# Physiology of Digestion

**Dr. Mahesha H B**
**Professor and Head**
**Department of Sericulture**
**Yuvaraja's College**
**University of Mysore, Mysuru, India**

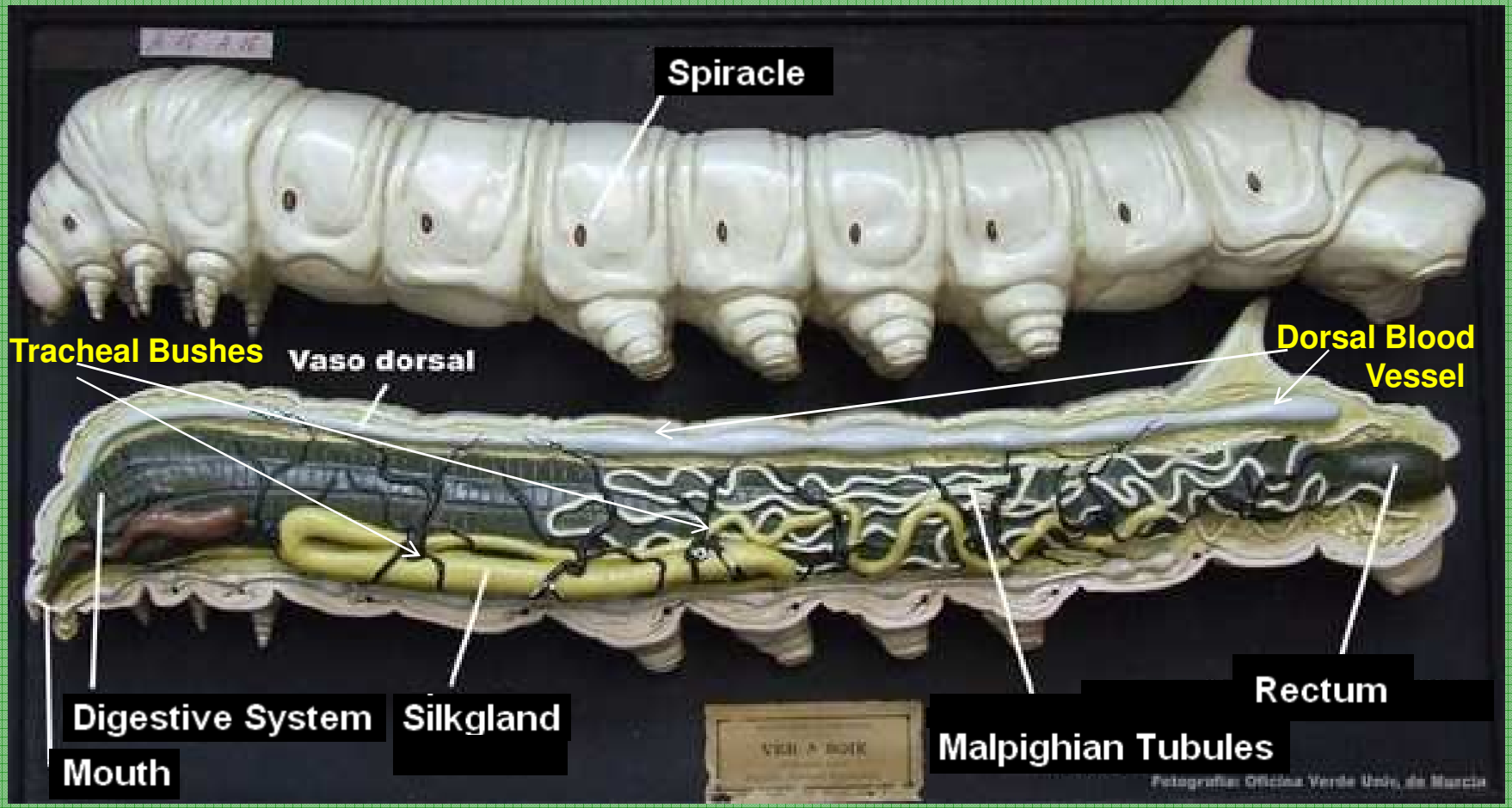
Physiology: The branch of biology that deals with the normal functions of living organisms and their parts.

or

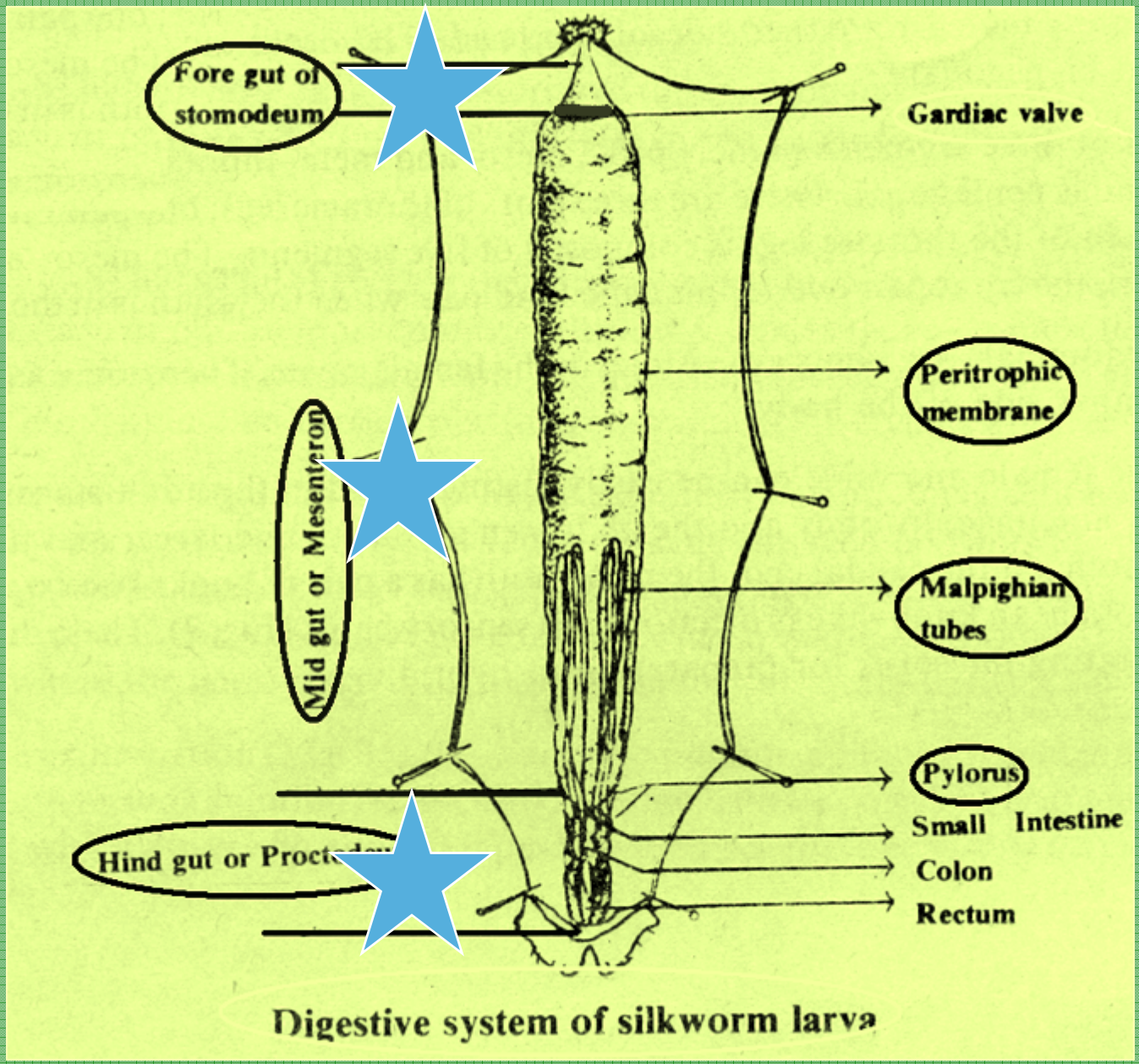
The way in which a living organism or bodily part functions.

**Digestion: The process of digesting food**

# Overall Morphology and Anatomy of Silkworm Larva

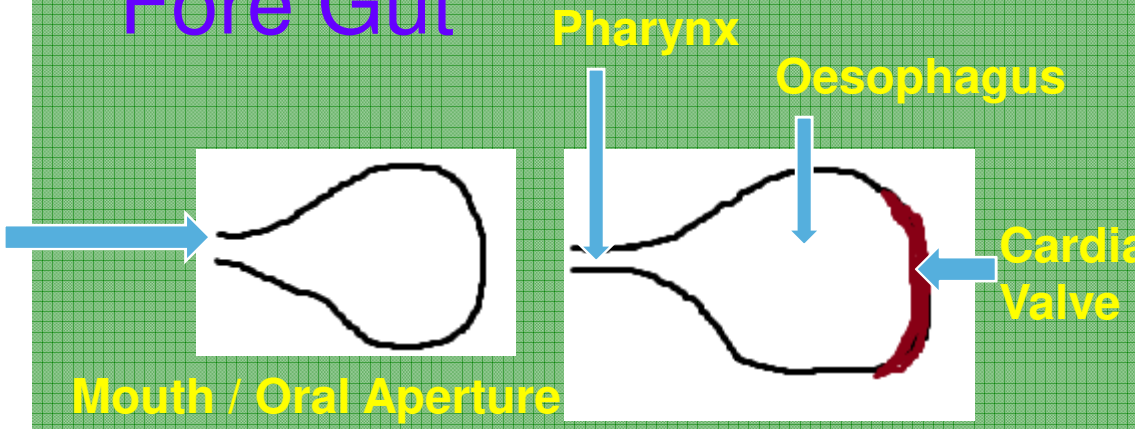


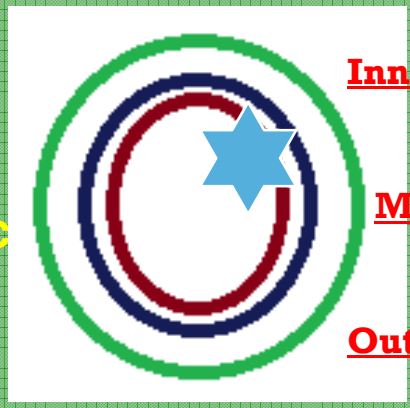
# STRUCTURE AND FUNCTION OF DIGESTIVE SYSTEM




Digestive system of silkworm larva

# Fore Gut




**The fore gut has a chitinous lining & also sheds at the time of moulting**

**A pair of Salivary glands and Salivary Reservoirs usually reside in the thorax (adjacent to the foregut). Salivary Ducts lead from the glands to the reservoirs and then forward, through the head, to an opening (the Salivarium) behind the Hypopharynx. Movements of the mouthparts help mix saliva (contains amylase) with food in the buccal cavity.**

**From the pharynx, food passes into the oesophagus by means of peristalsis (rhythmic muscular contractions of the gut wall). Food remains in the oesophagus until it can be processed through the remaining sections of the alimentary canal and 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.**

# Mid Gut

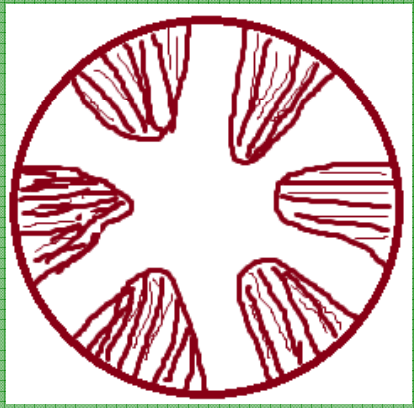
- **Digestion and Absorption**

**Goblet Cells at midgut Epithelium Secretes digestive Fluid**

**Cylindrical cells absorb digested food**

**The midgut is derived from embryonic endoderm so it is not protected by an intima. Instead, the midgut is lined with a semipermeable membrane secreted by a cluster of cells (the cardic epithelium) that lie just behind the Stomodeal 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 posterior end of the midgut is marked by another sphincter muscle, the Pylorus Valve. It regulates the flow of material from the mesenteron to the proctodeum.**

- **Hindgut**
- **Small Intestine, Colon and Rectum. Pylorus Valve**

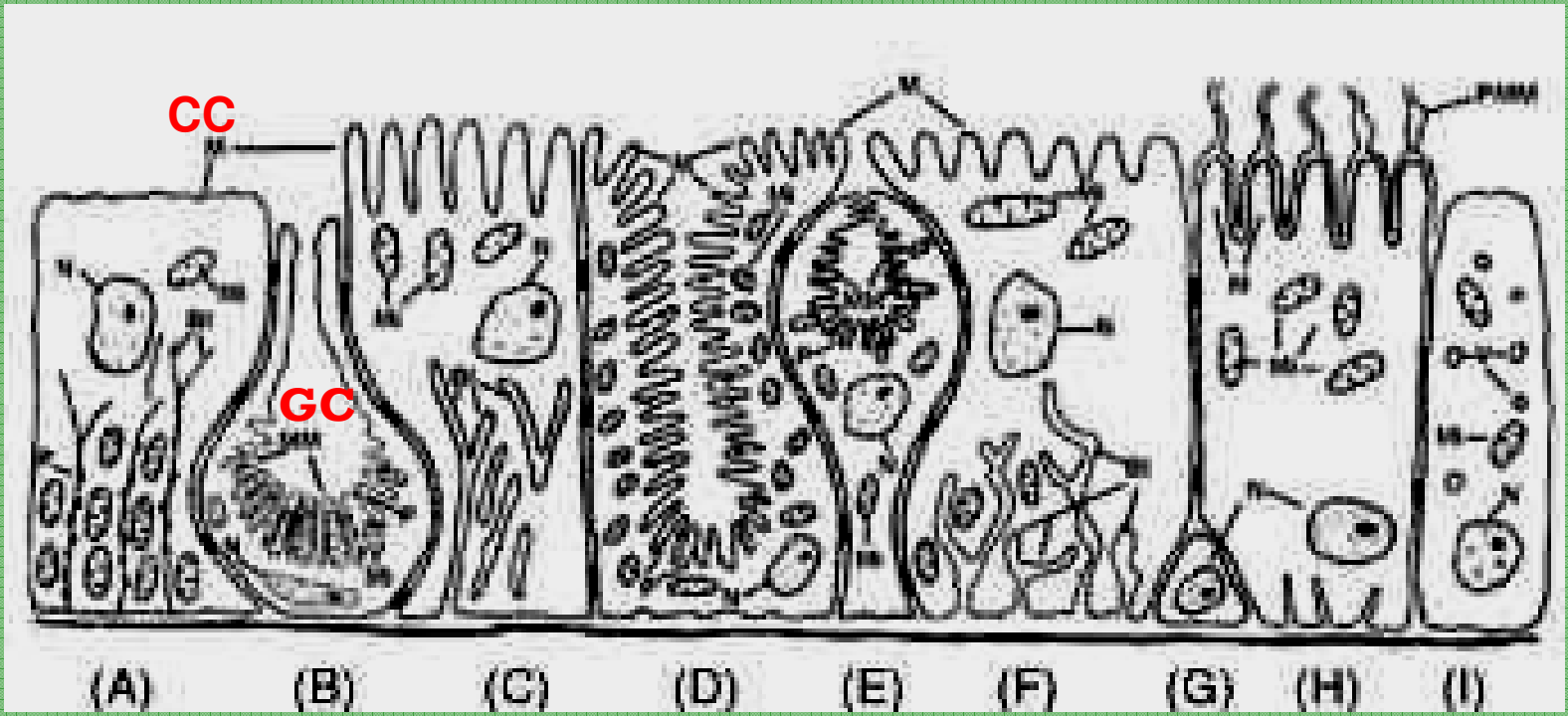


**The hind gut has a chitinous lining & also sheds at the time of moulting**

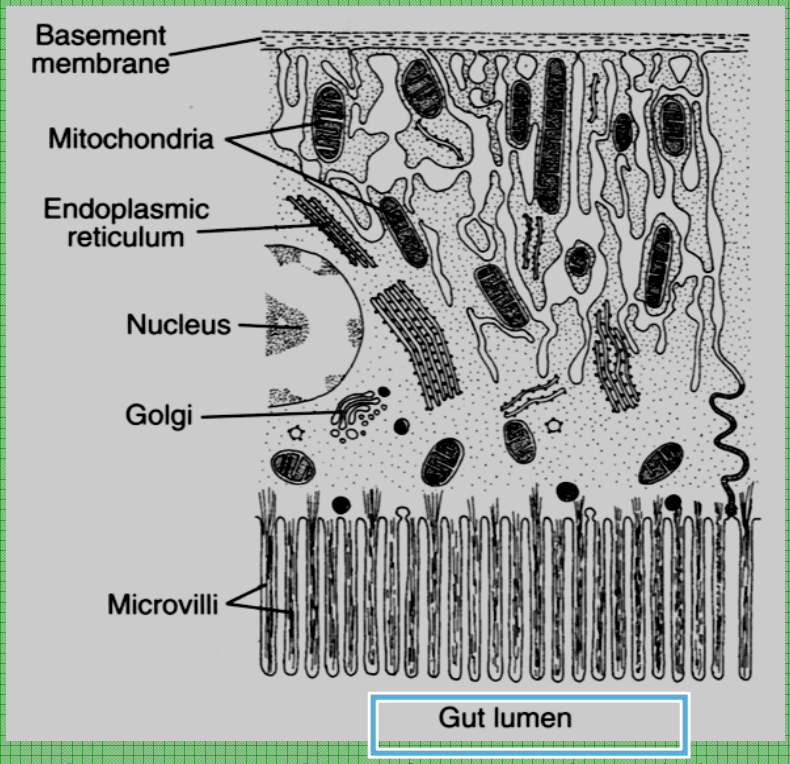
**Silkworm Excreta With Hexagonal Shape**

**The pyloric valve serves as a point of origin for Malpighian Tubules. These long, spaghetti-like structures 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 fecal pellet.**

- **The rest of the hindgut plays a major role in homeostasis by regulating the absorption of water and salts. In some insects, the hindgut is visibly subdivided into an small intestine, a Colon, and a Rectum. Efficient recovery of water is facilitated by six Rectal Pads. These organs remove more than 90% of the water from a fecal pellet before it passes out of the body through the anus.**
- **Just like the foregut, it is lined with a thin, protective layer of cuticle (intima). When an insect molts, it sheds and replaces the intima in both the foregut and the hindgut.**

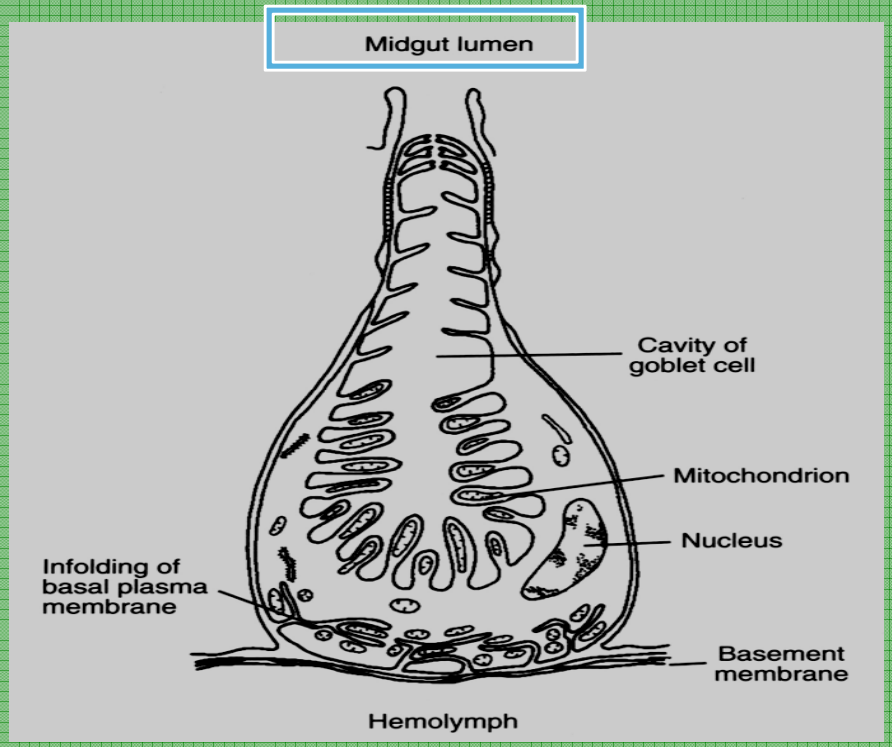



**Diagrammatic representation of typical insect midgut cells:**
**(A) columnar cell, usually occurring in fluid-absorbing tissues**
**(B) lepidopteran long-necked goblet cell**
**(C) columnar cell, usually occurring in fluid-absorbing tissue**
**(D) cyclorrhaphan dipteran oxyntic (cuprophilic) cell**
**(E) lepidopteran stalked goblet cell;**
**(F) columnar cell, frequently present in fluid-secreting tissue;**
**(G) regenerative cell;**
**(H) hemipteran midgut cell;**
**(I) endocrine cell.**




**Columnar Cell** forms microvilli. The microvilli greatly increase the area of the cell membrane through which absorption occurs.

## Long-necked goblet cell



# Phagostimulants and Feeding Deterrents

**The term "phagostimulant" can be defined as a substance which enhances the insect food intake by stimulating chemoreceptor cells.**

**Feeding Deterrent is a chemical agent that inhibits feeding without killing the insect directly while the insect remains near the treated foliage and dies through starvation.**

**Eg., Coumarin, Caffeine, and Nicotine, at micromolar to millimolar levels**

# Process of Digestion

Digestion & assimilation of food, take place mainly in the midgut.

## Digestion

Food ingested by insects is macromolecular (polysaccharides, proteins, lipids). Small molecules can only pass into tissues large molecules must be broken down into a component of suitable size before absorption occurs. Enzymes concerned with digestion in saliva and in midgut secretions. Also microorganisms in the gut may facilitate digestion.

In other words, it is the procedure of changing insoluble substances into soluble substances and also the impermeable substances into permeable substances.

Most digestion occurs in the mid gut in which the enzymes are secreted. The digestive juice is consisted of saliva and gastric juice. The saliva is a weak alkaline solution containing an enzyme called amylase. Gastric juice or gastric fluid is a strong alkaline solution. The pH of gastric juice is 9.2-10.3.

The principal enzymes contained in the gastric juice are tyrosinase, lipase, amylase, maltase and glycogenase, oxidase, peroxidase and catalase.

## Absorption

**The passage of food through the lining of the digestive tract in to the blood directly or indirectly through the lymph is called absorption.**

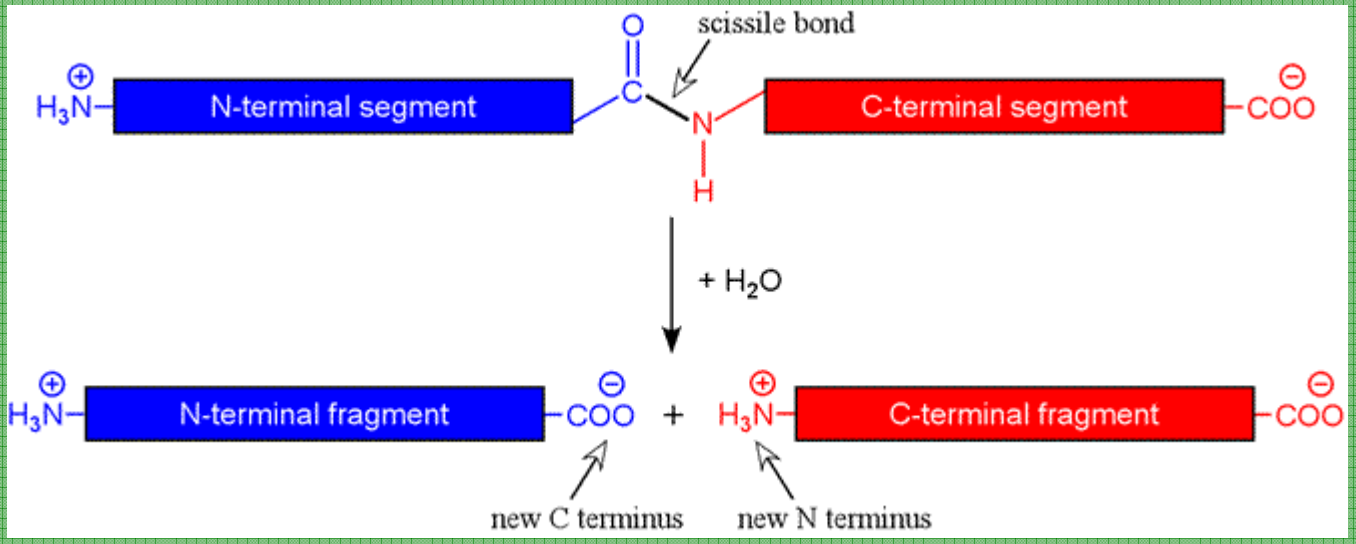
**Among the components of mulberry leaves, some elements, such as water, glucose, soluble salt *etc.* are absorbed directly by the cells of the mid-gut, but protein and other molecule of big size cannot permeate the cell wall of the mid-gut. So they should be decomposed into simple forms and absorbed.**

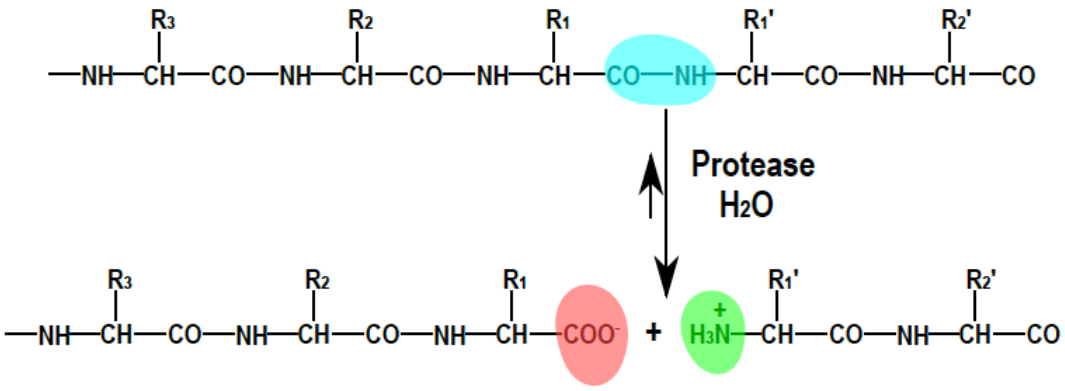
## Assimilation

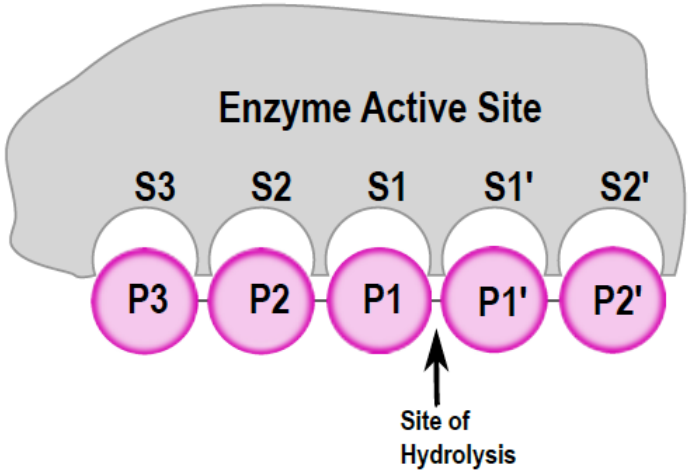
There is difference in the protein of mulberry leaves and the protein of silkworm body. The proteins of mulberry leaves is decompose by an enzyme into amino acids and peptone and absorbed by the cells of the mid-intestine and ultimately carried to the respective organ through haemolymph. In the respective organ the amino acids and peptones are again synthesized in to animal proteins. This process is called assimilation.

Others matter also assimilated in the silkworm body, such as fat is synthesized from the fatty acids and glycerol. Besides this fat is also synthesized from carbohydrates. A greater part of mulberry carbohydrates synthesized into fats in the silkworm body.

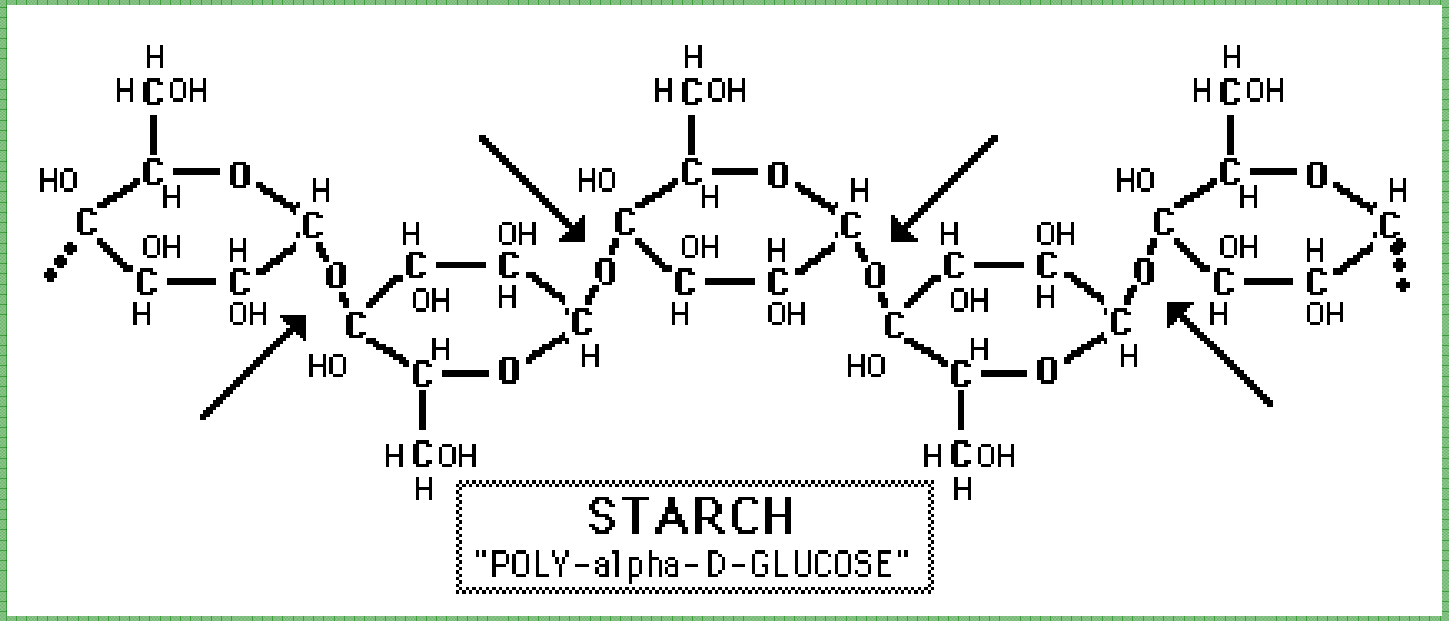
# Action of Protease



# Action of Amylase



# Action of Lipase

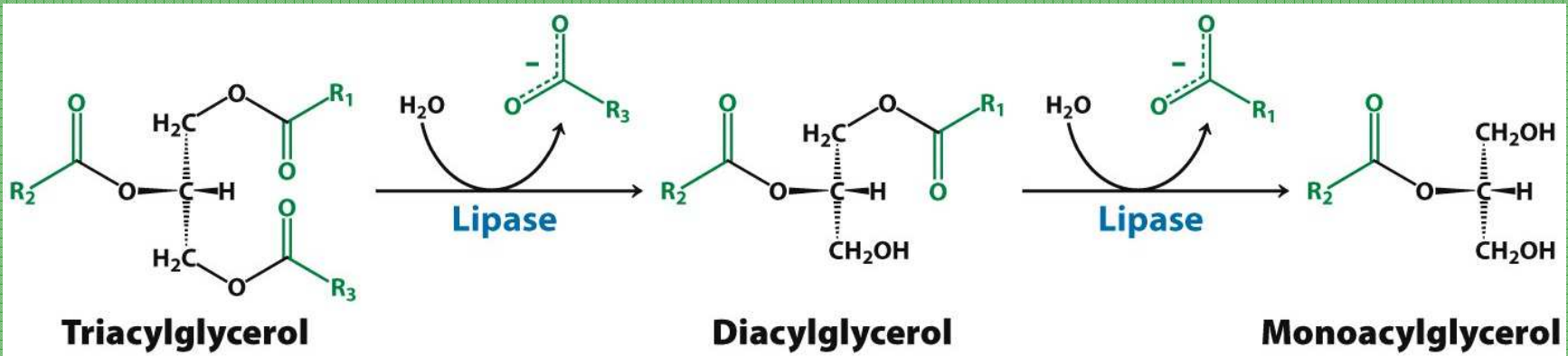



**Figure 22.3**
***Biochemistry*, Seventh Edition**

# Nutritive Requirements of the Silkworm

**Carbohydrates-Carbohydrate is a major source of energy.**

**Protein and Amino acid**

**They are used for structural purposes, as enzymes, receptors, for transport and storage.**

**Lipids**

**Lipids are the bound fatty acids, short & long chain alcohols, steroids and theirs esters, phospholipids & other groups of compounds in addition silkworms are able to convert carbohydrates into lipids. Fatty acids, are components of cell walls in addition to having other specific functions**

## Water

**Water is the best solvent and only in a solution state all kinds of nutrients can be absorbed into cells.**

## Fibre

**Fibre is not grouped under nutrients. It comprises largely of cellulose and lignin and these substances belong to polymeric carbohydrates. Its intake along with all diet is essential because of regulatory function and help to maintain the normal peristaltic movement of the intestine to remove waste product from the Intestine**

## Vitamins

Vitamins, a kind of organic active substance mainly are the component enzyme and other catalysts.

## Ascorbic Acid

Ascorbic acid has many important functions in the silkworm body. It is a powerful antioxidant, protecting against oxidative damage to DNA, membrane lipid and proteins

## Thiamine (B1)

Thiamine is important for energy metabolism.

## Riboflavin (B2)

Riboflavin is important in promoting the release of energy from carbohydrates, fats and proteins i.e. in the metabolic pathway for ATP production

## Niacin (B3)

Niacin, requires for cell respiration, help with the release of energy and metabolism of carbohydrates, lipid and proteins.

## Pantothenic Acid (B5)

Vitamin B5 functions as a cofactor for enzymes and are required in the diet of all the silkworms.

## Pyridoxin (B6)

Vitamin B6 in very much essential for silkworm but in low concentration. Low concentration of vitamin B6 increases the larval body weight, pupal weight, silk gland weight, cocoon and shell weight

## Biotin (B8)

Biotin has an important role in carbohydrate and fat metabolism.

## Choline and Inositol

Choline and inositol are required by silkworm in higher level because they are involved in the production of cell membranes

## Minerals

Minerals may represent a limiting factor for the growth of the insects, principally true for all types of diet composition. The salt significantly improved the growth of the developmental stages, increased the cocoon characters, elicited early cocoon production and increased the reproductive potential of the silkworms.

# Artificial diets and their composition

**The food which is not naturally derived by an organism, but prepared or synthesized is known as artificial diet. The concept of artificial diet was first developed by Boganow in 1908 for *Calliphora vanitoria* (Blue butterfly). The artificial diet was a mixture of meat extraction, starch, peptone and minerals. Bhottger (1942) and Bock (1919) developed an artificial diet for European corn borer (*Ostrinia nubiallis*) by using highly purified natural products.**

- The silkworm *Bombyx mori* is a monophagous insect which feeds only on mulberry leaves. The experiment initiated in 1950's to investigate the nutritional requirements of silkworm in Japan resulted in development of artificial diet.
- Researches in artificial diet began in 1953 and in the year 1960, Fukuda first successfully reared the silkworm from hatching to adult on artificial diet. The diet prepared in the early 1960's contained more than 50% of dried, pulverized mulberry leaves as one of the main ingredients along with other simple items of food. Larvae reared on those diets had retarded growth, the cocoons produced were of small size and adult produced eggs much less in number than the normal.

- **Simultaneously, attempts were made to improve the diets taking into consideration the nutrition of silkworms.**
- **After 1980, works were taken up mainly on cost reduction by substitution of low cost ingredients such as yellow corn powder to substitute for fats, starch and beta-sterol to blue green algae (*Spirufirm plutensis*) as the source of protein components used for live stock feed and mulberry branch powder in place of cellulose.**

- **The composition of the diet has been improved continuously since then. Now hundreds of diets of various purposes have been developed.**

- **In Japan, presently 80% commercial young age, 18% upto third instar and 2% upto late age silkworms are the cooperative rearing centers on artificial diets in order to stabilize the crops and to reduce the costs of rearing.**

## COMPOSITION OF ARTIFICIAL DIETS

- A successful formulation of any artificial diet depends to a large extent on the basic understanding of nutrition, composition of the natural food and feeding behaviour of the larvae.
- Primarily the diet should possess essential physical and chemical features that are acceptable to the silkworm.
- The diet should contain the essential nutrients in balanced proportion to support normal growth, development, and reproduction and to give high silk contents.

- **According to composition of diets, artificial diet can be divided into three types, as follows:**

**1. Oligidic diet, 2. Meridic diet, 3. Holidic diet**

- **Oligidic diet**
- **It consists primarily of crude natural materials such as mulberry leaf powder. These types of diet are used in mass rearing projects when the components readily available and are inexpensive. It is popular because of the general simplicity in preparation and low costs.**

- **Meridic diet**
- **The are composed mostly of defined chemicals but with one or more undefined components such as defated soya meal. It is considered to have crude source of nutrients such as vitamins, carbohydrates, amino acids etc. in the form of potato starch, soybean meal and salt mixture.**
- **Holidic diet**
- **These diets consists of entirely known pure chemicals. But in the strict sense a holidic diet for silkworm may not be possible as contaminants are commonly present in many of these components such as agar used in the diet.**

- **ADVANTAGES OF ARTIFICIAL DIET**
  - **When the mulberry leaf is not consistent in terms of moisture content as required by young age silkworms**
  - **Non-availability of leaf during unfavourable seasons**
  - **Continuous source of controlled ingredients for basic research**
  - **To maintain hygienic condition during rearing**
  - **Drastic reduction of labour requirement**

**Acknowledgements**
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