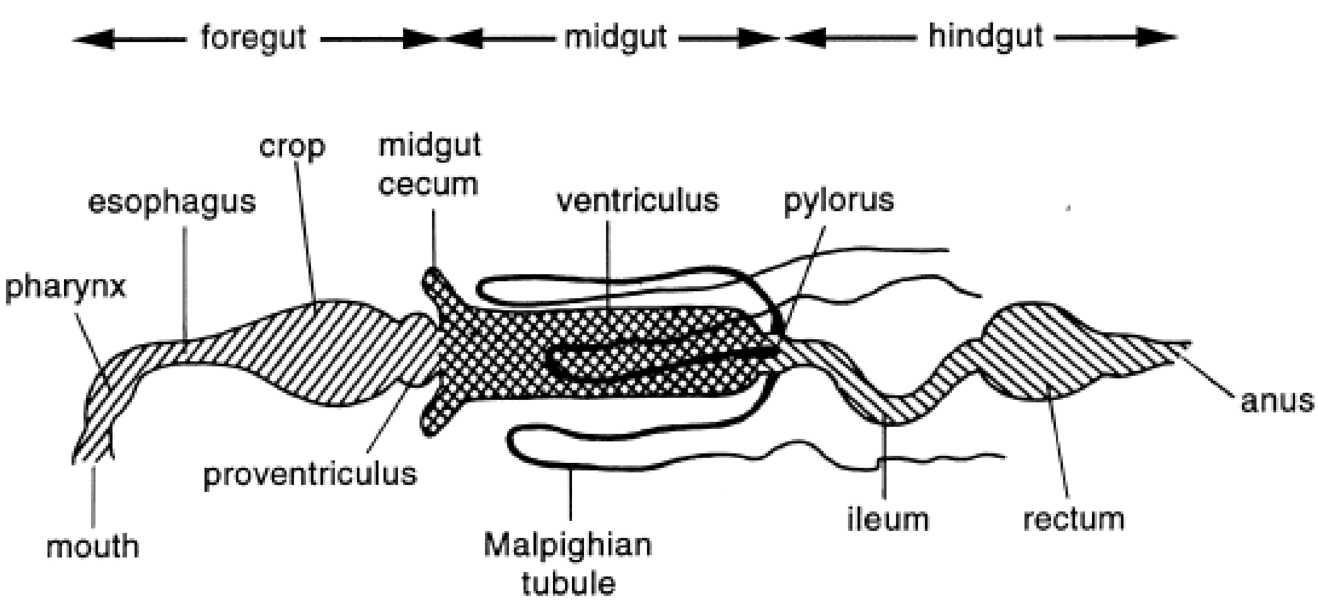
Anatomy

Digestive System (Alimentary canal):

The digestive tract consists of a tube of epithelial cells running from the mouth to the anus. It is divided into three major regions based on embryonic origins and physiological functions: the foregut, midgut, and hindgut. The stomodeum and proctodeum both arise as invaginations of the embryonic ectoderm and produce the foregut and hindgut, respectively. Since the foregut and hindgut are ectodermal in origin, the cells secrete cuticle which is continuous with that covering the outside of the body. The lining cuticle is known as the intima. It is shed and renewed at each molt .The midgut (mesenteron) forms from endodermal tissues. Although the midgut does not secrete cuticle, in most insects it does secrete a delicate peritrophic envelope around the food.

The cells of the foregut are usually flattened and undifferentiated since they are not involved in <u>absorption or secretion.</u>



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1-Foregut

Is commonly differentiated into the pharynx, esophagus, crop and proventriculus. The pharynx is concerned with the ingestion and backwards passage of food and has a well-developed musculature.

The esophagus usually has a simple tubular form, serving as a connection between the pharynx and the crop. The crop is a storage organ which in most insects is an extensible part of the gut immediately following the esophagus. The walls of the crop are folded longitudinally and transversely. The folds become flattened as the crop is filled, usually permitting a very large increase in volume. The proventriculus often forms a simple valve at the origin of the midgut, projecting a short distance into the midgut lumen .

2-Midgut

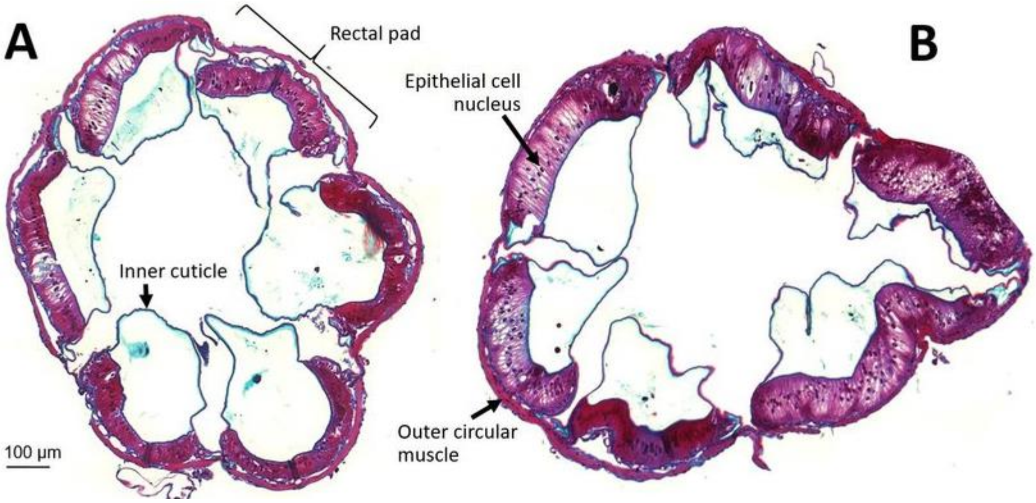
The tubular part of the midgut is known as the ventriculus. In many insects the midgut has diverticula known as ceca, usually at the anterior end .

The cells of the midgut are actively involved in enzyme production and secretion, as well as in absorption of nutrients. The majority of the cells, are tall and columnar and the membrane on the luminal side forms microvilli. The microvilli greatly increase the area of the cell membrane through which absorption occurs.

3-Hindgut

The hindgut is usually differentiated into the pylorus , ileum and rectum . The pylorus sometimes forms a valve between the midgut and hindgut. The Malpighian tubules often arise from it.

The ileum of most insects is a narrow tube running back to the rectum. Sometimes the posterior part is recognizably different and is called the colon. Amongst insects that have symbionts in their hind gut the ileum is expanded to house them. The expansion is called the paunch in termites. The rectum is usually an enlarged sac with a thin epithelium except for certain regions, the rectal pads, in which the epithelal cells are columnar. There are usually six rectal pads arranged radially round the rectum .



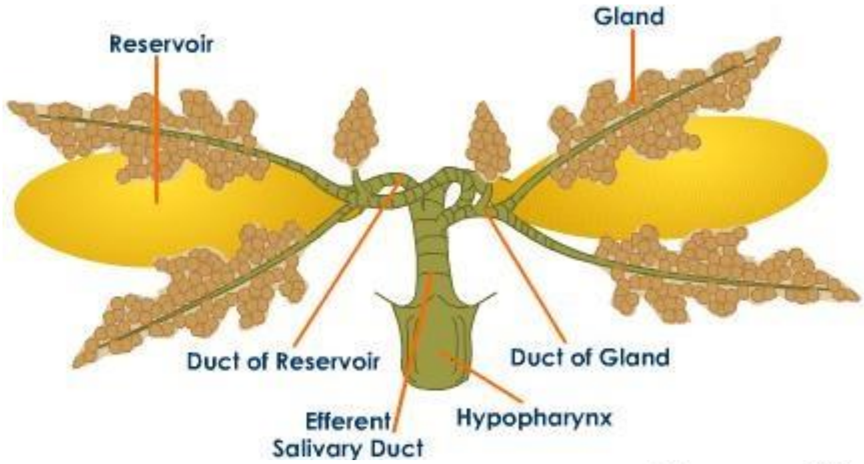
Muscles of the gut

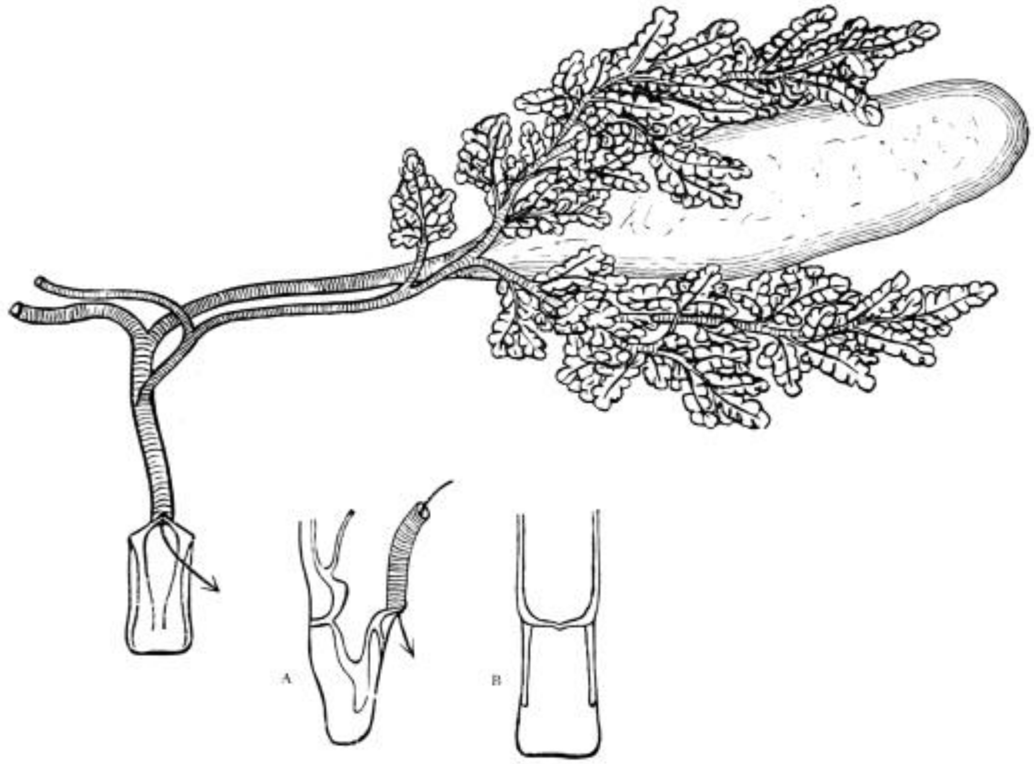
The muscles of the alimentary canal fall into two categories:
Extrinsic visceral muscles: which are associated with the foregut and hindgut and generally function as dilators of the gut. (arise on the body wall and are inserted into the gut.) The extrinsic visceral muscles of the hindgut are usually present as dilators of the rectum. They are especially well-developed in larval dragonflies (Odonata) that pump water over the gills in the rectum .

Intrinsic visceral muscles: which are associated only with the gut.
The intrinsic visceral muscles comprise circular muscles running round the gut and longitudinal muscles extending along parts of it. Intrinsic muscles are poorly developed round the midgut. The main longitudinal muscles are outside the circular muscles .The intrinsic muscle are commonly strong associated with the pyloric valve, where the Malpighian tubules join the gut.

Digestion

A large part of the food ingested by insects is macromolecular, in the form of polysaccharides and proteins, while lipids are present as glycerides, phospholipids and glycolipids. Generally, only small molecules can pass into the tissues and the larger molecules must be broken down into smaller components before absorption can occur. Enzymes concerned with digestion are present in the saliva and in the secretions of the midgut. In addition, digestion may be facilitated by micro-organisms in the gut.





Extra-intestinal digestion

Some insects inject saliva into their food before starting to ingest and, because it contains enzymes, considerable digestion may occur. Such extra-intestinal (or extra-oral)digestion may constitute a major part of the total digestion.
This is true in the predaceous Heteroptera (Belostomatidae, Reduviidae and Nabidae).
The stylet structure of most of these insects restricts their ability to ingest anything except fluids and very fine particles, so that food must be pre-digested.

Digestion in the gut lumen

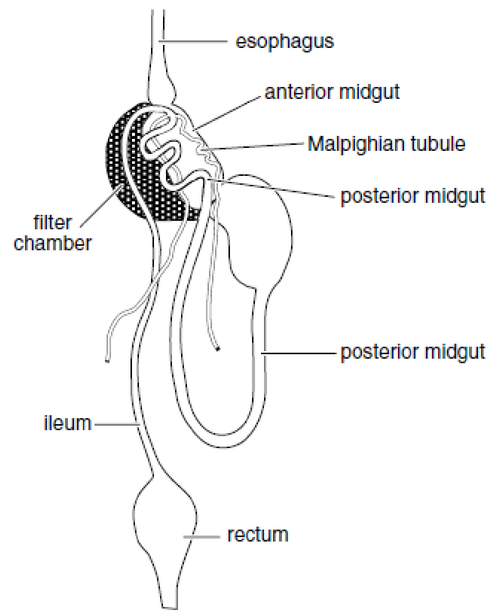
Regardless of their feeding habits, most insects must digest proteins, carbohydrates and lipids and so they have a similar array of enzymes in the midgut. However,the enzymes produced do reflect the type of food eaten by each species and stage. For example, in the tsetse fly, *Glossina*, that feeds exclusively on vertebrate blood, the array of proteolytic enzymes reflects the importance of protein in the insect's diet; in adult Lepidoptera that feed only on nectar, on the other hand, proteolytic enzymes are completely lacking.

Absorption

The products of digestion are absorbed in the midgut, but some absorption, specially of salts and water, also occurs in the hindgut (In terrestrial and saltwater insects water is absorbed from the rectum..)

Water absorption from the midgut

Water absorption from the midgut often occurs in localized areas. In cockroaches, grasshoppers and in the larvae of some flies (mosquitoes and Sciaridae), it occurs in the midgut ceca, while in blood-sucking insects water is removed from the stored meal in the anterior midgut. Modifications of the gut provide for the rapid elimination of the excess water taken. In most Homoptera, the anterior midgut forms a thin walled bladder that wraps round the posterior midgut and the proximal ends of the Malpighian tubules. This arrangement, which is called a filter chamber, enables water to pass directly from the anterior midgut to the Malpighian tubules . In this way the food is concentrated and dilution of the hemolymph is avoided.



Water absorption from the midgut. General arrangement of the gut showing the filter chamber.

Absorption of organic compounds (monosaccharides. ***,Amino acids,*** are absorbed mainly as

Lipids appear to be absorbed primarily as fatty Acids .

Nutrition

Nutrition concerns the chemicals required by an organism for its growth, tissue maintenance, reproduction and the energy necessary to maintain these functions. Many of these chemicals are ingested with the food, but others are synthesized by the insect itself. In some insects, microorganisms contribute to the insect's nutrient pool.

Nutritional Requirements

Amino acids

Amino acids are required for the production of proteins which are used for structural purposes, as enzymes. In addition, some amino acids are involved in morphogenesis. Tyrosine is essential for cuticular sclerotization and tryptophan for the synthesis of visual screening Pigments.

Lipids

Fatty acids, phospholipids and sterols are components of cell walls as well as having other specific functions.

Fat-soluble vitamins _-carotene (provitamin A) is probably essential in the diet of all insects because it is the functional component of visual pigments. Vitamin E is necessary for reproduction in at least some insects. It improves the fecundity of some moths and beetles .

Water-soluble growth factors

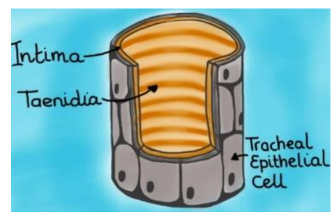
B vitamins The B vitamins are organic substances, not necessarily related to each other, which are required in small amounts in the diet because they cannot be synthesized. They often function as cofactors of the enzymes catalyzing metabolic transformations. All insects require a source of seven such compounds, either in the diet or produced by associated micro-organisms. These seven are:
thiamine, riboflavin, nicotinic acid, pyridoxine, pantothenic acid, folic acid and biotin.
Ascorbic acid The functions of ascorbic acid are not certainly known, but its deficiency is commonly associated with abnormalities at ecdysis, suggesting that it may be concerned with some of the processes involved in cuticular sclerotization. Most, but not all, insects that feed on living plants have a dietary requirement for ascorbic acid.

Inorganic compounds

Sodium, potassium, calcium, magnesium, chloride and phosphate are essential elements in the functioning of cells and are essential components of the diet of all insects.
Zinc is also essential, and manganese commonly so. Both metals appear to play a part in hardening the cuticle of mandibles in many insects.

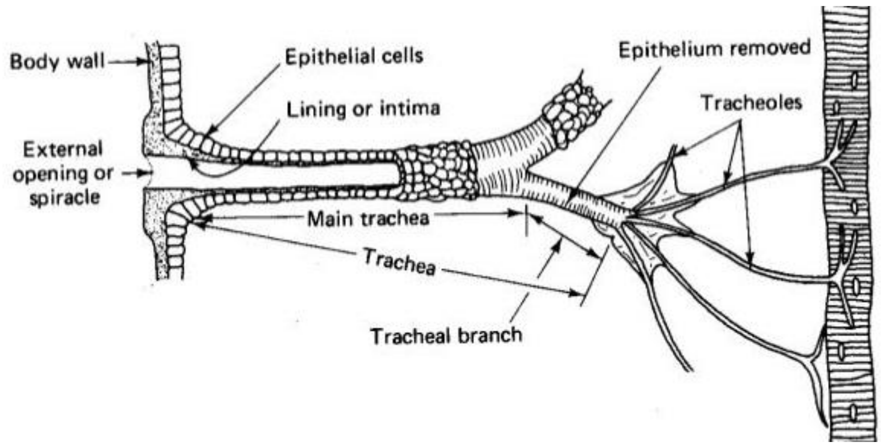
Respiratory system

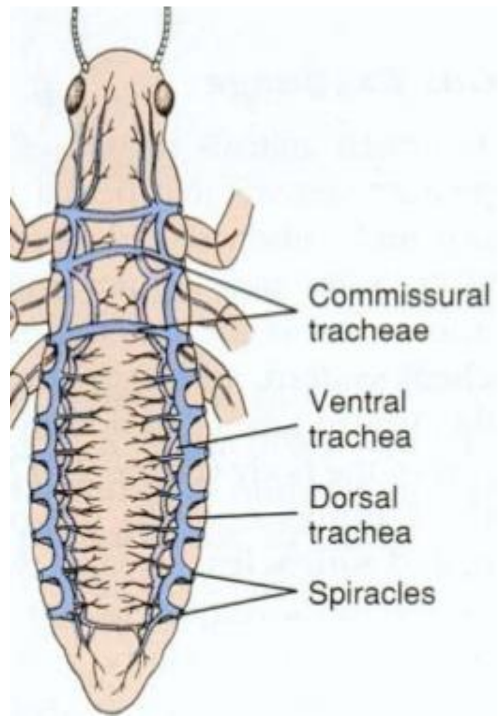
The tracheal system is a system of cuticular tubes (the tracheae) that externally open at the spiracles and internally branch and extend throughout the body .They penetrate the living tissues. The tracheae are lined with a layer of Cuticle, and in the larger branches this is thickened to form helical rings, called **taenidia,** that simultaneously give the tracheae strength (against collapse) and flexibility (to bend and twist). The tracheoles (also lined with Cuticle) are minute intracellular tubes with thin walls, and they often contain fluid. The **spiracles** are located laterally in the pleural wall and vary in number from 1 to 10 pairs (some species have no functional spiracles). There is typically a pair on the anterior margin of both the meso- and metathorax, and a pair on each of the first eight abdominal segments. They vary in size and Shape and usually have some sort of valvelike closing device. These valves therefore play an important in retaining body water. Water loss through Spiracles may be minimized in this way.



Open respiratory system

In insects with an open tracheal system (that is with functional spiracles), air enters the body through the spiracle then passes through the trachea to the trachaeole and oxygen ultimately enters body by diffusion. CO2 leaves the body in similar fashion. The spiracles may be partly or completely closed for extend periods in some insects'. Insects generally have longitudinal tracheal trunks connecting the tracheae from adjacent spiracles on the same side of the body and transverse commissures (com) connecting the tracheae on opposite sides of the body so that the entire systems interconnected.





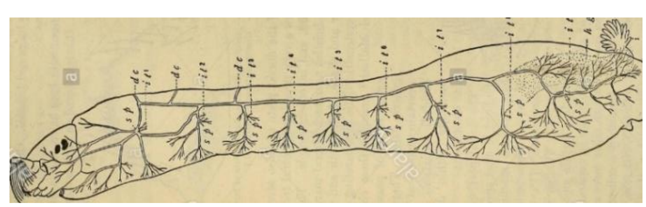
Horizontal section of an insect showing the arrangement of the principal tracheae

Aquatic insects obtaining oxygen from the air

Most aquatic forms obtaining air from above the water surface must make periodic visits to the surface, but a few have semi-permanent connections with the air that enable them to remain submerged indefinitely. The larva of the hover fly, *Eristalis* (Diptera), has a telescopic terminal siphon which can extend to a length of six centimeters or more in a larva only one centimeter long. By means of the siphon the larva can reach the water surface with its posterior spiracles, while the body remains on the bottom mud.

Diving beetle , *Dytiscus*, have an extra-tracheal air store (is beneath the elytra) , carrying a bubble of air down into the water when they dive. The spiracles open into this bubble, so that it provides a store of air additional to that contained in the tracheal system, enabling the insects to remain submerged for longer periods than would be possible without it.

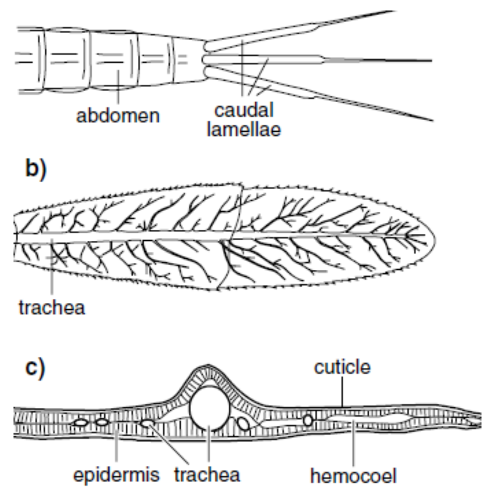
Closed tracheal system have spiracles permanently closed but have a , distributed either widely over the body or particularly below certain surfaces (the gills). Some aquatic and parasitic insects have closed systems. In these species, gases enter and leave the body by diffusion



across the body wall between the tracheae and the external environment, and gases move through the tracheal system by diffusion.

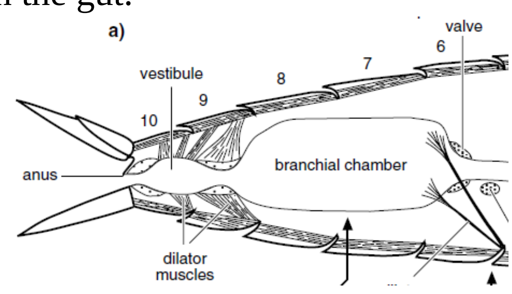
Endoparasitic insects (most parasitic Diptera) may obtain their oxygen directly from the air outside the host or by diffusion through the cuticle from the surrounding host tissues (cutaneous diffusion).
Simulium larvae, there is a network of tracheoles just beneath the general body cuticle.

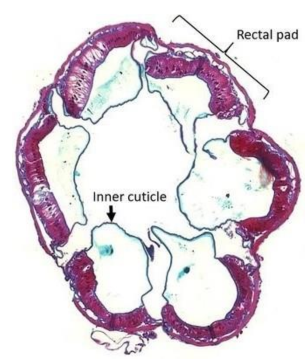
Zygoptera Larvae have three caudal gills (leaf-like extensions of the body). These are covered by very thin cuticle with a network of tracheoles immediately beneath and are known as tracheal gills.



Tracheal gills (caudal lamellae) of a damselfly larva (Zygoptera). (a) Dorsal view of the posterior end of the abdomen.(b) One lamella showing the tracheae. (c) Transverse section of a lamella

Larval Anisoptera have gills in the anterior part of the rectum, known as the branchial chamber . Water is drawn in and out of the chamber by the activity of muscles largely unconnected with the gut.





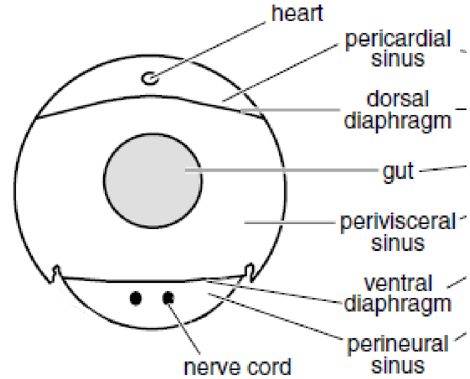
Longitudinal section through the abdomen. Numbers indicate abdominal segments. (b) Transverse section through the branchial chamber

Circulatory System

Structure

Insects have an open blood system with the blood occupying the general body cavity, which is known as a hemocoel. Blood is circulated mainly by the activity of a contractile dorsal ongitudinal vessel which opens into the hemocoel.

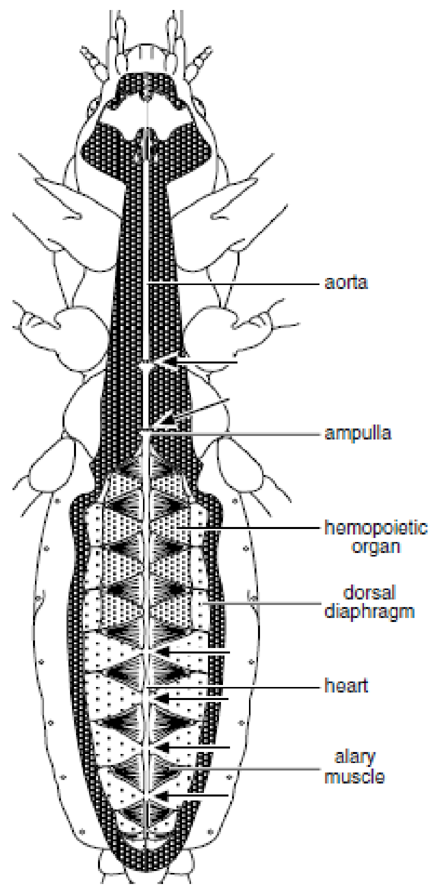
The hemocoel is often divided into three major sinuses; a dorsal pericardial sinus, a perivisceral sinus, and a ventral perineural sinus



Main sinus of haemocel

2- Dorsal blood vessel. The dorsal vessel runs along the dorsal midline, just below the terga, for almost the whole length of the body. The dorsal vessel is divided into two regions: a posterior heart in which the wall of the vessel is perforated by incurrent and sometimes also by excurrent openings (ostia), and an anterior aorta which is a simple,.tube .

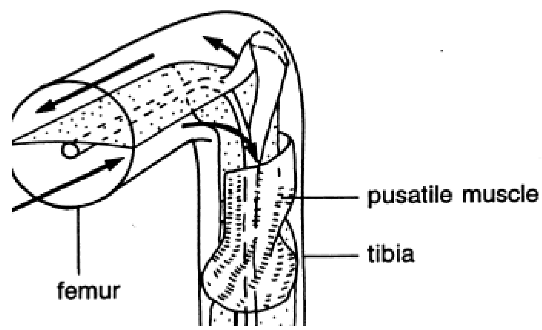
Ventral dissection of the field cricket, to show dorsal vessel and associated structures.



Heart remains in position with the help of alary muscles that are attached to the tergum of the abdomen on one side and to the dorsal diaphragm onother side. These alary muscles appear to be distributed fan like over the heart.

Heart consists of number of chambers marked by constrictions and the presence of the opening called the incurrent 'ostia' w**hi**ch allow the entry of blood from pericardial sinus in to the heart. The number of ostia depends upon the number of heart chambers which will be usually 9. The walls of heart also consists of muscles. Heart mainly functions as the pumping organ in to the aorta.

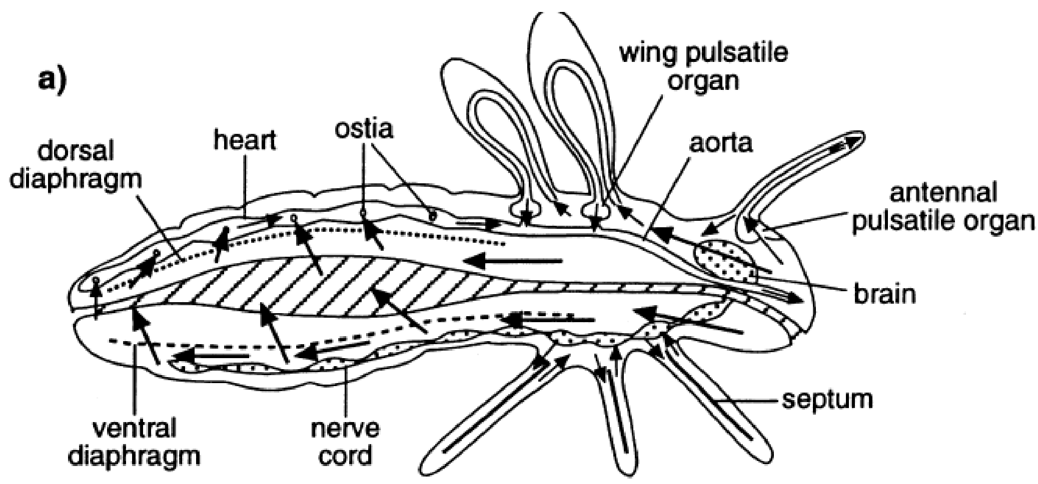
3- Accessory pulsatile organs: In addition to the dorsal vessel, insects have other pulsating structures that maintain circulation through the appendages. A pulsatile organ drawing blood from the wings is present in both wing-bearing segments of most adult insects, but only in the mesothorax of Diptera.



Leg pulsatile organ

Process of blood circulation:

Heart mainly function as a pulsatile organ whose expansion and contraction leads to blood circulation. It takes place generally in **ananti-clock** manner starting from posterior end to the anterior end in a forwarddirection. Circulation of blood takes place in two phases due to the action of the alarymuscles as well as the muscles of the walls of the heart.



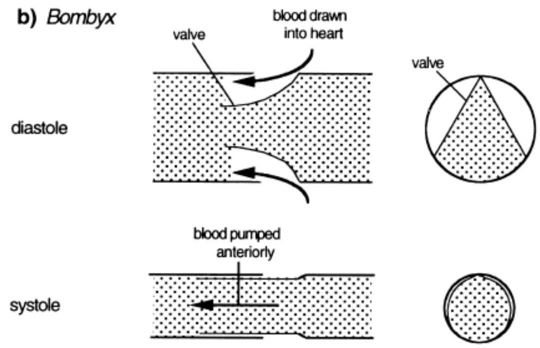
Diagrams of well-developed circulatory system. (Longitudinal section)

The two phases are

1. **Diastole**: During which expansion of heart takes place .
2. **Systole**: During which Contraction of heart takes place .

Diastole: Expansion of heart (diastole) occurs, when the alary muscles those are spread fan like over the heart and connected to the tergum get contracted. It results in increase of volume of heart and decrease in the area of pericardial sinus. This creates a pressure on the blood in pericardial sinus forcing the blood to enter into the heart through the incurrent ostia. These incurrent ostia allow only the entry of blood from the sinus in to the heart and prevents its backflow from the heart to the sinus.

Systole: Contraction of heart (systole), is brought about by the expansion of the alary muscles as well as contraction of the muscles of the heart wall. This creates pressure on the blood within the heart leading to its forward movement in to theaorta. From the aorta blood enters in to the head and flows back bathing the visceral .



Incurrent ostia of *Bombyx* shown during diastole and systole The valves are prevented from opening outwards at systole by a unicellular thread attached to the inside of the heart

Hemolymph

The blood, or hemolymph, circulates round the body, bathing the tissues directly. It consists of a fluid plasma in which blood cells, hemocytes, are suspended

Hemocytes

Suspended in the blood plasma are blood cells or hemocytes. Many different types of hemocyte have been described, but a comprehensive classification is difficult appearances under different conditions and a variety of techniques have been used in their study because individual cells can have very different appearances. There are six main types: 1.Prohemocytes, 2. Plasmatocytes, 3. Granulocytes (which are probably the same as cystocytes or coagulocytes), 4. Spherule cells (spherulocytes),

5. Oenocytoids and 6- Adipohemocytes.

Prohemocytes (stem cells) are small (10 µm or less in diameter), spherical, whose nucleus fills almost the entire cytoplasm. They are frequently seen undergoing mitosis and are assumed to be the primary source of new hemocytes and the type from which other forms differentiate.

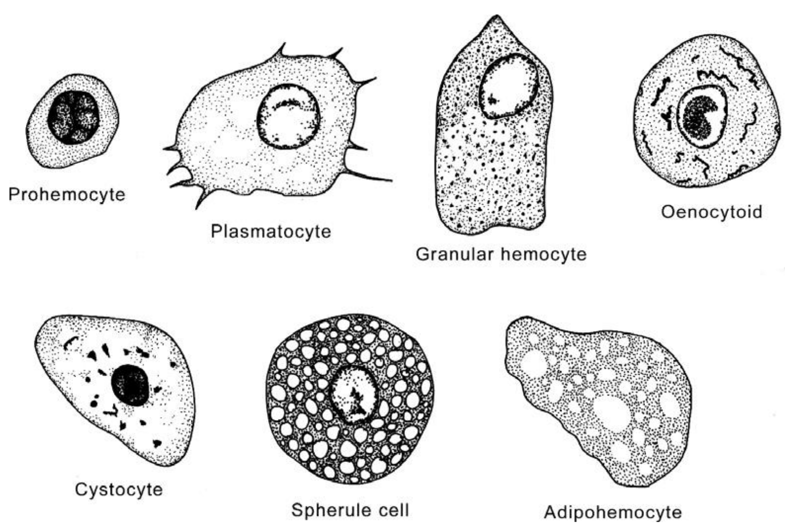
Plasmatocytes (phagocytes) are cells of variable shape and size, with a centrally placed, spherical nucleus surrounded by well vacuolated cytoplasm. The cells are capable of amoeboid movement and are phagocytic.

Granulocytes are usually round or disc-shaped, with a relatively small nucleus surrounded by cytoplasm filled with prominent granules.

Adipohemocytes are cell whose cytoplasm normally contains droplets of lipid. In addition to lipid droplets, the cytoplasm may have non-lipidvacuoles and granules that contain carbohydrate material.

Oenocytoids are spherical or ovoid cells with one, occasionally two, relatively small, eccentric nuclei.

Spherule cells are readily identifiable cells whose central nucleus is often obscured by the mass of dense spherical inclusions occupying most of the cytoplasm.



Different types of hemocytes.

Functions of blood:

1- Transport of minerals or food materials: blood transports minerals, digested products, hormones to different parts of the body.

2- Helps during the process of moulting for splitting up of the old cuticle.

3- Encapsulation: to protect from the large metazoan parasites, the haemocytes of blood, become aggregated around the foreign body forming a capsule of 2-3 layers. This leads to the death of the foreign bodies due to lack of O2 supply.

4- Phagocytosis: to get protection from microorganisms like bacteria, viruses and fungi, the haemocytes completely engulf the foreign body and gets autolysed (this is the principal function of haemocytes)

5- Immunity: blood gives immunity by producing antibodies to restrict further infections.

6- Thermoregulation (heat distribution, protection against freezing).

7- Wound healing (or) coagulation: haemocytes extend pseudopodia which forms a cellular network over the wounded site (or) plasmtocytes coagulate forming a plug over the wound (or) haemocytes are arranged in to multi layered sheaths over the wounded site, thus helping in wound healing.

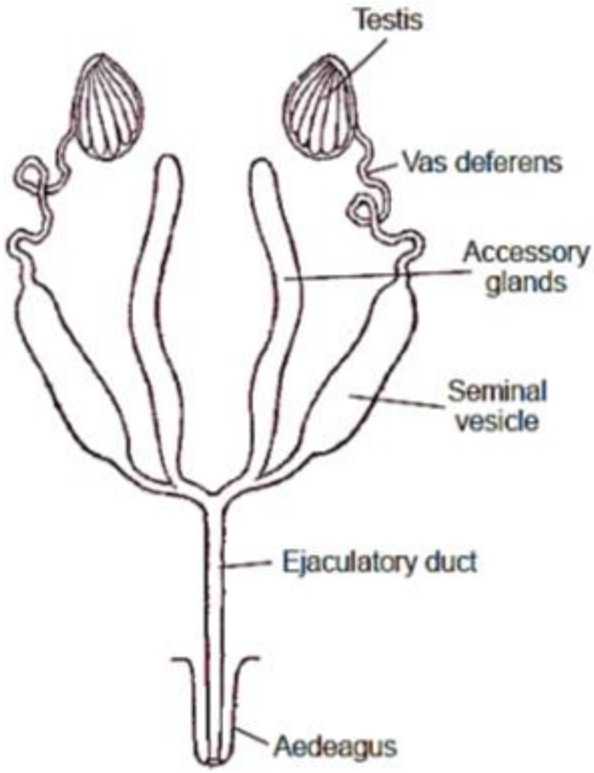
Reproductive system

The reproductive system is divided in to two parts namely **internal genitalia** and **external genitalia** . The internal genitalia serve to the development of germ cells. The external genitalia accomplish the union of two sexes and enable the female to deposit eggs.

Male reproductive system

The male reproductive organs typically consist of a pair of testes connecting with paired seminal vesicles and median ejaculatory duct (Fig.1). In most insects there are also a number of accessory glands which open into the vasa deferentia or the ejaculatory duct.

1-Testis: The testes may lie above or below the gut in the abdomen and are often close to the midline. Usually each testis consists of a series of testis tubes or follicles ranging in number from one in Coleoptera Adephaga to over 100 in grasshoppers (Acrididae). Each containing a series of testicular tubes or follicles (in which spermatozoa are produced), each individual follicle is divided into a series of zones (or) areas characterized by the presence of the sex cells i.e. sperms in different stages of development .



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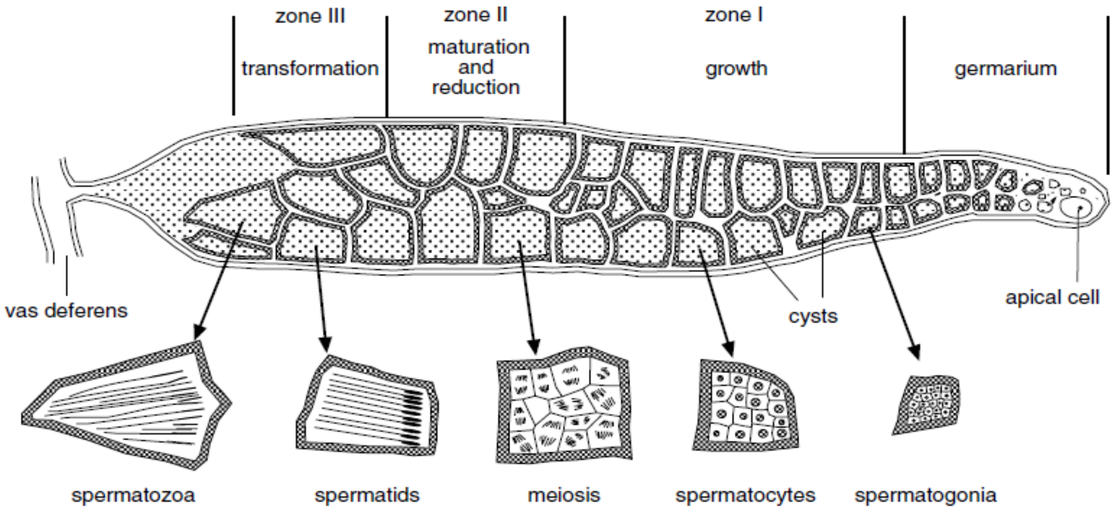
(i) Germarium: It is the region containing primordial germ cells or spermatogonia which undergo multiplication. (Zone of spermatogonia)

(ii) Zone of **growth**: It is the area where spermatogonia increase in size, undergo repeated mitosis and develop in to spermatocytes.(Zone of spermatocytes).

(iii) Zone of **division and reduction**: It is the area where spermatocytes undergo meiosis and give rise to spermatids (Zone of spermatids).

(iv) Zoneof **transformation**: It is the area where spermatids get transformed in to spermatozoa (Zone of spermatozoa). Spermatozoa are a group of cells which are enclosed in testicular cyst cells from which they are released in to **vasa efferens**, the tubular connections of the follicles which combine together to form the **vasa deferens,** which usually expands posteriorly to form a sperm-storage organ, or **seminal vesicle (**storage of spermatozoa for some time) **.**



zones of maturation in testis follicle.

2-Vas deferens: pair of simple tube leading away from testis. The vasa deferentia run backwards to lead into the distal end of the ejaculatory duct

and seminal vesicle

From each testis follicle,

vas efferens : a fine, usually short, arise from each testis follicle connects with the vas deferens .

The seminal vesicles, , are dilations of the vasa deferentia in many insects , in which sperm are stored before transfer to the female. The cellular lining of the seminal vesicles is glandular and in Drosophila is responsible for the secretion of male reproductive proteins.

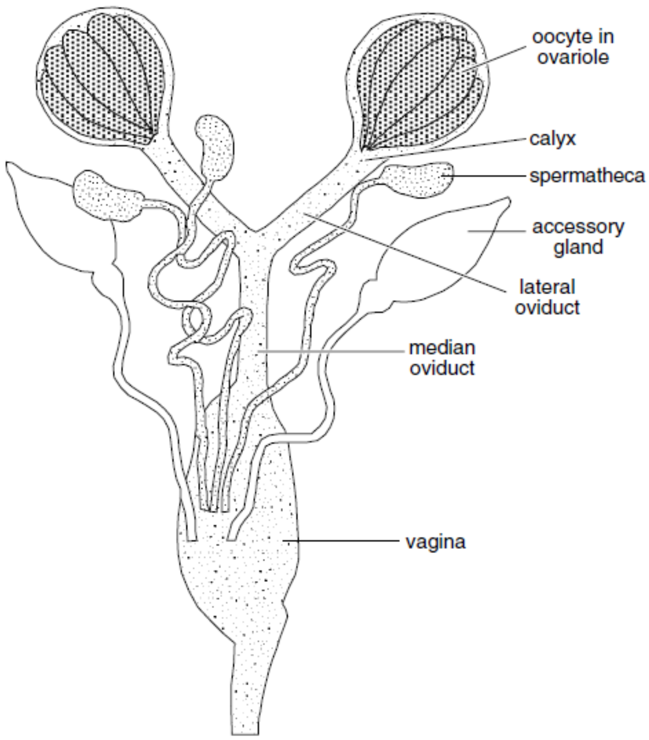
The accessory glands : The number and arrangement of accessory glands varies considerably between different groups of In Lepidoptera there is a single pair of glands become functional in the adult insect. Their secretions are involved in producing the spermatophore, where one is present,in providing nourishment and protection to the sperm, a Gryllus has over 600.

Sometimes there are no morphologically distinct accessory glands. This is the case in Apterygota,Ephemeroptera and Odonata, and muscoid Diptera.

Female reproductive system

The female reproductive system consists of a pair of ovaries, which connect with a pair of lateral oviducts. These join to form a median oviduct opening posteriorly into a genital chamber. Sometimes the genital chamber forms a tube, the vagina, and this is often developed to form a bursa copulatrix for reception of the penis.

Opening from the genital chamber or the vagina is a spermatheca for storing sperm, and, frequently, a pair of accessory glands is also present.



The ovaries: The two ovaries lie in the abdomen above or lateral to the gut. Each consists of a number of egg-tubes, or ovarioles, comparable with the testis follicles in the male. The oocytes develop in the ovarioles. The number of ovarioles in an ovary varies in relation to size and life style of the insect as well as its taxonomic position. The viviparous Diptera, *Glossina*, have only two in each ovary and some viviparous aphids have only one functional ovary with a single ovariole. At the other extreme are the queens of a queen honeybee have 150–180 ovariole.

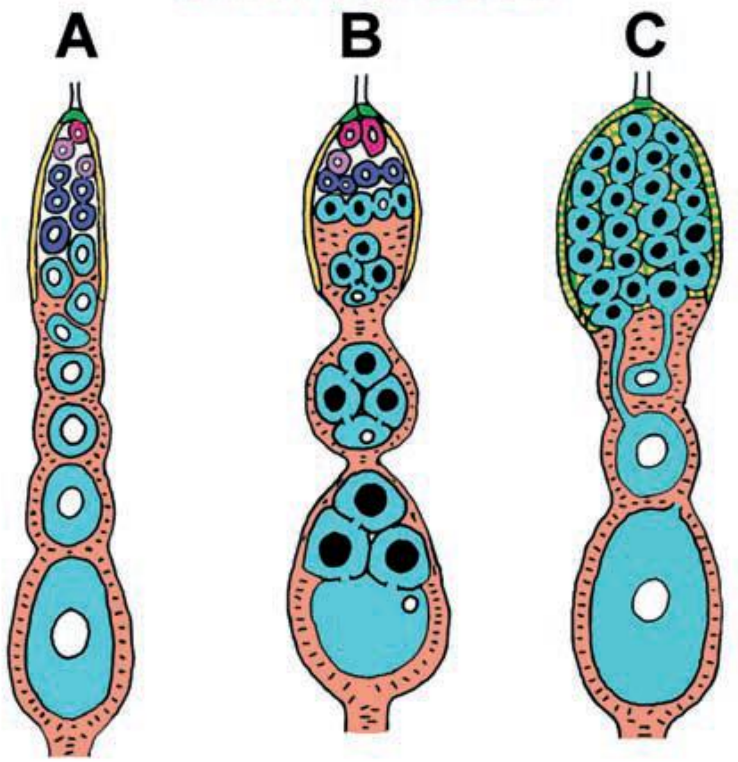
Types of Ovariole

Panoistic ovarioles : In these, the nutritive cells are absent and the development of oocytes takes place with the help of follicular epithelial cells e.g.: Odonata, Dictyoptera, Orthoptera and Ephemeroptera. (in which there are no special nurse cells) .

B- Polytrophic ovarioles : where developing oocyte and trophocytes arranged alternatively within the vitellarium.e.g.:.(Each developing egg is associated with an adjacent group of nurse cells which are responsible for producing some fractions of the yolk. (in which trophocytes are closely associated with each oocyte and are enclosed within the follicle.)

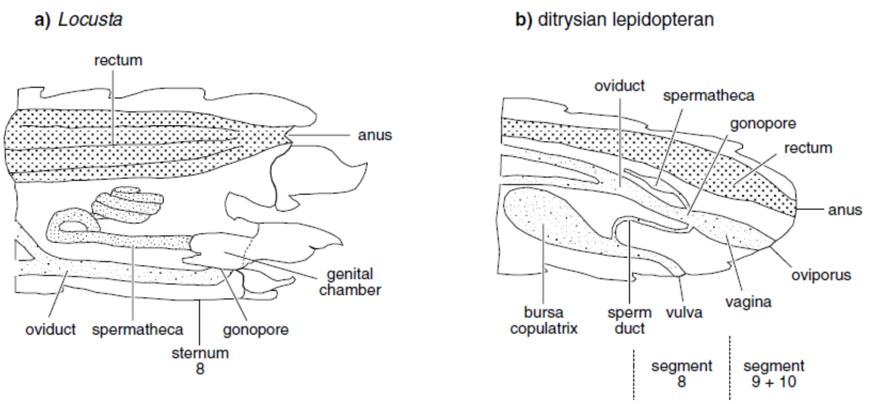
The number of trophocytes associated with each oocyte, is characteristic for each species. *Aedes* (Diptera) have seven trophocytes associated with each oocyte .

C-Teletrophic ovarioles where the trophocytes are present in the germarium (apex) and are connected with the growing or developing oocytes by cytoplasmic strands. e.g.: Hemiptera and Coleoptera.



Oviducts The oviducts are usually two lateral tubes join a median oviduct. The median oviduct is opens at the gonopore which, in Dermaptera, is ventral onthe posterior end of segment 7, but in most other groups opens into a genital chamber invaginated above the sternum of segment 8.

The females of the ditrysian Lepidoptera are unusual in having two reproductive openings. One, on segment 9, serves for the discharge of eggs and is known as the oviporus; the other, on segment 8, is the copulatory opening, known as the vulva. The latter leads to the bursa copulatrix which is connected with the oviduct by a sperm duct.



Spermatheca :

A spermatheca, used for the storage of sperm from the time the female is inseminated until the eggs are fertilized, is present in most female insects. Typically, it consists of a storage pouch with a muscular duct leading to it. A gland is often associated with it, or the spermathecal epithelium may itself be glandular. The contents of the spermatheca, derived from the glands, are known to contain several proteins and include a carbohydrate–protein complex. The functions of these secretions are not known for certain, but they probably provide nutrients for the sperm during storage.

Accessory glands: Female accessory glands often arise from the genital chamber or the vagina. Where such glands are apparently absent the walls of the oviducts may themselves be glandular. This is the case in grasshoppers where the lateral oviducts also usually have a wholly glandular anterior extension (1a).

Role of the accessory glands

The function of the female accessory glands is generally to fix eggs in position or protect them from desiccation and predators. Many insects attach their eggs on or close to the larval food source. Lice fix their eggs to hairs; many plant feeding Heteroptera and Lepidoptera lay eggs on the host plant. The glue holding the eggs in position comes from the female accessory glands.

In *Chrysopa* (Neuroptera), the eggs are laid on tall stalks formed from silk produced in the accessory glands.

Oothecae Species from several insect groups lay their eggs in oothecae formed by secretions of the female accessory glands. Oothecae are produced by a majority of Blattodea, Mantodea These structures have precise and characteristic forms which permit respiration by the eggs and the escape of the newly hatched larvae while, at the same time, protecting them from desiccation and from predators.

Oogenesis

Each ovariole consists of a distal germarium in which oocytes are produced from oogonia, and a more proximal vitellarium in which yolk is deposited in the oocytes. The germarium contains prefollicular tissue and the stem line oogonia and their derivatives. The stem line oogonia are derived directly from the original germ cells .The vitellarium in a mature insect forms by far the greater part of the ovariole. An oocyte with its surrounding follicular epithelium is termed a follicle.

Ovulation

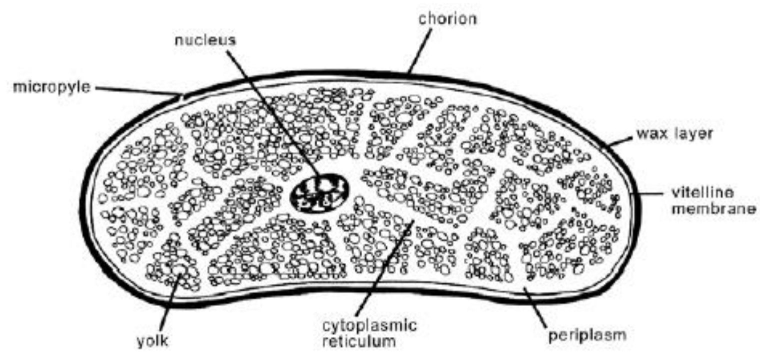
The passage of the oocyte into the oviduct, a process known as ovulation, involves the oocyte's escape from the follicular epithelium and the breakdown of the epithelial plug at the entrance to the pedicel.

Fertilization Of The Eggs

The egg is fertilized as it passes into the genital chamber when a few sperm are released from the spermatheca. The release of sperm in *Schistocerca* is in direct response to mechanosensory input produced by an egg entering the genital chamber. In the some insects, the female clearly has the capacity to release or withhold sperm according to environmental cues.

Male Hymenoptera are haploid, developing from unfertilized eggs. Queen bees lay male eggs in large cells in the comband female eggs in smaller cells. Sperm entry to the oocyte is facilitated by the orientation of the egg in the genital chamber where the micropyles are aligned opposite the opening of the spermathecal duct.

Egg structure. The egg of an insect is a cell with two outer coverings, a thin vitelline membrane surrounding the cytoplasm and an outer chorion. The chorion, which is the hard outer shell of the egg, has a minute pore or set of pores (the micropyle) at one end, through which sperm enter the egg . just inside the vitelline membrane is a layer of cortical cytoplasm. The central portion of the egg, inside the cortical cytoplasm, is largely yolk.



Special Forms of Embryonic Development

Insects are bisexual; they can undergo sexual reproduction for producing either the eggs (or) the young ones. However they also reproduce by other means. Different types of reproduction in insects are:

1. Oviparity: Insects reproduce by laying eggs by the female on any substrate either singly (or) in mass (or) in groups which later hatch and produce the young ones. e.g.: moths and butterflies.

2. Viviparity: fertilized eggs may be retained within the female reproductive tract for varied periods of time so that a young insect may hatch from the egg almost as soon as or even before the latter is laid.

3. Parthenogenesis : females may produce viable offspring from unfertilized eggs. It has been recorded from all the insect orders except Odonata, Dermaptera, Neuroptera.

4. Paedogenesis : It is a phenomenon where the immature insects or stages give birth to young ones. This usually occurs due to the hormonal imbalance.Most of the insects which reproduce by paedogenesis also reproduce by parthenogenesis. e.g.: cecidomyids.

5. Polyembryony :several embryos develop from one fertilized egg as in parasitic Hymenoptera