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HIGHLIGHTED HANDOUT

ZOO518T

Applied Entomology and Pest Management (Theory)

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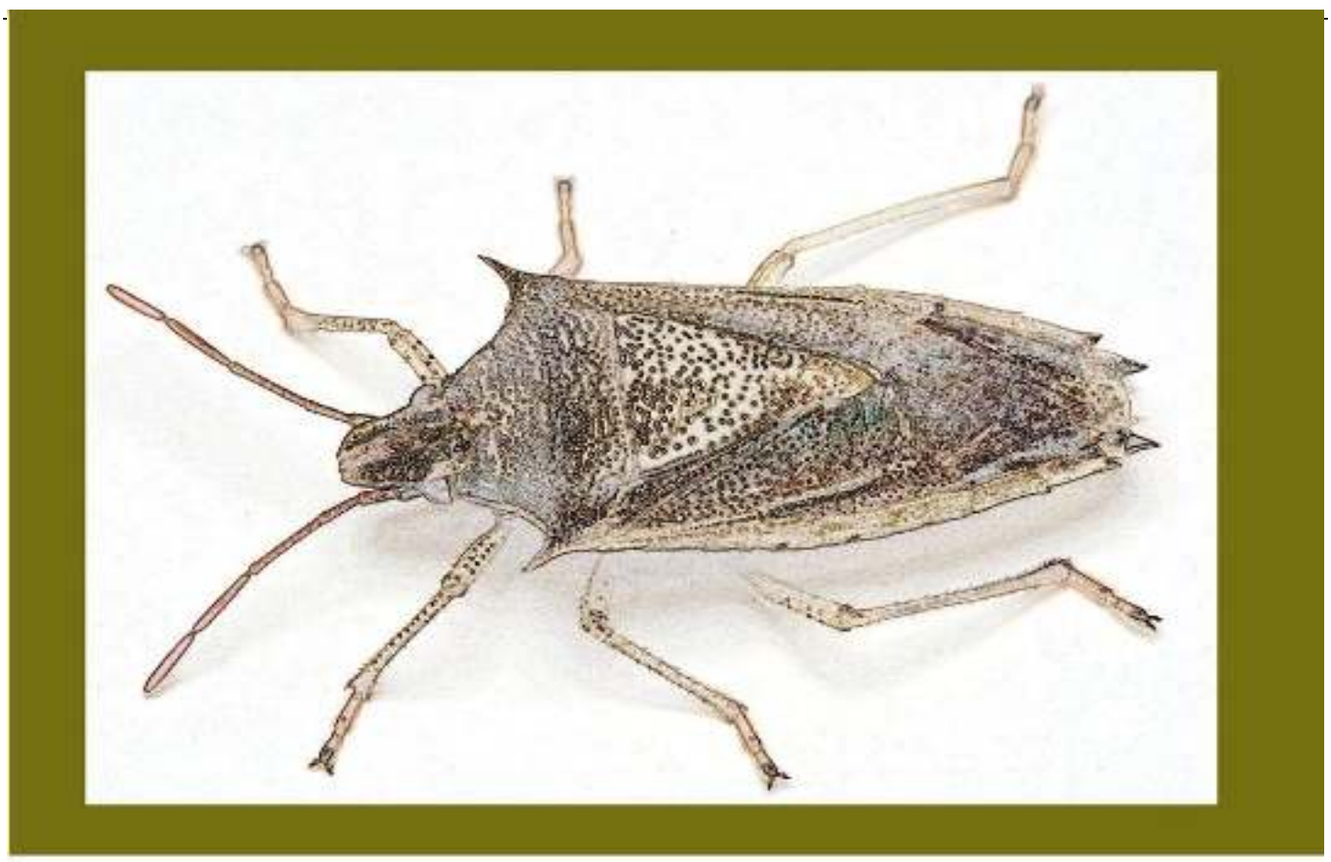
M.SC ZOOLOGY

ZOO506-Applied Entomology And Pest Management



Entomology and Pest Management

HANDOUTS TOPIC NO 1 TO 134

MUHAMMAD IMRAN

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Topic no 1 to 59 mid term and 60 to 134 final term syllabus

ZOO506-Applied Entomology And Pest Management

1-Relationship of insects with other animals

Groups of animals

Among the larger groups of animals now recognize~ by science, the one known as the Chordata is naturally the most familiar Including the mammals, birds, reptiles and fishes, besides numerous forms less well known Another group, also familiar, called the Mollusca, includes the snails, clams, etc The starfish and sea urchin, often seen at the seashore, belong with other similar animals to a third group called the Echinodermata A multitude of tiny beings, almost all too small to be seen without the aid of a microscope, are included 'in the group Protozoa A fifth large group is composed mainly of soft, jellylike animals, the more common larger members being called jellyfish, and to this group the name Coelenterata is applied.

Several other groups including various kinds of worms and less familiar forms are also known Arthropoda

The largest group of all, however, is the Arthropoda

Its members found in the seas, in fresh water, on land or even flying freely

A group with remarkable differences of structure, and so abundant that all the other animals taken together are less than one-sixth as many as the arthropods

Well-known members of this group are

The lobsters, cray fish and crabs

Scorpions, spiders, mites, ticks

The centipedes and millipedes

Last, and most abundant of all, the insects

2-Characteristics of Arthropod

No one feature will serve to separate the arthropods from' all other animals

But the possession by an animal of several of those here described will enable the observer to determine in each case whether he is examining one of this group.

In arthropods the body is composed of a series of more or less similar pieces or segments

Placed one behind another, the line of attachment of these to each other being usually somewhat evident on parts of the body at least

This character is also shown, and indeed more clearly, in some worms, such as the common earthworm Another character of the arthropods is the presence of jointed legs (or appendages of some kind), as is indicated by the name of the group, and these are not possessed by worms

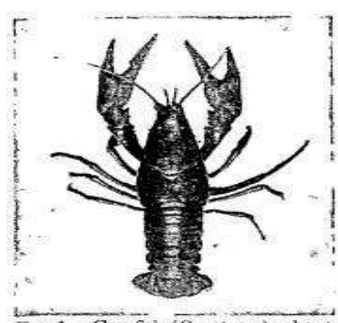

FIG. 1.—Crayfish (*Crustacea*); about one-half natural size.

The surface of the body is covered by a secretion which hardens on exposure to the air, forming an outside shell or external skeleton called exoskeleton

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There being practically no internal structures supporting the soft organs within this shell except as ingrowths from the outside

Distinctive Characters of Arthropods Groups

INSECTS AND OTHER ANIMALS 5

DISTINCTIVE CHARACTERS OF THE MAIN ARTHROPOD GROUPS

	Where found	Body divisions	Antennae	Legs	Breathe by	Reproductive organs open
Crustacea	Mainly in water	Head and body: often a cephalothorax	Two pairs generally	Numerous: may be built for swimming	Gills or through body surface (rarely by air tubes)	Well forward
Diplopoda	On land	Head and body	One pair	Many: two pairs on most body segments	Air tubes	Near head
Chilopoda	On land	Head and body	One pair	Numerous: one pair on each body segment	Air tubes	Next to last body segment
Arachnida	Mainly on land	Cephalothorax and abdomen (no divisions in a few cases)	None	Eight: joined to cephalothorax	Air tubes, book lungs or body surface	Front part of abdomen (a few exceptions)
Hexapoda	Mainly on land	Head, thorax, abdomen	One pair	Six: joined to thorax	Air tubes	Near hind end of abdomen

3-Characteristics of Arthropod II

In the possession of this external skeleton these animals have a seeming resemblance to the shells (Mollusca) But the materials of which the skeleton is composed are quite different Being largely calcium carbonate in the Mollusca And chitin which somewhat resembles horn in its nature, sometimes with calcareous salts·deposited in it, in the Arthropoda .The simple members of arthropod have bilaterally symmetrical body, though this condition is concealed somewhat by secondary changes in many of the group .The possession of a bilaterally symmetrical body consisting of a series of segments, an exoskeleton of chitin and the presence of jointed legs are, then, distinctive features of the arthropods .To separate the various groups of arthropods, other characters must be Used Aside from several small sections not often seen, there are five large and important divisions which call for recognition

Groups of Arthropods

1. The Crustacea, including the lobster, crab, beach flea, sowbug and many Others
2. The Diplopoda or millipedes
3. The Chilopoda or centipedes
4. The Hexapoda or insects
5. The Arachnida, including the scorpions, pseudo-scorpions, spiders, mites, ticks, etc.

4-Crustacea

The Crustacea are mainly water-inhabiting animals which breathe either by gills or, in the smaller forms, through the surface of the body

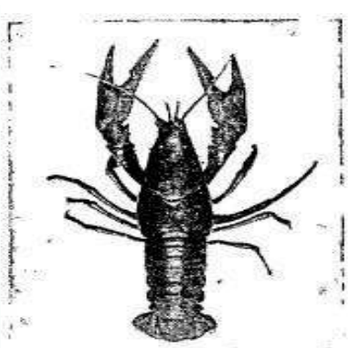


FIG. 1.—Crayfish (*Crustacea*); about one-half natural size.

In those cases where its members live on land the gills are still present, though in a somewhat modified condition.

FIG. 2.—Sow-bug; slightly enlarged. A crustacean living on land.

They have numerous pairs of legs and generally two pairs of antennae (jointed "feelers")

Often some of the bug; body segments are fused with the head to form a crustacean cephalothorax

5-Diplopoda

The Diplopoda are land animals breathing by air tubes opening on the sides of the body, these tubes carrying the air into all the internal parts of the animal

The head bears a pair of antennae and is followed by a series of segments all practically alike and each, except the first three, with two pairs of legs

The reproductive organs open far forward on the body

In most of the more common members of this group the body is quite cylindrical, and when disturbed the animal usually curls up in a sort of close spiral

Small diplopods about the diameter *of the lead of a pencil and gray in color are often found boring* into potatoes and roots in the ground In the fall and are sometimes wrongly called wireworms

The Common name, millipede, refers to the large number of legs possessed by these animals

6-Chilopoda

The Chilopoda are also land animals

Like the diplopods they have antennae and breathe by air tubes, and the body segments are practically all alike

The general form, however, is rather flattened

Each segment bears only one pair of legs The reproductive organs open at the posterior end of the body The front leg on each side is modified to serve as a poison claw The numerous legs present in these animals have resulted in their receiving the common name, centipede

7-Arachnida

The Arachnida generally have the segments of the body grouped into two sections called

1-The cephalothorax

2-The abdomen.

FIG. 5.—Hairy spider (*Arachnida*); about natural size.

FIG. 6.—Large-bodied spider (*Arachnida*); about natural size.

FIG. 7.— Adult female castor-bean tick (*Arachnida*); natural size. (*From U.S. Dept. Agr. Farmers' Bull.* 1057.)

FIG. 8.—Adult female European dog tick (*Arachnida*); natural size. (*From U.S. Dept. Agr. Farmers' Bull.* 1057.)

No antennae are present and the eight legs are all attached to the cephelothorax

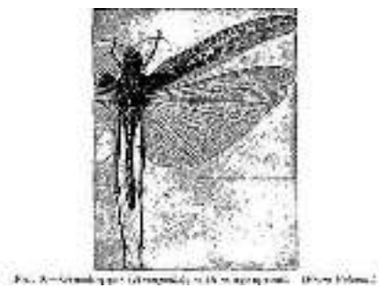
They breathe by air tubes somewhat similar to those of the other groups

By sacs containing many thin plates resembling leaves of a book, whence these structures take the name of book lungs In the smallest forms, they directly breath through the body surface In the mites there is no evident division of the body into sections .Though most of the group are land forms, a few are aquatic

8-Hexapoda

In the Hexapoda or insects the segments of the body are grouped in three distinct sections:

1. Head
2. Thorax
3. Abdomen



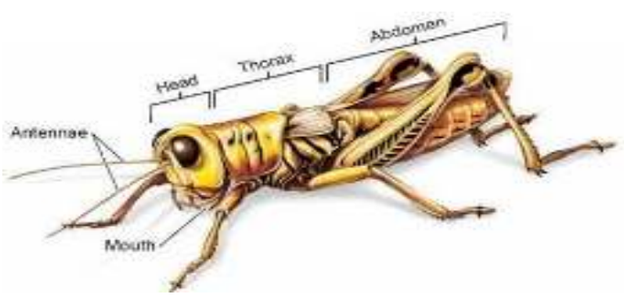
- A pair of antennae is present on the head
- The six legs are attached to the thorax
- The four wings usually present
- The animals breathe by air tubes

Insects living under a great diversity of conditions, the group as a whole is emphatically a terrestrial one though in many cases their early life is spent in water

9-General features of Insects

THE INSECT: ITS EXTERNAL STRUCTURE

Bringing together the facts already stated about insects we find that an adult insect is: a bilaterally symmetrical animal consisting of a series of segments one behind another;



that these segments are grouped into three regions, The head in front Followed in order by the

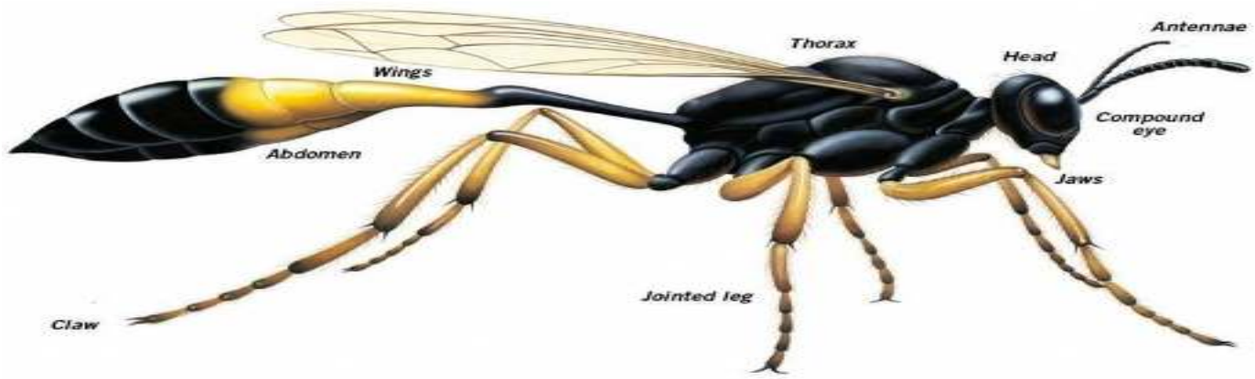
thorax

The abdomen as shown in Fig

that the animal is covered by a skeleton, shell-like in that it is on the outside of the body, but horny in
its nature

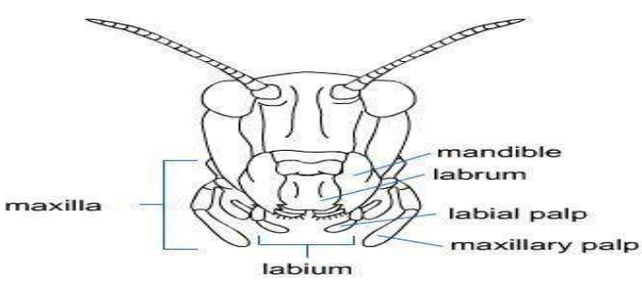
10-General features of Insects

three pairs of jointed legs attached to the thorax

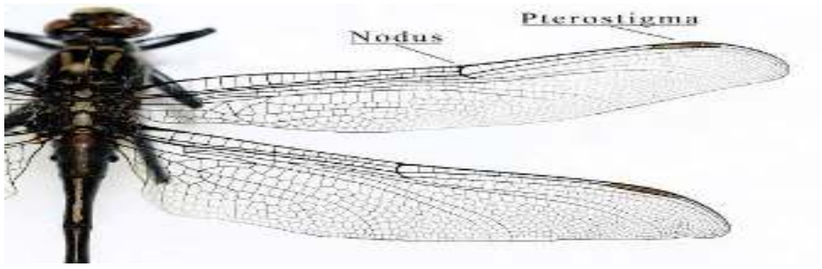


that a pair of antennae

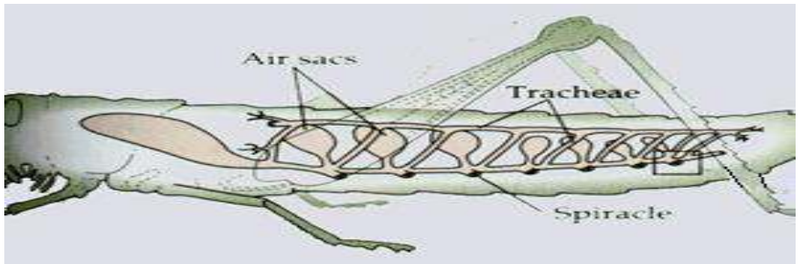
mouth parts



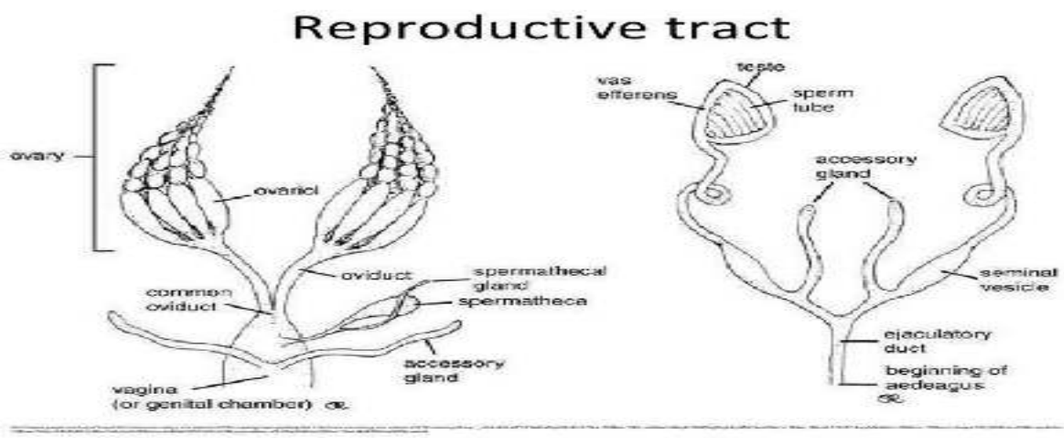
and usually two pairs of wings are present



that it breathes through air tubes



that the reproductive organs open near the hinder end of the body.



11-General Segmentation in Insects

In the body of the adult insect there are apparently from 7 to 15 segments

1 in the head, 3 in the thorax and from ,3 to 11 in the abdomen

In the egg, however, the embryo shows the presence of 6 segments in the head, 3 in the thorax and 11 or 12 in the abdomen

Indicating that the original total number was 21

This change to the adult has been brought about in the head by an extreme amount of fusion and condensation and in the abdomen partly by fusion

Partly by a sort of telescoping or gradual shifting of one segment within another until it has been partly or entirely concealed

12 13-Cuticle or External Skeleton

The skeleton of the body, or cuticula as it is called, supports and protects the soft, living tissues within it

It rests on the outer surface of a layer of living cells, the hypodermis

It seems to be formed in part from a fluid poured out from the hypodermis and in part by a transformation of a portion of the hypodermis cells themselves

The cuticula hardens quickly after its production and consists quite largely, at least, of a nitrogenous substance called chitin

It varies in thickness and is flexible where movement is needed, but thicker, more rigid and usually darker colored elsewhere

The hypodermis along certain lines forms folds which project inward, carrying its cuticular secretion along with it

Where these infoldings occur at places that need to be movable the cuticula remains flexible

Thus forming the movable joints; along the other infoldings it hardens (becomes sclerotized) and becomes rigid and such places show on the surface only as slight grooves or scratches called sutures

These sutures and the joint lines divide the cuticula into areas called plates or sclerites

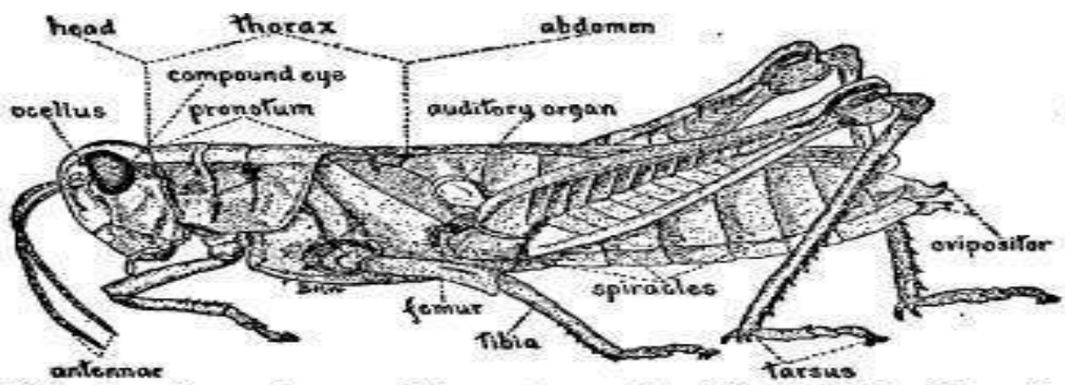
The sutures and joint lines are sufficiently regular in position in most insects to make them convenient landmarks in descriptions

The sclerites on the back of each segment are usually together termed the notum or tergum; those on each side, the pleuron; and those below, the sternum

In the head the sutures are few in number, so only a few plates or sclerites are gener ally in evidence

In the thorax they are more numerous, and in the abdomen often only a dorsal and aventral sclerite for each segment are found

Occasionally weakly sclerotized areas are quite large (queen white ant) *and elastic.*



10.—Side view of grasshopper with parts named. (*From Walden, Conn. Geol. & Nat.*

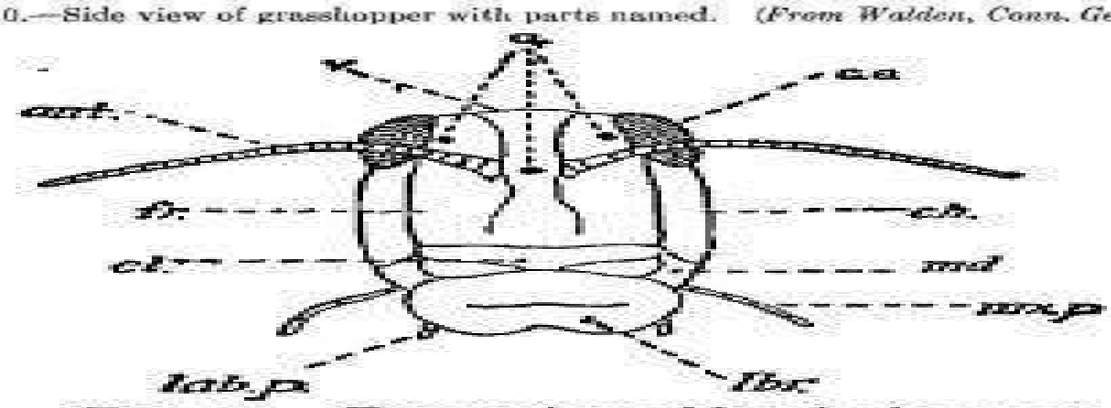


FIG. 11.—Front view of head of a grasshopper showing a hypognathous head: ant., antenna; c. e., compound eye; ch., cheek; cl., clypeus; fr., frons; lab. p., labial palpus; lbr., labrum; md., mandible; mx. p., maxillary palpus; o., ocelli; v., vertex.

14-Structure of Head

The heads of different insects vary much in form and in the location of the mouth In some cases this is on the underside; in others it is practically on the front.

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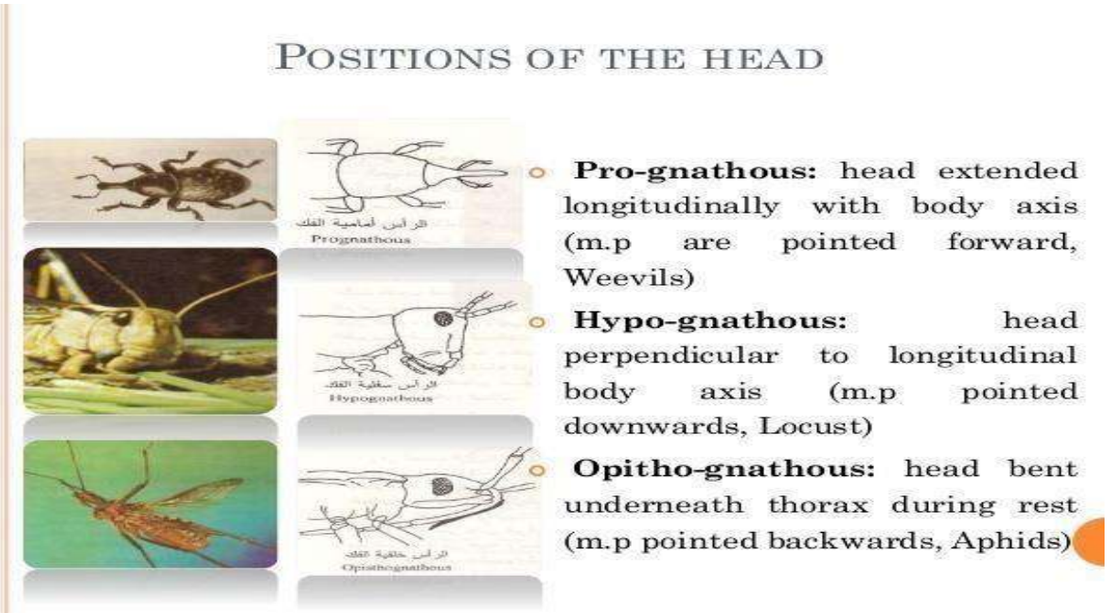


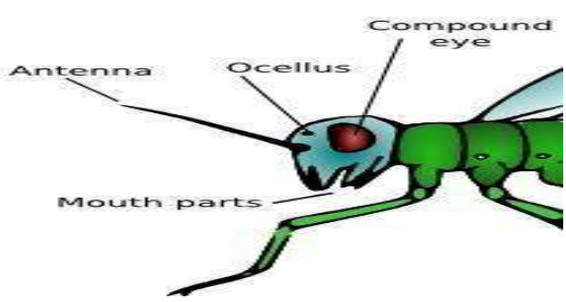
Heads with the mouth beneath are called hypognathous those with it in front are prognathous.

Structures found on the head are

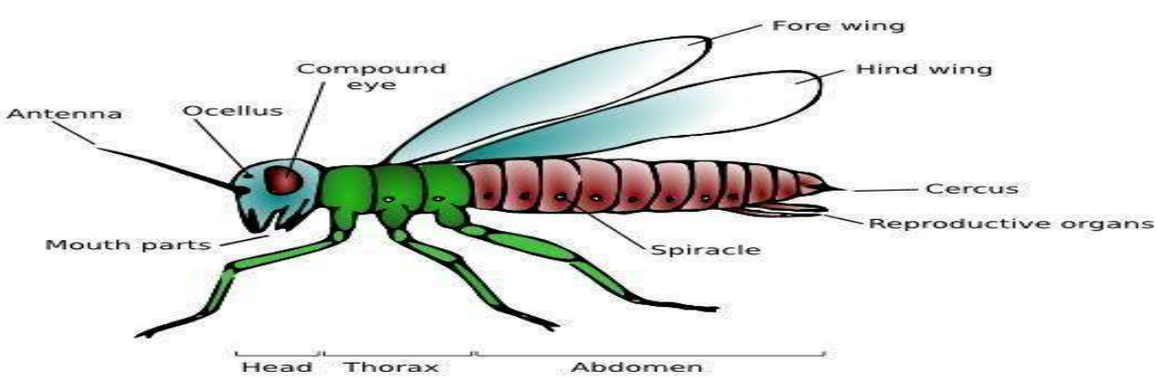
A pair of antennae

Two compound eyes (ocelli)

The mouth parts



On the thorax are the wings and legs; on the abdomen are various organs such as the ovipositor, sting, cerci and styli, present in some cases, absent in others.



15-Antennae

Antennae are nearly always present

They are usually slender, jointed

Therefore more or less flexible organs, varying greatly in the number of segments composing them

They are sometimes very short; sometimes long; often thread-like; sometimes enlarged near the tip; in many cases with fine branches either on one or both sides, so that they resemble feathers or plumes; rarely they fork; in fact they arc of many forms

FIG. 14.—Antenna of cecropia moth. (*Samia cecropia* L.) About twice natural size.

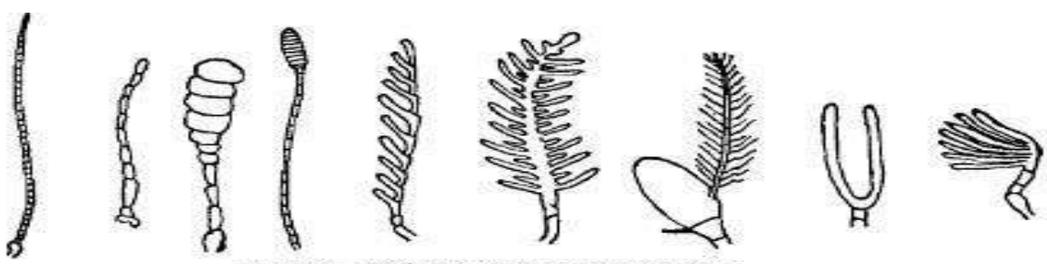


FIG. 13.—Different forms of insect antennæ.

Sense organs are present on them for the sense of touch, and probably also for smell and hearing, at least in Some cases

16-Eyes

The eyes are of two kinds

There is a pair of compound eyes, each of which is a group of similar structures which usually are like tall, slender pyramids in form

Only the bases of these pyramids Show on the surface, the remainder being within the head

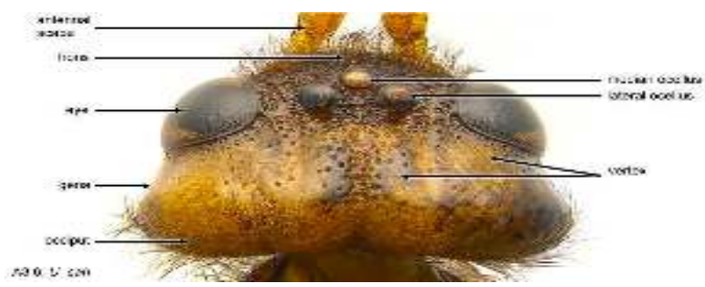
The bases, closely pressed together, are usually more or less hexagonal, and their outlines can often be easily seen with a magnifying glass

They are called facets, and the eyes themselves are sometimes termed the faceted eyes

The other kind of eyes, called Ocelli, may be absent or, if present, may vary in number in different insects, three being perhaps the most usual.

Each, as seen from "the surface, is a nearly circular, convex spot about the size of one of the facets of a compound eye

It may be larger than this but is never equal to an entire compound eye in size



The cuticula of the surface of the body is transparent where it covers the surface of an eye, permitting access of light to the sensory structures within; elsewhere it is usually pigmented and rather opaque

17 18 19-Mouth parts of insects

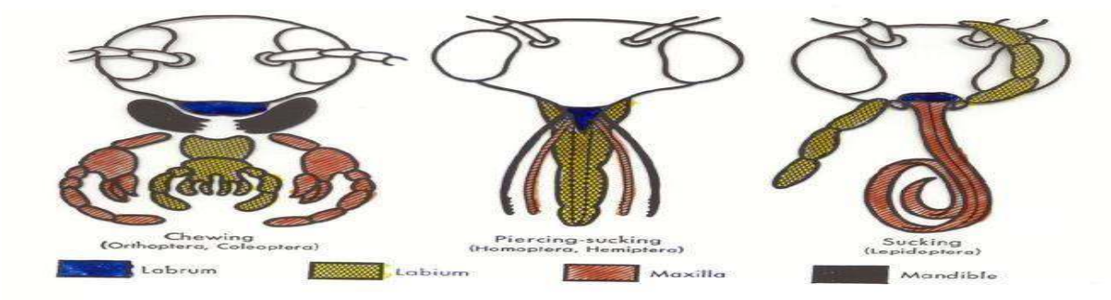
The mouth parts of insects vary extremely in their structure

Apparently the original mouth parts were for biting and chewing, and this type is very common

In some groups, however, they have been transformed into a sucking apparatus

Biting mouth parts, being the more primitive and simple, are described here

While sucking mouth parts having been differently transformed in different groups will be taken up in connection with those groups



In front of (in hypognathous heads) or above the mouth opening (prognathous heads) is the front lip or labrum

It is a thin flap, hinged to the skeleton of the head, and moves forward and backward

Attached on the outer side of each maxilla, not far from where the latter articulates with the head, is a sort of tiny antenna like structure consisting of from one to six (usually five) segments, which is called the maxillary palpus

Behind the maxillae and closing the mouth opening behind, is the hinder lip or labium

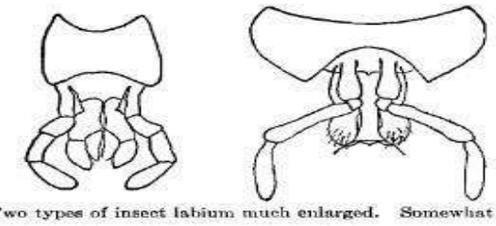


FIG. 17.—Two types of insect labium much enlarged. Somewhat diagrammatic.

It is often more or less divided by a central notch at the middle of its free edge Its inner surface, forming the roof of the mouth, is often called the epipharynx

At the sides of the mouth opening, immediately behind the labrum, is a pair of jaws, the mandibles These differ greatly in form in different insects

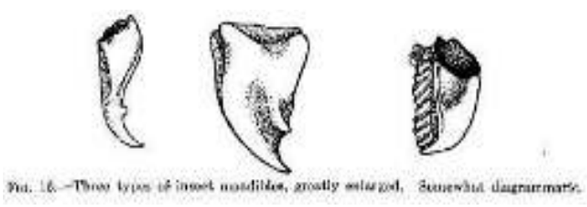


FIG. 18.—Three types of insect mandibles, greatly enlarged. Somewhat diagrammatic.

They are often stout, heavy structures with crushing faces bearing blunt projections or teeth; sometimes they are long, curved and rather slender

In general their form is adapted to the feeding habits of the insect

Immediately behind each mandible at the side of the mouth is a second appendage, the maxilla

This differs markedly from the mandible) being much weaker and composed of a number of pieces

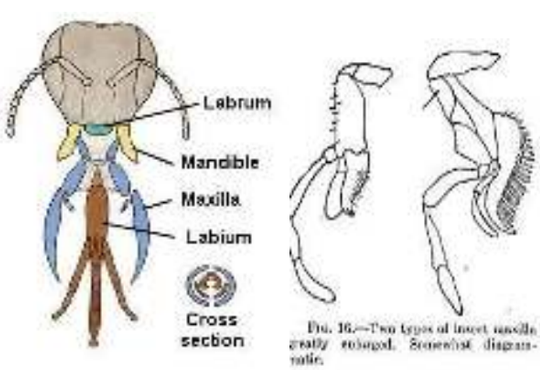


FIG. 16.—Two types of insect maxilla, greatly enlarged. Somewhat diagrammatic.

The tips and outer internal margins of the maxillae usually bear numerous spines or hairs

But this condition varies according to the nature of the food of the insect

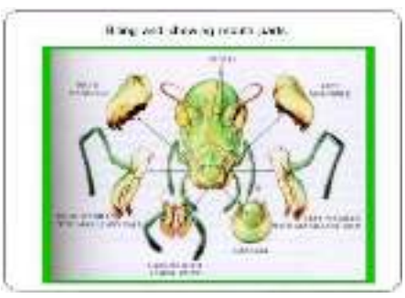
This was evidently once a pair of jaws somewhat similar to the maxillae, but with no mouth cavity between to separate them their inner edges have grown together to varying degrees in different insects

In some, only one or two of the pieces nearest the head have fused

In others, fusion all the way to the tip has been accomplished; and all intermediate stages also occur

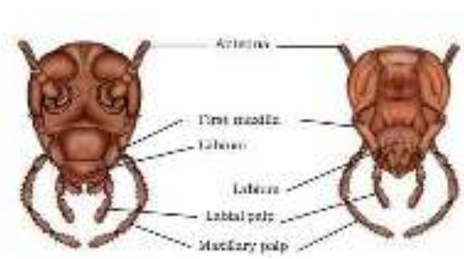
Thus producing a structure which now moves forward and backward like the front lip, but which may be complete, or partly or almost entirely cleft in the middle line

The function of the maxillae appears to be to hold and retain the food in the mouth while it is being worked upon by the mandibles, and also to aid these in breaking it up



The presence of sense organs on the maxillary palpi suggests that these are possibly concerned with the sense of smell

Both mandibles and maxillae move sideways



Like the maxilla the labium has li, pal pus on each side arising from near its base, and composed of three (rarely four) segments

The function of these labial palpi appears to be similar to that of the maxillary palpi

Near the base of the labium on its inner or mouth side there is frequently a fleshy swelling more or less covered by bristles or hairs, which is called the hypopharynx, lingua or tongue

It varies greatly in size and form

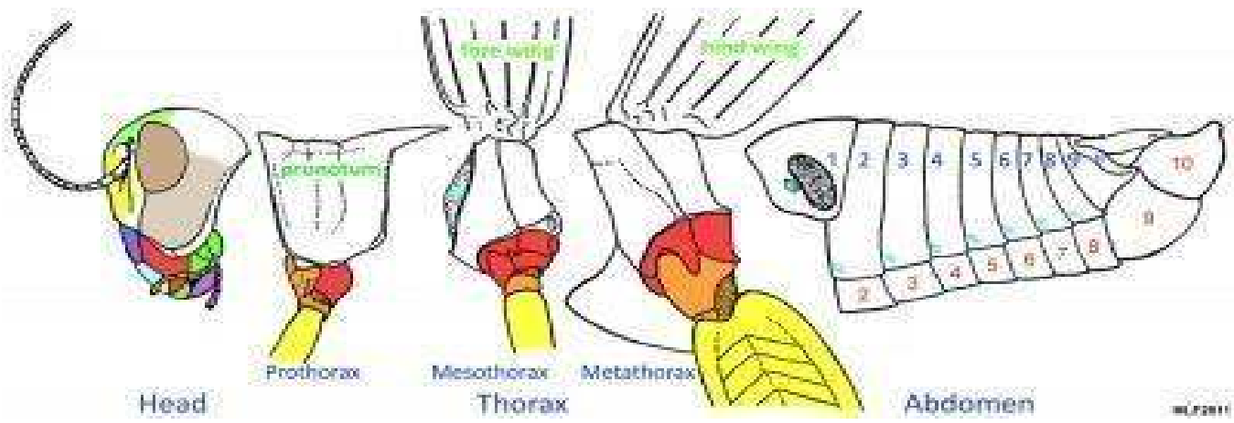
20-Structure of Thorax

The thorax has its three segments usually quite clearly marked

1-Prothorax

2-Mesothorax

3-Metathorax



Each segment bears a pair of legs, but the prothorax, or first of the three behind the head, bears no wings

On the second, or mesothorax, and on the third, or metathorax, both wings and legs occur in the majority of insects

There is a tendency in some groups, carried farthest in the higher Hymenoptera, for the first segment of the abdomen to consolidate more closely with the metathorax

Than with the second abdominal segment, which in such cases is often slender and gives thereby a semidetached appearance to the rest of the abdomen

As though the line of division between thorax and abdomen were at that place instead of farther forward

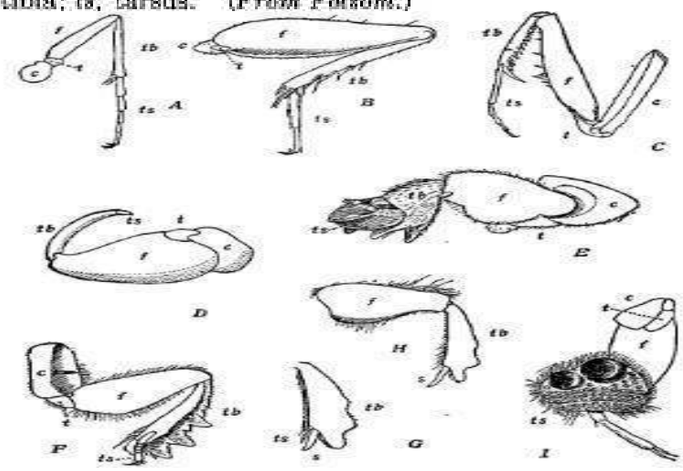
The first abdominal segment, when seemingly more apart of the thorax than of the abdomen, is called the median segment or ropodeum

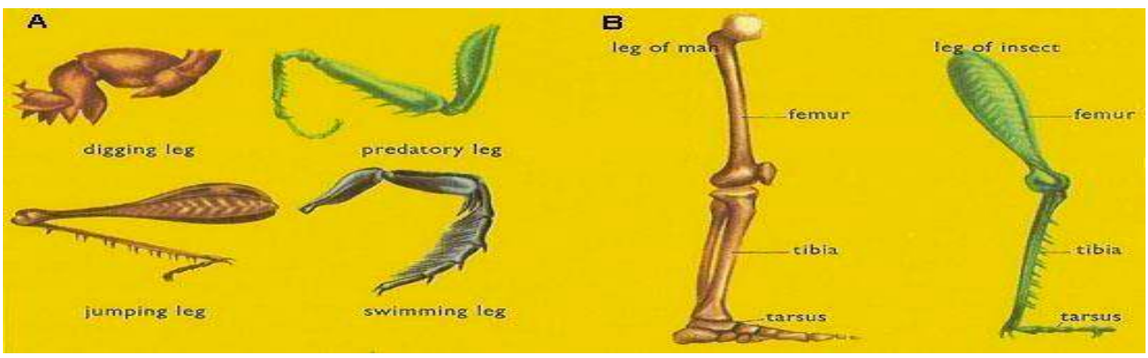
21 22 -Structure of Legs

The three pairs of legs may be quite similar or differ widely, according to the uses to which they are put In running and walking insects they are usually most similar But when, for example, the forelegs are used for capturing other insects, their form will depart greatly from that of the others The jumping power of the grasshopper is due to the great development of its hind legs as compared with its others

Different types of legs are shown in Figure

FIG. 18.—Different forms of insect legs: *A*, *Cicindela sexguttata* Fab. (beetle); *B*, *Nemobius fasciatus* De G. (cricket) hind leg; *C*, *Stagmomantis carolina* L. (mantis) foreleg; *D*, *Pelocoris femoratus* P. B. (carnivorous bug) foreleg; *E*, *Gryllotalpa hexadactyla* Perty (mole cricket) foreleg; *F*, *Canthon lævis* Dru. (a digging beetle) foreleg; *G*, *Phanæus carnifex* L. (a digging beetle) fore tibia and tarsus of female; *H*, same, fore tibia of male; *I*, *Dytiscus fasciventris* Say, male (water beetle) foreleg. *c*, coxa; *f*, femur; *s*, spine; *t*, trochanter; *tb*, tibia; *ts*, tarsus. (*From Folsom.*)

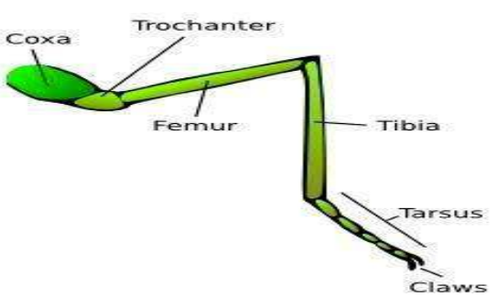




Whatever may be the variations in form and details of the legs

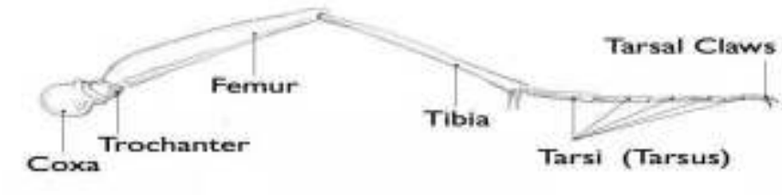
All are composed of a definite number of pieces or segments, connected by hinge joints so arranged that, by combining the motions of these a leg can be placed in nearly in any position desired The leg is composed of coxa trochanter (two in a few cases), femur, tibia tarsus

The last is really not a single segment but a row of from one to five, small, and on the whole rather resembling each other.



The coxa is the segment that articulates with the body, frequently partly lying in a more or less cupshaped hollow of the latter

It may be short or long and is generally freely movable on the body and powerful

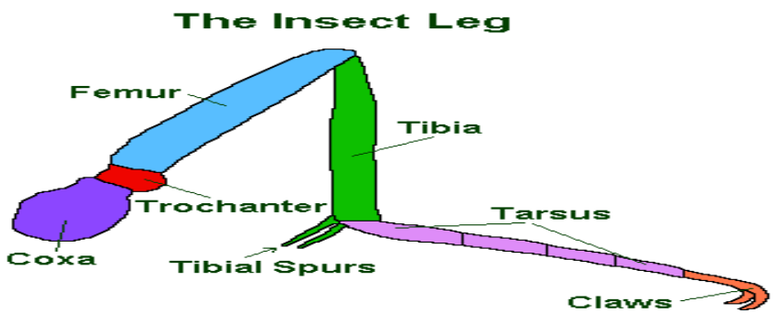


The trochanter is usually small and may not be visible on all sides of the leg

It is followed by the femur, generally the largest and stoutest, but not often the longest leg segment

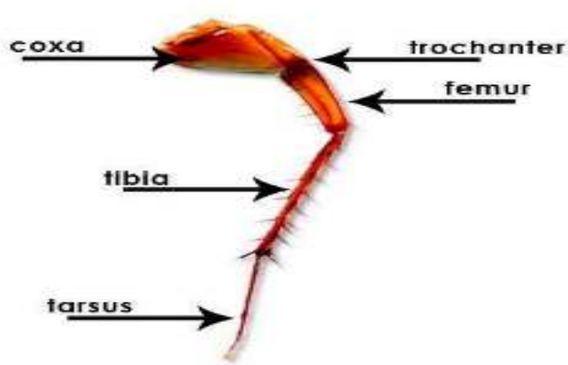
The tibia is in most cases quite long, more slender than the femur and often provided with downwardly projecting spines or other structures which are of assistance to the insect in climbing plant stems and other objects, to help prevent slipping

The tarsal segments are generally rather small, short, tend to be broadest at their outer ends and vary greatly in details of structure

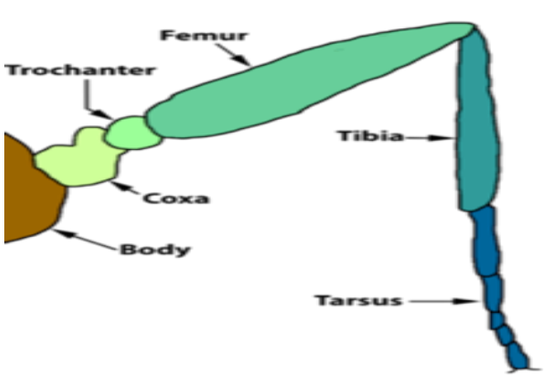


At the end of the last a pair of claws is generally found, and between them a sort of pad or cushion, the pulvillus

Sometimes there are three of these, in which case the outer ones are called the pulvilli and the middle one the empodium



Where the tarsi are reduced to a small number of segments, only one claw may be present.



23 24 -Structure of Wings

The wings are chitinous outgrowths from the body which vary much in size and form in different insects

Each consists of two delicate membranes in contact with each other except along certain lines

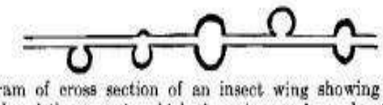


FIG. 20.—Diagram of cross section of an insect wing showing the two membranes somewhat separated and the ways in which the veins are formed. (*Modified from Woodworth.*)

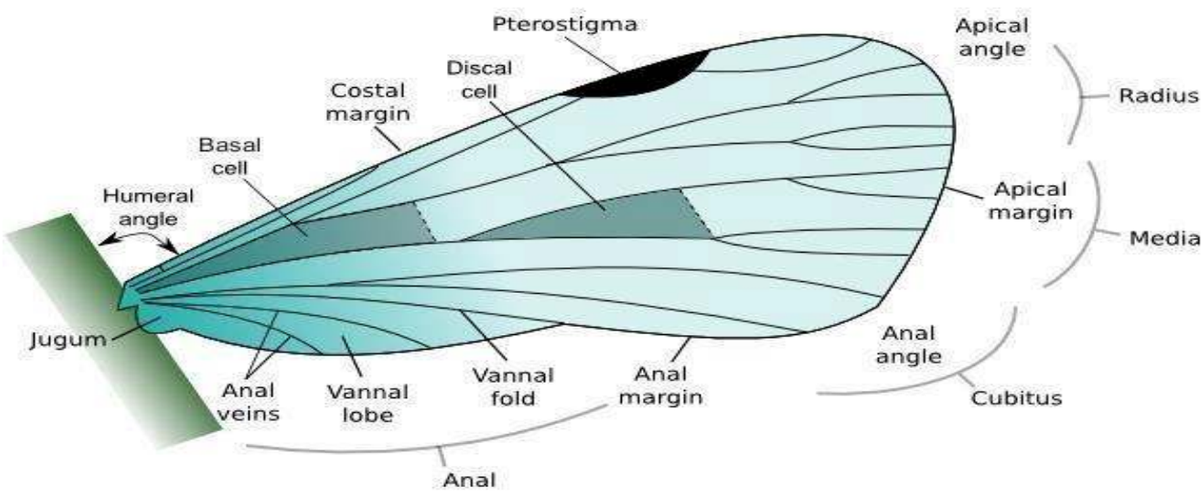
Along these lines each membrane thickens and also rises above the general surface

So that if the two membranes could be separated and examined from the inner surface, they would appear uniform except for grooves with thickened sides and bottoms, running here and there

When the membranes are brought together again, these grooves combining form hollow rods which, being stronger than the rest of the membrane, serve as its support and hold it stiff

These hollow rods are usually called veins or nerves, though they are nothing of the sort.

The main and largest veins arise at the base of the wing and extend outward, branching as they go, and some branch several times before they reach the wing margin



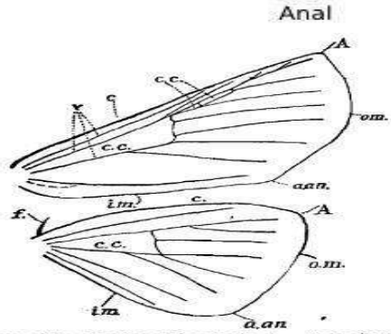


FIG. 21.—Diagram of the margins and veins in the wings of moths: *A*, apex; *a. an.*, anal angle; *c.*, costa; *c.c.*, closed cell; *f.*, frenulum; *i.m.*, inner margin; *o.m.*, outer margin; *v.*, veins.

Cross veins also occur, connecting' the radiating main veins or their branches

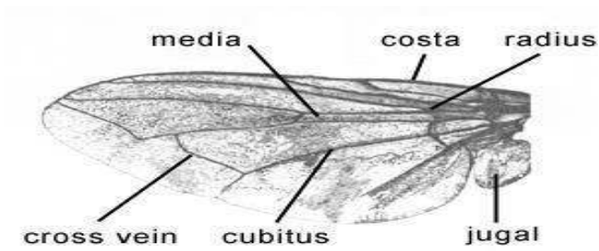
Areas of membrane between veins are termed as cells and where entirely surrounded by veins are called closed cells

These may be relatively few or many, according to the number of veins and their branches present

The arrangement and number of the chief veins and their branches are of importance in identifying insects

There is usually a point or tip called the apex, somewhere along the margin of the wing, though frequently the outline is so rounded that the exact apex is uncertain

The front margin of the wing from where it joins the body to where the edge begins to turn backward (in an extended wing) is called the costa



Wings are entirely absent in some groups of insects

It is probable that some of these are direct descendants of the earliest forms before wings were developed

In other cases where wings are absent this condition is associated with a parasitic life

Where they might be a distinct disadvantage, or with peculiar habits which would render them useless or even inconvenient; in such cases they appear gradually to have become lost

25 26 -Structure of Abdomen

The abdomen does not usually show great differences in its segments except in those near the hinder end

In the flies the hinder p es called halteres

Which may be modified for various purposes

Generally a dorsal plate (notum or tergum) and a ventral plate (sternum) are the only two skeletal plates evident in a segment

Small openings, usually a pair in each, or at least in some of the segments, are the openings of the breathing organs

Generally a dorsal plate (notum or tergum) and a ventral plate (sternum) are the only two skeletal plates evident in a segment

Small openings, usually a pair in each, or at least in some of the segments, are the openings of the breathing organs

And these also occur on some of the thoracic segments where they are ordinarily less notice able than on the abdomen

Legs are very rarely present on the abdomen in adult insects but are often found in the earlier stages

At the end of the abdomen in the females of those insects which lay their eggs within objects is a combination of pieces known as an ovipositor

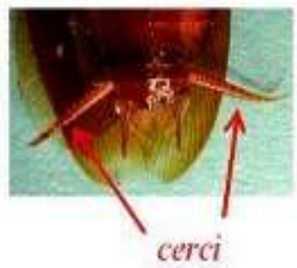
Ovipositor usually consists of about three pairs of parts, long or short, slender or stout, as the case may be, for the purpose of making a hale or sawing a slit in the object in which the eggs are placed and in guiding the eggs into the hole thus made

In one group which has apparently changed its habits and no longer needs to make holes for egg laying, the ovipositor being unnecessary for this purpose has been transformed into a sting

A pair of many-segmented, antenna-like structures, sometimes short, sometimes long, may occur at the end of the abdomen

And these are called cerci

They probably serve as organs of touch and possibly organ of smell in some cases



27-THE INTERNAL STRUCTURE OF INSECT

Few of the internal structures of insects are of any great importance from the standpoint of control methods but some knowledge of them and their arrangement is desirable

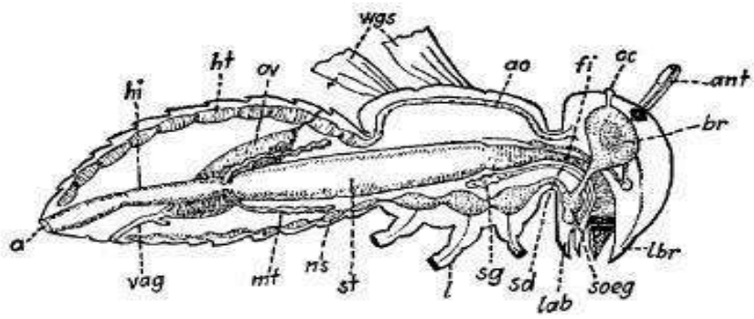


FIG. 23.—Diagrammatic longitudinal section of an insect to show the arrangement of the internal organs: *a*, anus; *ant*, antenna; *ao*, aorta; *br*, brain; *fi*, fore intestine; *hi*, hind intestine; *ht*, heart; *l*, leg; *lab*, labium; *lbr*, labrum; *mt*, Malpighian tube; *ns*, nervous system; *oc*, ocellus; *ov*, ovary; *sd*, salivary duct; *sg*, salivary gland; *soeg*, subesophageal ganglion; *st*, stomach (mid intestine); *vag*, vagina; *wgs*, wings. (*After Berlese.*)

The alimentary canal extends from the mouth through about the center of the body to the anus at the hinder end

In those insects whose food is most concentrated

It is in its simplest form

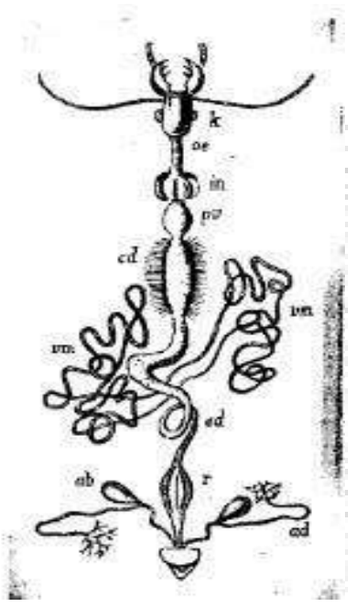


FIG. 24.—Alimentary canal of a carnivorous beetle: *ad*, anal glands; *cd*, stomach; *ed*, hind intestine; *in*, crop; *k*, head and mouth-parts; *oe*, esophagus; *pv*, proventriculus; *r*, rectum; *vm*, Malpighian tubes. (*Modified from Lang's Lehrbuch.*)

In those which feed on less concentrated food

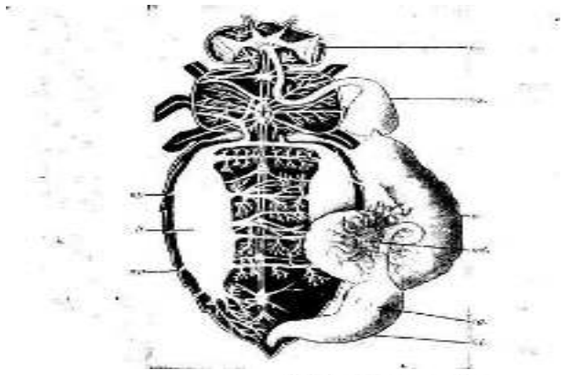
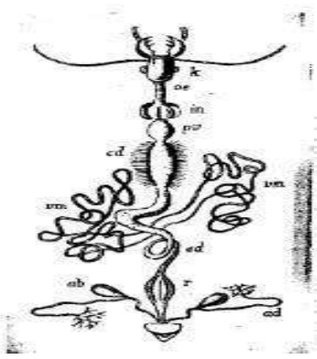


FIG. 25.—Internal anatomy of the honeybee showing alimentary canal, tracheal and nervous systems: ce., compound eye; *hi.*, hind intestine; *hs.*, honey stomach; *lt*, lateral trachea (enlarged); *md.*, Malpighian tubes; *rg.*, rectal glands; s, stomach; *sp*, spiracles. (*Modified from Leuckart's Wandtafeln.*)

28 29 30-Digestive organs

The alimentary canal extends from the mouth through about the center of the body to the anus at the hinder end In those insects whose food is most concentrated It is in its simplest form



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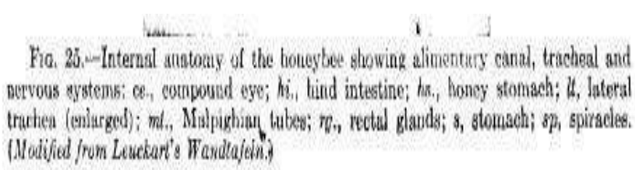

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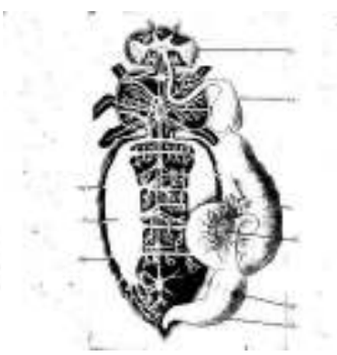
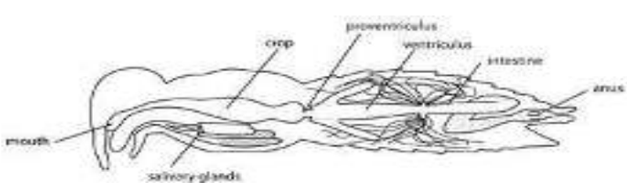


The necessity for a greater digestive and absorptive surface has resulted in an increase of its length And the accommodation of this within the body by the production of loops and coils



In the embryo the alimentary canal forms as three separate sections which connect later

1-One of these is an ingrowth from the surface where the mouth is to be

2-Another and similar ingrowth occurs where the anus forms

3-And a third, forming earlier than the other two, arises as two masses of cells

One near each end of the embryo, which move inward and toward each other, unite, and surround the yolk Later, when this has been absorbed, a space is left with which the two ingrowths already mentioned connect The hollow centers of all three joining to form the tube through which the food travels The ingrowth from the mouth is usually called the fore intestine The central portion the mid intestine and the ingrowth from the anus the hind intestine The first and last of these begin to grow inward from the surface of the body after that surface has begun the formation of its chitinous exoskeleton And accordingly they also have this power, and line the inside of the parts of the canal which they form, with chitin In that portion of the canal termed as the mid intestine However, this power does not appear to be present, and the mid intestine is without this lining The mid intestine forms the stomach of the adult insect The fore intestine forms those parts of the alimentary canal from the mouth of the stomach The hind intestine those from the stomach to the anus Each of these sections may sometimes have portions differing in structure, producing a greater or lesser number of subdivisions

Thus the fore intestine, by differences of structure, may sometimes consist of

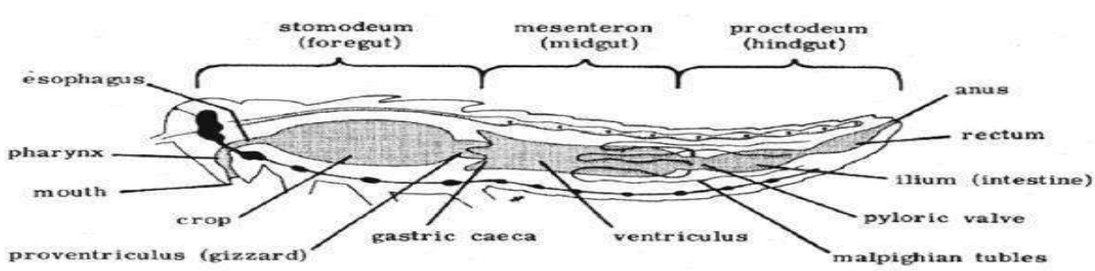
- Mouth cavity
- Esophagus
- Crop
- Proventriculus

The stomach may develop side pouches or gastric caeca

And the hind intestine is often separable by differences of structure into an

- Ileum,
- Colon
- • Rectum.

Lined as these parts are by chitin which often bears rough, tooth-like projections and spine Some persons have suggested that in insects where these structures are present in the fore intestine The food is masticated more thoroughly and mixed with digestive juicer before it reaches the stomach In the stomach, digestion is probably completed and absorption at least begun But the length of the hind intestine in many insects suggests the idea that absorption in those cases has not been completed when the food leaves the stomach but continues in the hind intestine Opening into the mouth is a tube leading to the salivary glands Which generally lie in the front of the thorax and appear to have a similar function to those in man In some cases other glands for different purposes ""are also present in the head or front of the thorax and open into the mouth Some of the poisons used in control measures are swallowed by the insert, passing to the stomach and there are dissolved by the digestive juices Thus dissolved, they set up inflammation of the stomach walls and finally cause death Poisons acting in this way arc called stomach poisons



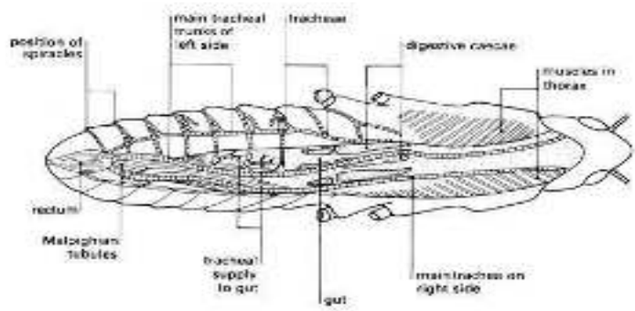
The "generalized" digestive system of insects.

31 32 -Breathing organs

Respiration in insects is accomplished by a method which is nearly unique

The oxygen needed, instead of being ,drawn into lungs and there being taken up by the blood and carried to 'the parts of the body

Where it is needed, as in man, is carried directly to those parts by a system of air tubes which open along the sides of the body



Here the air enters the tubes and proceeds through them to where it is utilized

The openings by which the air enters are called spiracles, and these occur in pairs on some of the thoracic and most of the abdominal segments,

Varying somewhat in number and in position "u the segment in different insects

The spiracles often have valves which they can be more or less completely closed at will

Each spiracle opens into a short tube or trachea which, with the others of that side, soon joins a similar tube running along the side of the body and quite close to its surface

From these longitudinal tracheae, branches pass off in various directions and in turn branch again and again until every part of the body is reached by its air supply

The tracheae frequently enlarge here and there, forming so-called air sacs

The tracheae are lined by chitin connected with that of the surface of the body

In these tubes, however, it is formed with spiral thickenings which act like a spring, keeping the tracheae open when not under pressure

There is probably considerable pressure on them in different places by the movements of various parts of the body in walking and other activities

As well as by regular respiratory movements, and the resulting temporary variations in diameter aid in the circulation of air in these tubes

Not only are the tracheae of use in: carrying oxygen to all parts of the body

But they also receive much of the carbon dioxide gas produced by the activities of the cells and permit it to escape through the spiracles from the body

Thus per forming both of the functions which the blood, so far as gases are concerned, accomplishes in man

Blood then, in this gas enters the spiracles and follows along the tracheae to the living tissues, which take it in place of the oxygen usually received in this way, and the insects are killed

It was formerly supposed that certain materials called contact insecticides, which kill insects by contact with their bodies

Caused death by entering the spiracles and closing them up, thus producing suffocation.

This has now been proved to be incorrect in most cases

Insects which in their early stage of live in water cannot, of course, breathe air into their bodies through spiracles during that period of their live

There are enclosed in such cases and the animal obtains and usually through special structures called tracheal gills

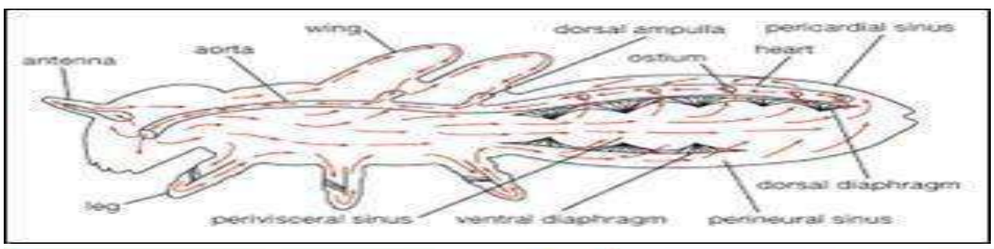
These will be described in connection with the insects that possess them

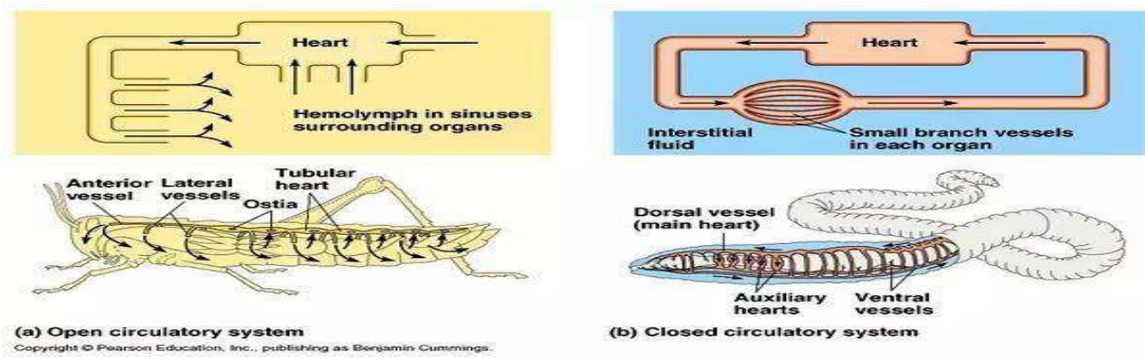
In a few small water inhabiting forms, the chitin covering the surface of the body is so thin that oxygen present in the water can pass directly through it into the body and to the parts there that need it, and carbon dioxide passes in the reverse direction,

33 34 35 -Circulatory organ

Insects have only an incomplete system of blood vessels

A tube lies in the middle of the body close beneath the back, beginning near the hinder end of the animal and extending forward into the head





In the abdomen this tube is constricted, forming chambers, and the chambered portion is called the heart

There is a pair of openings on the' sides of each chamber through which blood can enter, and valves there which prevent its going out again

In the abdomen this tube is constricted, forming chambers, and the chambered portion is called the heart

There is a pair of openings on the' sides of each chamber through which blood can enter, and valves there which prevent its going out again

Blood in the heart, being unable because of the valves to pass out at the sides, is pressed forward by this contraction wave

And at the front end of the heart finds itself in a tube without chambers or valves, called the aorta

Through which it is led to the head where the aorta may divide into a few short branches or may be unbranched

In either case, at this point the blood pours out of it into the body, the system of blood vessels coming to an end

There is now no definite and particular path for the blood to follow

But it would, in theory at least, remain near where it escaped from the aorta or gradually pass into any spaces it might find unoccupied between the different structures in the head

With each heartbeat, however, more blood is poured out of the aorta, increasing the pressure upon that already in the head

It therefore is gradually forced backward and to other parts of the body

Each particle probably taking the path where there is least resistance to its passage

In this way a general backward direction is given to the flow

As it approaches the heart, another influence appears

During each contraction, the heart occupies less space, which leads to less than normal pressure near it

And blood close by naturally flows closer to it

Upon its expansion again and the opening of its valves, the direction of-least resistance is now through the valves and into the heart

As the blood passes back through the body, a given particle may at one circuit go over certain organs, and at the next over entirely different ones

All the internal organs, however, have their surfaces bathed by blood

And this as it passes over the stomach or other parts of the alimentary canal will pick up any food

Which having been digested has passed through the canal walls

Likewise in passing over any organ needing this food, it is given up to those organs

The blood therefore serves as a distributor of food from the place where it is digested to all the parts that need it

We have already seen that the living parts of the body-the cells-need oxygen and as the result of their activities give off carbon dioxide gas

But that this exchange is accomplished by the aid of the tracheae

In a somewhat parallel way, the cells that need food obtain it from the blood

The cells by their activities produce not only carbon dioxide gas but also waste material nitrogenous in nature which must be removed like all wastes from the body

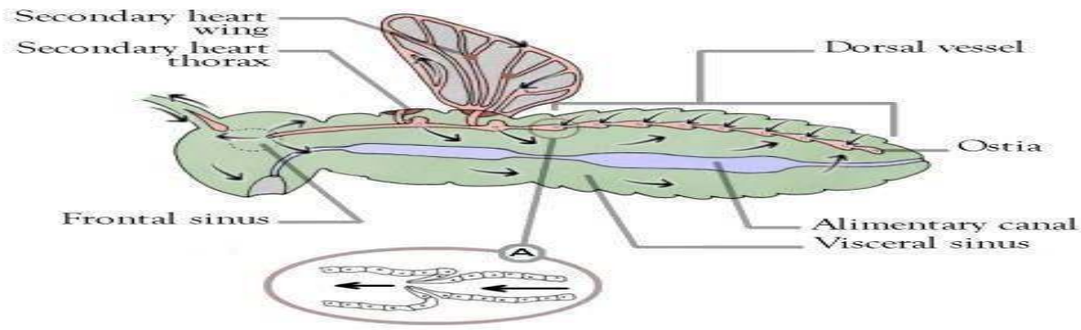
36 37 -Excretory organ

This nitrogenous waste is picked up at the cells by the blood and carried along, perhaps for some time, before a place to dispose of it can be found

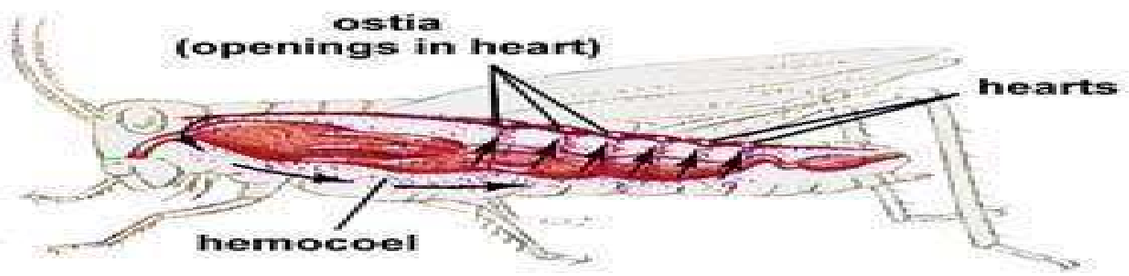
Sooner or later, however, a particle of blood containing this waste material will wash over certain structures called Malpighian tubes, to be described in the next section

And the cells which form these tubes have the power to collect this waste material from the blood as I it flows over them, thus purifying it

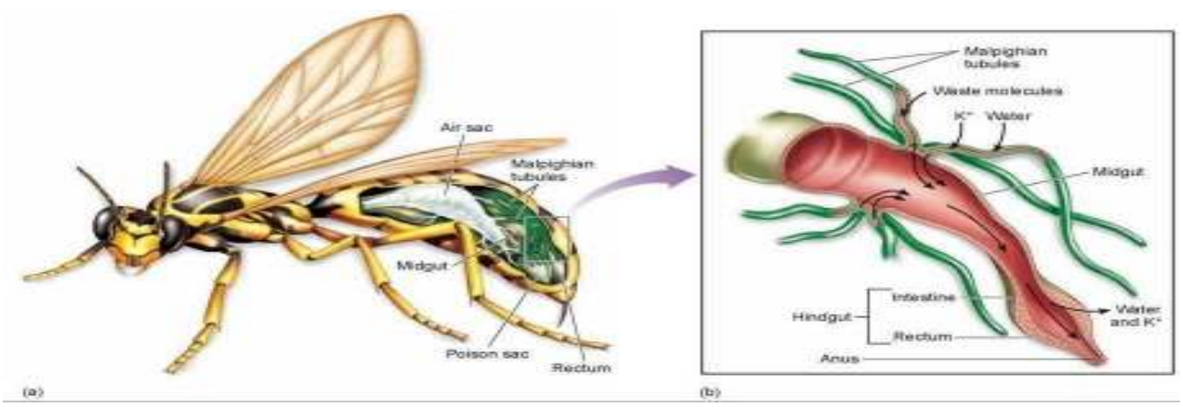
The blood itself is usually a colorless, yellowish, reddish or greenish fluid, in which are corpuscles resembling the white corpuscles of human blood



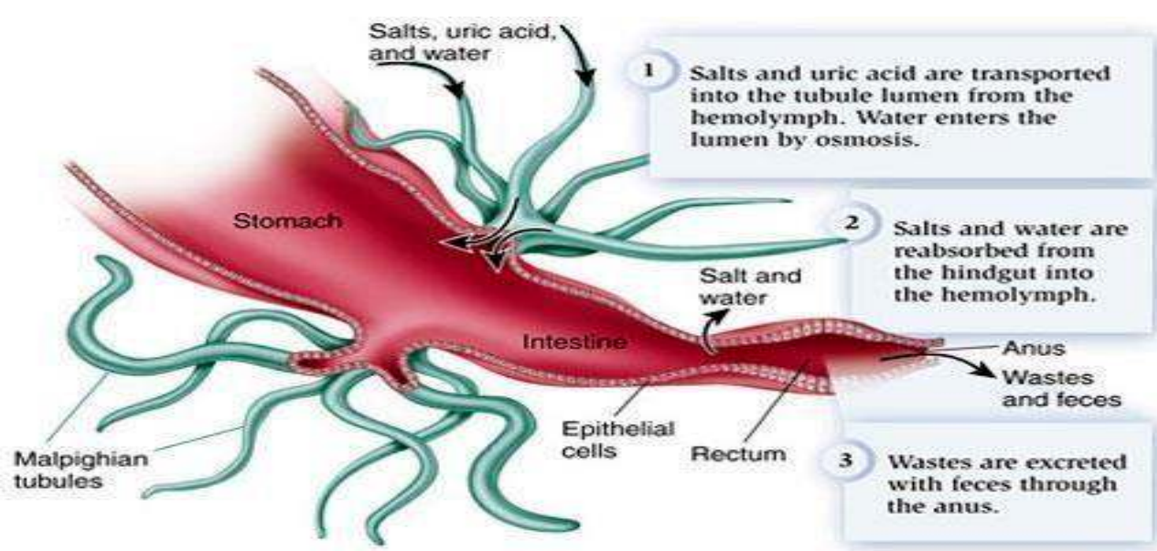
It appears to serve to carry food to the tissues and waste matter from them, and therefore has no need of structures in it like the red blood corpuscles of man The work of which in insects is done mainly by the tracheae



The organs that eliminate the nitrogenous wastes from the body and correspond in function to the human kidneys are known as Malpighian tubes



These are blind-ended tubes, the walls of which consist of a single layer of cells surrounding a central channel which at one end open into the hind intestine, Usually near its front, just behind the stomach

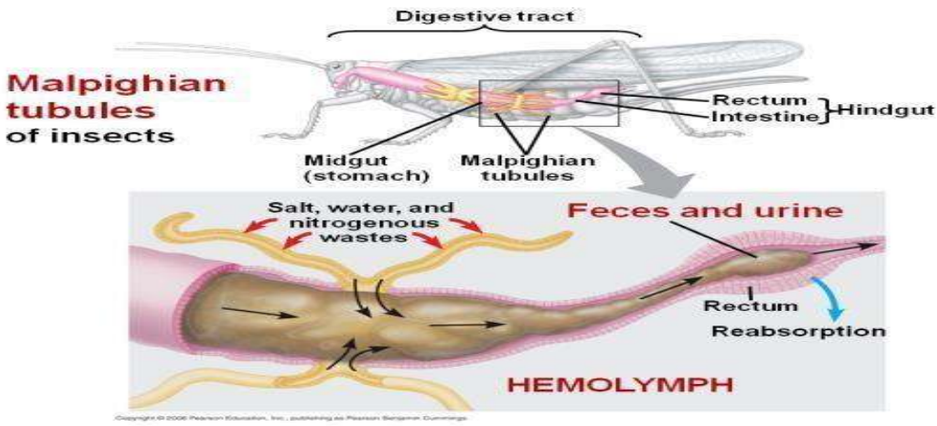


When blood containing nitrogenous waste matter washes over the outer surface of a Malpighian tube

The cells of which it is composed have the power of taking this matter out of the blood into their own substance and passing it through them

Solves into the channel between them, dowln which it moves until it enter the hind intestine, from which it is finally expelled at the anus

The Malpighian tubes may be few or many, long or short

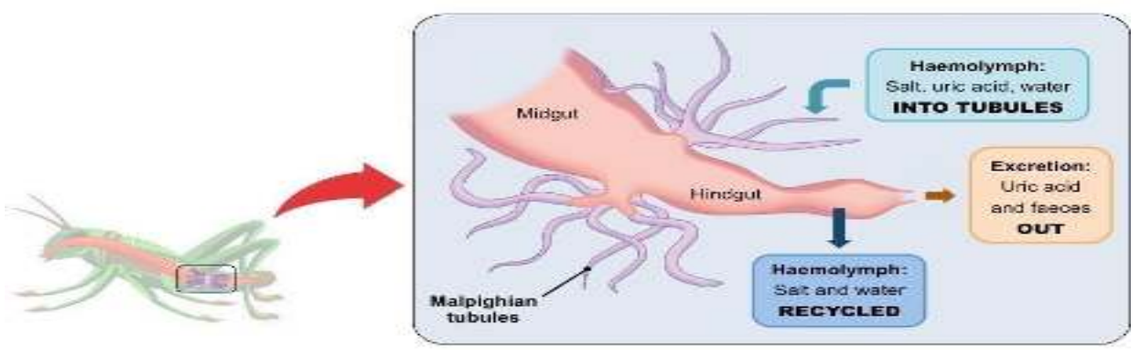


They show a tendency to collect in groups and to unite near the hind intestine

So that their outlets into this are much fewer than the number of tubes.

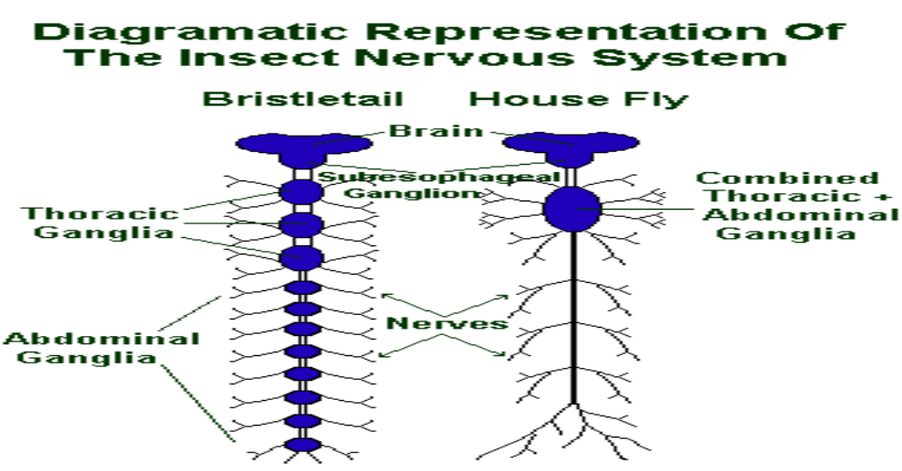
It seems possible that a certain amount of poison entering the body by way of the stomach can be eliminated by the Malpighian tubes

Which may explain the varying degree of resistance to such poisons by different insects



38 39-Nervous system

The nervous system of insects is located along the middle line of the body quite near its under surface As in animals generally, it is composed of cells and fibers



The former are for the most part gathered together in clusters which are called ganglia

And from each of the cells in a ganglion one or more nerve fibers pass out, to connect either with some other nerve cell or with some structure of the body

The larger nerves are really bundles of the fibers running side by side like the wires of a telephone cable

Apparently each segment of the insect body once had but with the fusion of the segments tube of a fly

Greatly many of these have also fused, reducing the separate ganglia in adult insects to a smaller number, which varies central in different kinds

This fusion has been produced by the hinder ganglia moving forward until in some cases none is found in the abdomen

Different degrees of this are shown in Figure

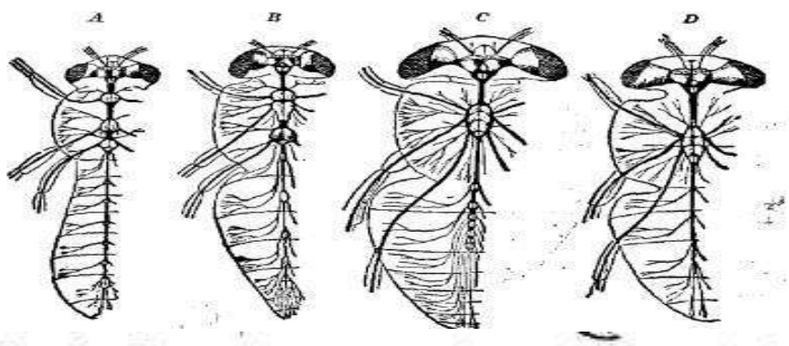


FIG. 29.—Diagram showing various degrees of concentration forward of the nervous system of four species of flies: *A*, *Chironomus plumosus*, little concentrated; *B*, *Empis stercorea*; *C*, *Tabanus bovinus*; *D*, *Sarcophaga carnaria*, most concentrated. (*After Brandt, from Lang's Lehrbuch.*)

Each ganglion is connected to the one in front and the one behind by one or two bundles of nerve fibers which are called commissures

Each consists of numerous fibers which taken together form the means of communication between the different parts of the system

In the head, in front of or above the esophagus, is the largest ganglion of the body, called the brain, produced by the fusion of several ganglia

In addition to its two commissures, which connect it with the ganglion next behind, it has nerves which lead to the eyes, to the antennae and to other parts of the front of the head

Below or behind the esophagus is a second ganglion, also in the head, called from its position the sub esophageal ganglion

As the esophagus lies directly between this and the brain, the commissures connecting the two do not lie close together but separate far enough to permit the esophagus to pass between them

The sub-esophageal ganglion, besides being connected with the brain in front

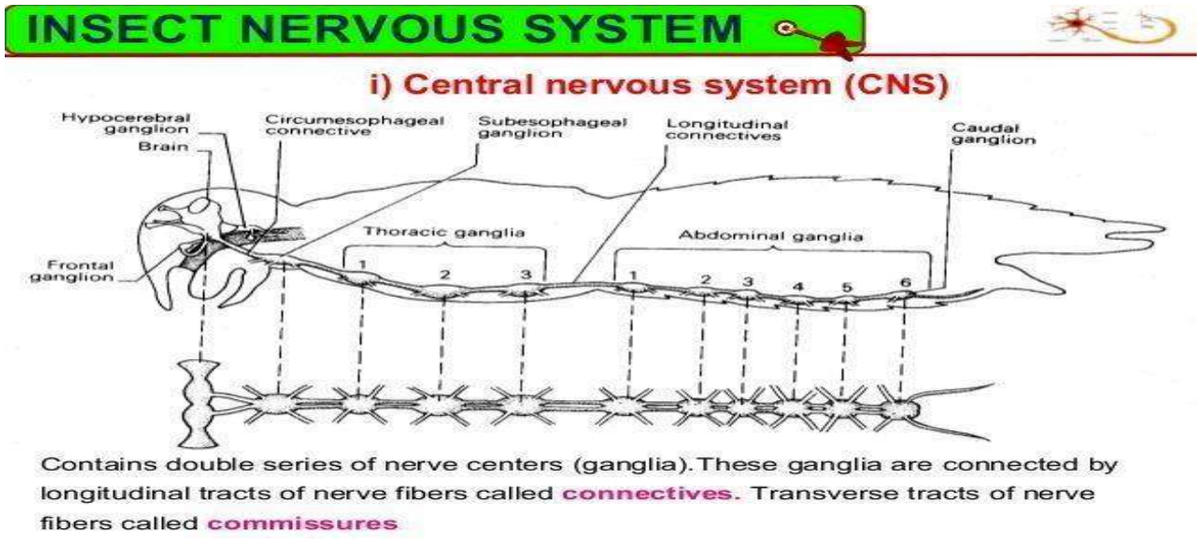
And the first thoracic ganglion behind it, by commissures, sends nerves to the mouth parts and other near-by regions of the head.

The thoracic ganglia may be more or less separate or fused and may have fewer or more of the abdominal ganglia added commissures

However, connect all separate ganglia, and these also send out nerves to all the parts of the segments to which they belong, no matter what their final location may be

In this way, the wings, legs, muscles and other parts receive their nerve supply

A small" sympathetic nerve system" also present, appears to concerned chiefly with the nerve supply of the alimentary canal tracheae



40-Sense organs

All the more evident senses possesed by men appear to be present in *insects Except possibly taste, but not in all cases in the same individual*

Thus some cave-inhabiting insects have no eyes

It is almost certain also that insects have other senses not possessed by man

Reproductive organs

Insects are of distinct sexes, male and female

In many cases, however, individuals occur incapable of reproduction, their sexual organs not having become fully developed

Such inserts may be termed neuters

Most of these appear to be really undeveloped females, though undeveloped males are also known

They are found in colonial insects where division of labor occurs

As in the honeybee, ants and termites, and are known according to their duties, as workers or soldiers or by other names

Conventional signs for the various forms of insects, as a convenience, are if male ♂ female ♀ or worker

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42 43 -Female Reproductive Tract

In the female the eggs are produced in a pair of ovaries located in the upper front part of the abdomen

Each is a cluster of ovarian tubes whose walls are cells

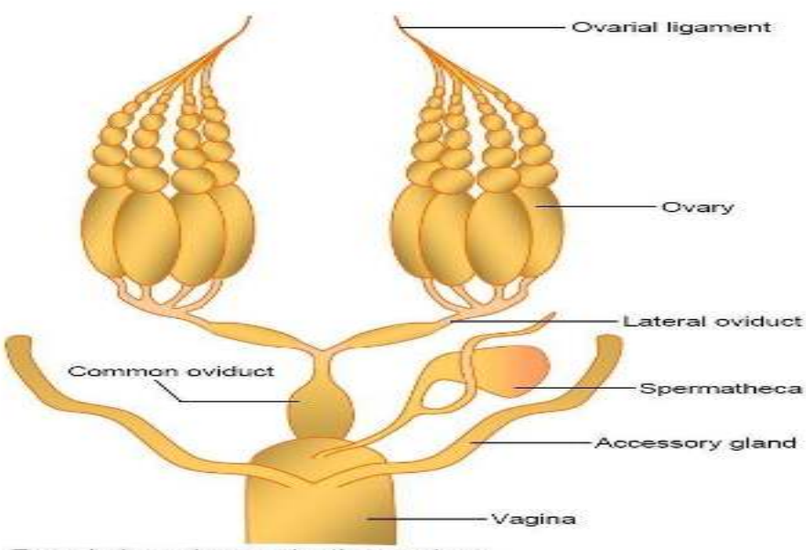
Some of these cells grow and separate from the others to lie in the central cavity of the tube and then pass downward

Growing till they reach its hinder end

Which connects with the similar ends of all the ovarian tubes of that side to form a single tube called the oviduct

This extends downward and back ward around the side of the alimentary canal

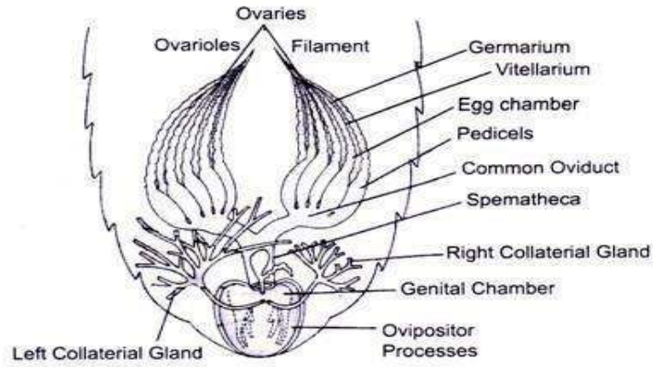
Below which it joins with a similar oviduct from the other side of the body to form a single duct



Female insect reproductive system

The vagina, which lies between the alimentary canal and extends backward to its outer opening which is located

In most cases, in front of the next to the last abdominal segment.



Surrounding this opening may be external structures known as ovipositor

For the purpose of together making holes in some object (the ground, wood, etc.) in which to deposit the eggs

A side pouch called seminal receptacle is connected with the vagina is for the storage of the sperms which fertilize the eggs

A gland-producing material, which forms the egg shell and is known as the shell gland, also opens into this portion

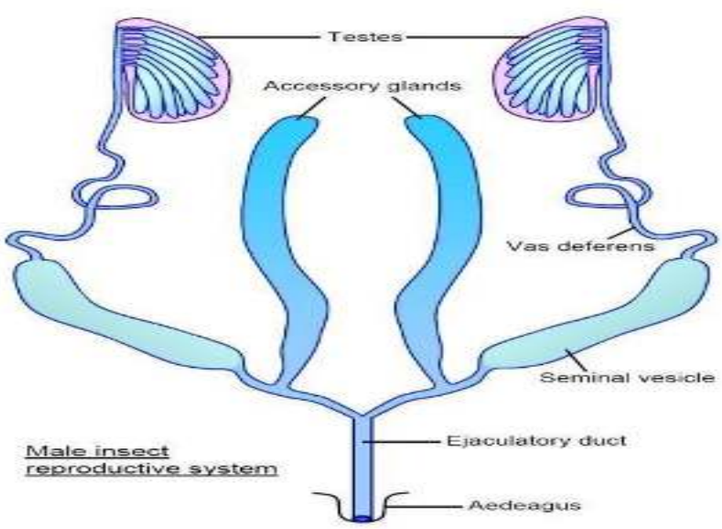
And other glands similarly connected with the vagina may also be present.

44-Male Reproductive Tract

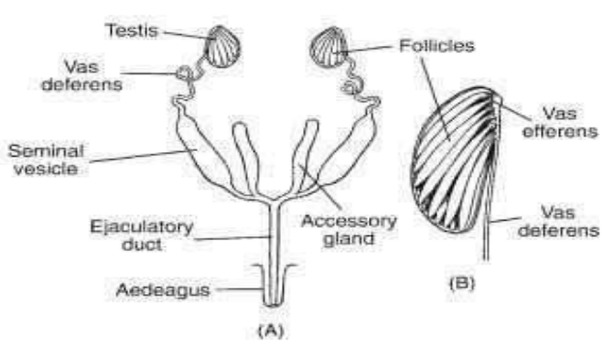
In the male the arrangement of the organs closely corresponds to that in the female

A pair of spermaries or testes is present in the upper front part of the abdomen

Each consisting of a rather closely coiled mass of tubes in which the sperms are produced.



The tubes on each side unite to form a single tube, the vas deferens (plural, vasa deferentia) These differ from the oviducts usually, in being much longer and coiled or twisted



They pass downward and backward, however, and unite on the middle line of the body below the alimentary canal

Forming a single tube, the ejaculatory duct, corresponding to the vagina in position

Which leads backward to an opening in front of the last segment

An enlarged portion of the vas deferens is often present, for the temporary storage of the sperms, and is termed the seminal vesicle

Accessory pouches opening into the ejaculatory duct appear to be, in part at least

For the production of mucus and secretions to mix with the seminal fluid

45-THE DEVELOPMENT OF INSECTS (Egg Types)

Most insects lay eggs from which the young hatch after a longer or shorter time

Though in some cases the egg appears to be retained within the body of the parent until after it has hatched

The young then being produced in an active stage

Those which lay eggs hatching later are termed oviparous

Those having eggs that remain in the body of the parent for a time after hatching are termed ovoviviparous

A few insects that supply nourishment to the young before its birth are termed viviparous

Insect eggs are usually very small, vary greatly in form and may be laid singly or in clusters (Fig. 32).

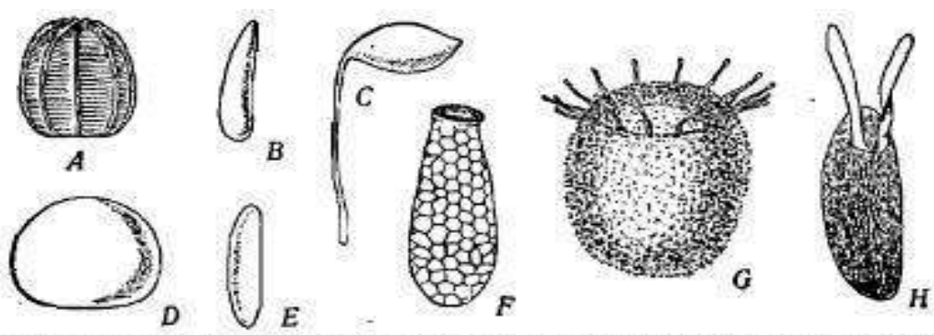


FIG. 32.—Eggs of various insects: *A*, butterfly; *B*, housefly; *C*, chalcid (*Bruchophagus*); *D*, butterfly; *E*, midge; *F*, bug (*Triphleps*); *G*, bug (*Podisus*); *H*, pomace fly. All much enlarged. (*From Folsom.*)

46-Structure of eggs

They are covered by a chitinous shell, the chorion, which often bears markings in the form of ridges, reticulations

And frequently are also colored

At one place on the surface is a minute opening or group of openings through the shell, called the micropyle

Believed to be for the entrance of the fertilizing sperm

The length of time spent in the egg differs in different insects from a few hours to many months, and in some cases the eggs

Do not hatch until the second season after they are laid

In hatching, the shell breaks and out of it crawls the young insect

In the majority of cases quite unlike the adult it is to become

In order to reach maturity it must now grow and undergo changes in structure and appearance

These together are expressed by saying that most insects in order to become adult undergo a metamorphosis

47-Metamorphosis

In some of the simpler inflects, a few changes and growth only are needed to make them mature

And these are therefore usually grouped together as the Ametabala, or insects having practically no metamorphosis

The remaining insects, from this standpoint, form two groups:

Hemimetabola, or Paurometabola: Those which on hatching generally show some resemblance to the adults and reach maturity by a series of gradual changes

Holometabola: And those which on hatching are totally unlike the adults and become adults by a somewhat different process

These names suggesting the amount of metamorphosis required for members of each group to become adult

A member of the group Ametabola upon hatching, will begin to feed and grow

Growth, however, is restricted because the insect is enclosed by a cuticula which, while elastic, to some extent, at least at its thiner places, has its limitations in this regard

Thus the insect is unable to reach its adult size within its cuticula, and a process called molting takes place

This is begun by a pouring out of fluid by the outside layer of living cells, the hypodermis, between it and the cuticula, separating the two

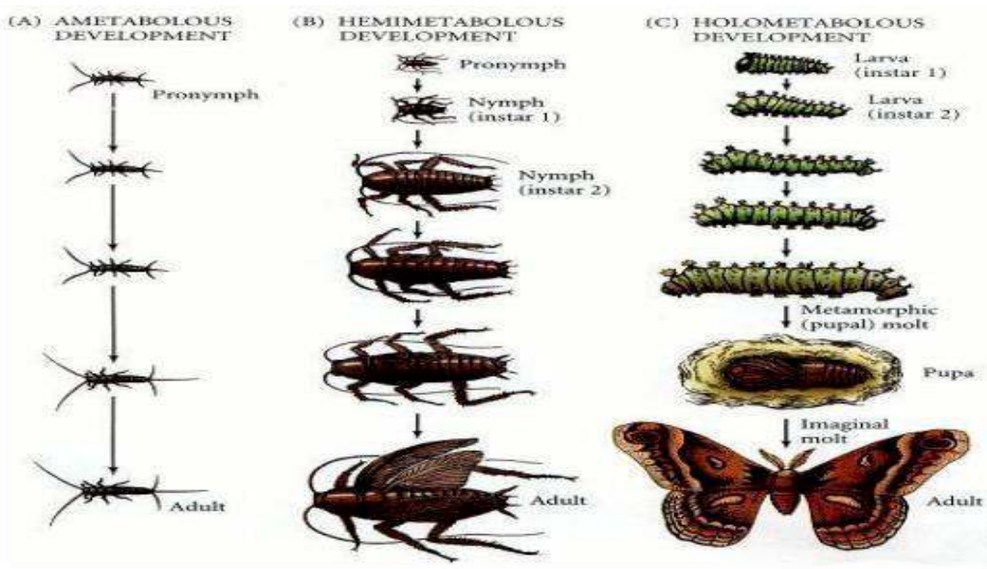
Next a spilt appears somewhere in the cuticula usually along the back and the insect crawls out of its skin, i.e., molts.

48 to 50 -Types of Metamorphosis

Until the fluid poured out has had time to harden, the insect is able to grow

But in a short time it hardens to become a new cuticula and there after only such growth occurs as the elasticity of the new shell will permit

In theory there should be some Ametabola that do not molt, the cuticula being so elastic it will stretch enough to permit growth to the adult



In fact, however, they· all appear to molt at least two or three times in a few cases it seems to occur at intervals throughout life

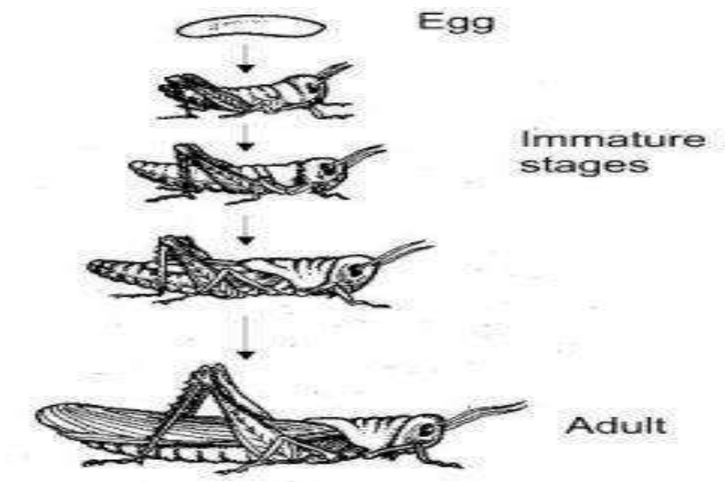
In any case the reproductive organs appear not to be mature at the time of hatching and only gradually become so during the period following

In the Hemimetabola (or Paurometabola) the young insect on escaping from the egg, though resembling its parent to some extent

Undergo many change in structure and a considerable increase in size as well before reaching maturity

Thus a young short-horned grasshopper, on hatching, will need to grow to be about ten times as long before becoming adult

It is without wings, which will need to be developed; its reproductive organs are not mature and must become so; and other differences occur



All of these must be transformed into their condition in the adult; and to accomplish this, energy is necessary

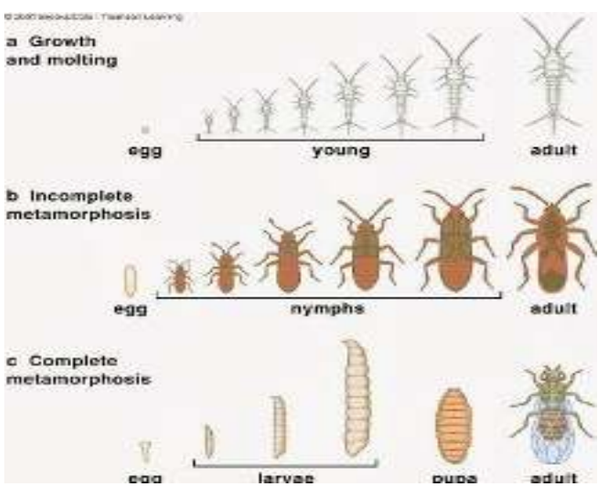
In the egg the energy for development has been provided by the yolk; after hatching the young insect must provide it by gathering food

The young insect, therefore, soon after hatching seeks for food and haring found it begins feeding

The nourishment thus obtained results , in growth so far as this is possible within a shell which is tightly fitting and only to some degree elastic

When no further growth in this way can occur and the body has stored within it all the materials needed for a greater increase in size

It proceeds to molt in the manner already described for the Ametabola



On escaping from its old skin or shell, how ever, besides a rapid increase in size, changes of structure also occur

So that a difference in appearance now becomes evident

These changes must be produced quickly, as the hypodermal cells of these parts, as well as of all the surface, are producing a new chitinous skin

When this has once hardened, no further changes and little further growth are possible

Molting, then, marks the beginning of a brief period-a day, more or less-of increase in size and of changes in appearance

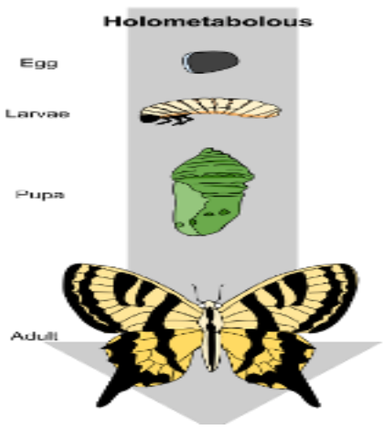
These last all being in the direction of making the young insect more nearly like the adult it is to become

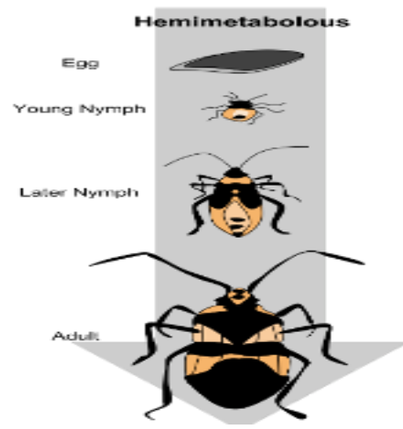
When the new shell has become hardened, the insect resumes its feeding

After another feeding period the young insect is again confronted with the same difficulties as before, and it meets them in the same way, by molting, and immediately thereafter

Before its new shell has hardened, it seizes the opportunity to grow and change its appearance further

Finally, after some molt, full adult size for the insert is attained and all its organs have also fully developed and matured, producing the adult insect itself



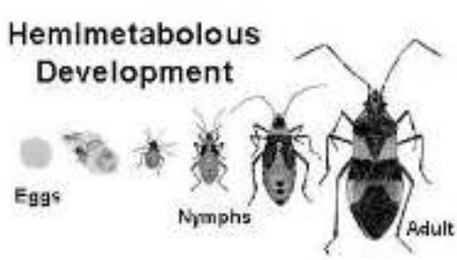


51 to 53 -Hemimetabola

The number of molts, and consequent opportunities for change that occur, vary in different Hemimetabola There may be only two or three in some kinds; five is perhaps the average number though more are not uncommon; forty-five are known to occur in one species

Certain names for these different conditions are convenient for use

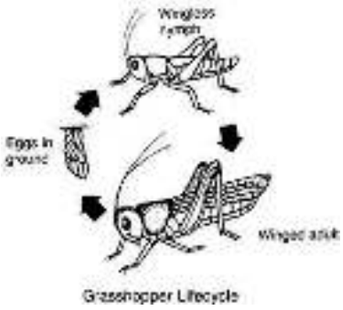
The feeding periods between the molts (or ecdyses) are called instal's



So that the progress of an insect from hatching to adult is by an alternation of instal'S and molts

The insect itself, from hatching until maturity, is generally called a

nymph The changes in appearance of a grasshopper after each molt



The term Hemimetabola was used for many years to include all those orders in which the insects underwent incomplete metamorphosis in the course of their development

Found in In three of the orders

1-Ephemerida

2-Odonata

3-Plecoptera

In three of the orders, the young live and develop in water and differ greatly from their adults in appearance

In recent years this has led some entomologists to divide the Hemimetabola into two groups

The three just named were left under the Hemimetabola and the others were given the group name Paurometabola which means a gradual metamorphosis

The young in the Hemimetabola thus limited are called naiads; those in the Paurometabola, nymphs

This is by no means a classification of the insects themselves, but only of the different types of develop meant that occur

This classification has not been adopted in this book.

With the remaining group of insects, the Holometabola, although there is a little similarity in the metamorphosis to that in the Hemimetabola

But there are also many differences.

When a young holometabolous insect hatches, it in no way resembles its adult

A caterpillar is totally different in appearance from the butterfly it finally becomes the white grub in the earth

It is called June bug (May beetle) into which it transforms

Nevertheless, this young insect-called a larva has to meet the same problems of growth and transformation to the adult condition as do the Hemimetabola

And uses the same means for accomplishing the needed results,· viz., the utilization of the energy derived from its food

Upon hatching, in the Holometabola, a feeding period or instar comes first, followed by a molt and growth

At this point the story *of the metamorphosis differs from that of the hemimetabola, for* after the molt no change in appearance to make the young insect more nearly like the adult takes place

It may be different in some regards, besides size, from what it was before the molt, but these differences do not increase its resemblance to what it finally becomes

This holds through out the feeding period of its existence, so that after three, four or more molts a caterpillar is still caterpillar, a grub is still a grub, and this is

Equally true for all holometabolous insects

With in the insect during this period, however, changes not perceptible on the surface are taking place, by the construction of portions of the adult

which are forming as buds or ingrowths from various parts of the body and are termed imaginal buds (from "imago," the adult)

They are closely compacted and many at least are enfolded somewhat like buds, becoming finally ready to open when the proper time comes

And during its feeding instars, the larva is storing energy from its food not only for its growth at each molt but also to carry it on through a period yet to be described

During which it must transform into the adult condition while unable to feed and obtain the energy needed for this purpose

54 to 58 -Development in insects

After a varying number of feeding instars and molts, the young insect or larva has grown sufficiently and has stored within it energy

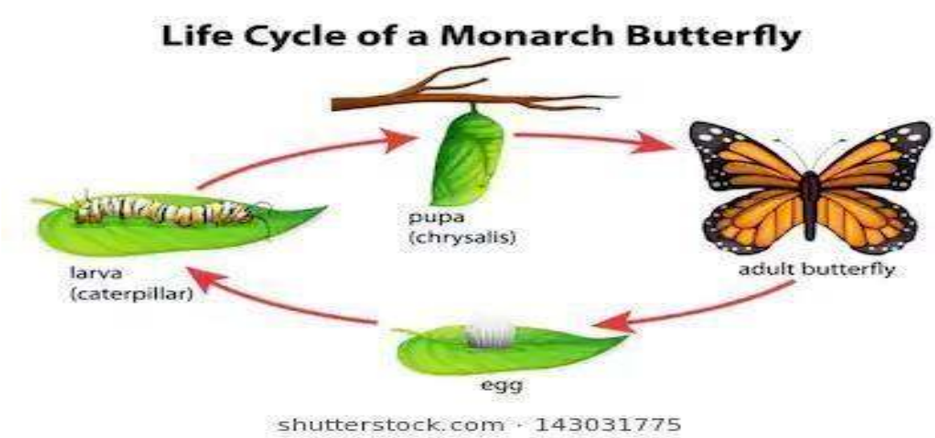
Enough to carry it through the remainder of its changes, and internally the essential parts for the adult condition have been formed as far as it possible under existing conditions

As the next change will produce an animal practically helpless in most cases and unable to protect itself from its enemies, its next step is to find as much protection as possible

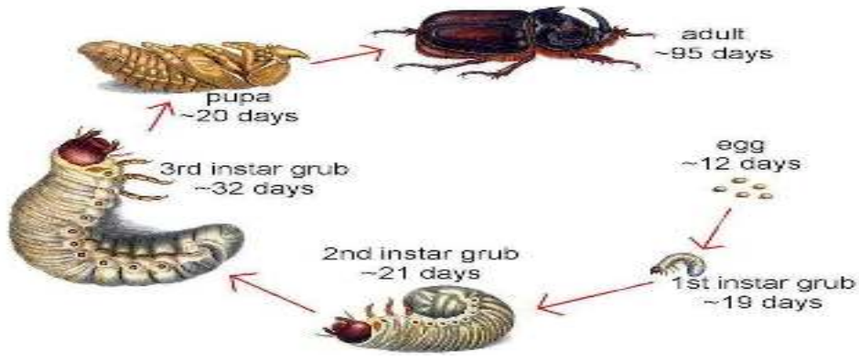
Accordingly, the full-grown larva usually, though not always, leaves the place where it has been feeding and elsewhere prepares for its next change

Many larvae begin this by spinning around themselves a thread of silk, produced by glands within the body and opening to the surface on the lower lip

This thread is spun backward and forward and around the body until it sometimes forms a complete outer covering, entirely concealing the larva within from view. This case or cocoon appears to be protective in its function



Some larvae go underground for this change Here a cocoon, as such, seems unnecessary



But after digging into the earth a few inches, the insect forms a little earthen chamber or cell in which to lie and generally lines this more or less densely with silk, probably to keep the earthen walls from falling in and crushing it

A larva transforming in tunnels in wood where it has fed may make a partial cocoon with more or less of the chewed wood fragments mixed in

One staying above ground but not in tunnels or otherwise protected will spin more or less of a cocoon as already described

The completeness of the cocoon, however, varies greatly with different insects

Instead of being a thick, dense wrapping which entirely conceals the insect, it may be so scanty that the animal within can be seen to some extent

In other cases it is merely a sort of network, in no degree giving concealment and in still others, a few scattered threads to hold the insect in place are all that represent it

Sometimes hairs from the body of the larva, held together by silk, form most of the cocoon

In the case of butterflies only threads enough to attach the hinder end of the body at the place where it is to transform and usually to form a supporting loop around its middle

The ends of the loop also being fastened to what it rests on, are produced

In some flies the larva shrinks within its larval skin and transforms, this skin, now called a puparium, functioning like a cocoon

The reason for such variations in a structure, presumably formed for the purpose of protection, can only be guessed at

Possibly in the course of generations some insects found less need of this than others and gradually reduced it

Thereby saving the vital energy so much needed for transformation, which would otherwise be expended in cocoon making

Whether the larva forms a dense or scanty cocoon, or none whatever, the next step in the process is a molt

When the insect escapes from this skin, however, a great change in it appearance is evident, and it is now called a pupa

In a general way it may be said that it has at this one molt changed more than halfway to its adult condition

This is due in part at least to the unfolding of the imaginal buds already referred to

Which contribute largely to form the new surface of the body in which

Head

Thorax

Abdomen are evident

Antennae,

Legs, stubs of wings

Many of the internal organs of the larva, though, were necessary for use till the last moment before it became a pupa

Then, too, the arrangement of the muscles in the larva would not be that needed by the adult

Accordingly, most of the internal organs now gradually break down, losing all their earlier form and structure and new ones to meet the needs of the adult are constructed to take their place

During this breaking down and the reconstruction period, the pupa is practically helpless in most cases; hence generally the need for the protecting cocoon or earthen cell it constructs

When the structure of the adult insect has been completed, another molt takes place, the pupa skin splitting and setting free the insect

If it was enclosed in a cocoon, it now produces a fluid which sufficiently softens the silken threads so that it can push its way out and it escapes or "emerges."

It is now soft its wings are only partly expended as in most cases there would be no room for full-sized wings in a pupa, and because of its reconstruction there is considerable waste matter in its body

The insect crawls upon whatever it may find to hold on to, expels the waste matter, and its wings begin to grow rapidly

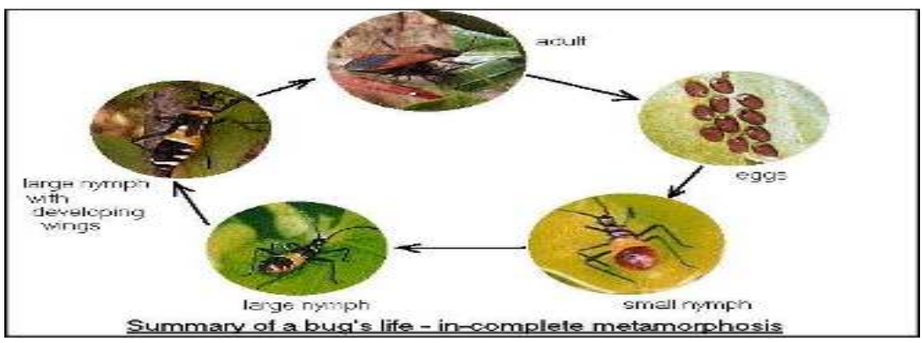
Drying out also takes place and in a short time (a few hours) the adult thus produced is in every way fully matured

In some cases maturity of the reproductive organs is not complete until a little later

To summarize the differences in metamorphosis of the three groups it may be said that in the Ametabola

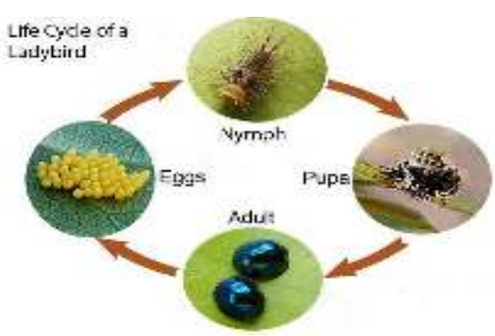
The insect hatches from the egg practically in an adult condition; *i.e.,* there is little or no metamorphosis

In the Hemimetabola the insect hatches from the egg in a form somewhat resembling the adult (except in the Ephemerida, Odonata and Plecoptera) but much smaller



It becomes adult by alternating periods of feeding with molts, at which times growth and changes bringing it nearer To the adult occur, the last molt completing the growth and adult structure

In this life history we have a change; but as there was a resemblance to the adult from the start, the change to it (metamorphosis) is only an incomplete or partial one



In the Holometabola the insect hatches from the egg in a form totally unlike the adult

Where as feeding periods followed by molts and growth give increase in size, no external evidence of any changes making the insect more like the adult can be found.

59-THE DEVELOPMENT OF INSECTS

These changes are largely made after the end of the feeding and growing periods during a pupa (generally quiet) stage

In which the breaking down of the larval, and construction of the adult, structures is completed.

The difference between the larva on hatching and the adult is so great that an entire change (complete metamorphosis) takes place

It should be evident from the foregoing that, when the adult condition is once reached

If any growth is possible and that the belief so common that "big flies grow from little flies" is without any basis of fact

The nymphs of the Hemimetabola appear not to have attracted sufficient attention to receive any special common names

In the Holometabola the larvae of various groups differ greatly in appearance many are large and noticeable and some of them have, as a result, received special names.

Types of larvae:

Larvae of butterflies and moths are commonly called caterpillars

Those of beetles are usually called grubs

Those of flies are called maggots.

Larvae found boring in wood, however, whether they will become moths, beetles or other insects, are uniformly called borers.

In the Hemimetabola, then the stages of life are

- Egg
- Nymph
- Adult

In the Holometabola they are egg, larva, pupa, adult

Whether or not the pupa is enclosed by a cocoon depends upon circumstances

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ZOO506 - Applied Entomology and Pest Management

Final term 60 to 134

60-61-62-63-64-ECONOMIC IMPORTANCE OF INSECTS (INSECT DAMAGES)

Introduction

A. Of the many thousands of insect species known to man some affect him and his property only slightly; some are beneficial; others are injurious in various degrees

B. Only rough estimates can be made of the monetary losses and gains by insect activities and even these are made with difficulty

C. Although it is the general practice to express losses in terms of dollar valuation

D. It probably would be safer to give them in bushels, tons, etc., because the relative values of different crops and products change from year to year

E. No crop of either vegetable or animal origin appears to be entirely free from insect injury

F. Field, truck and fruit of crops, both growing and in storage, household goods and food products, forests and the wood products derived from them, domestic animals and animal products, all are more or less liable to insect attack

G. Because there never has been a season free from the ravages of insects which might serve as a standard for comparison, much of this loss is not appreciated

H. If there could once be such a year entirely insect free, the difference would be apparent at once

INSECT DAMAGES

A. It is the general conclusion that the loss to all sorts of crops by insect damage in an average year is about 10 per cent

B. This estimate covers field crops, forests and forest products, farm wood lots, domestic animals and their products, stored articles, shade trees and ornamental plants, household goods and foods.

C. Generally the injury to fruit and truck crops is believed to be more than one tenth

D. Hyslop estimated in 1938 that the annual loss to agricultural crops by insects, including the costs of control, amounts to somewhat over 1,600 million dollars

E. No estimate of injury to human health is included

F. To value this destruction we have as a criterion only the price for which crops sell

G. If the tenth of all crops destroyed had been saved, the price of the whole might have been no greater than it was for the nine-tenths actually produced

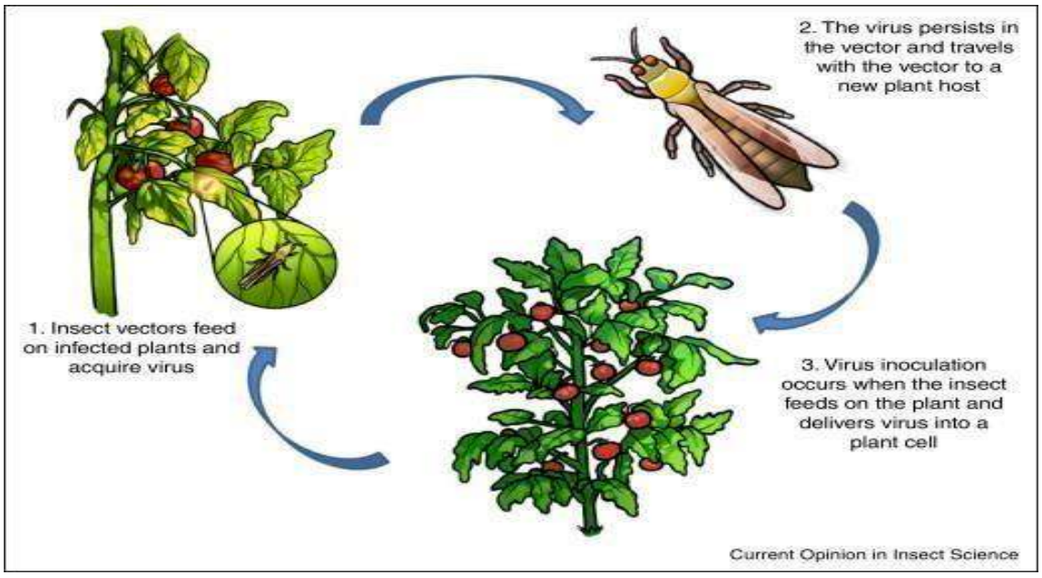
H. The loss by insect injury usually far exceeds the actual quantity consumed.

I. Insect-contaminated food products originally intended for human consumption often must be destroyed or used in stock feeds

J. Blemishes in fruit caused by insect bites impair the sale value much more than is accounted for by the actual loss in substance.

Plant Diseases

- The most obvious losses are those caused by the feeding of insects
- But it is now known that some of the most serious plant diseases are carried by them.
- The organisms that cause these, whether they are
- Filterable viruses
- Fungi
- Bacteria,


2. The virus persists in the vector and travels with the vector to a new plant host
1. Insect vectors feed on infected plants and acquire virus
3. Virus inoculation occurs when the insect feeds on the plant and delivers virus into a plant cell
Current Opinion in Insect Science

List of Insect Vector Transmitted Plant Diseases

Crop	Insect Vector	Techanical Name	Insect Photo	Pathogen Transmitted	Disease	Disease Photo
			Viral Diseases			
Cotton	Whitefly Homoptera: Aleyrodidae	*Bemisia tabaci*		Gemnivirus Particle	Cotton Leaf Curl Virus	
Papaya	Whitefly Homoptera: Aleyrodidae	*Bemisia tabaci*		Gemnivirus Particle	Papaya Leaf Curl Virus	
Banana	Aphid *Hemiptera: Aphididae*	*Pentalonia nigronervosa*		SSRNA Particle	Banana bunchy Top Virus	
Potato	Beetle Coleoptera: Coccinellidae	*Epilachna ocellata*		Potato Virus X	PVX	
	Aphid *Hemiptera: Aphididae*	*Macrosiphum euphorbiae*		Potato Virus Y	PVY	
	Aphid *Hemiptera: Aphididae*	*Myzus persicae*		RNA virus	Potato Leaf Roll Virus	
Tomato	Whitefly Homoptera: Aleyrodidae	*Bemisia argentifolii*		PLRV	Tomato Leaf Curl Virus	
	Tomato Thrip Thysanoptera: Thripidae	*Frankliniella schultzei*		TSWV	Tomato Spotted Wilt Virus	
Chilli	Aphid *Hemiptera: Aphididae*	*Aphis gossypii*		CMV	Chilli Mosaic	
	Whitefly Homoptera: Aleyrodidae	*Bemisia tabaci*		Gemnivirus Particle	Chilli Leaf Curl Virus	
Rice	Rice Leafhopper Hemiptera: Cicadellidae	*Nephotettix nigropictus*		DSRNA Particle	Rice Dwarf Virus	
Wheat	Planthoppers Delphacidae: Hemipter	*Javesella pellucida*		SSRNA Particle	Wheat Striate Mosaic Virus	
	Wheat Curl Mite Acari : Eriophyidae	*Aceria tulipae*		Mite	Wheat Spot Mosaic Virus	
	Wheat aphid	*Diuraphis noxia Hemiptera : Aphididae*		WYLV	Wheat Yellow Leaf Virus	

Barley	Aphid Hemiptera: Aphididae	*Schizaphis graminum*		Geminivirus Particle	Barley Yellow Dwarf Viruses	
Fig	*Eriophyid Mite Acari : Eriophyidae*	*Aceria fici*		SSRNA Particle	Fig Mosaic Virus	
Peach	Fastidious Bud Mite Acari : Eriophyoidea	*Eriophyes insidiosus*			Peach Mosaic Virus (PMV)	
Maize	Small Brown Planthopper, Delphacidae: Hemipter	*Laodelphax Striatellus*		DSRNA Partical	Maize Rough Dwarf Virus	
	Maize Leafhopper Cicadellidae: Hemipter	*Cicadulina Mbila*		Geminivirus Partical	Maize Streak Mosaic Virus	
Fungal Diseases						
Mango	Bark Beetle Coleoptera: Curculionidae	*Hypocryphalus mangiferae*		MSDS	Mango Sudden Death Disease	
	Mango bud (or gall) mite, Acari : Eriophyoidea	*Aceria mangiferae*		fungal	Mango malfomation	
Elm	European Elm Bark Beetle Coleoptera: Curculionidae	*Ophiostoma ulmi*		spore	Dutch Elm Disease	
Oak	Sap Beetle Coleoptera: Nitidulidae	*Carpophilus lugubris*		*Ceratocystis fagacearum*	Oak Wilt Disease	
Bacterial Diseases						
Citrus	Asian Citrus Psyllid Hemiptera: Psyllidae	*Diaphorina Citri*		*Labri Bacteri*	Citrus Greening	
Sesame Indicum	Leaf Hopper Cicadellidae: Hemiptera	*Orocious Albicineous ; O. Orientalis*		Phytoplasma	Phylodi	
Pear	Pear Psylla Hemiptera: Psyllidae	*Cacopsylla Pyricola*		Phytoplasma	Pear Decline Phytoplasma	
Potato Psllid	Potato Psyllid Triozidae : Hemiptera	*Bactericera Cockerelli*		Psyllid-Borne Bacterium	Potato Zebra Chip Disease	
Nematodal Diseases						
Milkweed	Milkweed Bug Hemiptera : Lygaeidae	*Oncopeltus fasciatus*		Nematode	Trypanosomes	

Terminology

A. Vector

a. An agent that transports a microorganism from one host to another. Insects that transmit plant disease are called vectors.

B. Disease

a. Any condition that impairs the normal functioning of an organism or body. Or Disorder of normal functioning of an organism

C. **Epidemiology**

a. The study of disease in populations of an organism.

65-66-67-INSECT DAMAGES

Transmission

Transmission is the passing of a pathogen causing communicable disease from an infected host individual or group to a particular individual or group .Regardless of whether the other individual was previously infected

Physical Transmission

In case of mechanical transmission the pathogen is simply carried externally or internally by the insect .Mostly Caused insects that have biting/chewing mouthparts.

Biological Transmission

Specific insect and the specific viral pathogen have some kind of association or relationship between the two .Mostly Caused insects that have sucking mouthparts

1-The pathogens may enter the plant through feeding injuries made by either the chewing or the sucking type of insect

2-Through punctures made for egg laying and by way of the burrows and galleries of insects in wood

Particularly in the case of the filterable viruses, those little-known agents causing the so-called mosaics and related plant diseases .insects become carriers of the disease from plant to plant.

1. In such cases the insect involved is usually of the piercing-sucking type
2. Often this insect is essential to the overwintering of the disease, sometimes even necessary to carry the disease from one plant to another

Insect Vector born Diseases in Human

Another field in which insects are highly injurious is that of human and animal health and comfort .Some insects, notably mosquitoes and flies, annoy man and other animals by their bites and stings .Other insects such as lice have become adapted to more or less continuous life upon animals and cause much discomfort and loss of vitality

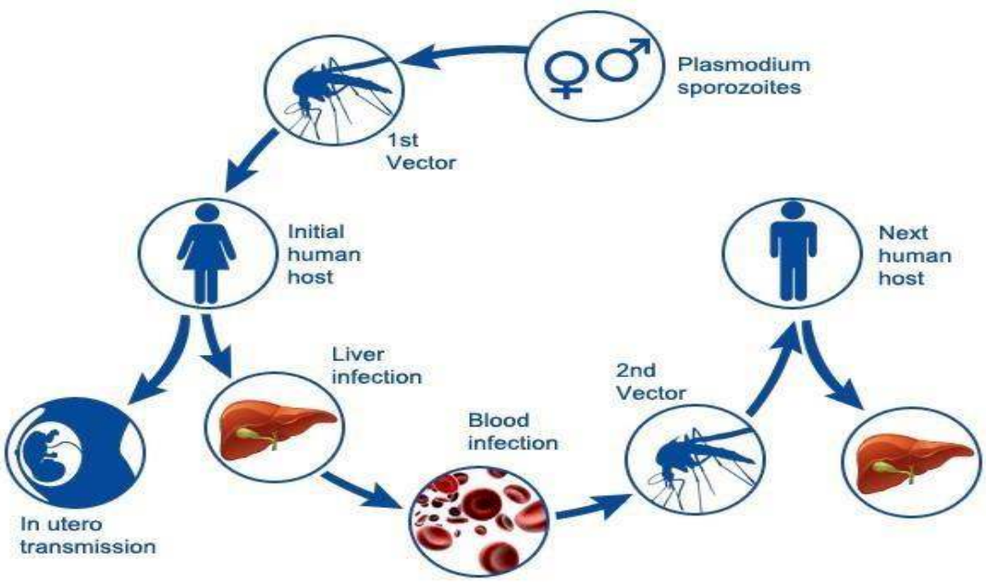
Not only do insects live externally on animals but also internally in the skin tissues, and in a few cases within the flesh and in the alimentary tract

Besides the mental and bodily loss due to their presence, insects transmit disease organisms from one person or animal to another

Just as in the transmission of plant diseases the insect may be an accidental agent or an essential carrier

A few of the more important insect-borne disease in organisms are

- Malaria
- Bubonic plague
- Typhoid
- Typhus
- Yellow fevers.



3. Allergy (hay fever, asthma, etc.) are frequently caused by exposure of susceptible persons to dried insect scales and hairs

4. Not only is the loss of life because of insect-borne diseases a very serious matter but the total loss of productive labor through illness is tremendous

Disease	Causative agents	Vectors	Methods of infections
Malaria (commonest)	Plasmodium	Anopheles mosquitoes	Bite
Dengue fever	Virus	Aedes mosquitoes	Bite
Encephalitis	Virus	Culex mosquitoes	Bite
African sleeping sickness	trypnosomas	Tse tse fly	Bite
Dysentry (amoebic)	Protozoan	Housefly	Contamination of food
Dysentery (bacilary)	Bacterium shigella sp.	Housefly	Contamination of food
Cholera	Vibrio cholerae	Housefly	Contamination of food
Onchocerclosis	Parasite worm, onchocerco volvulus	Black flies	Bite
Plague	Bacterium, pastaurella pestis	Oriental rat flies and other fleas	Bites of contact with infected rodents
Typhoid	Salmonella typhi	Houseflies	Contamination of food
Typhus	Ricketsia prowzeki	Human louse flies	Contamination or bite
Yellow fever	Viruses	Aedes mosquitoes	bite

68-69-INSECT BENEFITS

- The benefits to man from their activities are frequently overlooked in summing up the economic importance of insects
- Although in many cases it is impossible to say how much good is derived from insects

1-Attack on injurious species

- Reliable statistics are easily obtained relative to the production of useful insect products
- Those insects which attack injurious species probably form the most important group

They are divided into two sections:

- 1-The parasites that live in or on the different stages of other insects, then called hosts
- 2-The predators that capture and devour other insects
- Parasites usually, though not always, live in or on a single host insect during their entire development
- Whereas a single predator may derive its nourishment from many victim insects.
- Parasites are of many species, frequently so specialized in their habits that one kind of parasite attacks only one or a few host species
- In some cases the parasites work only in insect eggs and thus prevent any feeding loss by the host insect

- Other parasites attack early stages of the pests, in some instances killing them soon
- In others not until the pests have completed their feeding in spite of being parasitized.
- In the latter the benefit is less, but at least there are fewer adults to produce the next generation
- All stages are known to be attacked in different species by one parasite or another

70-INSECT BENEFITS

Pollination

- Some plants, as the Smyrna fig, clovers, melons, tomatoes, beans, peas and most of the common fruits, require the visits of insects before the seeds or fruits can form
- Another highly important group of insects includes those which pollinate flowers during their visits for nectar and pollen, thus enabling the plants to produce seeds
- The value of these crops which require the services of insects in the United States amounts to over two billion dollars

3-Commercial Products

- A third group of insects is responsible for a number of commercial products
- **1-Silk**
- **2-Honey**
- **3-Beeswax**
- **4-Shellac**

4-Diet of certain birds, mammals

- Insects provide the entire diet of certain birds, mammals, etc., and an important part of the diet for many others

5-Serve as Food

- Even man in some parts of the world consumes large quantities of grasshoppers, crickets, ants and other insects
- The great value of some insects and the great losses, sometimes enormous, caused by others make it obviously important to encourage the beneficial forms while striving to prevent or at least to reduce the losses caused by the injurious ones

71-Insect Pest Management

- The stud of principles and experimental approaches to the science that underpins the development of working integrated pest management systems

Types of insect control

- **A-NATURAL CONTROL**
- **B-ARTIFICIAL CONTROL:** Measures for the artificial control of insects may be divided into six groups:
- (1) mechanical control
- (2) cultural control

- (3) biological control,
- (4) legislative control
- (5) physical control
- (6) chemical control.

72-A-NATURAL CONTROL

1. Under the heading of natural control fall those various factors which affect the distribution and welfare of insects
2. But do not depend upon man for their success

They include

(1) **climate include**:

a. Temperature

b. Humidity

3. Air movement
4. (2) **Topography** include

a. Land and water barriers

b. Soil ,texture and composition

(3) **Parasites and predators**

c. Include insects and other animals

(4) **Diseases** caused by

d. Fungi or bacteria, etc.

Where no disturbing influence is introduced by man or any other agency, the insect population tends to be more or less completely held in balance by these natural factors

73-74-Climate

1. Climate, including temperature, moisture, etc.
2. Climate is probably the most important factor affecting the distribution of insects.
3. **I- Temperature**: No insect can live and develop at **temperatures** higher or lower than a certain range
4. The temperature at which development is most rapid, is about midway of this range; at other points either higher or lower the development is proportionately slower
5. **II- Moisture**: The same statements hold true for air moisture although variation due to moisture differences is usually less marked
6. The favorable range of either temperature or moisture varies with different insect species, often even during the stages of development

7. **III- Weather Conditions**: It is easy to understand from these facts why some insects are prevented by winter temperatures from living in the northern United States, and why some can live only there

8. After several favorable winters

9. An insect pest may become very numerous, then disappear suddenly when a severe winter occurs

10. One combination of weather conditions in summer may favor one type of insect pest; another set of conditions may suppress the first pest but favor others equally serious

11. Not only the annual temperature range but the fluctuations that occur within short periods are often important in limiting the range of an insect

12. Frequent small showers have a different effect from infrequent cloud bursts; the latter may produce the greater total rainfall but actually supply less air moisture

13. Wipds may carry some insects for considerable distances, and they may also bring moisture from large bodies of water or in other localities have a drying effect

14. Sunshine has much to do with insect flight, hence with the speed of insects

75-Topography

1. **Mountain ranges and large bodies of water** are more or less effective barriers to the spread of animals (including insects) and plants

2. Low lands are barriers to the spread of mountain types, because any region unsuited to the development of an insect presents a barrier to the spread of that species if the area is extensive enough

3. Because so many insects are dependent upon plant life for their food, either directly or indirectly

4. Those factors which limit plant development may indirectly form barriers to insect spread

5. It must be understood that most insects are limited to certain plants, many to only one kind or a few closely related plant species

6. In seasons unfavorable to the growth of its food plant an insect will be reduced in numbers, either by starvation or by the inability of the adult females to find food plants upon which to lay their eggs

7. Sometimes such numbers of an insect occur that the food plant is consumed almost completely and many of the insects starve as a result

76-Parasites and Predators & Diseases

- Not only do mountains, oceans, climate and plant life control the size and distribution of insect populations

- But **insect parasites, birds, various diseases**, etc., are vital factors in limiting the numbers of insects

- The more abundant an insect becomes, the more food is available for its parasites

- Finally the parasites become so numerous that practically all the hosts will have been found and killed
- The next generation of parasites consists, of course, of many more individuals, but most of these will die for lack of food
- Under such conditions, a "**balance of Nature**" develops
- Though the scales may tip first to one side and then to the other, this balance is preserved within certain limits of fluctuation

B-ARTIFICIAL CONTROL

- **Factors of insect outbreak:** In the course of the development of agriculture, man has increased the number and magnitude of his **entomological problems**
- I- **Introduction of new plant species**: Before the settlement of this country there were, of
  course, native insects attacking the various plants growing here

77-Factors of insect outbreak

Factors of insect outbreak

1. New plants were introduced by the settlers and grown in greater abundance than the wild and scattered ones
2. An insect finding in any of these an acceptable food had at once a more abundant supply and rapid multiplication thus became possible and resulted in increase of the pest to injurious numbers
3. **II- Accidental introduction insect**: A second factor has been the accidental introduction of many insect pests from foreign countries
4. In the United States such forms have often failed entirely to maintain themselves
5. Unfortunately on the other hand some others have frequently found conditions favorable to a rapid increase
6. These multiply unchecked by their natural enemies which in most cases have not accompanied them to this country
7. **III- Destruction of insectivorous birds**: A third factor is that with the increasing occupation of the country, insectivorous birds have been destroyed or frightened away
8. Although some birds have adjusted themselves to the new conditions it is not likely that
   their increase makes up for the loss of other species

78-Artificial Control

1. Why Artificial Control ?
2. Nature tends to re-establish a balance after some new influence has upset the old state of affairs, although the process may require many years

3. Even then there will be certain years when the population, of a species will be large as the result of normal fluctuation
4. Man cannot wait a number of years for **Nature** to adjust matters, nor can he afford avoidable crop failures every few years
5. He requires artificial measures by which he can protect himself and his crops from the ravages of injurious insects
6. Measures for the artificial control
7. Measures for the artificial control of insects may be divided into six groups:

    (1) mechanical control

    (2) cultural control

    (3) biological control

    (4) legislative control

    (5) physical control

    (6) chemical control

8. Whatever the method and its effectiveness, the cost of control must be a deciding factor
9. It is evident no financial profit to an individual owner will be gained by attempting control when the cost is greater than the probable loss
10. Sometimes, however, the profit to the community over a period of years may warrant treatment controlling more than the loss for anyone year
11. Often it is not profitable to use any known method of control for insects injuring crops of small value

79-MECHANICAL CONTROL

1. Under mechanical control are included those methods by which insects are controlled directly by hand
2. **I- As in hand-picking from infested plants**
3. **II- By mechanical devices such as**
    a. window screens
    b. fly traps
    c. bands on trees
4. Frequently egg masses or nests of larvae may be cut from plants and destroyed as an important aid in the small-scale control of an insect pest
5. Where labor is cheap enough to make the method profitable over larger areas
6. Deep furrows, lines of creosote or low fences of sheet metal or paper are used as barriers against the migration of nonflying insects
7. Sticky bands on trees are utilized to capture climbing insects
8. Burlap and paper bands serve as localized hiding places from which the insects may be taken and destroyed

9. Paper collars are sometimes placed as insect barriers around individual plants, and the trunks of trees may be wrapped to ward off insect attack

10. Besides hand methods, traps and barriers, machines are used sometimes for actually crushing or grinding the insects

80-82-83-CULTURAL CONTROL

- **Cultural control has been defined as including" regular farm operations performed so as to destroy insects or prevent their injuries“**
- **Frequently a vigorous, healthy plant is not only better able to withstand insect injury**

Methods of Cultural Control

1. But also less liable to attack than one weakened by lack of proper nourishment or by disease
2. **1- Intelligent cultivation and use of fertilizers** is well as pruning to remove injured or diseased parts will aid in insect control
3. **2-** The **destruction of vegetable trash and weeds**, frequently called **clean culture**, is also an important factor, especially in the control of hibernating insects
4. Weeds not only interfere with successful crop growth by **crowding**, but they may reduce the vigor of the crop by **competing for plant food** in the soil
5. In winter they provide **hiding places for hibernating pests**
6. A pest appearing in the spring before its crop food plant is available may find certain weeds palatable until the crop has appeared
7. Other pests move to late summer and fall weeds after their particular crops have been harvested
8. **3- Decaying fruits and vegetables** also harbor insects and should be disposed of in such a manner that the insects will be destroyed
9. **Dead grass and leaves may be burned** to kill insects that would find protection under them
10. But the loss of soil fertility should be weighed against the possible value in insect control
11. **4- The destruction of weeds and brush** along fences is of advantage in the reduction of insects
12. But it results in the elimination of nesting and hiding places for insectivorous and game birds
13. **5-** A third farm operation useful in insect control is the **rotation of crops**
14. Often an insect pest may be reduced to unimportance if the crop which it affects is alternated with other crops not eaten by it
15. The various grains are related to, in fact actually are, grasses and are eaten by many of the same insects
16. Only a few general grass feeders are also injurious to clovers and other legumes.

17. It is therefore common practice to **rotate grasses and legumes**, cultivated crops also often being added to the rotation
18. How far this principle can be put into practice depends upon many factors besides the insect phase
19. **6-Time and method of plowing** and cultivating form a fourth factor in the cultural control of insects
20. Many insect pests overwinter in larval or pupal cells in the ground
21. These cells can often be broken up by fall plowing so the insects will not survive the winter
22. Cultivation in the summer frequently breaks up pupation cells
23. But plowing or cultivation to be effective must be timed according to the life history of the insect that is being controlled, otherwise it is useless
24. For the control of some insects it is necessary to **refrain from cultivation** at certain times
25. The **depth of plowing** varies sometimes according to the habits of the insect.
26. **7-** As in tillage practice the **time of planting and of harvesting** are also of importance in protecting crops against insect pests
27. It is sometimes passible to avoid the time of egg laying, to push young plants to the stage where they are not likely to be badly injured or even to mature a crop before the insects appear in dangerous numbers
28. The timing or wheat planting to **avoid infestation** by the hessian fly is the best example of the success of such practices
29. **8- Varieties or strains of some plants** have been found more resistant to insect attack than others
30. To develop resistant strains and to prove their value, however, frequently require long, expensive research in plant genetics
31. Instances in which some success has been obtained will be mentioned under the insect pests concerned

84-85-86-87-BIOLOGICAL CONTROL

1. **Parasitic and predaceous** insects as well as diseases of insects have already been discussed
2. As vital factors in the **natural control** of injurious insects
3. It is possible, however, for man to encourage such beneficial forms by introducing them into new areas
4. By growing them artificially for liberation whenever they become scarce in nature
5. Until recent years most of this work dealt with the introduction of parasites
6. From abroad **to combat those foreign insect pests** brought to this country accidentally but without their natural enemies
7. Certain **native parasites and predators** are now being reared in large numbers for liberation in areas badly infested with their host species

8. Probably the first introduction attempted from a foreign country was the now classic case of a **ladybeetle brought from Australia** to attack the **cottony cushion scale**
9. Which had already reached California and was endangering the existence of the citrus industry
10. Following this successful attempt many other parasites and predators have been imported
11. Which in many instances have proved valuable in reducing the numbers of foreign pests
12. Parasites should not be expected to kill off all their hosts
13. They will merely reduce the population to greater or less extent
14. Other control measures must also be used if the insect is to be exterminated
15. The discovery and introduction of parasites are expensive
16. However, since a successful parasite perpetuates itself, the initial high cost of establishment may be spread over a period of many years
17. Many dangers are involved in bringing parasites into a new country
18. These insects may attack not only the pest that is to be controlled
19. But also other parasites of the pest
20. In such cases the introduction may be of little value
21. There is always the chance also that their own secondary parasites may be imported along with the primary ones
22. Only thoroughly trained entomologists
23. Therefore, should be permitted to bring parasites and predators to this country if we are to avoid the introduction of undesirable insects along with the desirable ones
24. The liberation of insect diseases is not so generally successful as variations in natural conditions limit the growth of the disease
25. Many of the disease organisms are widely distributed and appear spontaneously
26. When suitable conditions prevail, even without any encouragement
27. The most systematic use of diseases in artificial insect control in the United States appears to be the annual distribution by the state of Florida of **fungi** that live on the **whiteflies that attack citrus**

88-89-LEGISLATIVE CONTROL

1. Various laws and regulations both Federal and state have been enacted to prevent the introduction of foreign pests:
    a. **To prevent their spread within the country**
    b. **To enforce control and extermination**
    c. **To ensure that chemicals used for controlling insects are neither adulterated nor misbranded**
2. These laws and regulations take the form of absolute quarantines, the inspection of plants to be shipped

3. The obligatory treatment of growing and harvested crops and the testing of insecticides.
4. Plants entering the country or crossing state boundaries must at least be inspected, and in some cases shipment is barred absolutely
5. If any pest in a state is the subject of a Federal quarantine, a limiting line may be fixed within that state by Federal authority to prevent shipment to points outside the quarantined area 6. Various regulations are in force controlling particular cases
7. But in general, plants, especially nursery stock, carried from one region to another must be passed by an authorized state or Federal inspector as free from insect pests and plant diseases
8. Before shipment will be permitted.
9. Because insects will spread by flight and by wind carriage and because many escape discovery during inspection
10. It is reasonably certain that in spite of quarantines these pests will gradually spread over such parts of this country as they are able to inhabit
11. The chief gains from legislation, then, are
    a. **(1) to delay the spread of pests** and protect un-infested localities from their attacks as long as possible
    b. **(2) to prevent new pests from entering the country**
12. It is believed that the tremendous expense involved in thus delaying the spread of new insect pests is far outweighed by the crop losses avoided
13. The time gained for preparing the country to control those pests which will eventually spread over it

90-91-92-93-94-Physical Control

- The extremes of both **temperature and humidity**, either high or low, are not only effective barriers in the natural control of insects
- But they are also useful in artificial control
- Light and electricity are other factors that come under this heading

Physical Factor Controlling Insects

- **1- Heat**
- **2-Cold**
- **3-Moisture**
- **4-Light** **5- Electricity**

1- Heat

2- Most insects cease reproduction and soon die at temperatures rom **100 to 1I0°F**

3- The temperature of their surroundings should be raised to **120° or higher** to kill them with heat artificially **within a few hours**

4- The length of period for effective treatment is more dependent upon the

a. time to heat the grain

b. clothing

c. other material in which the insects are located

5- Than upon the heat resistance of the pests themselves

6- Because no insect can survive more than an hour if actually exposed to a temperature of 120°F 7- Bales and bags are difficult to heat through

2- Cold

1. Although **low temperatures** are not so effective as high ones in killing insects
2. Many insect pests of stored products such as **furniture, rugs, clothing and seeds** become inactive at **40 to 45°F**.
3. Under these conditions infested materials suffer no further damage or increase in infestation
4. And materials free from insects when put into cold storage will remain so.
5. Those insects which hibernate outdoors withstand temperatures far below zero
6. Most insect pests of stored products, however, are unable to become dormant in the true sense and are killed in a relatively short time even at temperatures considerably above zero
7. The use of low temperatures in the artificial control of insects, there fore, is of two types
8. The more important is cold storage, as for furs, at temperatures just low enough to protect the stored materials from injury
9. The other use of cold actually to kill insects is feasible only on a large scale in zero weather in the north
10. Here as in the case of the heat-treatment much more time is required to chill grain, flour, clothing and other products than is usually realized

3- Moisture

- A conspicuous example of the manipulation of moisture to control insects
- Is the drying of grain to reduce the likelihood of **weevil injury**

4- Light

- It is well known that many insects are attracted to bright lights
- This fact has been used extensively to trap insects, sometimes for the purpose of studying their distribution, sometimes as a control measure
- Although considerable research is still required in this field it is apparent that insects are attracted more by lights of some colors than by those of others 5- Electricity

1. Devices are available for electrocuting insects
   a. I-Some in the form of **electrical window screens** for flies
   b. II-Others as **electric light traps** for moths and beetles
2. These are so arranged that an insect striking parallel wires of the device completes an electrical circuit and is killed by the shock

3. A machine for the electrical treatment of insect-infested grain and cereal products has been used successfully for several years

4. In which the insects are killed when the product is passed through a field of high frequency between two electrodes

95-CHEMICAL CONTROL

- The chemical control of insects includes control not only with **insecticides** in the true sense as discussed in the following chapters
- But also with various materials used to **attract and repel insects** without actually killing them

Attractants

1. Sometimes called **attrahents** are materials used to **lure insects** to traps and poisoned baits
2. The use of geraniol in **Japanese beetle traps**, **sugar sirups** for **ant baits**, and **fermenting sirup solutions** for trapping various moths are good examples.

Repellents

1. Repellents are those materials used to keep insects away from crops, animals and man
2. Various **coal-tar** and **pine** products are rather general insect repellents.
3. **Naphthalene** is a clothes moth repellent and oil of citronella is a common ingredient of preparations used to keep mosquitoes away from people

96-97-98-99-Insect Classification

Classification

1- Scientific Classification is a system used to classify all living things through a breakdown starting with the largest grouping called a Kingdom

2- And continuing down to the smallest grouping called species

3- Insects can be placed into groupings based upon their physical characteristics

4- Insects with similar characteristics, number of wings, mouthparts, etc. are placed in a group

5- Identification of insect orders aids in prevention and management plans

6- Insects belong in the Phylum **Arthropoda**

7- The **Phylum Arthropoda** is characterized by having segmented bodies and jointed appendages

<u>5 Classes of Arthropods</u>

1. **Class #1- Hexapoda:** Insects, six, jointed appendages
2. **Class #2- Chilopoda**- Centipedes, one pair of legs per body segment, multiple body segments
3. **Class #3- Diplapoda-** Millipedes, two pairs of legs per body segment, multiple body segments

4. **Class #4- Crustacea**- Crayfish, five pairs of jointed appendages
5. **Class #5- Arachnida**- Spiders, four pairs of jointed appendages

Classification

6. There are 31 different orders of insects in the **class Hexapoda**
7. Sixteen of which are considered of economic importance to agriculturists

Orders of Insects

The sixteen orders are:

- 1- Orthoptera
- 2- Hemiptera
- 3- Homoptera
- 4- Coleoptera
- 5- Lepidoptera
- 6- Diptera
- 7- Hymenoptera
- 8- Odonata
- 9-Neuroptera
- 10-Thysanura
- 11-Isoptera
- 12-Siphonaptera
- 13-Phthiraptera
- 14-Thysanoptera
- 15-Dermaptera
- 16-Blattodea

1-Orthoptera

1. **This order includes:** Indian House Crickets, Field Cricket, Short-horned, Grasshoppers, Katydid (Long-horned Grasshoppers)
2. **Mouthparts:** Chewing
3. **Metamorphosis:** Incomplete Metamorphosis
4. **Damage:** Chewing leaves, Crop grains
5. Over 20,000 species worldwide

2- Hemiptera – True Bugs

1. **Examples:** Assassin bugs, Kissing bugs, Leaf-footed bug, Lygus bug, Stink bug, Minute pirate bug,Big-eyed bug, Damsel bug
2. **Mouthparts:** Piercing-Sucking
3. **Metamorphosis:** Incomplete Metamorphosis
4. All of the true "bugs" are in this order
5. Most have a common v shape on their shield

3-Homoptera

1. **Includes:** Cicadas , Aphids , Armored scales , Cottony cushion scale, Cochineal scale,Leafhoppers, Treehoppers, Whiteflies
2. **Mouthparts:** Sucking
3. **Metamorphosis:** Generally incomplete

4-Coleoptera

- **Includes: Beetles and Weevils**
  1. Blister beetle
  2. Boll weevil
  3. Collops beetle
  4. Darkling beetle
  5. Dermestid beetle
  6. Dung beetle
  7. Fig beetle,
  8. Flea beetle
  9. Lady beetle
  10. Long-horned beetle
  11. Palo Verde root borer
  12. Metallic wood borer
- **Mouthparts:** Chewing, Weevil- Piercing Sucking
- **Metamorphosis:** Complete Metamophosis

5- Lepidoptera

- **Includes:** Butterflies and Moths

Examples: Bagworm, Two-tailed Swallowtail

Budworm/Bollworm, Pink Bollworm, Grape-leaf Skeletonizer Salt Marsh Caterpillar, Tomato Hornworm, Sphinx Moth

Monarch, Checkered skipper

- **Mouthparts**: Chewing – Caterpillars, Siphoning – adult
- **Metamorphosis:** Complete Metamorphosis

100 101: Insect Classification

6- Diptera

Includes: Flies, Midges, Mosquito

Examples: House fly , Crane fly , hover fly , Bee fly ,Tachinid fly, Bot fly, Deer fly, Mosquito, Gall Midge

- **Mouthparts:** Sponging, Piercing sucking- Mosquito
- **Metamorphosis:** Complete Metamophosis

7- Hymenoptera

- **Includes:** Bees, Wasps, Ants
- **Examples:** Horntail wasp, Sawfly, Gall wasps, Honey bee

Leaf-cutter bee, Carpenter bee, Bumble bee, Harvester ant ,Leaf-cutter ant, Fire ant, Velvet Ant, Paper wasp ,Ichneumon wasp, Thread-waisted wasp, Tarantula hawk

- **Mouthparts:** Chewing-Lapping
- **Metamorphosis:** Complete Metamorphosis

-

8- Odonata

- **Includes:** Dragonfly, Damselfly
- **Mouthparts**: Chewing-Lapping
- **Metamorphosis:** Complete Metamorphosis
- Live in the water the first year of their lives
- After leaving the water they only live a month
- Have been around 300 million years

101 Insect Classification

9-Neuroptera

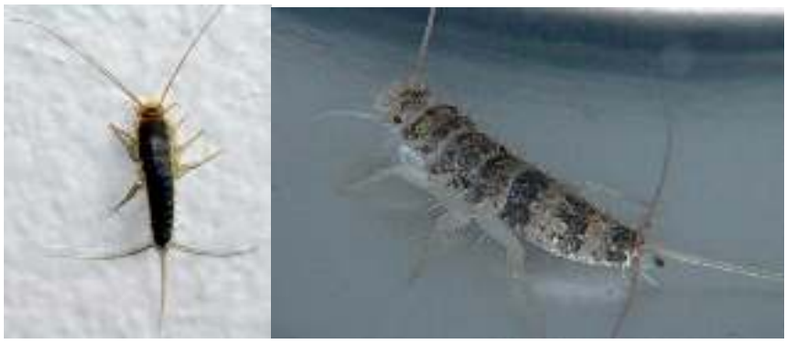
- **Includes:** Green Lacewing, Antlion
- **Mouthparts**: adults have hypognathous (directed downward) mouthparts and unique piercing– sucking larval jaws composed of the mandibles (directed downward) plus maxillae
- *Metamorphosis:* Complete Metamorphosis
- Both are beneficial insects
- Antlions creat a sand pit to capture unsuspecting prey

10- Thysanura

- **Includes:** Silverfish, Firebrat

  Mouthparts: Chewing

- **Metamorphosis:** Incomplete Metamorphosis
- Like to lay their eggs in books and wall paper because of the paper and glue Live 3-5 years Most primitive of all insects



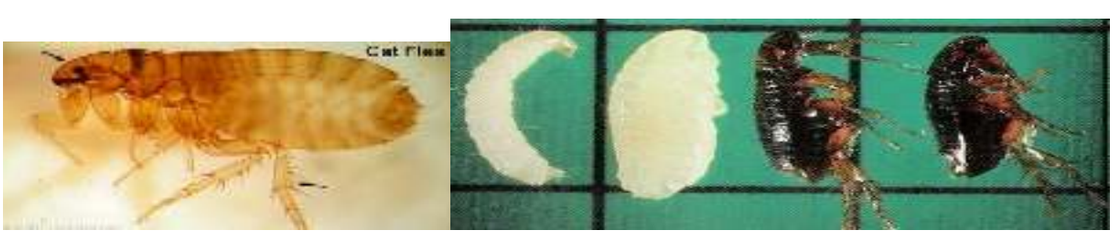
11- Isoptera

- **Includes:** Dry-wood termite, Subterranean termite
- **Mouthparts:** Chewing Mouthparts **Metamorphosis:** Incomplete Metamorphosis
- Live for 15 years.
- Lay 1 egg every 15 seconds
- Eat wood. Can destroy a house in 2-3 years
- Found in every US state except Alaska.
- Recycle wood in the soil

102 Insect Classification

12- Siphonaptera

- **Includes:** Cat and dog flea
- **Mouthparts**: Piercing Sucking
- **Metamorphosis:** Complete Metamorphosis
- Fleas can live 100 days without feeding
- Can jump 100 times their own length

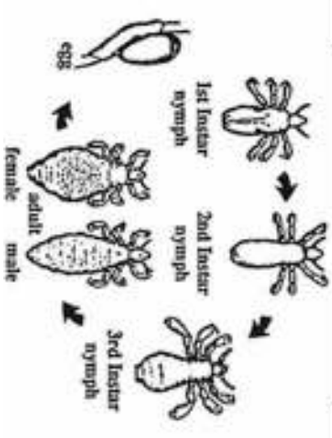


13- Phthiraptera

- Formally Anoplura and Mallophaga
- **Includes**: Lice, Chewing Louse, Sucking Louse

-

- **Mouthparts**: Chewing and Piercing-Sucking
- **Metamorphosis:** Complete Metamorphosis

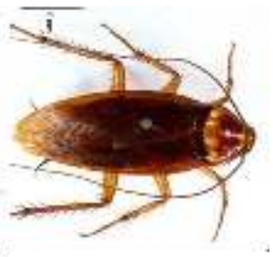


14- Blattodea

- **Includes:** Cockroaches, American Cockroach, Brown-banded cockroach

Desert Cockroach, Turkish Cockroach, German Cockroach

- **Mouthparts:** Chewing Mouthparts
- **Metamorphosis**: Complete Metamorphosis



103 Insect Classification

15- Dermaptera

- **Includes**: Earwigs
- **Mouthparts:** Chewing Mouthparts
- **Metamorphosis**: Complete Metamorphosis

  Live humid and dark areas

- Oldest known fossil dates back to Jurassic period

16- Thysanoptera

Includes: Thrip

- **Mouthparts:** Rasping-Sucking Mouthparts
- **Metamorphosis:** Complete Metamorphosis
- Common Pests on flowers, citrus and onions

104 Integrated Pest Management (IPM)

- A pest management philosophy that utilizes all suitable pest management techniques and methods to keep pest populations below economically injurious levels
- Each pest management technique must be environmentally sound and compatible with producer objectives

Utilizes all suitable pest management Ways

- Pesticide Control
- Cultural Control
- Mechanical Control
- Sanitary Control
- Natural Control
- Biological Control Host Plant Resistance

Pesticide Control

- Pesticides can to be used in an IPM program, however only as a last resort
- Pesticides are to be used when there is no risk of environmental damage or when benefits outweigh the risks
- Use pesticides only when other control practices aren't available, economical or practical
- Important aspect to use pesticides:
- Must monitor pest populations in the field.
- Identify the pest
- Compare pest population and the economic threshold

- Life stage susceptible to pesticide?
- Crop stage and preventable loss

105 Integrated Pest Management (IPM)

What is "Cultural Control"

Agronomic practices that are designed to:

- 1-Optimize growing conditions for the crop
- 2-Anything that increases a crop's competitive edge will result in increased tolerance to pests often resulting in reduced pesticide use
- 3- Create unfavorable conditions for the pest **What is Mechanical Control?**
- Uses machinery and/or other tools to control pests
- 1- Tillage: Tillage is the agricultural preparation of soil by mechanical agitation of various types, such as digging, stirring, and overturning 2- Physical barriers

What is Sanitary Control?

- **Methods to avoid introducing a pest into a field by**
- 1- Cleaning field equipment
- 2- Planting certified seed
- 3- Quarantines

What is Natural Control?

- Enhancement of naturally occurring pest management methods by introducing
- 1- Beneficial insects
- 2- Beneficial diseases

106 Integrated Pest Management (IPM)

What is Biological Control?

- **Manipulation of biological organism to control pests by:**
- 1- Release of predators/parasites/disease of an insect or weed Can be time consuming, expensive and difficult

What is Host Plant Resistance?

- Manipulating the crop to withstand or tolerate pests by
- 1- Natural breeding method

- 2- Genetically modified plants
- **Examples**: Glandular-haired Alfalfa, Bt Corn,

Important Steps of IPM

1- To Keep Pests Below the Economic Injury Level

- Economic Injury Level:

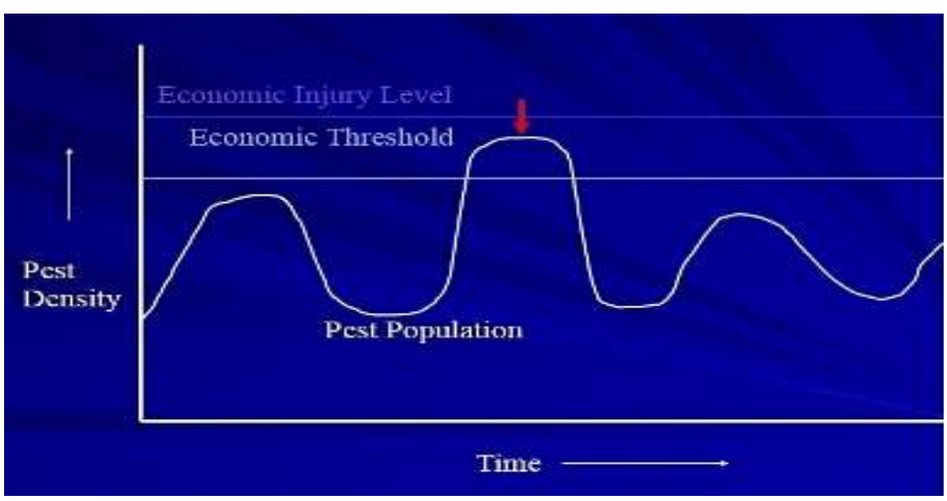
Cost of control = $ amount of damage caused by the pest

- Includes amount of pest damage
- Cost of each control practice
- Economic Injury Levels are determined through extensive research
- Economic Injury Level is the information that is necessary to develop an **Economic Threshold**, which is used by crop advisors

107 Integrated Pest Management (IPM)

Economic Threshold:

- "Pest Population at which a grower must take action to prevent a pest populations from reaching the economic injury level"
- Economic threshold is slightly below the economic injury level
- And pest populations must be increasing
- This graph explains the relationship of the Economic Injury Level to the Economic Threshold
- The red arrow may indicate a pesticide application which was applied at the economic threshold and did not allow the pest population to reach the Economic Injury Level



Four Basic Principles of IPM

- 1) Thorough understanding of the crop, pest, and the environment and their interrelationships
- 2) Requires advanced planning
- 3) Balances cost/benefits of all control practices
- 4) Requires routine monitoring of crop and pest conditions

1a. Understanding Crop Growth and Development

- How do you grow a healthy crop?
- When is the crop most susceptible to pest damage?
- When is the crop under stress?

108 Integrated Pest Management (IPM)

1b. Understanding the Pest

Proper identification of pest Understanding of Pest Life cycle When is it present

- When is it most susceptible to control-"Weak Link"

2) Requires Advanced Planning

- The IPM approach suggests that we focus on preventative management practices before relying on rescue treatments (i.e. pesticides)
- This inherently requires advanced planning
- you must have a thorough understanding of the crop, pest and environment,. Use this information to anticipate pest problems and to plan preventative management practices such as crop rotation, row cultivation, variety selection, etc.

3) Balances cost/benefits of all control practices

- To accomplishment the desire objective, crop advisors balance the cost/benefits of all management practices
- It can be possible through the use of economic injury levels and economic thresholds, but we must also have to apply that philosophy to other IPM techniques as well
- If one of management practices is to use row cultivation to control weeds,
- we must determine the cost of equipment, fuel and labor before we know if it is an economical practice
- If a grower is considering using a genetically modified corn hybrid for European corn borer control, they have to consider if the high cost of the hybrid will offset the amount of damage

109 Integrated Pest Management (IPM)

4) Requires routine monitoring of crop and pest conditions

- The backbone of any IPM program requires routine monitoring of pest populations and crop conditions
- Without this information you can not make an intelligent pest management recommendation

If you are not monitoring pest populations

- How do you know if you are at the economic threshold?
- How do you know when is the best crop stage to treat?
- How do you know if you have pests at all?
- Maybe you will have high pest populations and not even realize until it is too late
- Pest Monitoring, sometimes call **field scouting**, is an activity that can be accomplished by anyone with a little advanced training
- In the simplest sense, a field scout must be able to tell a healthy plant from an unhealthy plant
- Realistically, a field scouting must know:
- How to properly identify pests and their damage
- How to get an accurate assessment of pest populations

- A field scouts objective is to provide an accurate and unbiased objective of pest populations
- What tools and procedures do you use for alfalfa weevil for potato leafhopper, etc.
- Both of these examples are pests on alfalfa, however, the sampling procedure is different.

110 Integrated Pest Management (IPM)

4) Requires routine monitoring of crop and pest conditions

Alfalfa weevil are not easily dislodged with an insect sweep net and therefore require that we monitor the amount of foliage they consumed and make a damage recommendation based on that observation

- Potato leafhopper, on the other hand, do not chew on the alfalfa leaves, but instead suck plant sap.
- We can not monitor their damage, nor are they easily counted on alfalfa foliage because they are small and easily fly when disturbed
- Instead, we must use and insect sweep net and count the number of adults and nymphs caught
- For second generation corn borers one sweet corn, we count the number of eggs laid on the leaves
- Different pests require different scouting practices

Benefits of an IPM Program

- Protects environment through elimination of unnecessary pesticide applications
- Improves Profitability
- Reduces risk of crop loss by a pest
- Peace of Mind

Disadvantages of an IPM Program

- Requires a higher degree of management
- More labor intensive
- Success can be weather dependent

111 Pests of Cotton

- Cotton is a soft, fluffy staple fiber that grows in boll, or protective
- Cotton (*Gossypium spp),* the king of fibers, usually *commercial referred as* white gold and one of the important commercial crops, plays a pivotal role in human civilization, economic, political and social affairs of world.
- The four cultivated species of cotton viz. *Gossypium arboretum, Gossypium herbaceum, G. hirsutum and G. barbadense belong to Malvaceace family*
- The plant is a shrub native to tropical and subtropical regions around the world, including the Americas, Africa, and India

Economic importance of cotton

It is chiefly grown for its fiber which is used for manufacturing of clothes for mankind

- **Cotton lint:** It is the most important vegetable fiber and is woven into fabrics either alone or combined with other fibers
- **Fuzz:** It is used in production of mattresses, surgical cotton, photographic film and paper.
- **Cotton seed:** Depending on varieties, it contains 20-25% semi-drying edible oil which is used for cooking.
- **Cotton seed cake:** Seed cakes contain 40% protein and serves as a important concentrated feed for livestock
- **Cotton stem:** The stem can be used as organic manure or fuel.

112 Pests of Cotton

American bollworm/Fruit borer: *Helicoverpa armiger*

Family: Noctuidae

- **Order:** Lepidoptera
- It is one of the important major insect of cotton crop

Fig.Feeding injury

- Symptoms of damage
  - Bolls showing regular, circular bore holes
  - Larvae seen feeding on the boll by thrusting their heads alone inside and leaving the rest of the body outside
  - Presence of granular faecal pellets outside the bore hole.
  - A single larva can damage 30-40 bolls.

Fig.Circular bore hole

Management

- Avoid continuous cropping of cotton both during winter and summer seasonsin the same area as well as rationing
- Avoid monocropping. Growing of less preferred crops like greengram, blackgram, soyabean, castor, sorghum etc., along with the cotton as intercrop or border crop or alternate crop to reduce the pest infestation
- Removal and destruction of crop residues to avoid carry over of the pest to the next season, and avoiding extended period of crop growth by continuous irrigation.
- Optimizing the use of nitrogenous fertilizers which will not favor the multiplication of the pest.
- Judicious water management for the crop to prevent excessive vegetative growth and larval harbourage
- Releasing predator *Chrysoperla carnea @ 1, 00, 000/ha at 6th, 13th and 14th* week after sowing.
- During bolling and maturation stage, apply any one of the following insecticides (1000 l of spray fluid/ha):
- **Phosalone 35 EC 2.5 l/ha**

- **Quinalphos 25 EC 2.0 l/ha**
- **Carbaryl 50 WP2.5 kg/ha**
- **Pyraclofos 50 EC 1.5 l/ha**
- **Endosulfan 35 EC 2.5 lit/ha Cypermethrin 10 EC 600-800ml/ha**

113 Pests of Cotton

Pink bollworm: *Pectinophora gossypiella*

- **Family**: Gelechiidae
- Order: Lepidoptera
- It is a notorious pest of cotton in all cotton growing areas.
- It is a major chewing insect of cotton crop.

Fig.Larva

Fig. Adult

Symptoms of damage

- Rosetted flowers
- The holes of entry plugged by excreta of larvae which are feeding inside the seed kernels.
- Discolored lint and burrowed seeds.

- They cut window holes (interlocular burrowing) in the two adjoining seeds thereby forming "double seeds“
- The attacked buds and immature bolls drop off.

Management

- Clean cultivation and destruction of crop residues (fallen leaves, twigs etc.) before the onset of season
- Plough deeply to expose the hibernating larvae / pupae
- Avoid late sowing of the crop. Early sowing helps in early maturity facilitating escape
- Withholding irrigation water to avoid prolonged late boll production/formation to reduce the build up of over-wintering population
- Acid delinting of cotton seeds
- Release of egg parasitoids *Trichogramma chilonis or E. johnstoni*
- Spray triazophos 40 EC 2.5l/ha and Quinalphos 20% AF in alternation even after 100 DAS

114 Pests of Cotton

Spotted bollworms: *Earias vittella* Spiny bollworm: *Earias insulana* Family: Noctuidae

- **Order**: Lepidoptera
- It is also a chewing insect pest of cotton that causes great economic loss to cotton crops.

Symptom of damage

- Drying and drooping of terminal shoots during pre – flowering stage
- Shedding of squares and young bolls
- Flaring up of bracts during square and young boll formation stage
- Holes on bolls and rotting of bolls

Fig2.Bore holes and rotting . Drying - terminal shoots

Management

- Collect and destroy all the shed fruiting parts Planting trap crop of bhendi, uprooting and burning
- Don't extend the crop period.

- Set up pheromone traps
- Conserve and encourage the activity of spiders ***Thomisus sp., Neosiana sp.***
- Spray the following insecticide

115 Pests of Cotton

Armyworm /Tobacco Cutworm: *Spodoptera litura*

- **Family:** Noctuidae **Order:** Lepidoptera. It is a major and important chewing insect pest of cotton crop.

Adult

Symptoms of damage

- Scrapping the epidermal layer, leaving the skeleton of veins of leaf
- During severe attack, only the stem and side shoots will be standing in the field without any leaf or bolls
- Larvae feed the leaves by making small holes.

Larva

Management

- Use of light trap
- Set up the sex pheromone trap **Pherodin S.L. at 12/ha**
- Growing castor along border and irrigation bunds.

- Removal and destruction of egg masses in castor and cotton crops.
- Removal and destruction of early stage larvae found in clusters
- Collection and destruction of sheded plant parts
- Hand picking and destruction of grown up caterpillars.
- **Spray any one of the following insecticides**
- chlorpyriphos 20 EC 2.0 l/ha;
- dichlorvos 76 WSC 1 lit/ha;
- fenitrothion 50 EC @ 625 ml.

116 Pests of Cotton

Cotton aphid – *Aphis gossypii*

- **Family:** Aphididae
- **Order** Homoptera
- An important sucking insect of cotton crop.

Symptom of damage

- Infesting tender shoots and under surface of the leaves
- Curling and crinkling of leaves
- Stunted growth
- Blighted appearance when infestation is severe
- Development of black sooty mould due to the excretion of honey dew giving the plant a dark appearance

Management

- Seed treatment with imidacloprid 70 WS at 7 g/kg protect the crop upto 8 weeks
- Release predator *Chysoperla carnea or coccinella sp.*
- Monitoring the activities of the adult by setting up yellow sticky traps
- **Spray any one of the following insecticides (500 l spray fluid/ha)**
- Imidacloprid 200 SL at 100 ml/ha

- Methyl demeton 25 EC 500 ml/ha
- Dimethoate 30 EC 500 ml/ha
- Phosphamidon 40 SL 600 ml/ha
- NSKE 5% 25 kg/ha

117 Pests of Cotton

Thrips: *Thrips tabaci*

- These tiny yellow to black, selender insects are annual pest in cotton field.
- They are active in spring.
- It is a major sucking insect of cotton crop
- **Family** Thripidae
- **Order** Thysonaptera.

Symptom of damage

- Shriveling of leaves due to scrapping of epidermis and desapping
- Attacked terminal buds – have ragged edges
- Silvery shine on the undersurface of leaves

Fig. Adult thrip

Management

- Seed treatment with Imidacloprid 70 WS @ 7 g/kg protects the crop up to 8 weeks.
- **Spray any one of the following insecticides (500 l spray fluid/ha)**
- Imidacloprid 200 SL at 100 ml/ha
- Methyl demeton 25 EC 500 ml/ha
- Dimethoate 30 EC 500 ml/ha
- Phosphamidon 40 SL 600 ml/ha
- NSKE 5% 25 kg/ha

118 Pests of Cotton

Whitefly: *Bemisia tabaci*

- **Family:** Aleyrodidae

- It is important sucking insect pest of cotton crop

Symptom of damage

- Chlorotic spots on the leaves which latter coalesce forming irregular.
- yellowing of leaf tissue which extends from veins to the outer edges of the leave
- Severe infestation results in premature defoliation Development of sooty mould .
- Shedding of buds and bolls and poor boll opening.
- It also transmits the leaf curl virus diseases of cotton.

Management

- Growing cotton only once a year either in winter or summer season.
- Adopting crop rotation with non-preferred hosts such as sorghum, ragi, maize etc.
- Removal and destruction of alternate weed hosts like *Abutilon indicum, Chrozophore rottlari, Solanum nigrum*
- Timely sowing with recommended spacing
- Preferably wider spacing and judicious application of recommended dose of fertilizers
- Late sowing may be avoided and the crop growth should not be extended Field sanitation may be given proper attention.

Spray any one of the following in mid and late stages (1000 l spray liquid/ha)

- Phosalone 35 EC at 2.5 l/ha
- Quinalphos 25 EC at 2.0 l/ha
- Triazophos 40 EC 2.0 l/ha
- Acephate 75 SP 1.30 kg/ha

119 Pests of Cotton

Red cotton bug: *Dysdercus cingulatus*

- **Family :** Pyrrhocoridae
- **Order** : Hemiptera

Symptom of damage

- Red stained lint and rotting bolls.
- Inner boll wall with warty growth or water soaked spots
- Young bolls abort and turn dark brown

- The bacterium *Nematospora gossypii enters the site of injury and stains the* fiber.

Management

- Plough the field to expose the eggs.
- Spray Phosphamidon 100 EC@250 ml/ha

Dusky cotton bug: *Oxycarenus hyalinipennis*

Symptom of damage

- Sucks the sap from developing seeds in open bolls and stains the lint black.
- Seeds discolored and shrunken

- Management
- **Spray Phosphamidon 100 EC@250 ml/ha**

120 Pests of Cotton

Mealy bugs: *Phenacoccus sp., Ferrisa sp. and Maconellicoccus sp.*

- **Family**: Peudococcidae
- **Order**: Hemiptera
- They are considered pests as they feed on plant juices and act as vector of various diseases.

Symptom of damage

- Heavy clustering of mealy bugs usually seen under surface of leaves as a thick mat with waxy secretion.
- Excrete copious amount of honey dew on which the fungus sooty mould grow.
- Affected plants appear sick and black, resulting reduced fruiting capacity.

Management

- Spray application of any following insecticides viz.
- Carbaryl 50 WP @ 1kg/acre,
- Thiodicarb75 WP @ 250 g/acre
- Profenophos 50 EC @ 500 ml/acre
- Acephate 75SP @ 800 g/acre.

Cotton Stem Weevil: *Pempheres (Pempherulus) affinis*

- **Family:** Curculionidae
- **Order**: Coleoptera
- It is a serious pest of cotton crop.

Symptoms of damage

- Swellings on the stem just above the ground level
- Young plants are invariably killed
- Older plants that survive, lack vigor and strength, and when strong winds blow, these plants sometimes break at the nodes.

Shoot weevil: *Alcidodes affaber*

- **Family**: Curculionidae **Order:** Coleoptera.
- **Symptoms of damage**
- Terminal shoots with galls
- Bore hole surrounded by raised margins

 Management

- Soil application of Carbofuran 3 G @ 30 kg may be done on 20 days after sowing and earthed up.
- Basal application of FYM 25 t/ha or 250 kg/ha of Neem cake.

121 Pests of Sugarcane

Insect pest	Scientific name	Family	Order
EARLY SHOOT BORER	*Chilo infuscatellus*	Pyralidae	Lepidoptera
INTERNODE BORER	*Chilo sacchariphagus indicus*	Pyralidae	Lepidoptera
TOP BORER	*Scirpophaga nivella*	Pyralidae	Lepidoptera

ROOT GRUB	*Holotrichia serrata*	Melolonthidae	Coleoptera
TERMITE	*Odontotermes obesus*	Termitidae	Isoptera
SUGARCANE SCALE	*Melanapis glomerata*	Diaspididae	Hemiptera
SUGARCANE MEALY BUG	*Ripersia sacchari*	Pseudococcidae	Hemiptera
SUGARCANE LEAF HOPPER	*Pyrilla perpusilla*	Lophopidae	Hemiptera
WOOLY APHID	*Ceratobvacuna lanigera*	Aphididae	Hemiptera
WHITE FLY	*Aleurolobus barodensis*	Alerodidae	Hemiptera

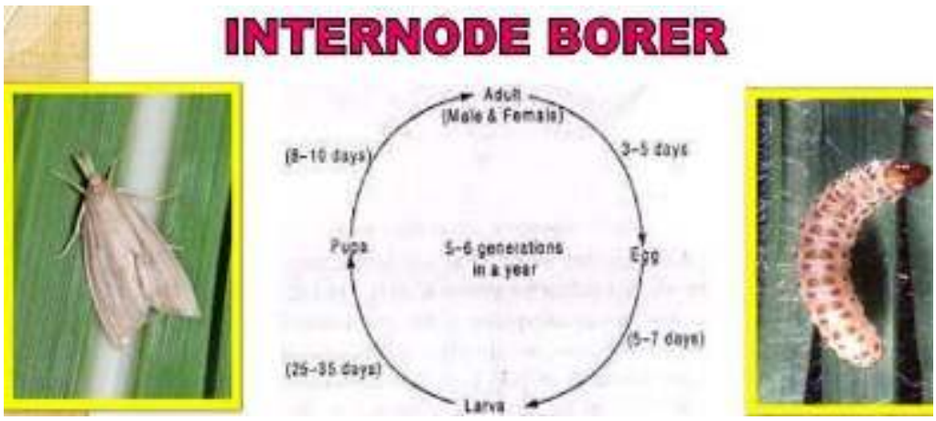
122 Pests of Sugarcane

Sugarcane Shoot Borer

SYMPTOMS OF DAMAGE

- Attack 1-3 month old crop and cause
- Dead heart , which can be easily pulled out
- Rotten portion of the cane colored dead heart emits an offensive odour.
- A number of bore holes at the base of the shoot just above the ground level

Internode Borer

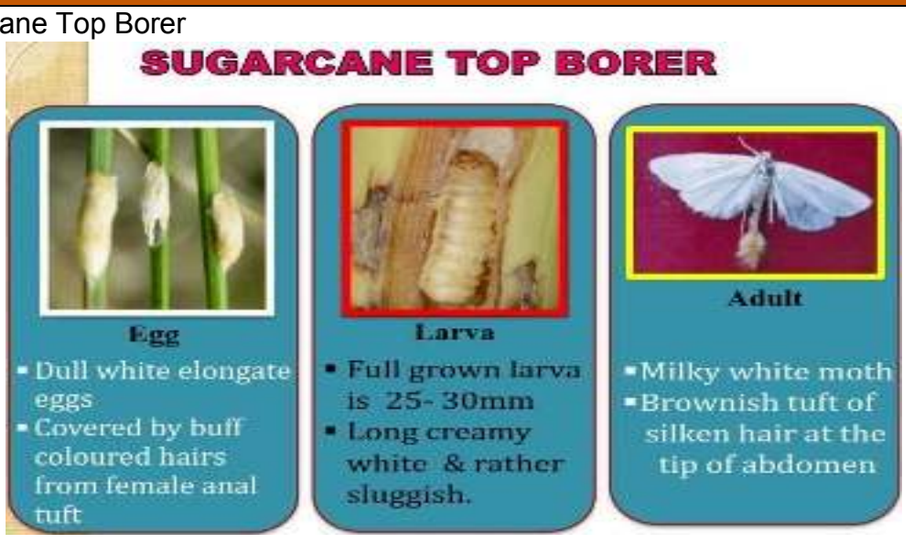


SYMPTOMS OF DAMAGE

- Constricted and shortened internodes, with a number of boreholes filled with excreta at nodal region
- Reddening of affected tissues inside the cane
- Fresh borer attack is mostly found in the top five immature internodes and its activity continues till harvest.

123 Pests of Sugarcane

Sugarcane Top Borer



SYMPTOMS OF DAMAGE

- Parallel rows of short holes in the emerging leaves causes a white streak which later turns reddish brown
- Dead heart in grown up canes reddish brown in color which cannot be easily pulled
- In tillering phase of the crop, the attacked shoots die, side shoots (tillers) develop Parallel rows of short producing a bunchy top appearance

IPM for Sugarcane borers(Cultural Control)

- **Time of planting**
- Early planting during December –January to escape the shoot borer incidence.
- Detrashing
- Internode borer and Stalk borer
- Manuring
- Avoid excess use nitrogenus fertilizers.

- Stalk borer and internode borer.
- Trash mulching and earthing up
- Removal and destruction of infested cane
- Early shoot borer
- Collection and destruction of eggs
- Internode borer and Top borer

124 Pests of Sugarcane

Biological Control

- **For Early shoot borer :**
- *Trichogramma chilonis* □ **For Top borer :**
- *Trichogramma chilonis or T. japonicum, Isotima javensis* □ **For Internode borer :**
- *Trichogramma chilonis*
- Cultivation of resistance variety
- Irrigation at closer intervals for managing
- Early shoot borer
- Practice deep harvesting to destroy stubbles
- Removal of water shoots to destroy
- Top shoot borer

Chemical Control

Insecticide and formulation	Dosage	Method and time of application
SHOOT BORER Chlorpyrifos 20EC	1kg a.i ha $^{-1}$ (5 litre)	Soil drenching at planting and if need be at 45 days after planting.
Cypermethrin10% EC	260-304 ml in 200-280 l of water/acre	Sprayed around the base of plants at 30days and if need be at 60days after planting.
Fipronil 5%SC	1500-2000 ml/ha	Properly sprayed on crop canopy as well as basal part of the plant after 30-45 days of planting
NSKE 5 %	25 Kg/ha	Sprayed on soil as well as on crop to prevent larval feeding
TOP BORER Carbofuran 3 G or Phorate 10 G	1 kg a.i./ha (33 kg) or 3 kg a.i./ha (30 kg)	Soil application during last week of June or first week of July against third brood of the pest in sub-tropical India.
INTER NODE BORER Monocrotophos 36 SL	3 kg a.i./ha (7.5 lit.)	Both foliar and Soil application during July-August.

125 Pests of Sugarcane

White Grub

SYMPTOMS OF DAMAGE

- Both grub and adult cause the damage
- Grub feeds on fine rootlets and then girdles of the main roots .
- Yellowing and wilting of leaves and finally dries out
- Affected canes come off easily when pulled

IPM for White grub Cultural Methods

- Collection and destruction of adult beetles from host trees.
- Picking of grubs manually from field
- Repeated ploughing & exposing various stages of grub to their natural enemies.

- The use of light trap.

Biological Methods Biological Methods

- *Bacillus popillae (Bacteria)*
- *Beauveria bassiana (Fungus)*

Chemical Methods

- The adult can be controlled by -
- Carbaryl 0.1%
- Monocrotophos 0.05%
- Chlorpyriphos 0.05% The grub can be controlled by - Phorate 10 G @25 kg per ha.
- Carbofuran 3G @35 kg per ha.

126 Pests of Sugarcane

Termite

 SYMPTOMS OF DAMAGE

- They enter through cut ends of setts & feed on the soft tissue.
- The tunnel is filled with the soil.
- The termites attack setts, shoots, canes and also stubbles Entire shoot dries up and can be pulled out easily

IPM for Termite

- The use of partially decomposed manure should be avoided
- Locate and destroy the termite colony near by field
- Irrigation water with crude oil emulsion.
- The removal of decaying organic matters cow dung, wood or dry stubbles from the field
- Setts treatment with Imidacloprid (0.1%) or Chlorpyriphos 20 EC 0.04 % for 5 min.
- Application of well rotten Neem cake manure @ 60 Cartloads/ ha.
- Spray Chlorpyriphos 20%EC 750 ml/ha Sugarcane Leaf Hopper
- **SYMPTOMS OF DAMAGE**
- Adults and the nymphs suck leaf sap from the under surface of the lower leaves.

- Leaves become yellow, top leaves get up and lateral buds germinate
- Hoppers exude honeydew, result the leaves are completely covered by the sooty mould. This affects photosynthesis.

dried

IPM for leaf hopper

- Burn trashes after harvesting canes
- Remove lower leaves bearing egg cluster.
- Ratooning should be avoided
- Balance Nitrogen should be applied.
- Dust malathion 5% @ 40kg/ha. or
- Spray malathion 50 EC @ 1.25kga.i./ha.
- Release of 8,000-12,000 cocoons or 3.2 to 4 lakh eggs of *Epiricania melanoleuca per ha.* during July-August
- Use *Metarhizium anisopliae (fungal pathogen)*

127 Pests of Sugarcane

Sugarcane Scale

- **SYMPTOMS OF DAMAGE**
- Nymphs and adults feed by sucking the juice and cause shrivelling up and stunting of canes
- Nodal region is more infested than internodal region
- Infested crop losses its vigor, canes shrivel, non-opening of leaves & ultimately cane dries up
- Such canes when slit open appear brownish red

IPM for Sugarcane Scale

- Stripping of cane leaves may minimize attack
- Select and plant the scale insect free setts
- Avoid water stagnation for the longer period
- Detrash the crop at 150th and 210th day of planting.
- Give hot water treatment before planting
- Presoak the setts in 0.1% solution Malathion 50 EC
- Spray 1.25 liters of Malathion 50 EC or 2 litres of Di-methoate 30 EC in 1250 liters of water per ha
- Spray methyl demeton 25 EC @ 2ml/lit of water

Sugarcane Mealy Bug

- SYMPTOMS OF DAMAGE
  - Nymph and adult suck juice from cane in group & reduces vigour of the plant
  - It also attack roots
  - Honey dew secretion leads to development of Sooty mould which gives blackish appearance to canes.

128 Pests of Sugarcane

IPM for Sugarcane Mealy bug

- Use resistant varieties like CO 439, CO 443, CO 720, CO 730
- Drain excess water from the field
- Detrash the crop on 150 and 210 Days After Planting.
- Apply methyl parathion 50 EC 1000 ml.
- Rubbing of setts with gunny bag pieces dipped in Malathion (0.1% solution.)
- **Biocontrol agents** (*Brumoides suturalis, Leptomastix dactyolopii)*

Sugarcane Wooly Aphid

- **SYMPTOMS OF DAMAGE**

- Nymphs and adult feed in groups and weaken cane
- Leaves turn yellow color because of sucking sap by these aphids
- Sooty mould growth on lower leaves of woolly aphid infested plant.

IPM for Sugarcane Woolly Aphid

- Removal of water shoots
- Detrashing of canes in woolly aphid prone areas.

129 INSECT PESTS OF RICE

Rice (*Oryza sativa* L.) is the most important staple food crop of the world

- More than 60 % of worlds population depend on it for food.

Major insect pests

- **1-Brown Plant Hopper**, *Nilaparvata lugens* (Homoptera: Delphacidae)
- **2-Yellow Rice Stem Borer**, *Scirpophaga incertulas* (Lepidoptera: Pyralidae)
- **3-Rice Ear-head Bug**, *Leptocorisa oratorius* (Hemiptera: Alydidae)
- **4-Rice Hispa,** *Dicladispa armigera (Coleoptera:* Chrysomelidae)
- **5-Rice Grasshopper**, *Hieroglyphus banian* (Orthoptera: Acrididae)

1. Brown Plant hopper
2. It is most destructive pest
3. Both nymph and adult feed on paddy, sugarcane and grasses by sucking cell sap

Symptoms of Damage

- Both nymph and adults cause damage by sucking cell sap from the leaves which turn yellow.
- A heavy infestation produce symptoms of **hopper burn"**i.e. leaves become dry and brown after insect feeding and patches of burned plants are often lodged.

130 INSECT PESTS OF RICE

- It has been noticed that even at low infestation the tillering is adversely affected and there diminished vigor and decreases in plant height.

- Under the favorable condition of high humidity, optimum temperature, high nitrogen application and no wind the population increases very rapidly.
- The insect is known to transmit the grassy stunt virus disease of rice.

Management

- Avoid closer spacing of planting
- Alternate drying and wetting the fields during peak infestation and draining out the standing water from the field 2-3 times
- Alleys 30 cm wide after every 3 meters of rice planting provide proper aeration to the crop which ultimately restricts the multiplication of the pest
- Grow resistant varieties IR26, IR36, IR56,IR56,IR64, & IR72
- Spray at economic threshold 5-10 insects per hill, 100 ml imidachloroprid or 625 g of Carbaryl 50WP or 2.0 lit of Quinalphos 25EC in 250 liter of water and repeat if hopper population is persist

131 INSECT PESTS OF RICE

2. Yellow Rice Stem Borer

- The yellow stem borer is a specific pest of rice
- The caterpillar alone are destructive, when full grown, they measure about 20mm and are dirty white or greenish yellow having brown head and pronotum

Symptoms of Damage

- The larval feeding damage may cause death of the central leaf whorl at the vegetative stage, which is known as **dead heart.**
- Damage at the reproductive stage causes ear devoid of grain, which is known as **white head.**

Management

- The removal and destruction of stubble at the time of the first ploughing after harvesting the crop
- Ploughing and flooding the field is also effective in killing the larvae
- Clipping of tips of seedling before transplanting can reduce the carryover of eggs to the field.
- Use trichocard with 50,000-1,00,000 *Trichogramma* per ha after 3-4 weeks
- The field showing more than 5% dead hearts should be sprayed 25kg of Cartap hydrochloride 4G or 15 kg of Fipronil 0.3 G per ha in standing water in the field.

132 INSECT PESTS OF RICE

3. Rice ear- head bug

- The adult of *Leptocorisa oratorius is green, light brown or* mixed yellow in color

The adult are slender and about 20mm long.

Symptoms of Damage

- The pest is essentially diurnal with highest activities in the morning and in the evening, seeking shelter during hotter parts of day
- Many generation are completed in a year
- Sucking of the grain sap causes empty or partially filled and chaffy grains and enhances subsequent fungal and bacterial infection
- Adult and nymph both suck the sap of developing rice grains at the milking stage and cause considerable yield loss

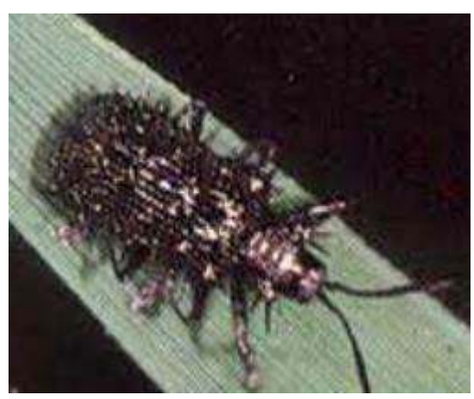
Management

- he population can be suppressed by killing the bug by using light traps
- Collection of adult bug using net
- Destroy weed to remove alternate host
- Keep on hanging the cattle urine soaked gunny bags or cow dung wrapped cloth in the field to attract the bug.
- Synchronize rice planting to maintain simultaneous crop maturity in the field in an area for equal distribution of bugs in all fields
- Conserve predator of rice bug like tiger beetle, ***Cicindela sexpunctata*** by using chemical pesticide judiciously
- Spray after at least 10 bug per 100 panicles with pesticide like carbaryl (Carbaryl 5% dust@25kg/ha)
- Spray Fenvalerate 20 EC 0.5ml/liter of water

133 INSECT PESTS OF RICE

4. Rice Hispa

- The adult is a small bluish black beetle
- Measuring 5mm in length and is recognized by numerous short spines on the body, which give it characteristics appearance



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Symptoms of Damage

- Larvae cause damaged like leafminer
- The adults also feed on green matter and produce parallel whitish streaks on the leaves
- The damage starts in nurseries and spread to the rice fields.

Management

- Clipping the infested leaf tip during transplanting
- Nursery bed is flooded and damaged beetles flooded in water
- Spray start at economic threshold level(1 adult per hill)
- Spay 2-5 liter Chlorpyriphos 20EC or 2. 0 lit of Quinalphos 25 EC in 250 liter of water per ha and repeat spray after 2 weeks if attack continue

134 INSECT PESTS OF RICE

5. Rice Grass hopper

Various species of grasshopper are widely distributed in Nepal They are polyphagous and feed on leaves of rice, maize, millets, sugarcane, grasses etc

Symptoms of Damage

Both adult and Nymph cause damage causing defoliating

Management

Fish cum Rice farming Larva of the banded blister beetle (*Mylabris phalerata) attack the eggs of the rice* grasshopper .Trimming the bund and field sanitation reduces the grasshopper population .Spray chlorpyriphos 2.5 lit Chlorpyriphos 20EC in 250 liter of water per ha.