ANATOMY OF SILKWORM *BOMBYX MORI*

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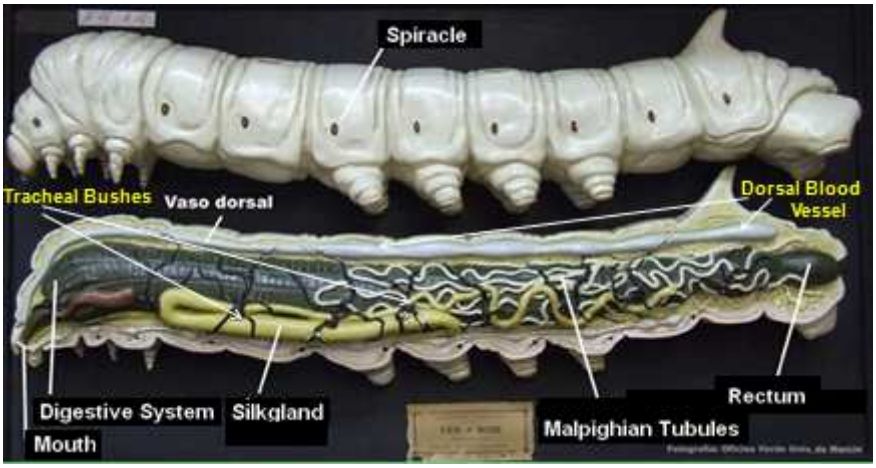
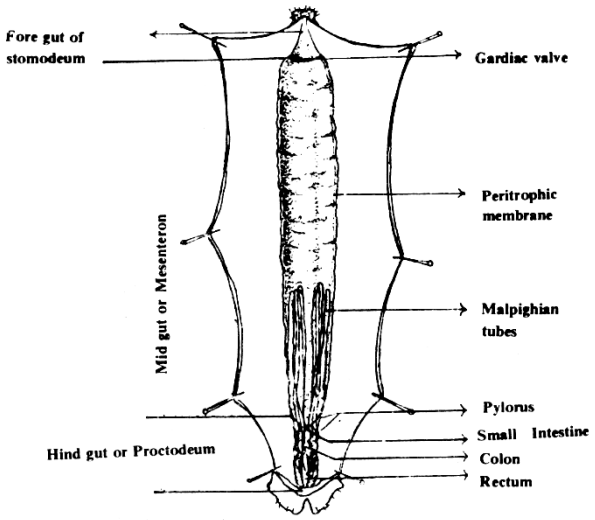
Anatomy is a branch of science concerned with the bodily structure as revealed by dissection. In case of silkworm larva, just under the skin at the median line of dorsal surface of the larva there is a dorsal vessel and around them many dorsal muscles and fat bodies are found. Inside the abdomen is occupied by the alimentary canal. On both the sides of the alimentary canal there are tracheae. On the ventral side of the alimentary canal there are silk glands around them many fat bodies are found. Under those organs there are ventral muscles. Along the median line of the ventral side of the body there is a nerve chord. The gonad lies on the dorsal side of the fifth abdominal segment, one by one on either side, right and left of the dorsal vessel. Malpighian vessels arise at the junction of the small intestine and colon in the hind gut of the digestive tract. Moreover, there are several endocrine glands are present. Main organs of the larval body are digestive organ, dorsal vessel, circulatory organ, malpighian tubules, respiratory organ, nervous system, sensory organs, reproductive organs, fat tissues and muscles.



DIGESTIVE SYSTEM OF SILKWORM LARVA:

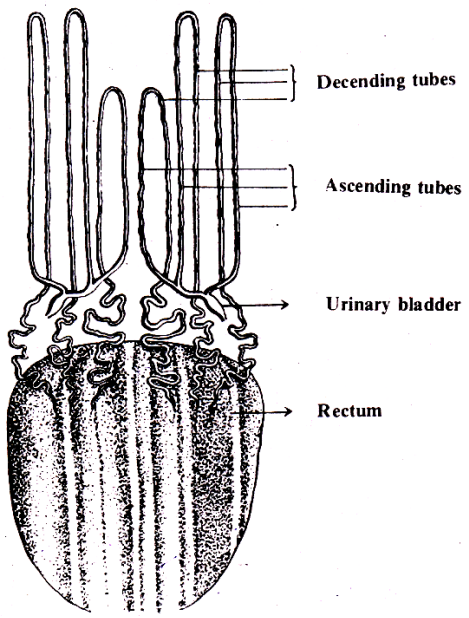
In the silkworm larva the digestive system is more or less a straight tube from the mouth to the anus divided into three main parts: the fore-gut or stomodeum, mid-gut or mesenteron, and hind-gut or proctodeum. The oral aperature opens into the mouth cavity which is followed by a narrow pharynx and oesophagus. The oesophagus is narrow at the anterior end and gradually widens towards the posterior end. 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. 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 fore and hind guts have a chitinous lining, but an inner layer of peritrophic membrane in the mid-gut generally protects the mid-gut epithelium from mechanical damage due to food particles. 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 hind gut is a passage for the absorption of a large portion of food moisture and elimination of digested food. In the anterio-posterior direction, the rectum has six muscles for pressing the excrements. The fecal matter is pressed in the rectum and expelled from the anus as faecal pellets bearing hexagonal marks.



Digestive system of silkworm larva

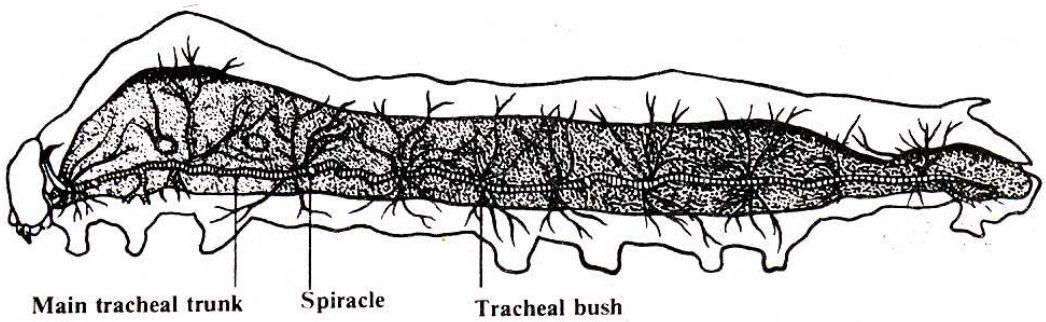
EXCRETORY SYSTEM OF SILKWORM LARVA:



Excretory system of silkworm larva

In silkworm special excretory organs called malpighian tubules are present. In the larva the Malpighian tubes arise at the junction of small intestine and colon in the hind-gut of the digestive tract. The tube arising on each side of the hind-gut is enlarged into an excretory chamber from which two branches arise. One of the tubes situated on the dorsal side branches further into three tubes. In all there are three pairs of malpighian tubes in the silkworm larva that 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 second tube runs along midgut to laterally and turns backwards at the point of center of 4th and 3rd abdominal segment. And the remaining one tube also passes along ventral wall of the midgut and turns backwards at the 3rd abdominal segment. Then all three tubes are ultimately open in to the rectum. The tubes passing towards the anterior side from the urinary bladder are referred as ascending limbs and the same tube turns back and passing towards rectum are called descending limbs (tubes). The nitrogenous compounds like protein are metabolized by these tubes and excreted principally as uric acid. They also excrete calcium oxalate. The malpighian tubes in the mature larvae are light yellow and their walls contain large quantities of yellow vitamin B_2.

RESPIRATORY SYSTEM OF SILKWORM LARVA:



Respiratory system of silkworm larva

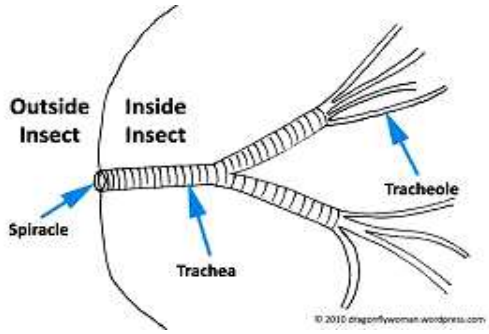
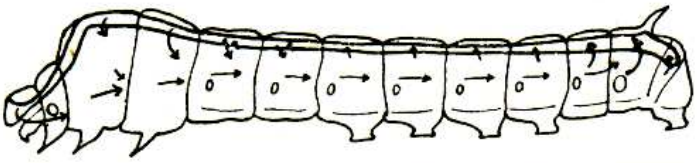


Diagram showing the trachea, tracheoles and movement of air

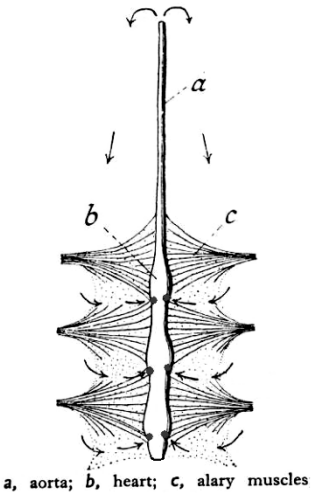
The respiratory function is carried out through the spiracles by the movements of the body wall. In the larva there are nine pairs of spiracles, one on each side of the pro-thorax from the first to the eighth

abdominal segments. Peritreme, sieve plate and atrium are the parts of the spiracles. The peritreme forms a ring round the spiracle. A slit can be seen along the median line of the sieve plate inside the ring. The external opening of the spiracle leads into a cavity, the atrium which contains the closing apparatus. There are two closing membranes and their movement can be observed if the sieve plate is taken off. The sieve plate prevents the entry of dust and air. A number of tracheal branches start radially from the spiracular cavity. There are also two large tracheas called main or lateral tracheal trunks connecting all the tracheal bushes. The ventral transverse tracheas connect the two tracheal bushes in each segment. The trachea ramifies repeatedly throughout the body and organs and ultimately form tracheoles. When the diameter of the tracheae is reduced to one micron, these finer tubules are called tracheoles and they carry oxygen directly to the cells and tissues. Through such a network of tracheae and tracheoles oxygen is carried to the various parts, tissues and cells of the body and carbon dioxide is removed, through the same channels. The terminus of each tracheole is a single cell and the oxygen supply is diffused from the tracheoles to the cells. Tracehae are similar in structure to the integument and also consist of a supporting thickened ring-like structure called the *taenidium* which keeps the tubes distended and prevents them from collapsing.

CIRCULATORY SYSTEM OF SILKWORM LARVA:



Course of blood circulation in the silkworm



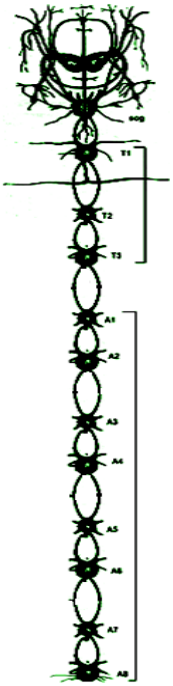
Circulatory System Enlarged

The circulatory system is an open one with a dorsal vessel, extending from the head to the last abdominal segment along the dorsal median line of the body. The dorsal vessel is associated with the circulation of the blood and is closed posteriorly while the front end opens in the head. The anterior portion of the dorsal vessel is a finely drawn-out tube and constitutes the aorta, while the posterior portion forms the heart. Each of the segments from the second thorax to the ninth abdominal segment

contains a pair of ostia. There are eight pairs of alary muscles which are attached to the body wall along the lateral parts of the dorsum. Systole (contraction) and diastole (expansion) of the heart are effected by the eight pairs of alary muscles and the musculature of the heart. The alary muscles function more or less like an elastic band and cause diastole and systole.

The blood enters the heart mainly through the ostia in the seventh and eighth abdominal segments and to a slight extent only through the ostia in the first six abdominal segments during diastole, and is forced forward during systole. As the heart is filled with blood, a steady wave of contraction progresses in a posterior - anterior direction. Hence normally the direction of flow of blood in the dorsal vessel is from behind forward and the blood is carried to the head and discharged. It leaves the dorsal vessel not only by the anterior end but also by the ostia in the meso and meta-thorax and sometimes by the ostia in the first and second abdominal segments. The blood flows backward through the body cavity. There is nothing to prevent the blood leaving the ostia, and the blood circulates throughout the body cavities and appendages transporting nutrients and removing waste products of the metabolism, and filling most of the space not occupied by the internal organs. In the silkworm, the blood cells or haemocytes do not enter the dorsal vessel through the ostia. Only cell-free plasma is circulated. The heart pulsates rhythmically and the frequency of pulsation varies with age, temperature, movements and the race of the larvae.

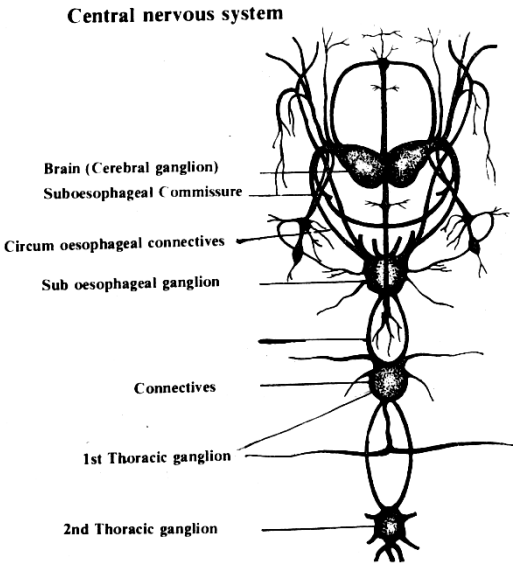
CENTRAL NERVOUS SYSTEM OF SILKWORM LARVA:



Ganglia of Thorax

Ganglia of Abdomen

CENTRAL NERVOUS SYSTEM



Anterior Portion – Enlarged

The central nervous system of the silkworm larva is divided into the brain or supra oesophageal (cerebral) ganglion, the sub oesophageal ganglion and the ventral nerve cord. The brain lies in the head, dorsal to the oesophagus and consists of two pear-shaped lobules. It is formed by the protocerebrum, deutocerebrum and tritocerebrum and is the dorsal ganglionic centre of the head. In the larval stages, the three regions of the brain are not marked externally. The brain innervates the ocelli of the larva, antennae and labrum. The ganglia of the mandibular, maxillary and labial segments have coalesced to form the sub esophageal ganglion which is the ventral ganglionic centre of the head and is connected with the brain by a pair of circum-oesophageal connectives that runs around either side of the oesophagus. The sub esophageal commissure arises from the circum-oesophageal connectives, very near to the origin of the latter from the brain. The sub esophageal ganglion of the larva innervates the mandibles, maxillae and labium with paired nerves.

Typically in insects the central nervous system consists of a double series of ganglia but the members of a pair are usually so closely fused that they appear to be a single ganglion.

In the silkworm larva the ventral nerve cord is formed by a series of ganglia on the floor of the thorax and abdomen below the alimentary canal. These are connected in a longitudinal chain by paired connectives arising from the posterior end of the sub esophageal ganglion. The thorax consists of three ganglia, one in each thoracic segments, and eight ganglia in the abdomen, one each in the first to the eighth abdominal segment. From each thoracic ganglion two pairs of principal nerves arise of which one pair innervates the general musculature and the other pair innervates the leg muscles. Each abdominal ganglion has a pair of principal nerves that innervate the muscles of the corresponding segment.

Visceral or sympathetic nervous system

The visceral or sympathetic nervous system is formed by an oesophageal sympathetic and a ventral sympathetic system. The oesophageal sympathetic system is directly connected with the brain innervating the fore and mid-gut, dorsal vessel and other parts. It consists of a median triangular frontal ganglion above the oesophagus in front of the brain and is connected to the brain by bilateral connectives. The frontal ganglion has anteriorly a frontal nerve which goes to the clypeus, and posteriorly a median recurrent nerve which travels along the mid-dorsal side of the oesophagus and ventrally to the brain for some distance, meets the hypocerebral ganglion, extends from there and ends in the ventricular or stomachic ganglion toward the rear end of the oesophagus. From here the adjacent regions of the fore and mid-gut are innervated.

The ventral sympathetic nervous system is formed by a pair of transverse nerves linked with the ventral nerve cord ganglia. A median longitudinal nerve connects each pair of transverse nerves with the

preceding ganglion. The transverse nerves innervate the spiracles of the corresponding segment.

The caudal sympathetic system innervates the reproductive system and the posterior portion of the gut and consists of nerves emerging from the composite (the last) ganglion of the abdomen.

Peripheral sensory nervous system

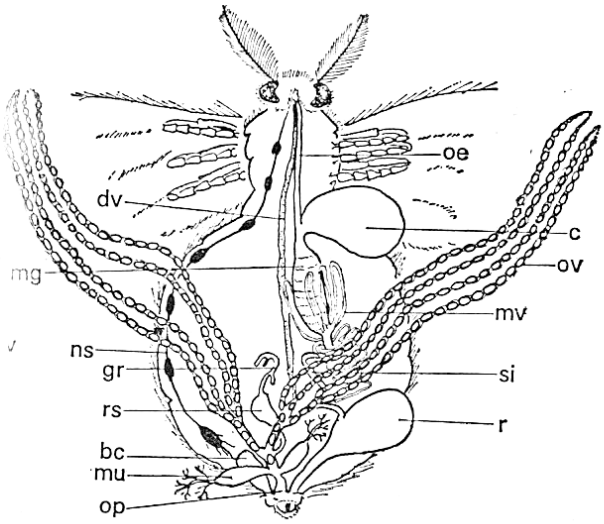
It is fine network of sensory bipolar neurons which have connections with the sensory hairs and the central nervous system, and multipolar neurons which make an elaborate plexus beneath the integument. The multipolar neurons have distal connections branching on the surface they supply and centripetal connection to the central nervous system ganglia.

REPRODUCTIVE SYSTEM

In the larva, the sexual phase develops in the late instars when it may be possible to note in the female, a pair of triangular ovaries (gonads) situated on the dorsal side of the sixth abdominal segment; from each of which a blind tube arises and terminates at the eighth abdominal segment. The pair of translucent spots seen ventrally on the eighth abdominal segment is the Ishiwata's foreglands and the pair on the ninth abdominal segment is the Ishiwata's hind-glands. These four ventral spots are prominent in the fifth instar and are used to identify the female larva.

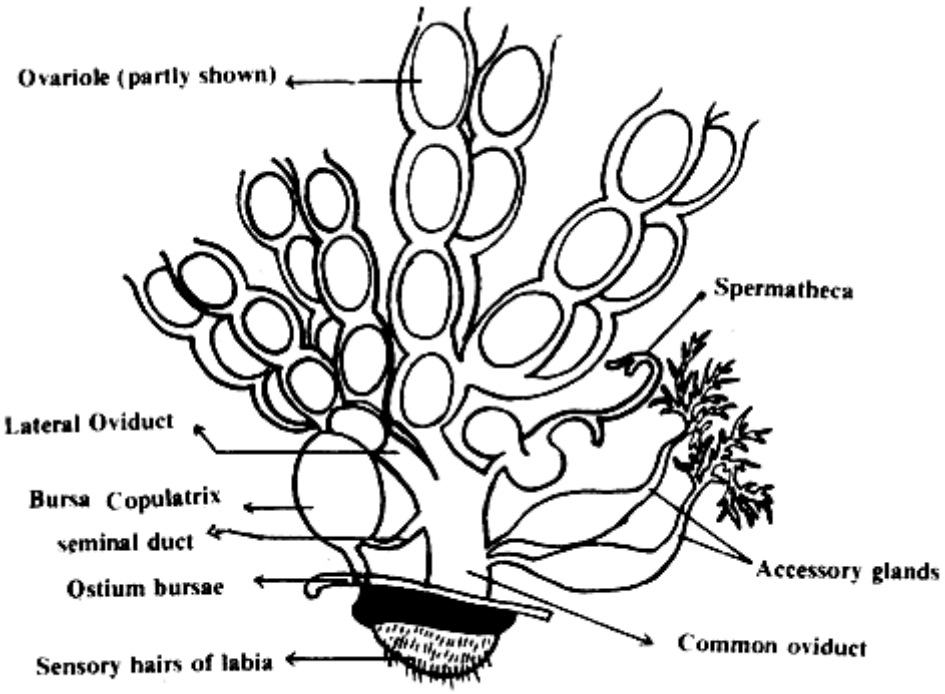
The male larva consists of a pair of kidney-shaped testes (gonads) on the dorsal side of the fifth abdominal segment and a blind tube which is connected with the Herold's gland - a milky white body-at the centre of the ventral side between the eighth and ninth abdominal segments.

In the female moth, paired ovaries occupy most of the abdominal space.



bc, bursa copulatrix; c, crop; dv, dorsal vessel; ag, Accessory gland; gr, glandula receptaculi; mg, mid-gut; mu, mucous gland; mv, Malpighian vessel; ns, nervous system; oe, esophagus; op, ovipositor; ov, ovarioles; r, rectum; rs, receptaculum seminis; si, small intestine; t, testes. Note: the relative length of the ovarioles is in fact greater (about 4 to 5 times) than shown.

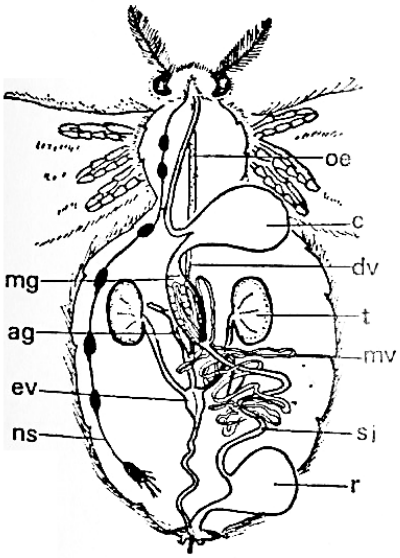
Overall Female Reproductive System



Female Reproductive System (Enlarged)

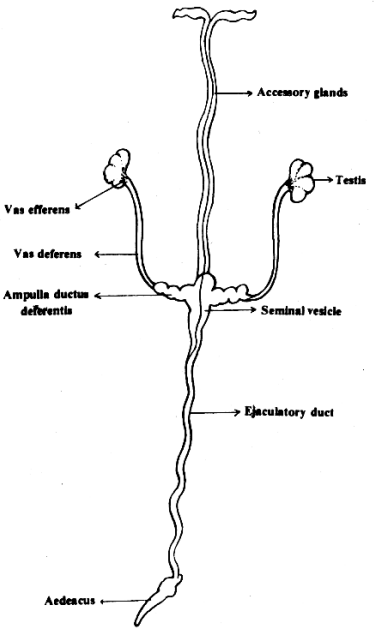
A pair of lateral oviducts arises from the ovaries and unites to form a single, wide common oviduct that ends in the ovipositor at the posterior end of the body. Each of the ovaries carries four egg tubes or ovarioles where the eggs are formed. The ovarioles are polytrophic and an alternating succession of nurse cells and oocytes (developing eggs) are found in the egg chambers particularly in the pupal stage. In the adult stage, the four pairs of ovarioles look like coiled strings of beads containing eggs. The *bursa copulatrix* is a sac-like structure situated ventrally to the common oviduct and continues as a tube to the outside posteriorly on the eighth abdominal segment. At the time of mating, the *aedeagus* is received by the opening, *ostium bursae,* of this tube. The *bursa copulatrix* also opens into the common oviduct by a narrow tube known as the seminal duct. Paired accessory glands occur dorsally to the common oviduct. The accessory glands produce an adhesive material which coats the eggs when they pass down the common oviduct and glues them to the substratum when they are laid. The spermatheca is a sac-like structure for the reception and storage of spermatozoa and opens into the common oviduct anterior to the accessory glands opening.

In male moth a testis is present in the fifth abdominal segment dorso-laterally on each side of the ventral nerve cord. The *vas efferens* of each testis leads into a *vas deferens* which opens into the seminal vescicle from where an ejaculatory duct arises and ends in the *aedeagus.* A pair of accessory glands open into the seminal vesicle by a common duct located between the two *vasa deferentia.* The membranous sac or the spermatophore is formed by the secretion of male accessory glands.



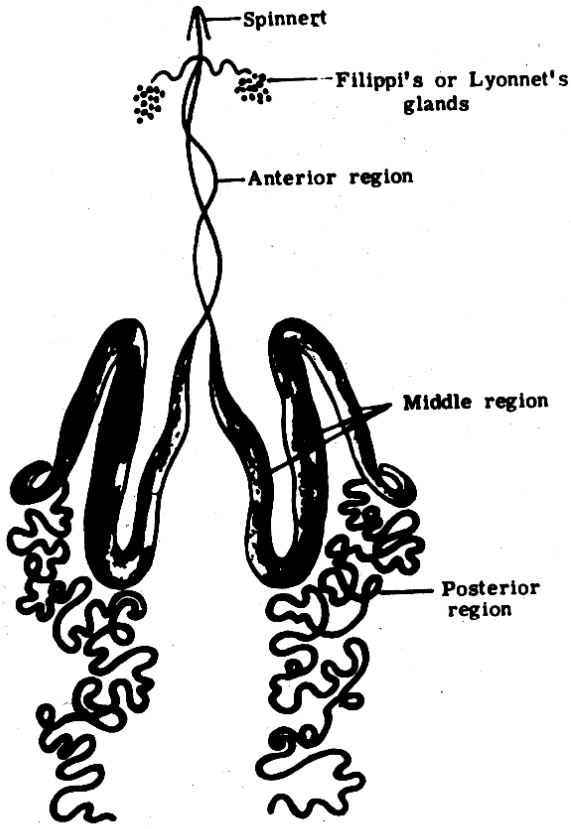
Internal organs of adult male

ag, Accessory gland; c, crop; dv, dorsal vessel; ev, ejaculatory vesicle; gr, glandula receptaculi; mg, mid-gut; mu, mucous gland; mv, Malpighian vessel; ns, nervous system; oe, esophagus; r, rectum; si, small intestine; t, testes.



Reproductive system of male moth

SILKGLANDS:



Silk glands of silkworm larva

These are transformed labial glands, ectodermal origin, cylindrical and tubular with characteristically branched nuclei. They are situated on the ventrolateral sides of the mid intestine and

the posterior ends are blind. Anteriorly the paired ducts unite and open in to the spinneret. Silk glands may be divided in to three distinct regions; anterior, middle and posterior. The anterior region is a straight tube opening at the fore end into the duct and posteriorly in to the middle region.

The middle region is the largest of the three regions and has three definite flexions. The middle region is again divided into three functionally different sections: anterior, middle and posterior. The beginning of the middle region is narrow but widens suddenly - the middle part is the widest and the end of the rear part is narrow. The posterior region is crooked and curved between the dermo-viseral muscles and the tracheae.

A pair of glands known as Filippi's or Lyonnet's glands is situated at the junction of the two anterior regions. A viscous fluid is secreted by these glands and their exact function is not clear.

The wall of the silk gland is composed of three layers, the *tunica propria,* the gland cells, and the *tunica intima* enclosing the lumen of the gland. The *tunica intima* is made up of thickly laid chitin throughout but the anterior portions are renewed at each ecdysis or moult.

Fibrion and sericin are secreted in the fourth and fifth ages. Fibrion, the silk protein, is secreted from the posterior region. The middle region acts as a reservoir for the maturation of fibroin and also secretes sericin around the fibroin as below. Sericin I, the innermost sericin, is secreted from the posterior section of the middle region; sericin II, the middle-layered sericin, from the middle section of the middle region; sericin III, the outermost sericin from the anterior section of the middle region. The anterior region of the silk gland does not secrete any particular substance; it is simply a passage and carries the silk substance from the reservoir (middle region) for freezing.

Acknowledgements

1. Sericulture Manual II, FAO, Rome, 1987.
2. The Principles of Insect Physiology by V B Wiggelesworth, 1972.
3. The silkworm – A Laboratory Tool by Y Tazima, 1979.
4. Internet.
