoir (SR) associated with each salivary gland (MSG). Each salivary reservoir is a white elongated sac-like structure, the posterior end of which is produced into a narrowly closed tubule. The cuticular intima lining of the reservoir is very thin. The reservoir often collapses on being empty due to the extreme thickness of its inner lining. The epithelial layer of the reservoir does not show any secretory activity which suggests that it is concerned with the storage of the salivary only. The epithelial layer of the reservoir close to its junction with the duct consists of tall columnar cells with distinctly visible nuclei.

3.6 Alimentary Canal

The alimentary canal of backswimmer *Notonecta glauca* Linnaeus commences at the hind end of the cibarium within the head a short distance in front of the brain. It passes through the circumesophageal ring

extends back into the abdomen segment. Three distinct regions of the alimentary canal can be easily recognised: the foregut-derived from the proctodaeum. The oesophageal valve mars the junction between the foregut and midgut, while the pyloric valve indicates the division between the midgut and the hindgut.

3.7 The foregut

The foregut is approximately one-fifth of the total length of the gut. It shows three distinct regions the pharynx, oesophagus, and crop. The pharynx (P) is the anterior most regions of the foregut into which the cibarium (CB) lies. It extends back to a distance behind the brain and it leads into the oesophagus (O). The part of the pharynx in front of the brain is more or less tubular and resembles the cibarium which consists of a layer of uninucleate cuboidal epithelial cell boundaries. The epithelium is lined with a fairly thick layer of chitinous intima (IM) which continues in front into the cibarium. No muscles are incorporated within the wall of the anterior portion of pharynx a condition noted in the cibarial as well. However, the pharynx is provided by external dilator muscles which arise in front of the head capsule and are inserted in the roof of the anterior portion of pharynx. These muscles are situated behind the level of the frontal ganglion and thus differ from the dilator muscles of the frontal ganglion. The posterior part of the pharynx commences at the level of the anterior margin of the brain and differs from the anterior portion in the absence of external dilator muscles. Structures of the epithelial layer of muscles are incorporated in the pharyngeal wall of this region. The epithelium is surrounded by a circular layer of muscle fibres (CM) which in turn is surrounded by a longitudinal layer of muscle fibres (LM). At the level of the anterior margin of the brain, the muscle layer is very thin, but as the pharynx passes back through the circumoesophageal ring, the muscle layer gradually thickens till just behind the brain it attains its maximum thickness and assumes a bulbous shape. Behind the bulbous region, a constriction marks the junction between the pharynx and oesophagus.

The oesophagus (O) is a long tubular region, a little narrower than the bulbous part of the pharynx. It extends back up to the end of the prothorax where it dilates to form a spindle-like region, which corresponds to the crop (CP) of other insects. The histological structure of the oesophagus and crop is similar to that of the posterior part of the pharynx. However, the epithelial layer, as well as the chitinous intima in the region of the crop, is produced into several internal folds which increase in size towards its posterior end.

3.8 The Oesophageal Valve

The oesophageal valve is a more or less funnel-shaped structure formed by the internal circular folds of the oesophageal epithelium, which project into the lumen of the crop. It is made up of several compactly placed elongated or oval uninucleate epithelial cells

(EPTH) with finely granular cytoplasm. The folds are lined by a layer of thick intima (IM) which is much thicker than in pharynx, oesophagus and crop, while externally these folds are surrounded by muscle layers consisting of an inner circular (CM) and an outer longitudinal layer of muscle fibres (LM).

The intravalvular spaces enclosed by the folds of the valve are penetrated by the muscle fibres, the trachea, and the connective tissue. A similar situation has also been reported by Parsons (1957, 1959) in *B. flumineum*, *Tingis buddleiae*. Sutton (1956) further claims the presence of the blood sinuses in the intravalvular space. Akbar, Sutton, Marks, and Parsons reported the presence of hair along the inner surface of the intima but are completely absent in *Notonecta glauca* Linnaeus.

3.9 The midgut

The midgut is the longest part of the alimentary canal, about three to four times the length of the foregut. It commences at the oesophageal valve and extends back from the mesothorax up to the fourth abdominal segment to open into the hindgut. Four distinct regions of the midgut can be recognised which may be referred to as the first, second third and fourth ventriculi.

The first ventriculus (1.V) forms the anterior one-third portion of the midgut. It is an elongated, wide, sac-like region with wrinkled walls and extends behind up to the second abdominal segment to open into the second ventriculus. The width of the first ventriculus varies according to the physiological state of the insects. In starved insects, it becomes greatly distended due to the presence of a large number of air bubbles, while in freshly fed insects the first ventriculus is less wide due to the absence of air bubbles. The second ventriculus (2.V) is a long uniformly tubular region approximately one half to one third the width of the preceding region. After its origin at the posterior end of the first ventriculus, it runs forwards along the left ventrolateral margin of this region till it reaches the metathorax. Then turns backward, crossing to the right, passes beneath the first ventriculus, the anterior part of second ventriculus is wider than the posterior part. The second ventriculus disposed into several coils and loops in the region of first and second abdominal segments. The third ventriculus (3.V) is a short dilated oval sac located between the third and fourth abdominal segments. Its lumen is constantly filled with a yellowish brown or greenish viscous fluid irrespective of whether the insect is well fed or starved. It is constricted at its posterior end and joins the fourth ventriculus. The fourth ventriculus (4.V) is long and coiled structure, generally dark pink in color. This region is provided with gastric caeca which are short, uniform in size, arranged in four rows along most of the length of the fourth ventriculus. Each row of ventriculus is divided transversely into fine uniform gastric caeca. Fourth ventriculus opens into the hindgut.

The midgut wall is made up of binucleate epithelial cells (EPITH) surrounded by an inner circular (CM) and an outer longitudinal layer of muscle fibres (LM) the two layers being of almost equal thickness. There is neither chitinous nor any peritrophic membrane within the lumen of the midgut. The free distal borders of all the cells are marked by fine, closely placed, radial striation (ST). The nature of the epithelial cells differs in the four different regions of the midgut. Epithelial cells of the first ventriculus are uniformly columnar and shorter in height. A large number of coarse granules (GR) appear in the cytoplasm of these cells. Such granules accumulate towards the striated border (ST.B) of the cells and finally, the granular cytoplasm is extruded through the striations into the lumen. The granular material appears to be the secretion produced by the epithelial cells of the first ventriculus. This mode of secretion is known as holocrine mode of secretion, similar mode of secretion has been reported by Kumar (1969) in *Sphaerodema rusticum*, *Ranatra elongata*, and *Notonecta glauca*. In this region, close to the oesophageal valve, the epithelium is produced into a few small internal folds which project into the lumen.

Epithelium of the second ventriculus is markedly different from that of the preceding region. It is composed of a layer of columnar cells, which are very narrow and show differences in their relative size. The entire epithelium (EPTH) is produced in a series of circular internal folds. The cells in the central region of each fold are the tallest and gradually become shorter towards the margin of the folds. The grooves in between the folds include the shorter epithelial cells. All these cells show an appreciable diversity in their shape and cytological character according to the state of their physiological activity. The epithelial cells again become full of vacuoles which accumulate towards the cell borders, but no vesicles or cytoplasmic spheres or granules are seen liberated in the lumen (L). However, secretion in the form of liquid is observed in the lumen by these cells.

In the third ventriculus, the condition of epithelial cells is short columnar and uniform in size. Their finely granular cytoplasm is full of certain globules (GL) which accumulate towards the cell borders and are finally discharged into the lumen in the form of viscous fluid. Rastogi (1961) in *Sphaerodema rusticum* reported that periodical delamination of the epithelium takes place in this region, thereby suggesting that what has been described by Rastogi (1961) in *S. rusticum* delamination may not be actually so in *Micronecta striata* Fieb.

In the fourth ventriculus also, the condition of the epithelial cells is very tall, columnar with uniformly granular cytoplasm, with striated border (ST.B). Amongst the several epithelial cells are a few regenerative cells (RG.C) which occur singly. The lumen of the fourth ventriculus is very narrow and shows no deposition of any secretory material.

The wall of gastric caeca is made up of a layer of epithelial cells, which differ from those of the fourth ventriculus in being shorter and cuboidal in shape. These cells are uninucleate and are filled with uniformly finely granular cytoplasm. The central lumen of each caecum is quite large and it is filled with some granular material.

Comparison of the midgut of *Notonecta glauca* Linnaeus with that of other heteropterous insects reveals some diversity in the degree of differentiation of the midgut. In a number of heteropterous insects, the midgut exhibits only two distinct regions viz. *Ranatra* and *Belostoma* (Locy, 1884), *Cimex* (Cimicidae, Cragg, 1914), *Pentatomidae murgantia* (Harris, 1938), *Ranatra elongata*, *Sphaerodema rustium* and *Laccotrephes maculatus*. *Micronecta striata* Fieb. Differs from all these forms in the fourfold differentiation of its midgut, which also occurs in the *Peliopelta* and *Pentatomid carporicis* (Glasgow, 1914), Coreid, *Leptocoris trivittatus* (Woolley, 1951), *Tingis buddleiae* (Livingstone, 1963) and *Dysdercus koenigii* (Khanna, 1964). It may also be pointed out that the first part of the midgut, situated just behind the oesophageal valve is sac-like in all the heteropterous insects. It has been differently named as stomach of first ventriculus by various workers. Certain workers, however, have referred to the sac-like region as the crop belonging to the foregut. Pruthi (1923) has applied this term in the case of *Dysdercus cingulatus* and Akbar (1957) in the case of *Leptocoris varicornis*. The fact that the region is devoid of a chitinous intima, lies behind the oesophageal valve, and includes glandular epithelial cells, shows the error in Pruthi's interpretation. In view of this, it is justified it as the first ventriculus and not the crop.

The pyloric valve is folded like projection of the wall of the mesenteron into the proctodaeum at the junction of Fourth ventriculus and intestine. The wall of this valve is composed of layer of tall columnar epithelial cells, which resembles the cell of fourth ventriculus. There is no lining of chitinous intima.

A similar differentiation of the hindgut into two regions has been reported in several heterogeneous species. However, there has been some differentiation of opinion concerning the identity of the two regions. In certain species viz, *Anasa tristis* (Breakey, 1936). The posterior part of the hindgut has been termed as rectal sac. The fact that in *Notonecta glauca* Linnaeus the anterior region of the hindgut is lined with chitinous intima behind the fact that valvula fold lined with intima is present between the anterior and posterior regions shows that is the rectal valve often present in the insect between the intestine and rectum (Snodgrass, 1935). On this basis, the anterior region of the hindgut should be recognised as the intestine and not pylorus, which in *Notonecta glauca* Linnaeus is shortened. The valvular fold at the front end of the intestine, immediately in front of the opening of the Malpighian ampulla, is evidently the pyloric valve comparable to a

similar valve in *Anasa tristis* (Breakey, 1936) in structure and position. Since it is composed of cells similar to those of the fourth ventriculus and is not lined by any intima, it is ventriculus and not proctodeal in origin.

References

- [1]. "General Entomology – Digestive and Excretory system". NC State University. Retrieved 2009-05-03.
- [2]. Aagaard, K. & Dolmen, D. (2006). Biologisk mangfold i dammer i Sør-Trøndelag 2003 og 2004. *NTNU Vitenskapsmuseet Zoologisk Notat*, 4: 1–32.
- [3]. Anand, A.N. & Lorenz, M.W. (2008). Age-dependent changes of fat body stores and the regulation of fat body lipid synthesis and mobilisation by adipokinetic hormone in the last larval instar of the cricket, *Gryllus bimaculatus*. *J Insect Physiol.* 54(10-11): 1404-12. doi: 10.1016/j.jinsphys.2008.08.001.
- [4]. Bogiawlensky, K.S. (1925). Digestive system of Notonectidae. *Rev. Zool. Russe.*, 5: 8-31.
- [5]. Candy, D.J. (2002). Adipokinetic hormones concentrations in the haemolymph of *Schistocerca gregaria*, measured by radioimmunoassay. *Insect Biochem. Mol. Biol.*, 32(11): 1361-7.
- [6]. Chinery, M. (1986). Collins Guide to the Insects of Britain & Western Europe. Collins. ISBN 0-00-219137-7.
- [7]. Cockrell, B.J. (1984). Effects of Temperature and Oxygenation on Predator-Prey Overlap and Prey Choice of *Notonecta glauca*. *Journal of Animal Ecology*, 53: 519–532. doi:10.2307/4531.
- [8]. Dolmen, D. (1989b). *Notonecta glauca* L. (Hemiptera, Notonectidae) in Trøndelag, zoogeographical notes. *Fauna Norv. Ser.*, B 36, 101–102.
- [9]. Elzinga, Richard J. (2003). Fundamentals of Entomology (6th ed.). Upper Saddle River, NJ: Prentice Hall. ISBN-13: 978-0130480309.
- [10]. Gäde, G. (2009). Peptides of the adipokinetic hormone/red pigment-concentrating hormone family: a new take on biodiversity. *Ann. N. Y. Acad. Sci.*, 1163: 125-36. doi: 10.1111/j.1749-6632.2008.03625.x.
- [11]. George C. McGavin (2001). Essential Entomology: An Order-by-Order Introduction. Oxford: Oxford University Press. ISBN 9780198500025.
- [12]. Gross, A., Sitte, H. & Werner, G. (1981). Light electron microscopic and morphometric analyses of the hindgut of the waterbug, *Notonecta glauca* L. (Heteroptera: Hyprocorisae). *Int. J. Insect Morphol. Embryol.*, 10: 275-295.
- [13]. Kjørstad, G. (2006). Invertebrater og amfibier i dammer og tjern i Levanger og Verdal. *NTNU Vitenskapsmuseet Zoologisk Notat*, 1: 1–19.
- [14]. Nation, J.L. (2002). Insect Physiology and Biochemistry. CRC Press, Boca Raton, Florida.
- [15]. Svensson, B.G., Tallmark, B. & Petersson, E. (2000). Habitat Heterogeneity, Coexistence and Habitat Utilization in Five Backswimmer Species (*Notonecta* spp.; Hemiptera, Notonectidae). *Aquatic Insects*, 22(2): 81–98.
- [16]. Tilseth, E. (2008). Kartlegging av salamanderlokaliteter i Trondheim Kommune 2007-2008. Trondheim kommune rapport nr. TM 2008/06.