



SANATAN DHARM COLLEGE MUZAFFARNAGAR
(Affiliated to Maa Shakumbhari University, Saharanpur)



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DR. ARUN RATN, Ph.D.

[CSIR-JRF/SRF, CSIR-NET/LS

GATE, CEEB-BIT (DBT-JNU)]

(ASSISTANT PROFESSOR)

(arunratnbt14@gmail.com)

DEPARTMENT OF ZOOLOGY,
SANATAN DHARM (P.G.) COLLEGE,
MUZAFFARNAGAR-251001,
UTTAR PRADESH (INDIA).

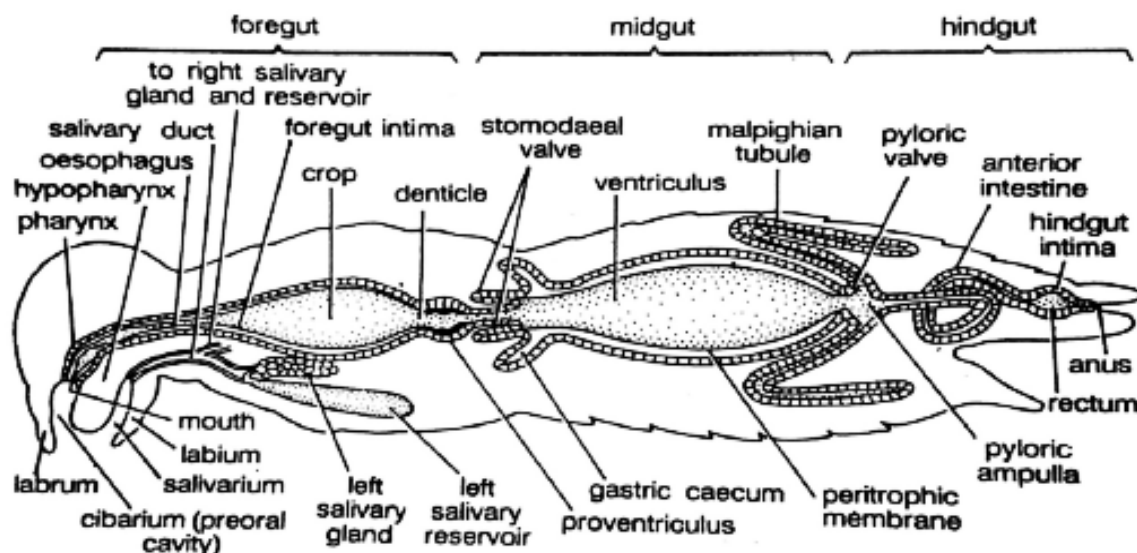
Anatomy of Digestive system

One of the major reasons for the biological success of insects is their ability to eat, digest and utilise an enormous diversity of foods. This ability allows the extreme diversity observed in the modification and specialisations of the alimentary system of insects.

The structural and biochemical modifications of the alimentary system of a particular species depend upon the type of food eaten. There are structural and functional differences in the way foods are obtained, stored, processed and absorbed between the sexes, e.g. caterpillars chew up plant material, whereas adults suck up only floral nectar and female mosquitoes suck up a vertebrate blood, whereas males suck up plant sap.

Alimentary canal

The insect's digestive system is a closed system, with one long enclosed coiled tube called the alimentary canal which runs lengthwise through the body. The alimentary canal only allows food to enter the mouth, and then gets processed as it travels toward the anus. The insect's alimentary canal has specific sections for grinding and food storage, enzyme production and nutrient absorption. Sphincters control the food and fluid movement between three regions. The three regions include the foregut (stomatodeum), the midgut (mesenteron), and the hindgut (proctodeum).



The insects also have paired salivary glands and salivary reservoirs. These structures usually reside in the thorax (adjacent to the fore-gut).

The salivary glands produce saliva; the salivary ducts lead from the glands to the reservoirs and then forward through the head to an opening called the salivarium behind the hypopharynx; which movements of the mouthparts help mix saliva with food in the buccal cavity.

Saliva mixes with food which travels through salivary tubes into the mouth, beginning the process of breaking it down.

The stomodeum and proctodeum are invaginations of the ectoderm and are lined with chitinous intima, which is continuous with the cuticle of the integument and therefore at the moult both foregut and hindgut and their contents are shed. The mesenteron is derived from endoderm and not lined with cuticle but with rapidly dividing and therefore constantly replaced, epithelial cells. The cuticle sheds with every moult along with the exoskeleton. Food is moved down the gut by muscular contractions called peristalsis.

Foregut or stomodeum

An insect's mouth, located centrally at the base of the mouthparts, is a muscular valve (sphincter) that marks the "front" of the foregut. Food in the buccal cavity is sucked through the mouth opening and into the pharynx by contractile action of cibarial muscles. These muscles, located between the head capsule and the anterior wall of the pharynx, create suction by enlarging the volume of the pharynx (like opening a bellows). This "suction pump" mechanism is called the cibarial pump. It is especially well developed in insects with piercing/sucking mouthparts.

From the pharynx, food passes into the oesophagus by means of peristalsis (rhythmic muscular contractions of the gut wall). The oesophagus is just a simple tube that connects the pharynx to the crop, a food storage organ. Food remains in the crop until it can be processed through the remaining sections of the alimentary canal. While in the crop, some digestion may occur as a result of salivary enzymes that were added in the buccal cavity and/or other enzymes regurgitated from the midgut.

In some insects, the crop opens posteriorly into a muscular proventriculus or gizzard. It is absent in fluid feeder but is well developed in orthopteroid insects (e.g. cockroach). This organ contains tooth like denticles that grind and pulverize food particles. The proventriculus, regulates the flow of food from the stomodeum to the mesenteron. The hard denticles inside the proventriculus are made from the intima.

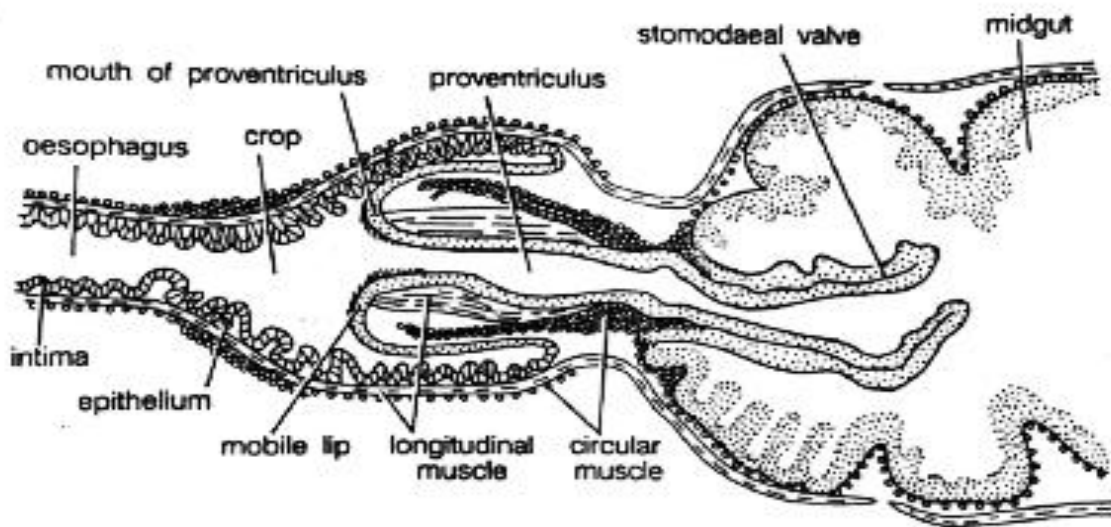


Fig. Longitudinal section of the proventriculus of honey bee

Midgut or mesentron or ventriculus

The midgut begins just past the stomodaeal valve. Near its anterior end, finger like projections (usually from 2 to 10) diverge from the walls of the midgut. These structures, the gastric caecae, provide extra surface area for secretion of enzymes or absorption of water (and other substances) from the alimentary canal.

The rest of the midgut is called the ventriculus -- it is the primary site for enzymatic digestion of food and absorption of nutrients. Digestive cells lining the walls of the ventriculus have microscopic projections (microvilli) that increase surface area for nutrient absorption.

The midgut epithelium of most insects is composed of three basic cell types:

Columnar digestive cells with microvilli forming a striated border regenerative cells and endocrine cells. The basal plasma membrane of digestive cells is characteristically infolded, and mitochondria are associated with these folds. These cells are involved in the synthesis of digestive enzymes and absorption of digestive food. At the bases of the midgut epithelial cells are small regenerative cells or replacement cells. These cells replace the actively functioning gut cells that die or that degenerate as a result of holocrine secretion.

The midgut is derived from embryonic endoderm so it is not protected by an intima. Instead, the midgut is lined with a semi-permeable membrane secreted by a cluster of cells (the cardial epithelium) that lie just behind the stomodaeal valve. This peritrophic membrane consists of chitin fibrils embedded in a protein carbohydrate matrix. It protects the delicate digestive cells

without inhibiting absorption of nutrient molecules. The bugs, which are fluid feeders lack a peritrophic membrane. The posterior end of the midgut is marked by another sphincter muscle, the puloric valve. It regulates the flow of material from the mesenteron to the proctodeum.

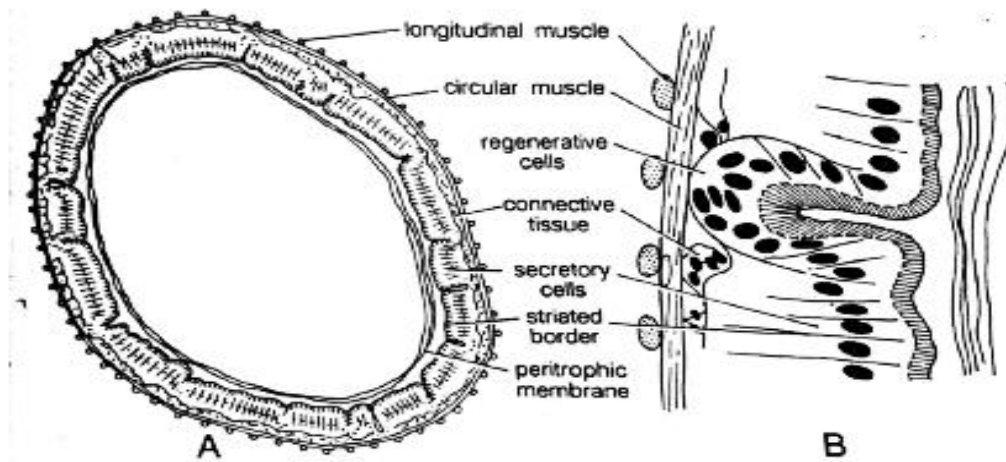


Fig. (A) Transverse section of midgut. (B) A section of midgut highly magnified.

The plant bugs in order to obtain adequate quantity of nutrients ingest large amount of sap. In them, the gut is modified to provide the rapid elimination of the excess of water taken in to avoid excessive dilution of the haemolymph and to concentrate the food to facilitate enzyme activity. In leaf hoppers and aphids, the rapid removal of water to the rectum is achieved by the anterior midgut forming a large thin-walled bladder which is closely bound to anterior hindgut and malpighian tubules by its own basement membrane. The chamber formed within this fold is called the filter chamber. Water passes directly from the hindgut along an osmotic gradient and there may be no significant flow of fluid through the lumen of the gut.

Hindgut or proctodeum

The hindgut is composed of cuboidal epithelial cells and is lined by a layer of cuticle which is thinner and more permeable than that of the foregut. The pyloric valve serves as a point of origin for dozens to hundreds of malpighian tubules. These long, spaghetti-like structures extend throughout most of the abdominal cavity where they serve as excretory organs, removing nitrogenous wastes (principally ammonium ions, NH_4^+) from the haemolymph. The toxic NH_4^+ is quickly converted to urea and then to uric acid by a series of chemical reactions within the malpighian tubules. The uric acid, a semi solid accumulates inside each tubule and is eventually emptied into the hindgut for elimination as part of the faecal pellet.

The hindgut is divided into three sections; the anterior is the ileum, the middle portion, the colon, and the wider, posterior section is the rectum. This extends from the pyloric valve which is located between the mid and the hindgut to the anus. The rectum usually contains a number of pads or papillae (usually six) that project into the lumen. These structures receive an extensive supply of tracheae and are metabolically very active. They play an especially important role in the excretory system.

Functions of the hindgut include the following:

- Water absorption from urine and faeces.
- Ion absorption from urine and faeces.
- Crypto-nephridial system for water conservation.
- Modifications in structure for housing symbiotic microorganisms (e.g., termites).

Salivary glands

Although there may be glands associated with the mandibles (e.g. silver fishes, queen honey bee), maxillae (e.g. proturans, spring tails), and hypopharynx (e.g. worker honey bee), salivary glands are typically associated with the labial segment. The salivary glands or labial glands are paired structure lie ventral to the foregut in the head and thorax and occasionally extend posteriorly into the abdomen. Depending on the type of food eaten and the insect species involved salivary glands vary in size, shape and the type of secretion produced.

Two basic types of salivary glands exist:

- a) Acinar (e.g. Orthoptera and Dictyoptera)
- b) Tubular (e.g. Diptera, Lepidoptera and Hymenoptera)

In the acinar type each acinus bears a tiny duct that communicates with other similar ducts, eventually forming a lateral salivary duct. Lateral salivary ducts run anteriorly and merge as the common salivary duct, which empties between the base of the hypopharynx and the base of the labium. This region is called the salivarium and in some sucking insects forms a salivary syringe that injects saliva into whatever is being pierced. The lateral salivary ducts may communicate with salivary reservoirs, as in the cockroaches.

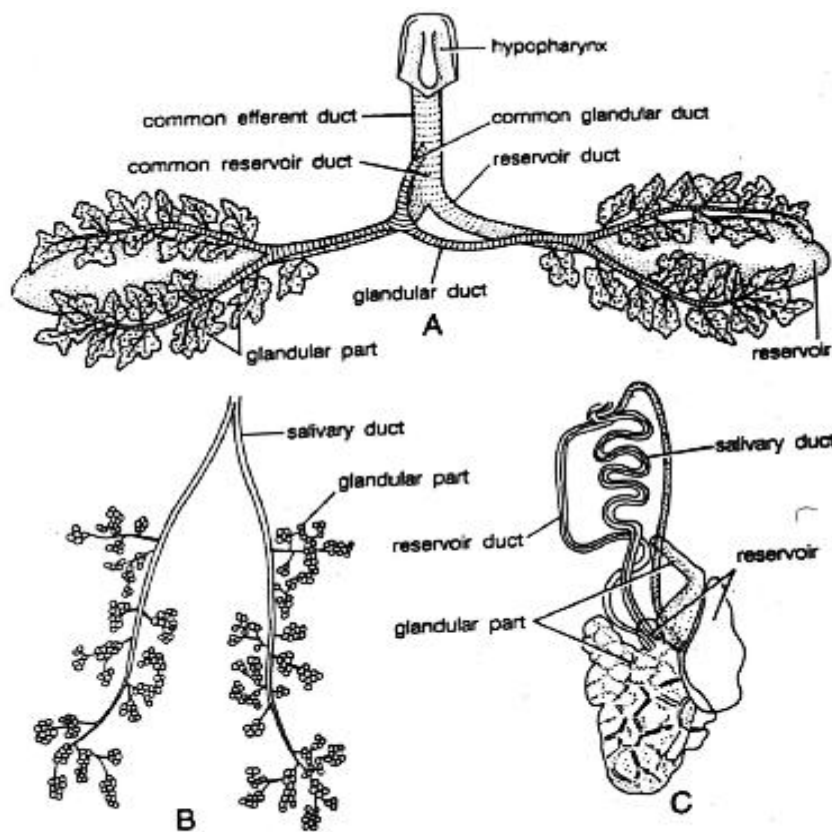


Fig. (A) Salivary glands of cockroach, (B) grasshopper and (C) red cotton bug.

Functions of salivary gland:

The secretory products of the salivary glands are generally clear fluids that serve a variety of functions in different insects:

1. They moisten the mouthparts and serve as a lubricant
2. They act as a food solvent
3. They serve as a medium for digestive enzymes and various anticoagulins and agglutinins
4. They secrete silk in larval Lepidoptera (caterpillars) and Hymenoptera (bees, wasps and relatives)
5. They are used to flue puparial cases to the substrate in certain flies
6. They serve for the production of toxins
7. They secrete antimicrobial factors (e.g. in certain blow fly larvae).

Amylase and invertase are the most common enzymes found in saliva of insects however the saliva may also contain lipase and protease. Aphids secrete a pectinase that aids their

mouthparts in the penetration of plant tissues. The spreading factor hyaluronidase which attacks a constituent of the intercellular matrix of many animals has been found in the assassin bug. Blood sucking (haematophagous) insects contain various anti-haemostatic agents.

Production and secretion of saliva in the dragonflies, grasshoppers and cockroaches are regulated by nervous innervations from both the stomatogastric nervous system and the subesophageal ganglion whereas in the Diptera (e.g. the adult blow fly) these glands are controlled by an unidentified neurohormone.

Salivation has been shown to be controlled by phago-stimulation of external chemoreceptors on the mouthparts. This same stimulus probably also activates the salivary pump.