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

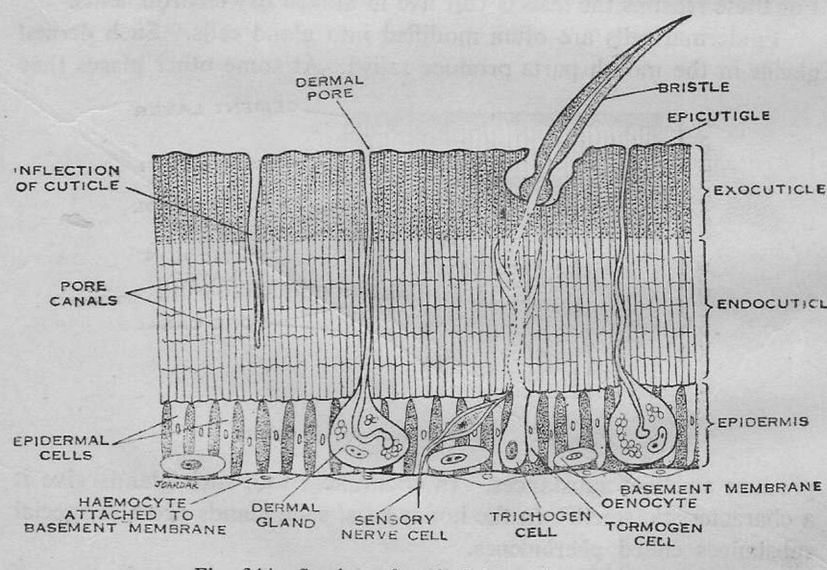

Fig. 344 Section of typical insect integument.

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 canals transport the newly produced cuticle to the surface where it keeps on replacing the old cuticle.

Cuticle layer itself is composed of three coats :

(i) **Endocuticle** which lies immediately over the epidermis, (ii) **exocuticle** in the middle, and (iii) **epicuticle** on top. Newly secreted cuticle first collects as a layer or lamina and becomes a part of the endocuticle. It is for this reason that the endocuticle appears to be laminated. As new layers are added from below, the older layers move up and by the time they reach the exocuticle, the cuticle becomes sclerotized and tanned. Thus, exocuticle is composed of sclerotized and tanned layers of cuticle.

Epicuticle, though a thin layer, is composed of four ultralayers: **cuticulin layer** below, next a **polyphenol layer,** then a **wax layer** and finally a **cement layer** on the top. The wax layer makes the cuticle smooth, water-proof and prevents loss of water in the form of vapour. For these reasons the insects can live in almost dry environments.

Epidermal cells are often modified into gland cells. Such **dermal glands** in the mouth parts produce saliva. At some other places they

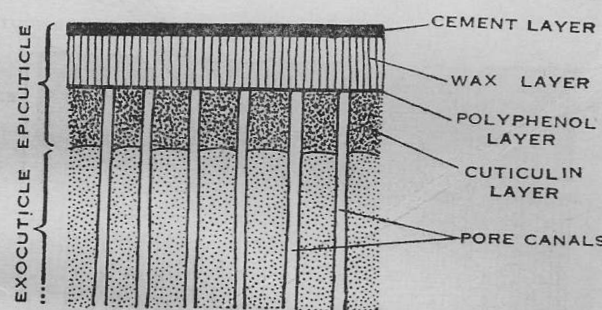

Fig. 345 Ultrastructure of epicuticle.

produce smelling substances. In cockroach, too, such glands give it a characteristic smell. In the honey bees, such glands produce special substances called **pheromones.**

Hairs or bristles over the skin of insects are also derivatives of epidermal cells called **trichogen cells.** Such cells are drawn out far into the cuticular bristles and are covered with layers of endo- and exo-cuticle. Basal part of a trichogen cell is protected within a membrane secreted by a modified epidermal cell called **tormogen cell.** Neurosensory cells are also scattered in the epidermis. Specialized epidermal cells known as **oenocytes** are probably endocrine in nature and produce hormones. **Haemocytes,** a variety of blood cells, are commonly adhering to the basement membrane.

Alimentary canal—The functional mouth cavity is a space in front of the mouth into which the food is received; it may be called a **pre-oral cavity.** This cavity is bounded in front by the labrum and an **epipharynx** which is a chitinous lining of the labrum, posteriorly is the labium, and on each side is a mandible and a

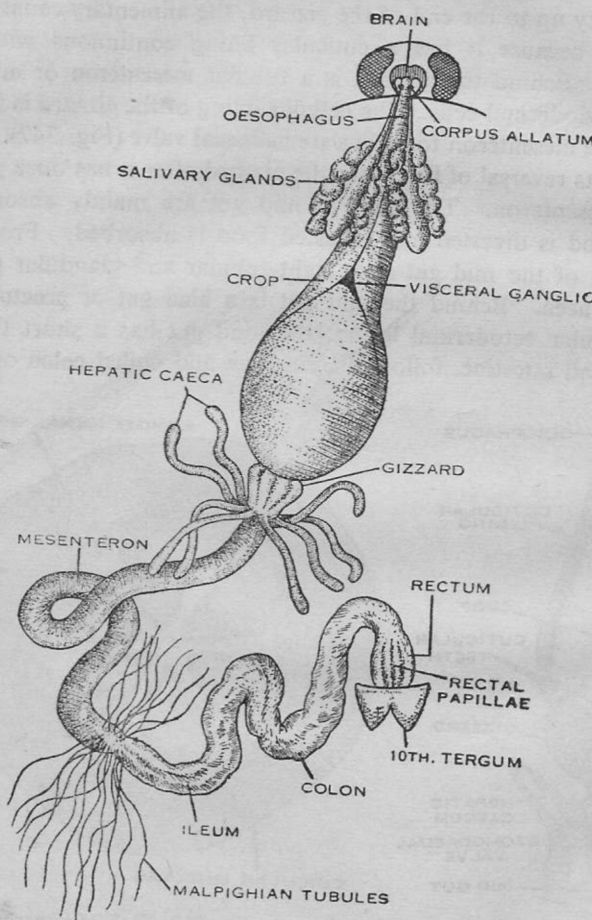

Fig. 346 Alimentary canal of *Periplaneta.*

maxilla; inside the pre-oral cavity projects a large tongue-like hypo-pharynx. At the base of the pre-oral cavity is the mouth leading into a tubular **pharynx** which passes vertically upwards, then it bends backwards into an **oesophagus** which passes through the neck into the thorax. The oesophagus dilates into a large thin-walled **pear-shaped** bag, the **crop,** which extends well into the abdomen; the crop opens into a **gizzard** or **proventriculus.** The gizzard is a round, thick-walled knot, its lining has six large cuticular thickenings or teeth with deep grooves between them having fine bristles. Food is crushed in the gizzard and strained through bristles. From the pre-oral cavity up to the end of the gizzard, the alimentary canal is the **stomodaeum** because it has a cuticular lining continuous with the exoskeleton. Behind the gizzard is a tubular **mesenteron** or **mid gut** lined with endodermal cells. The cellular lining of the gizzard is folded back into the mesenteron to form a **stomodaeual valve** (Fig. 347). The valve prevents reversal of food into the gizzard after it has once passed into the mesenteron. The cells of mid gut are mainly absorptive. Here the food is digested and digested food is absorbed. From the anterior end of the mid gut arise eight tubular and glandular **gastric** or **hepatic caeca.** Behind the mid gut is a **hind gut** or **proctodaeum** with a cuticular ectodermal lining; the hind gut has a short tubular **ileum** or small intestine, followed by a long and coiled **colon** or large

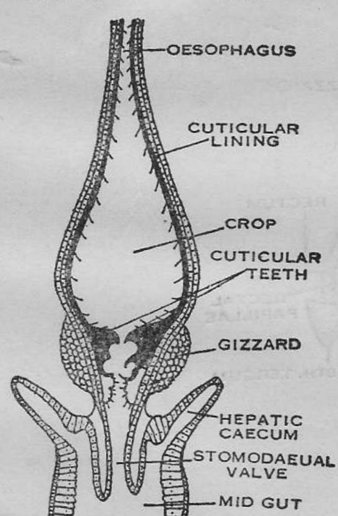

Fig. 347 L.S. of foregut and anterior part of midgut of cockroach.

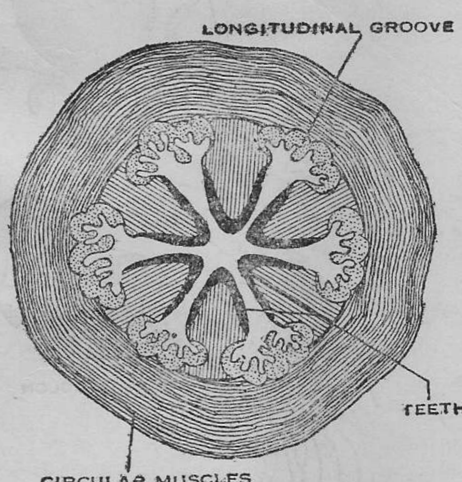

Fig. 348 T. S. of gizzard.

intestine, finally it terminates in a broad **rectum** which opens by an **anus** lying posteriorly below the 10th tergum. The cuticular lining of 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.

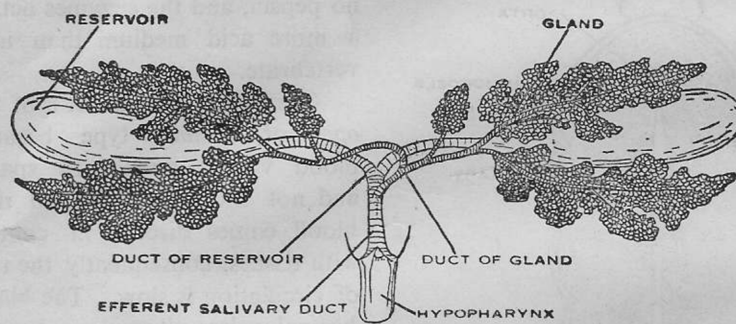

Fig. 349 Salivary apparatus.

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, allowing only small food particles to pass into the mid gut. Enzymes are produced by the mid gut and hepatic caeca; they digest proteins and fats changing them into peptones and an emulsion respectively. The food forms a bolus which gets enclosed in a thin chitinous tube called a **peritrophic membrane,** which is secreted by the gizzard. Peritrophic membrane is permeable to both enzymes and digested food, and the process of digestion is completed in it. It also protects the lining of mid gut from hard food particles. Digested food is absorbed in the mesenteron and hepatic caeca. The rectum takes out water from undigested parts and thus conserves the much-needed water. Some of the absorbed food is stored as reserve in the form of fat, glycogen, and albuminous substances in the **fat body** lying in the haemocoel. Digestive enzymes of cockroach are the same as in a vertebrate, except that there is no pepsin, and the enzymes act in a more acid medium than in a vertebrate.

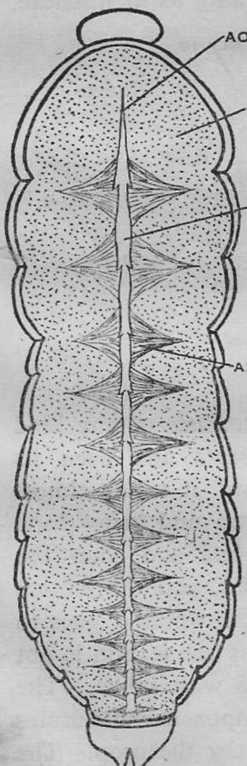

Fig. 350 *Periplaneta* heart (dorsal view).

Circulatory system—It is of the *open* or *lacunar* type because blood vessels open into spaces and not into capillaries, so that blood comes directly in contact with tissues, consequently the rate of circulation is slow. The blood has colourless plasma or **haemolymph,** containing numerous white corpuscles, but has no respiratory pigment, hence colourless and does not take part in respiration. Blood of cockroach and other insects differs from the vertebrate blood in several other ways also. Vertebrates rely on inorganic ions, such as Na^+ and Cl^-, as osmotic regulators of the body fluid. In insects, the inorganic ions have been replaced by organic molecules, especially free amino-acids. Haemolymph also contains high concentrations of dissolved uric acid, organic phos-

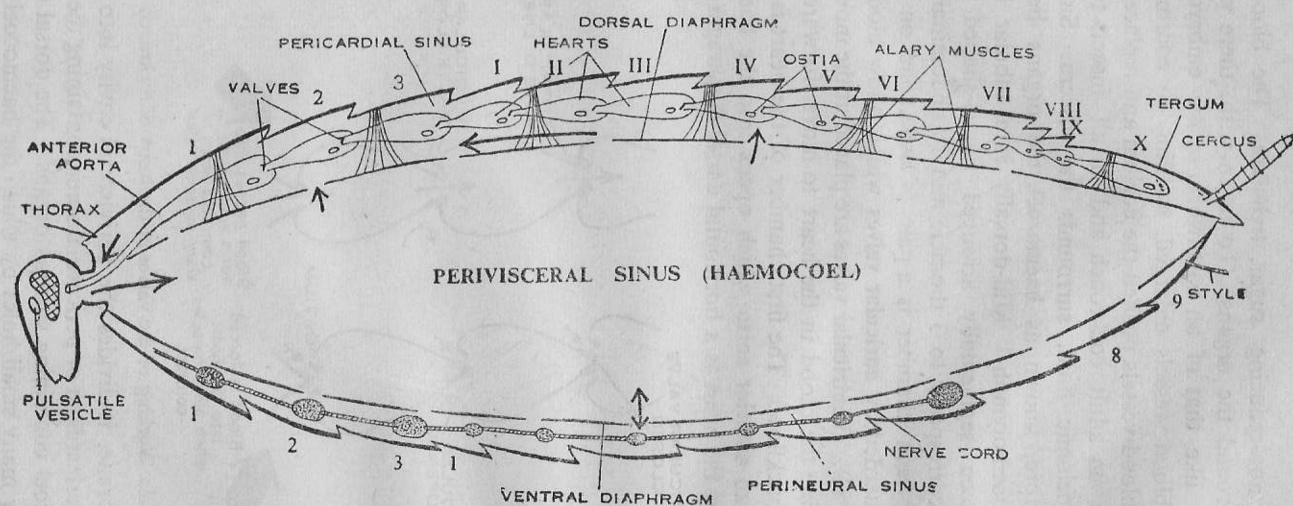

Fig. 351 Circulatory system of cockroach.

phates and a non-reducing sugar, **trehalose.** The blood fills all spaces in and around the organs. To begin with, there was a perivisceral coelom like that of an earthworm in the embryonic stage. Later on, the blood vessels enlarged, swelling to enormous sizes. These swelling blood vessels pushed the coelom and replaced it completely. Thus in an adult cockroach and in all insects too, blood, and not the coelomic fluid, surrounds the viscera. Such a body cavity is, therefore, known as **haemocoel,** the organs lie freely in the blood or haemolymph. Mid-dorsally is a tubular **heart** consisting of thirteen segmentally arranged funnel-shaped chambers. The chambers correspond to 3 thoracic and 10 abdominal segments. At the sides of each chamber is a pair of **ostia,** one on each side, the ostia are guarded by **auricular valves** which allow blood to enter the heart (Fig. 352). **Ventricular valves** are placed at the mouth of each chamber, allowing the blood in the heart to move forward only and closing for the backflow. The first chamber of the heart is continued anteriorly into an **anterior aorta** which opens into the haemocoel in the head. Below the heart is a horizontal **dorsal diaphragm** which is a

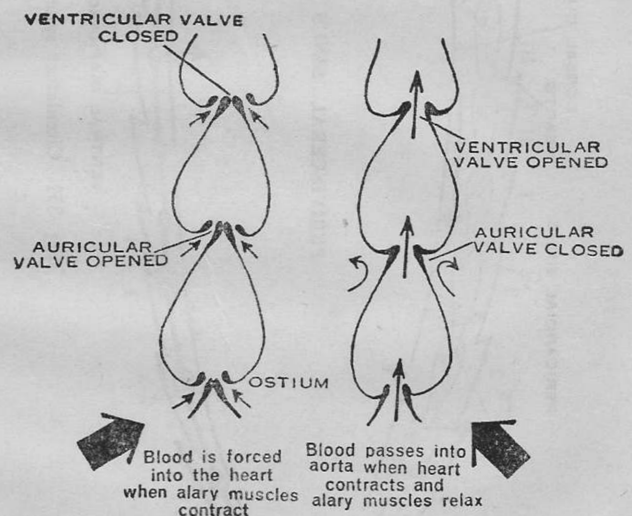

Fig. 352 Working of the valves in the heart of cockroach.

muscular membrane, it divides the perivisceral cavity into two parts, a small dorsal **pericardium** or pericardial sinus containing the heart, and a large haemocoel containing various organs. The dorsal diaphragm is perforated by many small holes by which the haemocoel communicates with the pericardium. Attached to the dorsal diaphragm are a series of paired **alary muscles**; they are triangular in shape and their pointed outer ends are inserted into terga. By contractions of alary

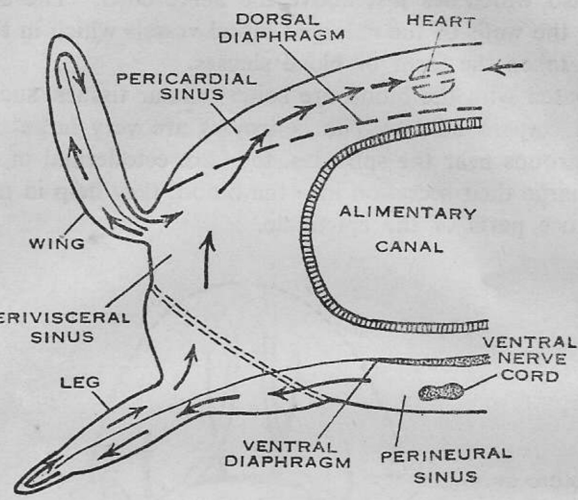

Fig. 353 Diagram showing the body cavities and course of blood in cockroach.

muscles the blood passes from the haemocoel into the pericardium and then into the heart through the ostia. The muscular wall of the heart contracts in a wave which starts from behind and moves forward, as such the blood is forced into the anterior aorta from where it re-enters

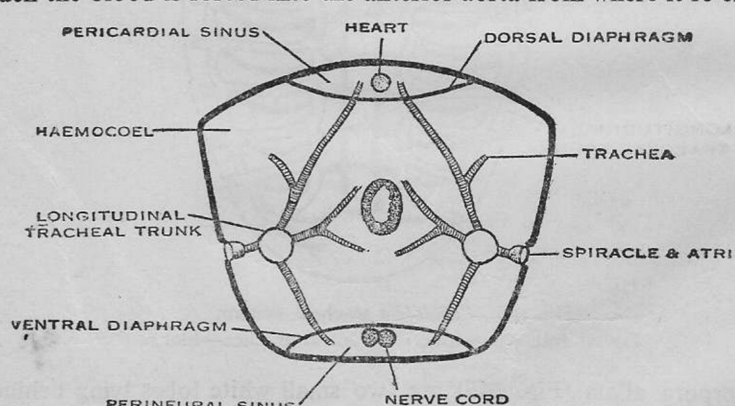

Fig. 354 T. S. of abdomen showing sinuses and tracheae.

the haemocoel and goes slowly to the organs and appendages. In cockroach there is an **accessory pulsatile vesicle** at the base of each antenna which also pumps blood. The haemocoel has a **ventral diaphragm** also which lies just above the nerve cord. The diaphragms are really the walls of the enlarged blood vessels which in the haemocoel have taken the form of **blood sinuses.**

Associated with the blood are some cellular tissues, such as **oenocytes** and **corpora allata.** The oenocytes are very large cells which occur in groups near the spiracles, they are ectodermal in origin and they discharge their secretion into the blood, they help in metabolism and produce parts of the epicuticle.

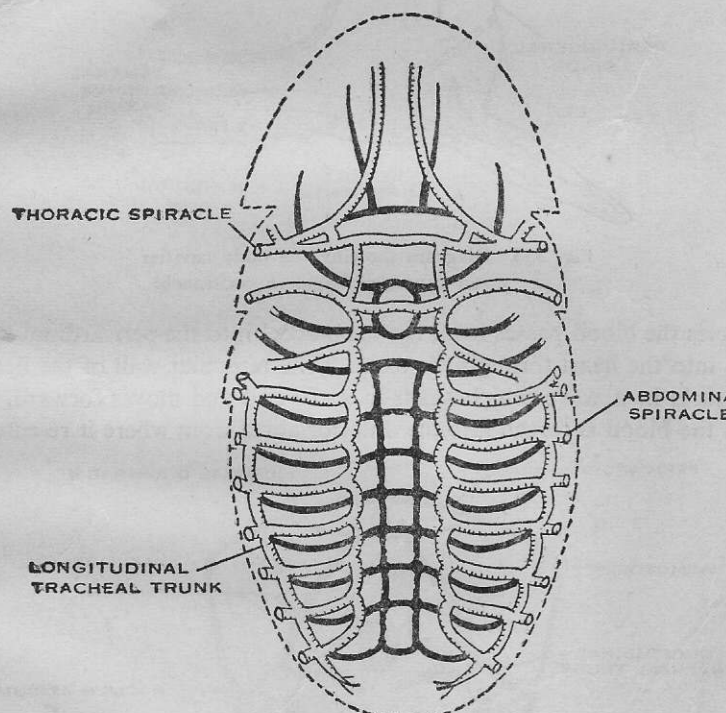

Fig. 355 *Periplaneta* tracheal system.
Dorsal trachea—white, Ventral trachea—black.

Corpora allata (Fig. 346) are two small white lobes lying behind the brain and above the oesophagus. They are ectodermal in origin and are ductless glands; they secrete a hormone into the blood which controls growth, metamorphosis and moulting in the young, and controls egg production in the adult.

Respiratory system—There are ten pairs of spiracles arranged segmentally, two pairs are on the thorax and eight pairs in the first eight abdominal segments. The first pair lies on the pleuron between the prothorax and mesothorax, the second between the mesothorax and metathorax. The first abdominal spiracles lie dorsally on the tergum, but the remaining seven pairs lie on the pleura of segments two to eight. The spiracles are closed or opened by valves operated by special muscles. Each spiracle is a slit in an oval chitinized area, the slit leads into a cavity, the **atrium,** from which arises a tube or **trachea.** The tracheae are silvery, ectodermal tubes with a delicate single-layered epithelium, having a cuticular lining called **intima,** which forms spiral or ring-like thickenings and prevents the tracheae from collapsing. The thoracic spiracles lead into several **tracheal trunks,**

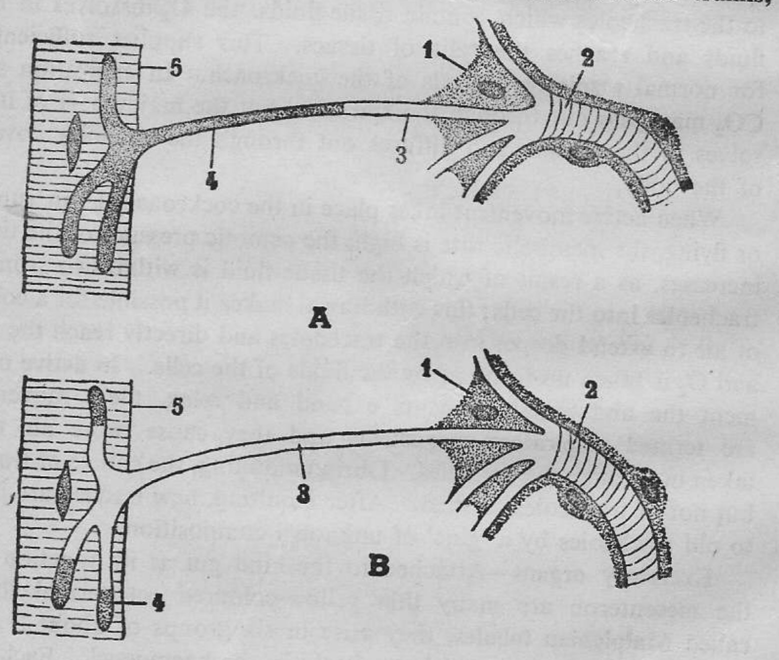

Fig. 356 Tracheal respiration.

A—Resting state.
B—During activity.

1. Tracheal end cell.
2. Trachea.
3. Tracheole containing air.
4. Tracheole containing liquid.
5. Muscle.

but each abdominal spiracle leads into a single tracheal trunk. The main tracheal trunks join two longitudinal trunks, one on each side of the body, and then divide into dorsal and ventral trunks, which further divide and sub-divide, and then anastomose to form a network lying in every part of the body. The ultimate branches of tracheae end in **tracheole cells** or **tracheoblasts** from which arise very fine tubes called **tracheoles.** The tracheoles have thinned cuticular lining and they end blindly in the cells of tissues. In a resting insect when the respiratory activity is not high, the tracheoles are filled not with air, but with a fluid from the cells of tissues, in which the oxygen dissolves. By means of this system of tracheae the cells of the body and their fluids are in direct communication with the outside air.

Inspiration and expiration take place through the spiracles; expiration is an active process, but inspiration is passive. Air enters the spiracles during inspiration and comes to the tracheae, then it comes to the tracheoles which contain tissue fluids, the O_2 dissolves in these fluids and reaches the cells of tissues. This supplies sufficient O_2 for normal respiratory needs of the cockroach. In expiration some CO_2 may pass out through the spiracles, but the major part of it dissolves in the plasma and diffuses out through the cuticular covering of the body.

When active movement takes place in the cockroach, as in running or flying, the metabolic rate is high, the osmotic pressure of the tissues increases, as a result of which the tissue fluid is withdrawn from the tracheoles into the cells; this withdrawal makes it possible for a column of air to extend deeper into the tracheoles and directly reach the cells, and O_2 is taken up from air by the fluids of the cells. In active movement the abdominal segments expand and relax, these movements are termed **respiratory movements** and they cause more air to be taken in through the spiracles. During moulting, the cuticle of trachea, but not of tracheoles, is shed. After moulting, new trachea are joined to old tracheoles by a 'glue' of unknown composition.

Excretory organs—Attached to the hind gut at its junction with the mesenteron are many thin yellow-coloured ectodermal threads called **Malpighian tubules,** they arise in six groups of about a dozen tubules in each group and hang freely in the haemocoel. Each Malpighian tubule is formed of a single layer of glandular epithelial cells having microvilli (not cilia). *They are not the organs of excretion in cockroach but are osmoregulatory* (Srivastava & Gupta 1961). A major part of excretion are the end-products of protein-metabolism, hence nitrogenous wastes are very important. The Malpighian tubules extract nitrogenous wastes and water from the haemolymph and

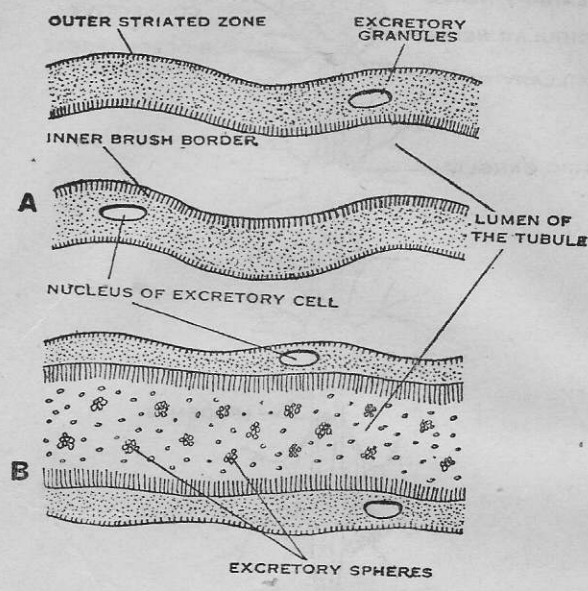

Fig. 357 Malpighian tubules—distal part above, and proximal part below.

secrete them as urates of potassium that pass into the ileum. In most insects, the distal parts of the tubules allow the entry of substances from the blood, while the proximal end selectively reabsorbs water and nutrients, excretory matter passes into the lumen of the tubule as excretory granules or excretory spheres. No uric acid has been found in the Malpighian tubules of cockroach. Some of the salts and water are reabsorbed in the ileum to maintain the osmotic balance of the body fluids. Uric acid is mainly put out by the rectum and is eliminated with the faeces. Hence, in cockroach the rectum is the excretory organ. The fact that the tubules empty their excretions into the hind gut is an adaptation for conserving water.

Fat body and **nephrocytes** are also believed to have excretory function. The fat body is large in quantity and consists of many lobules filled with fats and glycogen, it stores uric acid as waste. The nephrocytes are chains of cells found along the heart or associated with the fat body, they also store nitrogenous excretions which may later be removed by the blood.

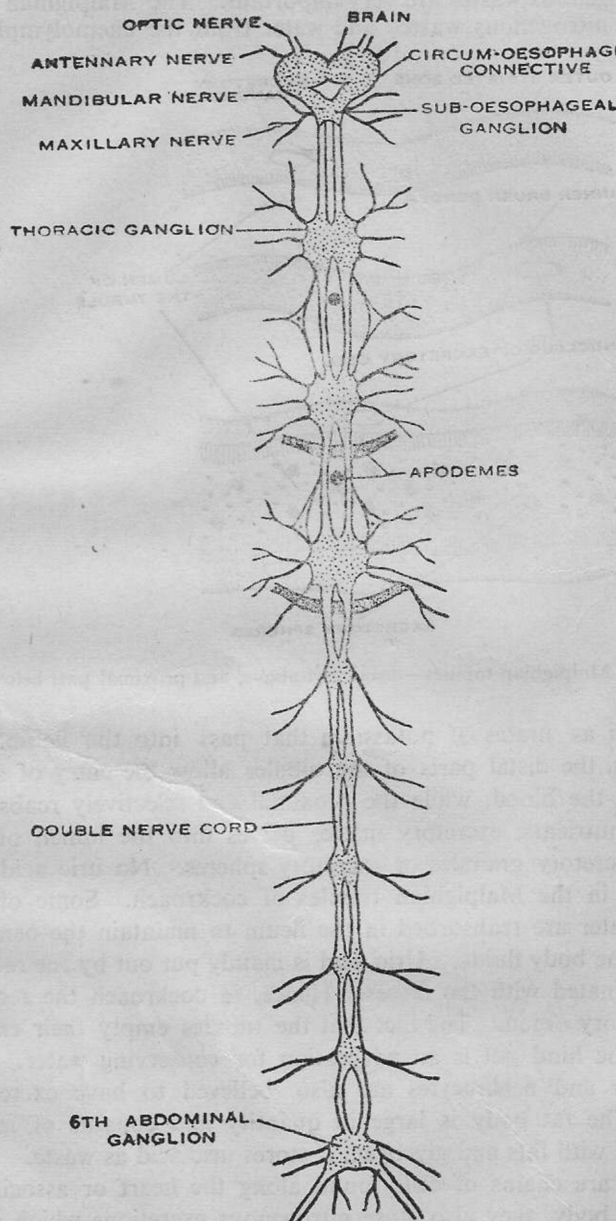

Fig. 358 Nervous system.

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 on antennae, but the olfactory sense is also located in other parts, probably in the feet, because the insect still has an olfactory sense after removal of antennae. **Gustatory sensillae** are found on maxillae which are said to possess a sense of taste. **Auditory** or **chordotonal sensilla** is more complicated and is covered by thinned cuticle. In cockroach the cerci possess auditory sensillae, they can detect even those sounds which the human ear cannot hear.

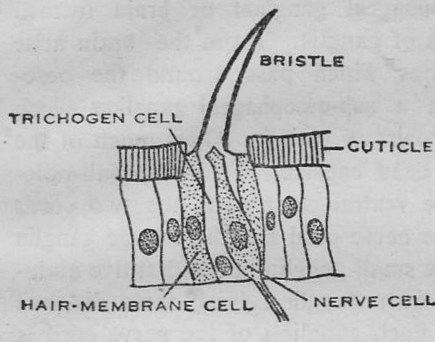

Fig. 359 Tactile sensilla.

Eyes—Two types of eyes are found in insects—**simple eyes** or **ocelli** and **compound eyes**; but the cockroach has only compound eyes.

Ocelli—The ocellus is in the shape of a cup. The cuticle above the cup is transparent and thickened to form a **lens.** Below the lens are colourless transparent cells continuous with the epidermis, they are the **corneagen cells** which also act as a lens. There is a pigment ring around the cup. The lower part, inside the cup, is the **retina**; it has several longitudinal optic rods called **rhabdoms.** Rhabdom is secreted by sensory cells, the **retinulae,** surrounding the rhabdom. The retinulae receive nerve fibres and may also contain pigment. The ocelli are sensitive to light but do not have the ability to form images.

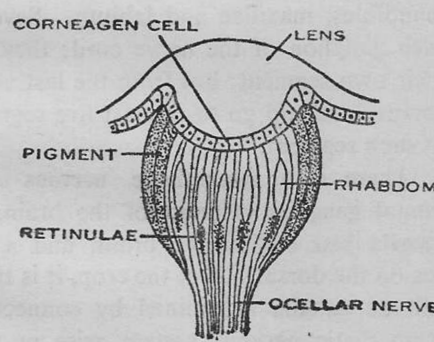

Fig. 360 V.S. of an ocellus.

Compound eyes are lateral in position in cockroach; they are kidney-shaped, their upper part is broader than the lower part. Each compound eye is formed of bundles of rod-like **ommatidia** which are arranged radially and covered by transparent cuticle which forms hexagonal **facets.** An ommatidium has a biconvex **lens** or **cornea** which is formed by the cuticle becoming thickened and transparent, these form the facets. Below the lens the epidermis forms two clear

corneagen cells or **lenticular cells** which secrete the lens. Below the corneagen cells is a transparent **crystalline cone** surrounded by

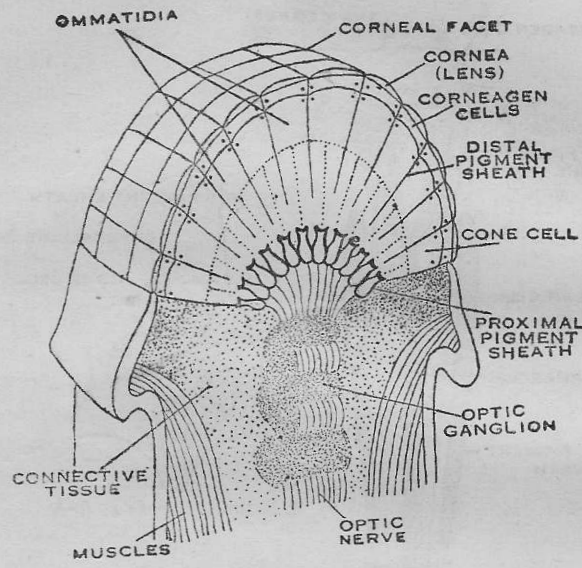

Fig. 361 V.S. of compound eye.

four **vitrellae** or **cone cells.** The vitrellae secrete the crystalline cone, they taper downwards. All this forms the focussing or **dioptrical region.** Below the cone, and in contact with it, is a spindle-shaped refractive body, the **rhabdom,** surrounded by seven **retinular cells** or **retinulae** which are elongated cells. The retinular cells secrete the rhabdom which is made up of seven parts, the **rhabdomeres,** one for each retinular cell. The rhabdom and retinulae constitute the **receptor region,** and below it is a **basement membrane** of the eye. Each retinular cell joins a nerve fibre at its base, and the fibres enter the optic nerve. Surrounding each ommatidium and separating it from its neighbours, there are heavily pigmented cells arranged in two groups—an **iris pigment sheath** around the cone and cone cells, and a **retinal pigment sheath** around the rhabdom and retinular cells. However, the retinal pigment sheath is absent in some insects.

During bright light the pigment layers are extended, isolating the ommatidia, and only those rays of light will form an image on the rhabdom which pass directly through the centre of the lens, or the thin pencil of rays which are parallel to the longitudinal axis of an ommatidium, the other rays of light are stopped and absorbed by the pigment sheaths and they cannot pass from one ommatidium to

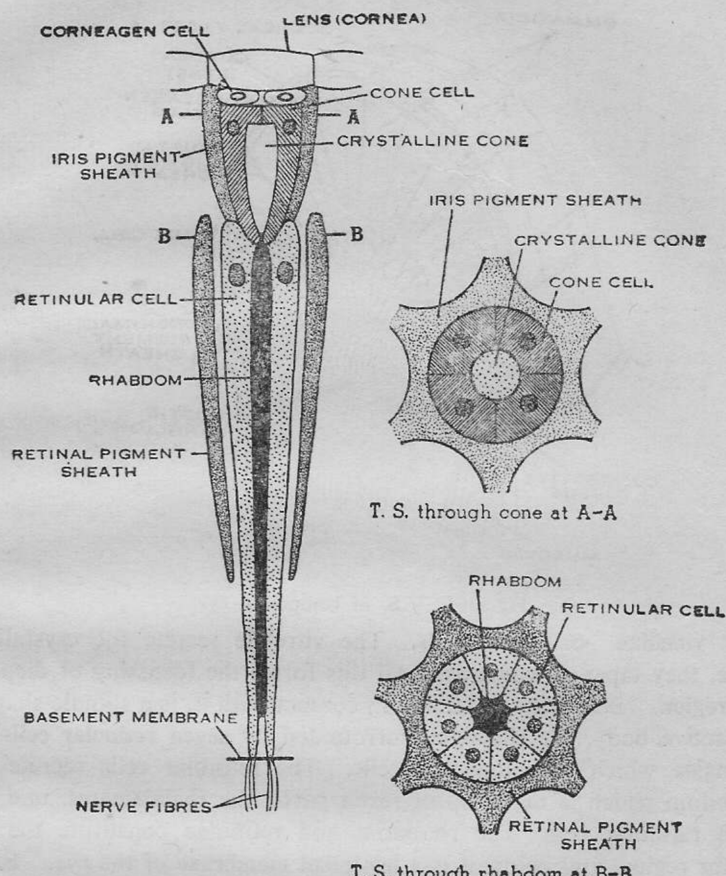

Fig. 362 L. S. of an ommatidium.

another. Thus each ommatidium forms a different but adjacent image, but all images combine to form a single coherent picture. The entire compound eye produces **apposition images** or **mosaic vision** composed of as many separate but adjacent images as there are ommatidia. In mosaic vision images are sharp but separate, and the eye can use only bright light. When the light is dim, the iris pigment sheath moves up and the retinal pigment sheath moves down, so that the ommatidia are not isolated, light can pass from one ommatidium to another, and each ommatidium forms a complete image of the field of vision, and all the images together form a partly overlapping or **superposition image.** The superposition images are less sharp than the apposition images, but they are stronger in proportion to the amount of light present. But recent studies have shown that the pigment sheaths are not retractable in many insects including the cockroach.

The compound eye of an insect is convex with a large number of ommatidia, hence it has a very wide range of vision, though it may not clearly see the form of objects, except those which are very close to the eye, but it can detect the movements of objects at once. The insect eye can also distinguish different colours, though it cannot see all the colours of a spectrum. It can also perceive ultraviolet rays.

Reproductive system—In the male cockroach there is a pair of

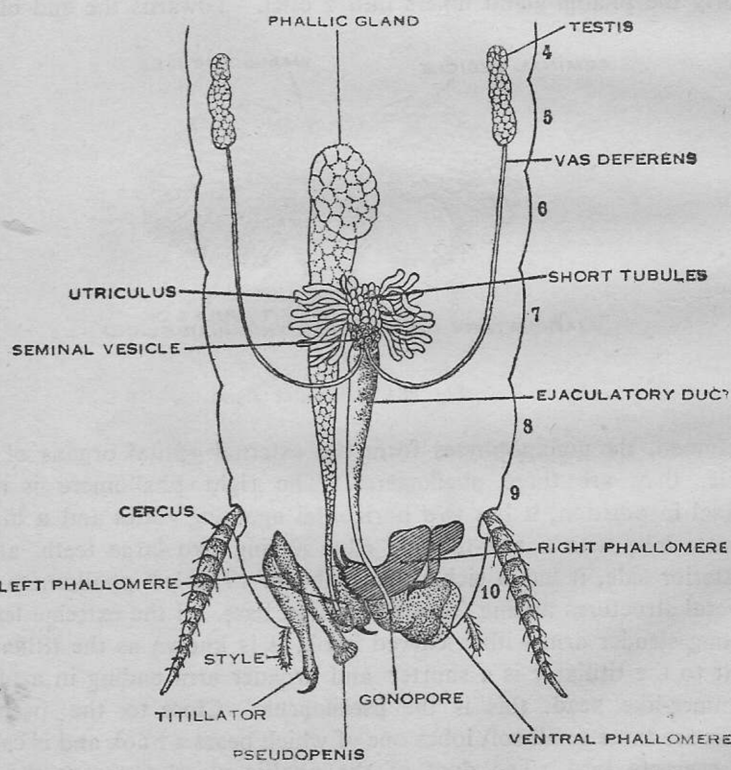

Fig. 363 Reproductive organs of male *Periplaneta.*

3-4-lobed **testes.** The testes lie dorso-laterally in the fourth and fifth abdominal segments in the fat body. The testes are full of sperms in a young cockroach, but some spermatozoa may still be found in the testes of an old adult. From each testis arises a thread-thin white **vas deferens.** The two vasa deferentia pass backwards and downwards and meet in the middle to enter an **ejaculatory duct** which runs backwards. At the junction of the vasa deferentia with the ejaculatory duct and attached to them is a large white-coloured **utricular gland.** It has a mass of glandular tubules of three kinds, the peripheral tubules are long, central tubules are short, and behind the short central tubules are some short but more bulbous and spotted white tubules which are the **seminal vesicles** filled with sperms.

There is a long, flat, white **phallic gland,** its broader anterior end lies in the sixth segment slightly to the right of the nerve cord, posteriorly the phallic gland tapers into a duct. Towards the end of the

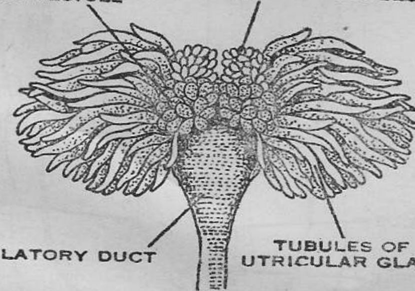

Fig. 364 Utricular gland.

abdomen, the gonapophyses form the external genital organs of the male, they are three **phallomeres.** The right phallomere is mid-dorsal in position, it has two horizontal **opposing plates** and a broad **serrate lobe** with a saw-toothed edge having two large teeth, at its posterior side, it has a sickle-shaped **hook.** The left phallomere has several structures arising from a common base, on the extreme left is a long slender arm with a curved hook, it is known as the **titillator;** next to the titillator is a shorter and broader arm ending in a black hammer-like head, this is the **pseudopenis.** Close to the pseudopenis are three small soft lobes one of which bears a hook and is called an **asperate lobe.** The duct of the phallic gland traverses the left phallomere and opens between the asperate lobe and pseudopenis.

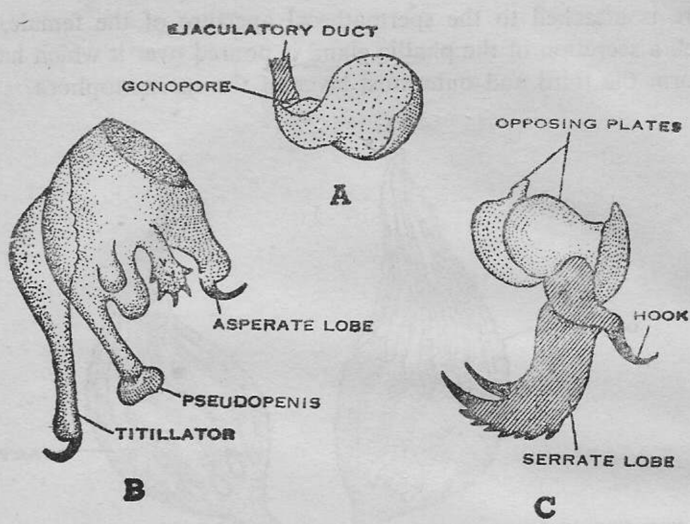

Fig. 365 External genitalia of male. A—Ventral phallomere. B—Left phallomere. C—Right phallomere.

The ventral phallomere lies partly below the right phallomere, it has a large brown plate. The ejaculatory duct opens to the outside by a **gonopore** close to the ventral phallomere.

Before copulation, the sperms of each tube of the seminal vesicle are stuck together to form a single **spermatophore.** A spermatophore is a pear-shaped capsule, about 1·3 mm. in diameter, and its wall is composed of three non-cellular layers; first the innermost layer is formed by the secretions of the long peripheral tubules of the utricular

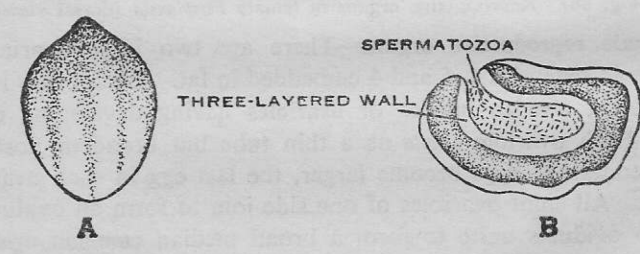

Fig. 366 A—Spermatophore. B—T.S. of spermatophore.

gland, this layer then receives sperms from seminal vesicles and a liquid from the short central tubules of the utricular gland. As this bag of sperms passes down the ejaculatory duct it receives the second layer from the cells of the ejaculatory duct. During mating the spermatophore is attached to the spermathecal aperture of the female, after which a secretion of the phallic gland is poured over it which hardens to form the third and outermost layer of the spermatophore.

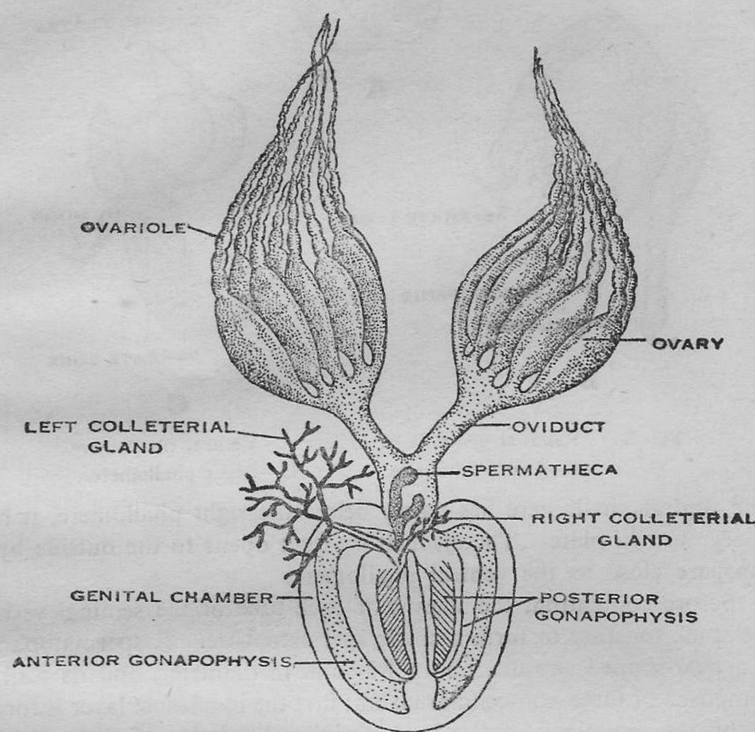

Fig. 367 Reproductive organs of female *Periplaneta* (dorsal view).

Female reproductive organs—There are two large ovaries lying laterally in segments 4, 5 and 6 embedded in fat. Each ovary is formed of eight **ovarian tubules** or **ovarioles** having developing eggs in rows. Each ovariole starts as a thin tube but broadens posteriorly as the contained eggs become larger, the last egg in each ovariole is mature. All eight ovarioles of one side join to form an oviduct, and the two oviducts unite to form a broad median **common oviduct** or **vagina** which opens by a gonopore into a **genital chamber** or **gynatrium.** The gonopore is an aperture in the eighth sternum which lies inside the genital chamber inflected above the 7th sternum. There is a pair of much-branched **colleterial glands**; the left colleterial gland is large and well developed, the right colleterial gland is small.

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

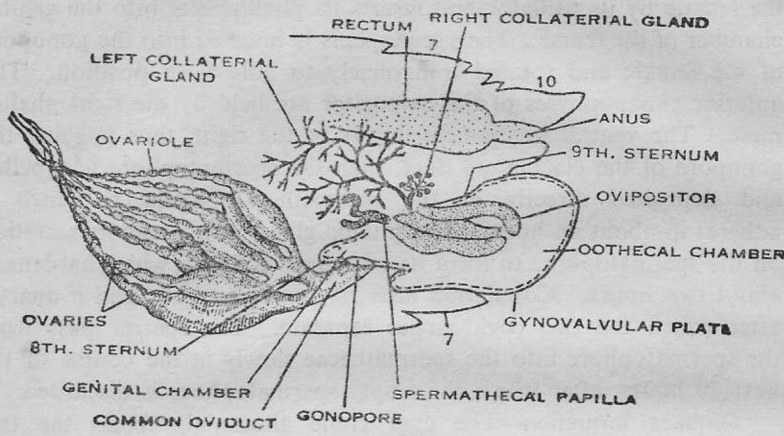

Fig. 368 Reproductive organs of female *Periplaneta* (lateral view).

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.

Copulation—The male and female cockroaches come together by their posterior ends. The male opens the gynovalvular plates of the female by its titillator and inserts its phallomeres into the genital chamber of the female. The pseudopenis is inserted into the gonopore of the female and rotated transversely to hold it in position. The anterior gonapophyses of the ovipositor are held by the right phallomere. The ventral phallomere moves to the right, thus opening the gonopore of the ejaculatory duct, then the spermatophore is expelled and deposited directly on the spermathecal papilla to which it adheres in about an hour. The phallic gland now pours its secretion on the spermatophore to form its outermost covering which hardens in about two hours. Copulation lasts for about an hour and a quarter after which the two cockroaches separate. The sperms pass from the spermatophore into the spermathecae slowly in the course of the next 20 hours, after which the empty spermatophore is discarded.

Ootheca formation—The eggs come alternately from the two ovaries into the common oviduct and pass through the female gono-

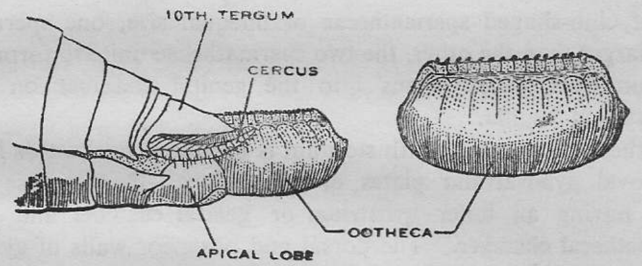

Fig. 369 Posterior end of abdomen of female with ootheca.

pore into the genital chamber where they are fertilized. The colleterial glands pour their secretions on the fertilized eggs, these secretions combine to form a dark brown **ootheca** around the eggs. The ootheca is shaped and moulded by the ovipositor and the walls of the oothecal chamber. The ootheca is a brown-coloured, non-chitinous, purse-shaped capsule of about 9 to 12 mm. in length. On one side it has a straight crest with a serrated margin, it contains 16 fertilized eggs standing vertically in two rows, the position of eggs can be seen on the outer surface of the ootheca. The ootheca is completed in about a day and it protrudes from the oothecal chamber, being held in place by the 10th tergum and gynovalvular plates. The female carries the ootheca for several days and finally drops it in some dark, dry place.

Metamorphosis—The young ones of a cockroach hatch from the ootheca by **splitting** of the serrated crest; they are known as **nymphs.** The nymph resembles the adult in structure and eats the same food, but it is white or pale in colour, smaller in size, it is devoid of wings, and the gonads are immature. As it feeds and grows, its outer exoskeleton is cast off; this process of shedding the exoskeleton is known as **moulting** or **ecdysis**; it is due to a hormone of **corpora allata,** the hormone separates the old cuticle from the hypodermis, then the hypodermis secretes both layers of the new cuticle. The nymph forms a new exoskeleton by its hypodermis before the old one is cast off, and growth can take place only before the new covering has hardened, because the tough exoskeleton does not permit increase in size. The cockroach nymph undergoes six or seven ecdysis to become an adult in about a year. During this period the nymph grows, wings are formed from the integument, and gonads become mature. After the last ecdysis no further increase in size occurs. The final moulting to form an adult is due to a hormone of a pair of **prothoracic glands** found in the first segment of the thorax; this hormone has been kept in suppression in earlier stages by the hormone of corpora allata. This gradual assumption of adult characters with hardly any change is called **incomplete metamorphosis** or **heterometabolic metamorphosis.** In all insects the interval between two ecdysis is known as a **stadium,** and the form assumed by the young insect during a stadium is called an **instar.** When the young hatches from the egg, it is said to be in its first instar; at the end of the stadium the first ecdysis occurs and the young insect assumes its second instar, and so on. The final instar is the adult which is called an **imago.**

Questions

1. What is 'cephalothorax' ? What is the number of segments in the cephalothorax of *Palaemon* ?
2. How would you identify the maxillipedes of prawn from other thoracic appendages?
3. Is there any sexual dimorphism in the prawn ? How will you identify the sexes in the prawn ?
4. Which appendage of prawn bears the statocyst ?
5. Differentiate between Periplaneta and Blatta ?
6. Where does the salivary duct open in a cockroach ?
7. Present the order of appendages working to transfer the food into the mouth.

8. Which of these are present only in the male cockroach ? anal cerci, anal styles, anal plates.
9. How is food prevented from passing back into the gizzard ?
10. What role the rectal folds and peritrophic membrane play in cockroach ?
11. What is a haemocoel ?
12. How many chambers are there in the heart of cockroach ?
13. What endocrine structures you know in the cockroach ?
14. What is the receptive part of the ommatidium ? Draw a diagram of an ommatidium.
15. Differentiate between apposition and superposition image.
16. How many ovarioles make an ovary of cockroach ?
17. What part of spermatophore is secreted by the phallic gland ?
18. How many young cockroaches are born out of one ootheca ?
19. Describe the male reproductive organs of a male cockroach. How is a male cockroach distinguished from a female cockroach?

CHAPTER 26

MOSQUITO AND HOUSE FLY

Mosquito and house fly are dipterous (di = two, pteron = wings) and most common insects. Both have two pairs of wings but only the first pair of wings is fully developed and used in flight.

Culex—the gnat (A Mosquito)

Genus *Culex* includes many common species of mosquitoes

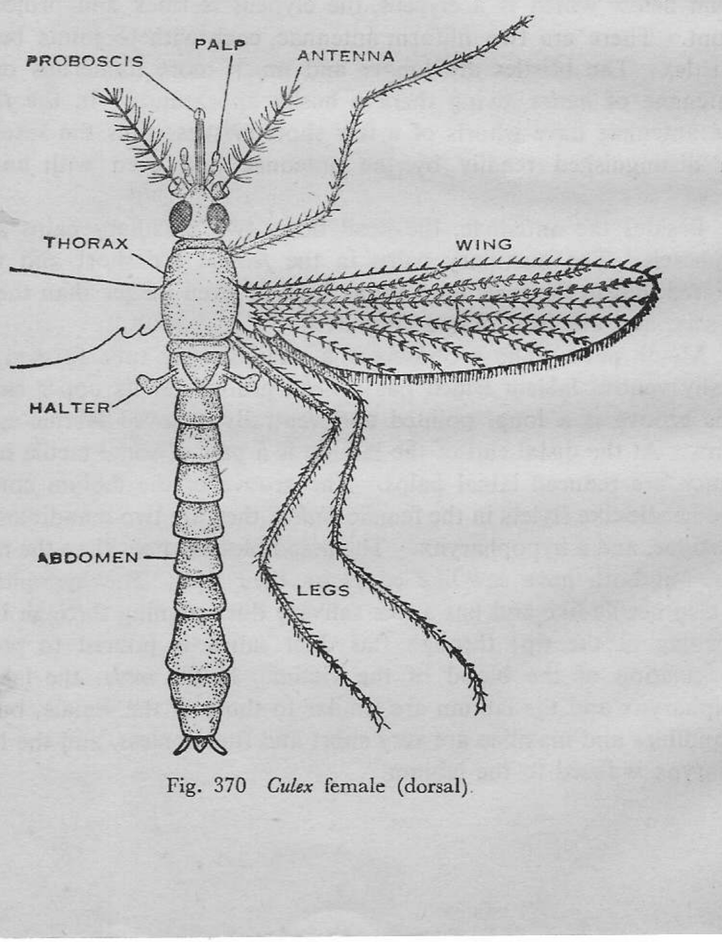

Fig. 370 *Culex* female (dorsal).

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.

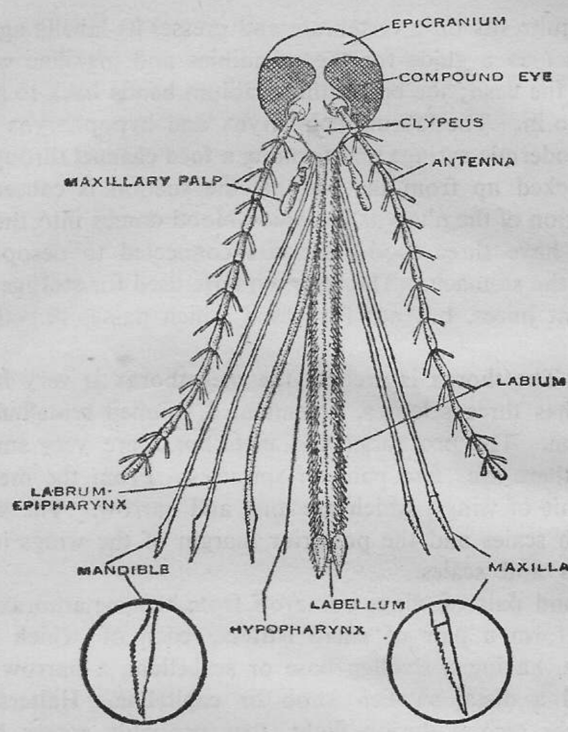

Fig. 371 *Culex*—Head and mouth parts of female.

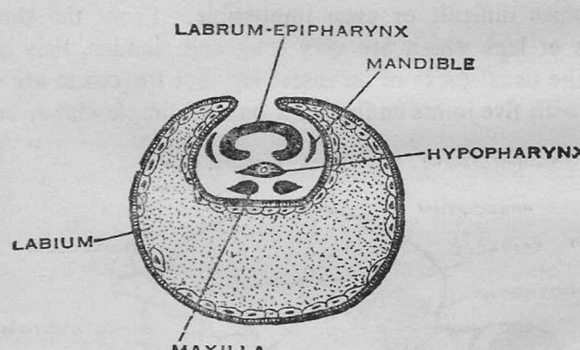

Fig. 372 *Culex*—T.S. of proboscis of female.

Feeding—The natural food of both sexes is nectar of flowers and juices of plants, but the female has its mouth parts modified for obtaining additional meals of blood of warm-blooded vertebrates. The female mosquito sits on a vertebrate and presses its labella against the skin, they act as a guide for the mandibles and maxillae which are pushed into the flesh; the ensheathing labium bends back to allow the needles to go in. The labrum-epipharynx and hypopharynx together act as a hypodermic syringe and forming a **food channel** through which blood is sucked up from the wound; the suction is caused by the pumping action of the pharynx by which blood comes into the mouth. Mosquitoes have three food reservoirs connected to oesophagus in addition to the stomach. The reservoirs are used for storage of food, such as plant juices, but not for blood which passes directly to the stomach.

Thorax—The thorax is arched, the mesothorax is very large and its tergum has three sclerites, a **scutum,** a trilobed **scutellum,** and a **post-scutellum.** The prothorax and metathorax are very small. On the thorax there are two pairs of spiracles. From the mesothorax arise first pair of wings, which are long and narrow. The wings are covered with scales and the posterior margin of the wings is fringed with bristles and scales.

The second pair of wings come off from the metathorax but are reduced to form a pair of small **halters,** each of which is like a hollow cone, having a swollen base or **scabellum,** a narrow stem or **pedicel,** and a distal swollen knob or **capitellun.** Halters vibrate 300 times per second during flight, they probably act as balancers but their function is doubtful; however, if halters are removed flight becomes difficult or even impossible. From the thorax arise three pairs of legs which are very long and slender, they are fragile and have the usual parts of an insect leg, but the coxae are short and tarsi long with five joints ending in a pair of simple claws, below each

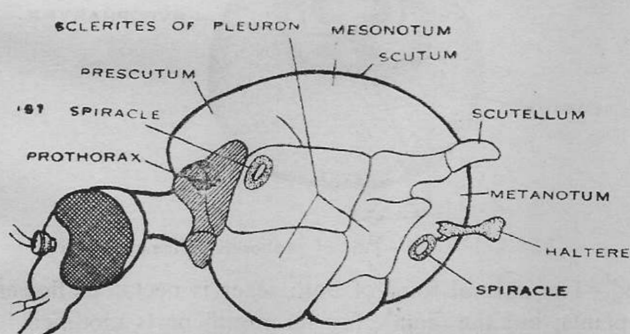

Fig. 373 Thorax of *Culex* (lateral view).

claw is a pad-like **pulvillus.** The legs also have many scales and bristles.

Abdomen—The abdomen consists of 10 segments of which the first is vestigial and fused to the metathorax; the second to the eighth are clearly seen, each has a pair of spiracles; the ninth and tenth segments are partly telescoped into the eighth. In the female the 10th segment is blunt and bears a pair of **cerci,** between them is a small **post-genital plate** which is part of the tenth sternum. In the male the 9th and 10th segments are complex, they undergo a torsion of 180° as soon as the mosquitoes are born, so that the terga and anus become ventral and the sterna dorsal. The ninth segment is ring-like with a bilobed ventral tergum, it bears a pair of large **claspers,** each with a broad basal **coxite** followed by a narrow **style** which ends in a **claw.** The 10th segment has a bilobed dorsal sternum from which project two processes with curved and toothed tips. The male intromittent organ or **aedeagus** projects posteriorly; it is formed by fusion of gonapophyses of ninth segment. During copulation the male holds the female by its claspers and the aedeagus is inserted into the vagina of the female.

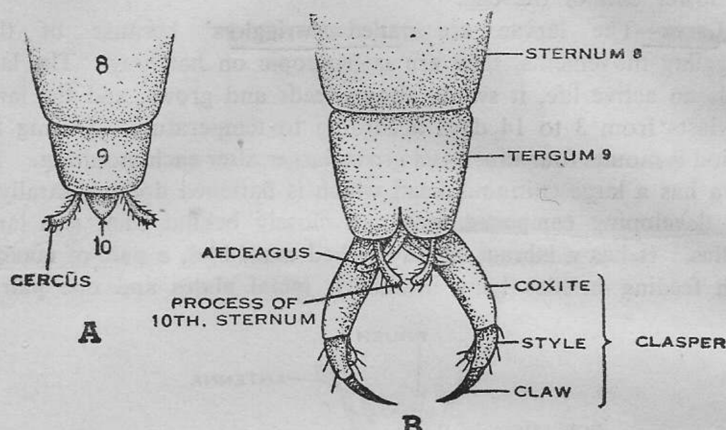

Fig. 374 *Culex*—end of abdomen (ventral); A—Female, B—Male

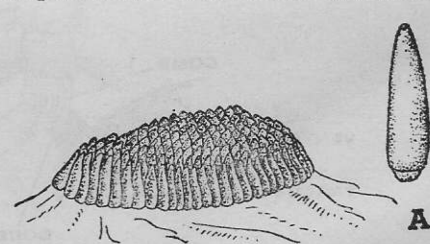

Fig. 375 Egg raft of *Culex;* A—Egg

Life-history—After mating, the female lays eggs on still water; the eggs may be laid on ponds, pools, or rain-filled containers. The eggs are laid at night and one female may lay up to 300 eggs. The eggs are cigar-shaped and tapering at one end. The eggs are laid side by side standing erect, they are glued together by the legs to form boat-shaped **rafts** which float on water. The eggs hatch in 1 to 3 days, and the larva emerges from the lower end of the egg.

Larva—The larvae are called **'wrigglers'** because of their wriggling movements, they are microscopic on hatching. The larva leads an active life, it swims about, feeds and grows, and the larval life lasts from 3 to 14 days according to temperature. During this period it moults four times and grows larger after each moulting. The larva has a large chitinous head which is flattened dorso-ventrally, it has developing **compound eyes** and closely behind each is a larval **ocellus.** It has a **labrum,** small-toothed **mandibles,** a pair of **maxillae** with feeding bristles lying internally, **labial plates** and one pair of

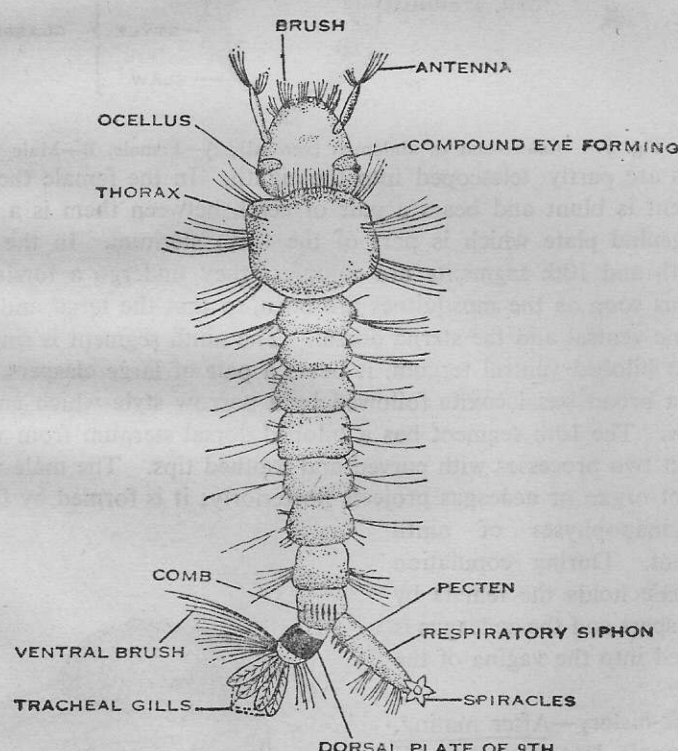

Fig. 376 Larva of *Culex*.

jointed **antennae.** It has a mouth over which is a pair of rotary **feeding brushes** formed of stiff bristles; the brushes cause a whirling current of water by which small particles of food are strained into the mouth. The food consists of algae and small organic particles, the larva feeds below the surface of water. The thorax is globular, its segments are fused together. On the head, thorax and abdomen are paired bristles, some of them forming bushy **tufts** especially on the thorax. The abdomen is slender and has nine segments, on the first seven abdominal segments are tufts of bristles. The eighth segment has a chitinous and tubular **respiratory siphon,** at the tip of the siphon are two spiracles leading into tracheal trunks. Around the spiracles are five leaf-like hydrofuge flaps. Thus the respiratory system is **metapneustic** in which only the last pair of abdominal spiracles are open. The larva, though aquatic, breathes air through the siphon and comes to the surface to take in air. When resting, the larva pierces the surface film of water by its siphon which projects just above the surface. The movement of flaps around the spiracle is passive. They are separated automatically, when above the water surface, by surface tension forces, thereby exposing the spiracle. Air is then exchanged through the spiracle. The flaps close over the spiracle when under water. Larva hangs by the siphon with its head downwards but it is inclined at an angle. The siphon on its ventral side has two tufts of bristles, and two rows of flat spines each called a **pecten.** On the eighth segment is a patch of small scales in one or two rows forming a **comb.** In some species of *Culex*, the comb has scales in several rows. The ninth segment of the abdomen is slender and covered by a chitinous **dorsal plate.** At the end of the ninth segment is an **anus** surrounded by four leaf-like **tracheal gills** which differ from true gills in having tracheae instead of blood vessels. The ninth segment has a tuft of **dorsal bristles** at its tip and ventrally a bushy tuft of bristles called **ventral brush.** The larva sinks in water being heavier, and it rises by wriggling movements of the abdomen. After the fourth moult the larva changes into a pupa.

Pupa—The pupa is comma-shaped and is often called a **'tumbler'.** It has a large cephalothorax formed by the head and thorax. On the mid-dorsal side of the cephalothorax is a pair of prothoracic tubular **respiratory trumpets** which are broader at the distal end, they communicate with the anterior pair of thoracic spiracles. By means of the trumpets, the pupa hangs from the surface film of water and takes in air through their distal ends which project slightly above water.

Data Structures and Algorithms Assignment Set – 2

1. Define an ADT for Polynomials.

Write C data structure representation and functions for the operations on the Polynomials in a Header file.

Write a menu-driven main program in a separate file for testing the different operations and include the above header file.

2. Define an ADT for Sparse Matrix.

Write C data structure representation and functions for the operations on the Sparse Matrix in a Header file.

Write a menu-driven main program in a separate file for testing the different operations and include the above header file.

3. Define an ADT for List.

Write C data structure representation and functions for the operations on the List in a Header file with array as the base data structure.

Write a menu-driven main program in a separate file for testing the different operations and include the above header file. Two data structures with and without using sentinels in arrays are to be implemented.

4. Define an ADT for Set.

Write C data representation and functions for the operations on the Set in a Header file, with array as the base data structure.

Write a menu-driven main program in a separate file for testing the different operations and include the above header file.

5. Define an ADT for String.

Write C data representation and functions for the operations on the String in a Header file, with array as the base data structure, without using any inbuilt function in C.

Write a menu-driven main program in a separate file for testing the different operations and include the above header file.

6. Given a large single dimensional array of integers, write functions for sliding window filter with maximum, minimum, median, and average to generate an output array. The window size should be an odd integer like 3, 5 or 7. Explain what you will do with the boundary values.

Input Output examples for problem no. 6

Input: 4, 5, 1, 13, 3, 25, 27, 18, 10, 3, 4, 9

Window size: 3

Max filter output: 5, 5, 13, 13, 25, 27, 27, 27, 18, 10, 9, 9

Min filter output: 0, 1, 1, 1, 3, 3, 18, 10, 3, 3, 3, 0

Median filter output: 4, 4, 5, 3, 13, 25, 25, 18, 10, 4, 4, 4

7. Take an arbitrary Matrix of positive integers, say, 128 X 128. Also take integer matrices of size 3 X 3 and 5 X 5. Find out an output matrix of size 128 X 128 by multiplying the small matrix with the corresponding submatrix of the large matrix with the centre of the small matrix placed at the individual positions within the large matrix. Explain how you will handle the boundary values.

8. Find whether an array is sorted or not, and the sorting order.

9. Given two sorted arrays, write a function to merge the array in the sorting order.

10. Write an application in C that would read an array of digits which is forming a number currently (will be called as given number). Next, it would find the just next greater number which can be formed using digits of given number.

11. Write a C program to move the negative elements in an array to the front of array.

Input Output example for Problem 11

Input will be:

2 -7 10 12 5 -2 32 -4

Output will be:

-7 -2 -4 2 10 12 5 32