

STRUCTURE AND FUNCTIONS OF DIGESTIVE SYSTEM

The alimentary canal of insects is a long, muscular, and tubular structure extending from mouth to anus. It is differentiated into three regions viz., Foregut, Midgut and Hindgut.

I. FOREGUT

Foregut is ectodermal in origin. Anterior invagination of ectoderm forms foregut (**Stomodeum**). Internal cuticular lining is present. Terminal mouth parts leads into a **preoralcavity**. Preoralcavity between epipharynx and hypopharynx is called as **Cibarium**. Preoralcavity between hypopharynx and salivary duct is **Salivarium**. Behind the mouth a well muscled organ called **Pharynx** is present which pushes the food into oesophagus. Pharynx acts as a **sucking pump** in sap feeders. **Oesophagus** is a narrow tube which conducts food into crop. **Crop** is the dilated distal part of oesophagus acting as food reservoir. In bees crop is called as honey stomach where nectar conversion occurs. **Proventriculus or Gizzard** is the posterior part of foregut and is muscled. It is found in solid feeders and absent in fluid feeders or sap feeders. The internal cuticle of gizzard is variously modified as follows.

- i. Teeth like in cockroach to grind and strain food.
- ii. Plate like in honey bee to separate pollen grains from nectar
- iii. Spine like in flea to break the blood corpuscles

Food flow from foregut to midgut is regulated through **Cardiac valve or Oesophageal valve**.

II. MIDGUT

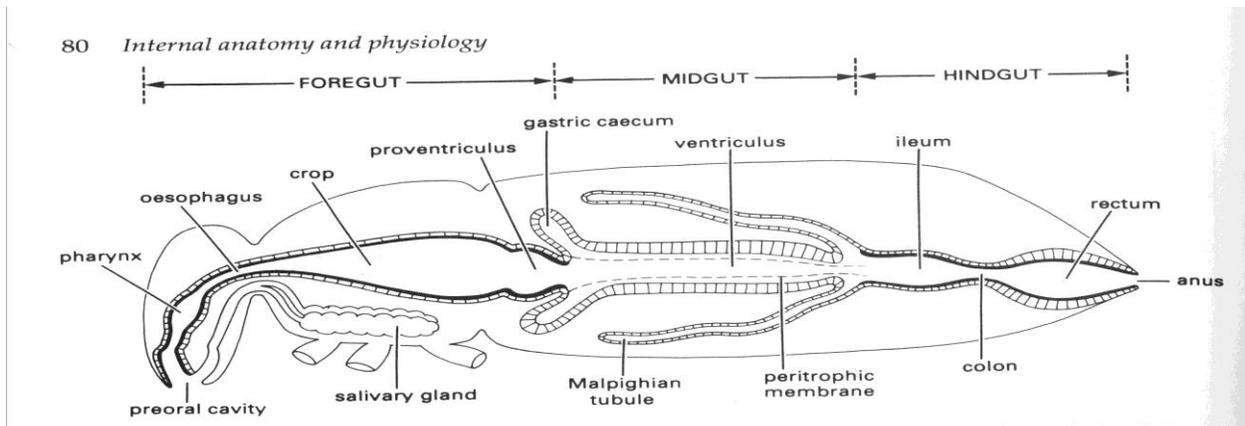
Midgut is endodermal in origin and also called as **mesentron**. This part contains no cuticular lining. Midgut is made up of three types of epithelial cells. (i) Secretory cells (Columnar cells) (ii) Goblet cells (aged secretory cells), (iii) Regenerative cells which replaces secretory cells.

Important structures present in midgut are as follows:

(i) **Peritrophic membrane**

It is the internal lining of midgut, secreted by anterior or entire layer of midgut epithelial cells. Present in solid feeders and absent in sap feeders. This layer is semipermeable in nature to digestive juices and digestion products. Its functions are

- (a) Lubricate and facilitate food movement
- (b) Envelops the food and protects the midgut epithelial cells against harder food particles.



(ii) **Gastric caecae:** (Enteric caecae or Hepatic caecae)

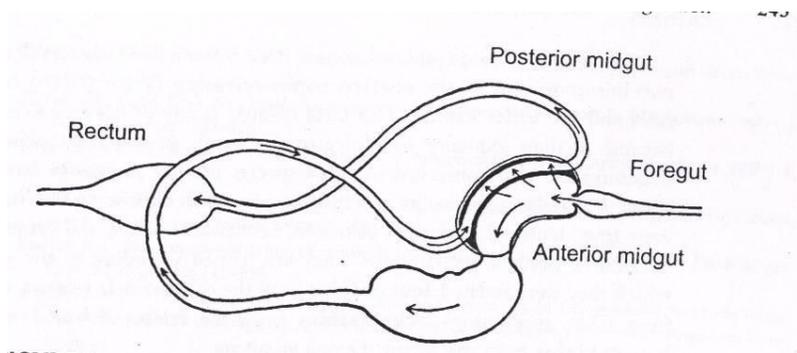
Finger like outgrowths found in anterior or posterior ends of midgut. This structure increases the functional area of midgut and shelter symbiotic bacteria in some insects.

(iii) **Pyloric valve:** (Proctodeal valve)

Midgut opens into hindgut through pyloric valve, which regulate food flow. In certain immature stages of insects midgut is not connected to hindgut till pupation. e.g. Honey bee grub.

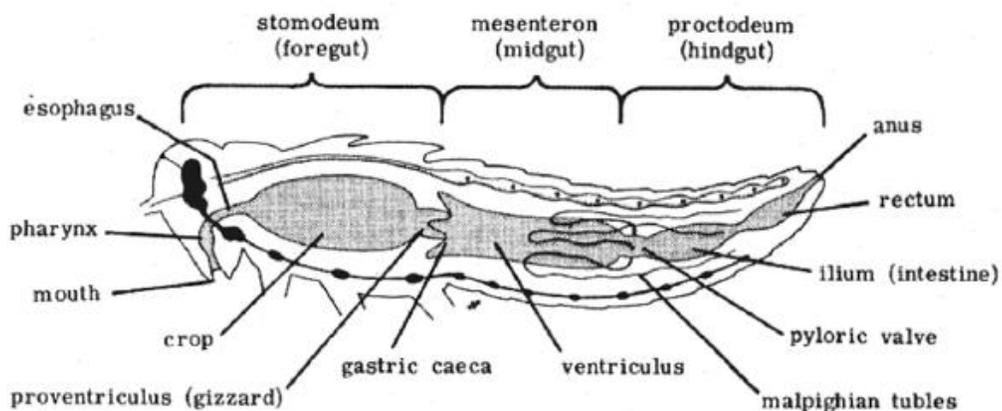
(iv) **Filter chamber:**

Filter chamber is a complex organ in which two ends of ventriculus and the beginning of hind gut are enclosed in a sac. This is useful to short circuit excess water found in liquid food in homopteran insects. This process avoids dilution of digestive enzymes and concentrates food for efficient digestion. Also helps in osmoregulation by preventing dilution of haemolymph.



III. HINDGUT

Hindgut is ectodermal in origin and produced by the posterior invagination of ectoderm. Internal cuticular lining is present, which is permeable to salts, ions, aminoacids and water. The main functions of hindgut are the absorption of water, salt and other useful substances from the faeces and urine. Hindgut is differentiated into three regions viz., ileum, colon and rectum. In the larva of **scarabids** and **termites**, ileum is pouch like for housing symbionts and acts as fermentation chamber. Rectum contains **rectal pads** helping in dehydration of faeces and it opens out through anus.



The "generalized" digestive system of insects.

IV. GUT PHYSIOLOGY: Primary functions of the gut is to digest the ingested food and to absorb the metabolites. The digestion process is enhanced with the help of enzymes and microbes which were produced by digestive glands and special cells.

A. Digestive glands

(a) Salivary glands

In Cockroach a pair of labial glands acts as salivary gland where the salivary ducts open into salivarium. In caterpillars mandibular glands are modified to secrete saliva, where the salivary glands are modified for silk production.

Functions of saliva

- (i) To moisten and to dissolve food
- (ii) To lubricate mouthparts
- (iii) To add flavour to gustatory receptors
- (iv) In cockroach the saliva contains amylase for the digestion of starch.
- (v) In honey bee saliva contains invertase for sucrose digestion
- (vi) In Jassid saliva contains lipase and protease for lipids and protein digestion. Jassid saliva also contains toxins which produces tissue necrosis and phytotoxemia on the plant parts.
- (vii) In plant bug saliva contains pectinase which helps in stylet penetration and extra intestinal digestion.
- (viii) In mosquito, saliva contains anticoagulin which prevents blood clotting.
- (ix) In gall midge saliva contains Indole Acetic Acid (IAA) which produces galls on plant parts.
- (x) In disease transmitting insects (vectors) the saliva paves way for the entry of pathogens.

(b) Hepatic caecae and midgut epithelial cells: It secretes most of the digestive Juices.

Two types of cells were involved in the enzyme secretion.

- (i) **Holocrine** : Epithelial cells disintegrate in the process of enzyme secretion.
- (ii) **Merocrine** : Enzyme secretion occurs without cell break down.

B. Digestive enzymes

Insect group	Enzyme	Substrate
Phytophagous larvae	Amylase	Starch
	Maltase	Maltose
	Invertase	Sucrose
Omnivorous insects	Protease	Protein
	Lipase	Lipid
Nectar feeders	Invertase	Sucrose
Wood boring Cerambycid grub and Termites	Cellulase	Cellulose
Meat eating maggots	Collagenase	Collagen and elastin
Bird lice	Keratinase	Keratin

C. Microbes in digestion: In the insect body few cells were housing symbiotic microorganisms called as **mycetocyte**. These mycetocytes aggregate to form an organ called **mycetome**.

- (i) **Flagellate protozoa** - It produces cellulase for cellulose digestion in termites and wood cockroach.
- (ii) **Bacteria** - It helps in wax digestion in wax moth.
- (iii) Bed bug and cockroach obtain vitamin and aminoacids from microbes.

These microbes were transmitted between individuals through food exchange (mouth to mouth feeding) called **trophallaxis** and through egg called as **transovarial** transmission.

In plant bug and ant lion grub partial digestion occurs in the host body prior to food ingestion called as **extra intestinal digestion**. In most of the insects digestion occurs in mid gut.

Absorption

In many insects absorption of nutrients occurs through microvilli of midgut epithelial cells by diffusion. Absorption of water and ions occur through rectum. In cockroach lipid absorption occurs through crop. In termites and scarabaeids (White grubs) absorption occurs through ileum. In solid feeders, resorption of water from the faeces occurs in the rectum and the faeces is expelled as pellets. In sap feeders (liquid feeders) the faeces is liquid like. The liquid faeces of **homopteran bugs** (aphids, mealy bugs, Scales and psyllids) with soluble sugars and amino acids is known as **honey dew**, which attracts ants for feeding.

Alimentary system of cockroach

The alimentary canal is a long tube (Holotrophic) extending from mouth to anus. It is convoluted in the posterior end. It is mainly divided into three regions viz., foregut or stomodaeum, midgut or mesenteron or ventriculus and hindgut or proctodaeum. Mouth leads into pharynx which leads immediately into a narrow tube called oesophagus. The distal end of the oesophagus enlarges into a large sac like structure called crop which is useful to store the food prior to digestion. The posterior part of the crop narrows down to a small sac, the gizzard or proventriculus. Inside the gizzard, six chitinous cuticular teeth are present which help in pulverizing the food. Midgut is the main site of digestion and assimilation. Hindgut is differentiated into a narrow ileum, wider colon and sac like rectum. Salivary glands and hepatic caecae are digestive glands associated with alimentary tract. Salivary apparatus consists of two pairs of salivary glands and a pair of salivary reservoirs. Hepatic caecae are finger like projections found at the junction of foregut and midgut, which serve as enzyme source for digestion. Associated with the alimentary tract at the junction of midgut and hindgut are many yellowish, hair like structures called malpighian tubules which eliminate nitrogenous waste from blood.