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Nervous system—In front of the oesophagus and above the tentorium is a bilobed **supra-oesophageal ganglion** or **brain** formed by complete fusion of three pairs of ganglia. From the brain arise two **circum-oesophageal connectives** which pass around the oesophagus and below it they join a **sub-oesophageal ganglion** which is formed by the fusion of three pairs of ganglia. This much of the nervous system lies within the head capsule. From the sub-oesophageal ganglion arises a double **ventral nerve cord,** the two cords are not fused to each other. The nerve cord has three large ganglia in the three thoracic segments, five small ganglia in the first five abdominal segments, and a larger sixth ganglion lying some distance behind in the seventh segment. Each ganglion of the nerve cord is formed by fusion of two ganglia, except the 6th. abdominal ganglion which is formed by the fusion of several ganglia (probably 3 pairs).

From the central nervous system arise nerves which constitute the **peripheral nervous system.** Three pairs of nerves arise from the brain and go to the eyes, antennae, and labrum; from the sub-oesophageal ganglion also three pairs of nerves arise and go to the mandibles, maxillae and labium. Several pairs of nerves arise from each ganglion of the nerve cord; they innervate the various parts of their own segment; but from the last abdominal ganglion five pairs of nerves arise and go to the last five segments of the abdomen, one pair to each segment.

There is a **sympathetic nervous system** consisting of a small **frontal ganglion** in front of the brain, a pair of small **oesophageal ganglia** just behind the brain, and a large **visceral ganglion** which lies on the dorsal side of the crop, it is the principal ganglion (Fig. 346). All the ganglia are joined by connectives to the brain. From the sympathetic nervous system arise nerves which go to muscles, alimentary canal, and spiracles and control their activities.

Receptors—Insects perceive many stimuli and are sensitive to light, sound, changes of temperature and touch; they also possess senses of taste and smell. The receptors are modified epidermal cells which form **sensillae.** A sensilla has a modified bristle and two modified cells of the hypodermis called **trichogen cells,** it is provided with a nerve cell having a nerve fibre. The receptors of touch, taste, and smell have such isolated and simple sensillae, but those of hearing and sight have aggregations of sensillae which form elaborate organs. **Tactile sensillae** are found on antennae, palpi, legs, body and cerci. **Olfactory sensillae** are found chiefly

the rectum is raised into 6 long **rectal folds** or **papillae** for the absorption of water from the faeces. At the junction of the mesenteron and hind gut is a large number of very fine, yellow **Malpighian tubules,** they are the kidneys of cockroach and put out excretions into the hind gut.

In connection with the alimentary canal is a pair of **salivary glands** which lie one on each side of the crop. Each gland has two glandular portions and a bag-like **reservoir** or **receptacle.** From the glandular portions of the two sides arise ducts which unite to form a common duct. Similarly two ducts from the reservoirs also join to form another common duct. The two common ducts join to form an **efferent salivary duct** which opens in the pre-oral cavity at the base of the hypopharynx. The ducts of glands and reservoir are peculiar in having a spirally-thickened cuticular lining as in tracheae.

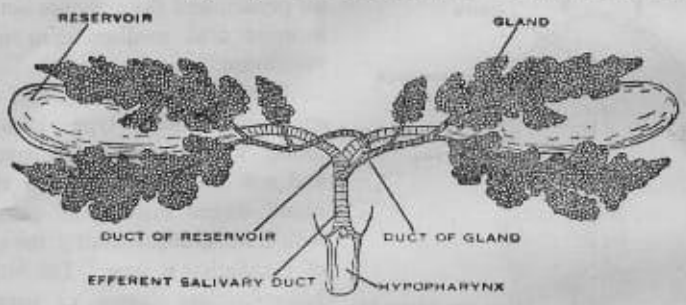

Fig. 349 Salivary apparatus.

Food and digestion—The food of cockroach consists of any kind of animal or plant matter; it eats dead insects and even its own cast-off cuticle, thus it is *omnivorous*; but it tastes almost anything it comes across. The maxillae pick up and bring food to the mandibles, the teeth of the mandibles bite and chew the food. The maxillae, prostheca of the mandibles, and the labium help to push the food into the pre-oral cavity from where it goes to the mouth, the function of the hypopharynx in this connection is not clear. In the pre-oral cavity, the food is mixed with saliva. The saliva contains an enzyme **amylase,** which acts upon carbohydrates changing them into glucose which is absorbed by the crop. The food then comes to the crop, where digestion occurs, because enzymes enter it from the mid gut through the grooves of gizzard. The teeth of the gizzard crush the food and the gizzard also acts as a filter,

between the mesothorax and metathorax. The abdominal spiracles are smaller than the thoracic ones, the first pair lies dorsally in the first abdominal tergum, the remaining seven pairs lie on the pleuron of segments 2 to 8 (Fig. 343 & 355).

Integument of cockroach and insects in general : There are two main layers in the skin, epidermis below and cuticle above. Epidermis or hypodermis is composed of a single layer of columnar epithelial cells supported over a **basement membrane.** Cuticle layer is thick and constitutes the exoskeleton of the insect. Chemically, cuticle is a mixture of polysaccharides and amino-acids called polyglucosamine or **chitin.** Chitin combines the strength and elasticity. It not only covers the whole of the insect body, but also lines parts of alimentary canal and respiratory system. At places chitin is hardened into plates called **sclerites.** Terga and sterna are such plates. Hardening is not due to calcification; instead, it is due to the impregnation of certain

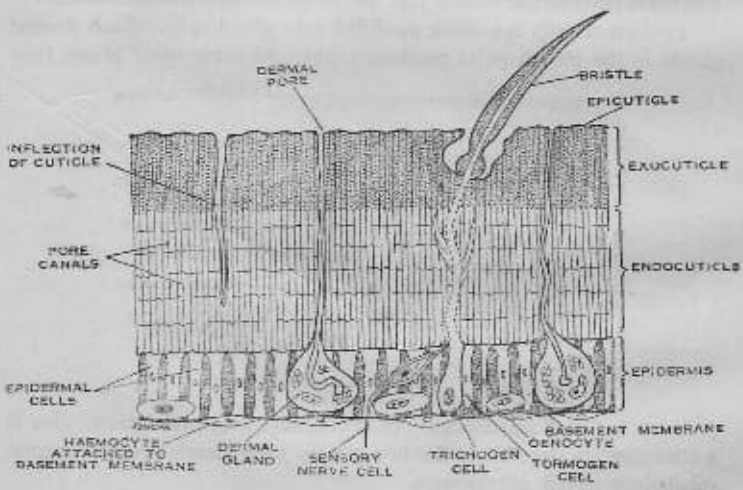

Fig. 344 Section of typical insect integument.

proteins (scleroproteins). Often certain phenolic oxidizing substances cause tanning of the chitin. At the junctions of sclerites, the chitinous cuticle becomes inflected to provide movement and flexibility at the joint. Cuticle is secreted in the cells of the epidermis, which keep on pouring the secretions into numerous **vertical pore canals.** Pore

The ducts of the two colleterial glands unite to form a common duct which opens into the dorsal side of the genital chamber. There is a

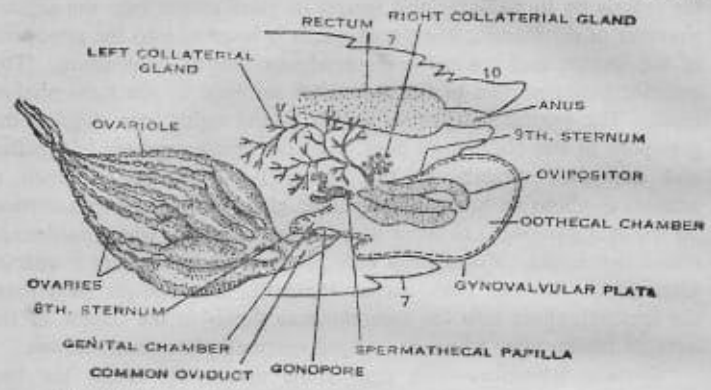

Fig. 368 Reproductive organs of female *Periplaneta* (lateral view).

pair of club-shaped **spermathecae** of unequal size, one spermatheca being larger than the other, the two spermathecae unite to form a short common duct which opens into the genital chamber on a small **spermathecal papilla.**

In the female, the seventh sternum is produced backwards into two large oval **gynovalvular plates** or **apical lobes,** they enclose a large cavity having an inner **gynatrium** or **genital chamber** and a posterior **oothecal chamber.** The dorsal and posterior walls of gynatrium and oothecal chamber are formed by the invagination of 8th and 9th abdominal sterna. The external genital organs lie concealed inside the gynatrium, they consist of an **ovipositor** formed by the gonapophyses. The ovipositor lies above and behind the gonopore. It has three pairs of elongate processes, a pair of long thick arms lying dorsally and enclosing two slender tapering arms, these two pairs of arms arise from a common base and they constitute the **posterior gonapophyses;** they belong to the 9th abdominal segment and are joined to the 9th tergum. The third pair of arms of the ovipositor are large, they converge and meet posteriorly lying below the posterior gonapophyses, they constitute the **anterior gonapophyses.** The anterior gonapophyses belong to the 8th abdominal segment and are attached to the outer margins of the 8th tergum. The ovipositor is used only to conduct fertilized eggs to the oothecal chamber.

which have a world-wide distribution, they are medium-sized and of a grey colour. *Culex pipiens* is found in temperate regions all over the world, and *Culex fatigans* throughout the tropics and sub-tropics. They live in houses, in cities and farms, and are abundant also in rural areas. They are most abundant from March to May and again from July to October; at other times they hibernate. The adults hide in hollows of trees, caves, crevices, barns, etc. The life span of male mosquitoes is seldom more than three weeks, they die after impregnating the females. The females live from four weeks to several months, but they die after laying their full quota of eggs. *Culex* has several generations in a year.

Externals—The body of a mosquito is divided into head, thorax and abdomen, it is covered with small scales. Head is globular and highly mobile on a slender neck. There are two very large black compound eyes, there are no ocelli, the top of the head has an **epicranium** below which is a **clypeus,** the clypeus is thick and projects in front. There are two filiform antennae, each with 15 joints bearing bristles. The bristles are longer and much more numerous on the antennae of *males* giving them a bushy appearance. In the *female* the antennae have whorls of a few short bristles; thus the sexes can be distinguished readily by the antennae and even with unaided eyes.

Besides the antennae, the head bears two maxillary palps and a **proboscis.** The maxillary palps in the *female* are short and three-jointed, but in the *male* they are as long or even longer than the proboscis, and are five jointed (Fig. 379).

Mouth parts—The proboscis is a straight long tube formed by a fleshy ventral **labium** which has a deep groove on its upper side, in this groove is a long, pointed and ventrally grooved **labrum-epipharynx.** At the distal end of the labium is a pair of small tactile **labella** which are reduced labial palps. The groove of the labium contains five needle-like stylets in the female *Culex*, they are two mandibles, two maxillae, and a hypopharynx. The mandibles are finer than the maxillae, but both have saw-like edges on their tips. The hypopharynx is also needle-like and has a fine salivary duct running through it and opening at the tip; through this duct saliva is poured to prevent coagulation of the blood of the victim. In the *male*, the labrum-epipharynx and the labium are similar to those of the female, but the mandibles and maxillae are very short and functionless, and the hypopharynx is fused to the labium.