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.

In the silkworm larva the digestive system is more or less a straight tube from the mouth to the anus divided into three main parts: the fore-gut or stomodeum, mid-gut or mesenteron, and hind-gut or proctodeum. The fore gut is the anterior part of the digestive tract. It is composed of three parts, the buccan cavity, the pharynx and the oesophagus. The oral aperature opens into the mouth cavity which is followed by a narrow pharynx and oesophagus. 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 helps to mix saliva (contains amylase) with food in the buccal cavity. The oesophagus is narrow at the anterior end and gradually widens towards the
posterior end. 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. There is a cardiac or stomodeal valve at the end of the fore-gut that retains the chewed mulberry leaf bits in the oesophagus for some time and also prevents the regurgitation (backward flow) of food from mid-gut to fore-gut. The mid-gut is a long, wide cylindrical tube narrow at the posterior end. It is the largest part of the alimentary canal ranges from second thorasic to ninth abdominal segments. The wall of the midgut is composed of a muscular layer, basal membrane epithelium and peritrophic membrane. 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 stomodeal valve. This peritrophic membrane consists of chitin fibrils embedded in a protein-carbohydrate matrix. It protects the delicate digestive cells from the mulberry leaf bits (food abrasion) and micro-organisms without inhibiting absorption of nutrient molecules. The posterior end of the midgut is marked by another sphincter muscle, the pyloric valve. It regulates the flow of material from the mesenteron to the proctodeum. Digestion and assimilation of food, take place mainly in the mid-gut. The digestive fluid is secreted principally from the goblet cells at the mid-gut epithelium and the cylindrical cells absorb the digested food. The goblet cells at midgut epithelium secretes digestive fluid, which is alkaline, yellow green in colour and pH is 9.2-10.3. This has many important enzymes viz., protease (protein digesting enzyme), lipase(fat digesting enzyme),, amylase, maltase, glycogenase (carbohydrate digesting enzymes), oxidase, peroxidase, catalase and tyrosinase (oxidizing enzymes). Important enzyme reactions are explained below.

1. Amylase, which converts starch in to simple sugars as shown in the following figure.
2. Protease, which converts proteins into amino acids as shown in the following diagramme.

![Protease Diagram](image)

![Polypeptide Amino Acid](image)

3. Lipase, which converts complex lipid/fat molecules into simpler ones as follows.

![Lipase Diagram](image)

The hind-gut consists of the small intestine, colon, and rectum, and a pylorus valve near the anterior end of the small intestine which guards and regulates the passage of digested food from the mid-gut to the hind-gut. 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 hind gut is a
passage for the absorption of a large portion of food moisture and elimination of
digested food. In the anterioroposterior direction, the rectum has six muscles for
pressing the excrements. The fecal matter is pressed in the rectum and expelled
from the anus as fecal pellets bearing hexagonal marks. These organs remove
more than 90% of the water from a fecal pellet before it passes out of the body
through the anus.

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PHYSIOLOGY OF RESPIRATION

In insects the intake of air for oxygen and distribution of air with in the body is
performed by a fine network of tubules called tracheal system. The tracheae are
invaginations of the cuticle, which branch everywhere, among the tissues which
convey the O2 directly to the site of utilization and the haemolymph is not
concerned with gas transport.

A spiracle consists of peritreme, sieve plate and a atrium. The spiracles bordered
by cuticular hard structure all around the spiracle called peritremes. The sieve plate
is situated inside the peritreme ring and a slit cab be seen along the median line of
the sieve plate. Which is perforated and prevents the entry of dust particles and air.
The external opening of the spiracle leads into a cavity called atrium. Which
contains closing apparatus. There are two closing membranes can be observed if
the sieve plate is taken off, they are called anterior and posterior valves.

The number of tracheal branches start radially from the spiracular cavity next to the
atrium and looks like bushes called tracheal bushes. All the nine tracheal bushes get
connected laterally by the longitudinal lateral tracheal trunks in each side of the
body. And the two tracheal bushes in the respective segments get connected by
means of transverse ventral tracheal commissures. The tracheae ramify repeatedly
throughout the body and organs and ultimately forms tracheoles and their diameter
is reduced to one micron. As the tracheal system is continuously exposed to the
atmospheric air, there is every chances of moisture loss from the tracheal system.
But to prevent this desiccation or moisture loss insects developed a perispiracular
glands. These perispiracular glands are distributed on the inner surface of the
tracheal system. These are unicellular glands, secrete a hydrophobic oily
substance all over the inner surface of the tracheal system, which keeps the surface
oily and moist. These secretions prevent the entry of water in to the tracheal system.
These trachea are lined by cuticle continuous with that of the body wall. This lining
has a characteristic striated appearance due to thread like ridges which run
helically around the inner circumference and form taenidium.

The function of this taenidium is to keep the tracheae distended i.e., prevents from
collapsing of trachea when the pressure increases or decreased and there by allow
the free passage of air. There is a membrane between the taenidia is called inter
taenedial membrane, it is very thin and highly flexible. As a result the trachea can
stretch to double length without breaking them. So the taenedia and thin membrane provide the necessary rigidity and flexibility to the tracheal system. The inter tracheal membrane is 0.01 to 0.02 micron thick.

The mode of ending of tracheae shows an equal diversity. Typically when the trachea has been reduced by repeated branching to a diameter of 2-5 micron it enters a large satellite cell, the tracheal end cell or transitional cell and there breaks up abruptly into a number of tracheal capillaries or tracheoles, which are less than one micron in thickness. These tracheoles are interconnected with each other and form a mat over tissues.

On anatomical grounds it is possible that most of the oxygen taken up enters the tissues through the walls of the tracheoles; for those are always most abundant in such organs as the wing muscles, ovaries etc., with high oxygen requirements. On the other hand, the tracheal walls permeable to gases, and impossible to say how much O2 consumed passes through them, but the volume of the tissue around the tracheae which could be supplied by diffusion through tissue fluids is insignificant in comparison with that of supplied by the tracheoles.

It is generally supposed that the passage of oxygen from tracheoles into the tissue takes place by physical diffusion. But several authors have suggested that the tracheal epithelium, and particularly the tracheal end cells play a more active part.

Breathing occurs by the movement of body wall. According to Mori 1932 the spiracles serve the function of both inspiration and expiration. The tracheoles end in the tissues in various ways. In the gut and salivary gland they ramify and pass between the cells without penetrating them. In the fat body and rectal papillae, however they may enter the cells, while in the flight muscle there is a net work of intracellular tracheoles. A solitary exception is the fore part of the solkgland which has no tracheation.
The function of the excretory system is to maintain a constant internal environment in the body, by the elimination or segregation of unwanted substances present in the blood, and by the retention or reabsorption of constituents needful to the organism. In silkworm special excretory organs called Malpighian tubules perform this function. They are found attached to the alimentary canal at the junction between small intestine and colon. Paired Malpighian tubules arise from each side.
of the hindgut. The two branches are further divided into three tubes. Each Malpighian tube (one group) emerges from the intestine is emerged into a sac called excretory chamber or urinary bladder. From which two branches arise. One of them situated on the dorsal side branches further into 2 tubes. Thus total three tubes are get arise in one side. Thus there are 3 pairs of Malpighian tubules in the silkworm body, which stick to the midgut and run towards the anterior side. One tube in one group runs along the dorsal wall of the midgut towards the anterior side and turns backwards at the 4th abdominal segment and 2nd tube runs along the midgut to laterally and turns backwards at the point of center of 4th and 3rd abdominal segments. And remaining one tube also pass along ventral wall of the midgut and turns backwards at the 3rd abdominal segments. Then all three tubes are ultimately open into the rectum. The tubes passing towards the anterior side from the urinary bladder are referred as ascending limbs and the same tubes turns back and passing towards rectum are called descending limbs.

In the larva waste products of metabolism are mainly excreted as urine together with faces. The excretion of urine takes place in both the mature larva and moth. The amount of excreted uric acid in adult urine is 5 to 15 mg per individual. The process of excretion is as follows: the winding tips of the Malpighian tubules which are bound to the rectum by a membrane have an active absorption function. Therefore water and some excreta diffused from the rectum are accumulated in the winding tips. Next, the winding long portion of the Malpighian tubules in the body cavity directly absorb uric acid, riboflavin, oxalic acid and other substances from the blood and then these substances are crystalized in the tubule. When the larval ecdysis occurs all the substances thus accumulated in the Malpighian tubules are discharged between the new and old cuticle through the urinary bladder of the tubule.