sides which are called superlinguae. Also note the hypopharyngeal apodemes.

II. Piercing-sucking type: e.g. red cotton bug *(Dysdercus koenigii)* (Fig. 20A): The mouthparts are greatly modified and visible only in the form of a long, slender beak or proboscis. The proboscis comes out from the front of the triangular head. It bends downwards and backwards and thus lies beneath the body between the legs when not in use. Try to straighten this structure two or three times with a dissecting needle. You will see that the labrum is automatically separated from its base. If this method is not satisfactory, lift the labrum from the base of the proboscis with a dissecting needle. Similarly lift out the needles (forming a single structure). Now separate the four hair-like needles by teasing them gently with a dissecting needle. Remove the insect head and study the structure of mouthparts as given below.

Labrum: It is a short structure, broad at base and narrowing towards apex. It is attached to the clypeus and covers the groove of the labium up to the end of its first segment. It keeps the needles in the groove of the labium by pressing them.

Mandibles: These are paired, long, hair-like needles called stylets. Their tips are slightly curved and serrated or provided with short teeth(when seen under high magnification) for piercing the plant. They form the outer pair.

Maxillae: These are also paired, long, hair-like needles called stylets. Each maxillary stylet has a double groove along its inner side (if seen under high magnification). When the two maxillae fit together, their grooves form two tubes or channels, the upper food channel or suction tube and the lower salivary channel or ejection tube. They form the inner pair.

Note: The stylets of mandibles and maxillae cling together to form a single structure, the fascicle. It lies in the groove of the labium.

Labium: It is the principal structure which is modified to form an antenna-like 4-segmented proboscis. It has a dorsal groove like that of a knife to accommodate the fascicle. Its tip is provided with small sensory hair. It does not penetrate into the plant.

Note: The head of a weevil is prolonged anteriorly to form a beak-like structure. This beak appears to be a sucking proboscis. But actually the mouthparts are of chewing type as this beak has the chewing mandibles at its tip.

III. Sponging type: e.g. house fly *(Musca domestica)* (Fig. 20B): The mouthparts are greatly modified and visible in the form of a short, thick, elbow-shaped fleshy proboscis on the lower side of the head. Press the head with a needle and see that the proboscis is dissected out. It consists of three main parts, viz., rostrum, haustellum and labellum.

Rostrum: It is the basal cone-shaped portion of the proboscis. A pair of unsegmented, club-shaped, hairy maxillary palpi are present on its distal end.

Haustellum: The part of the proboscis between maxillary palpi and labellum is called haustellum. It has a groove on its dorsal side (Fig. 20B shows the lateral view) which contains a pair of needle-like structures, the hypopharynx

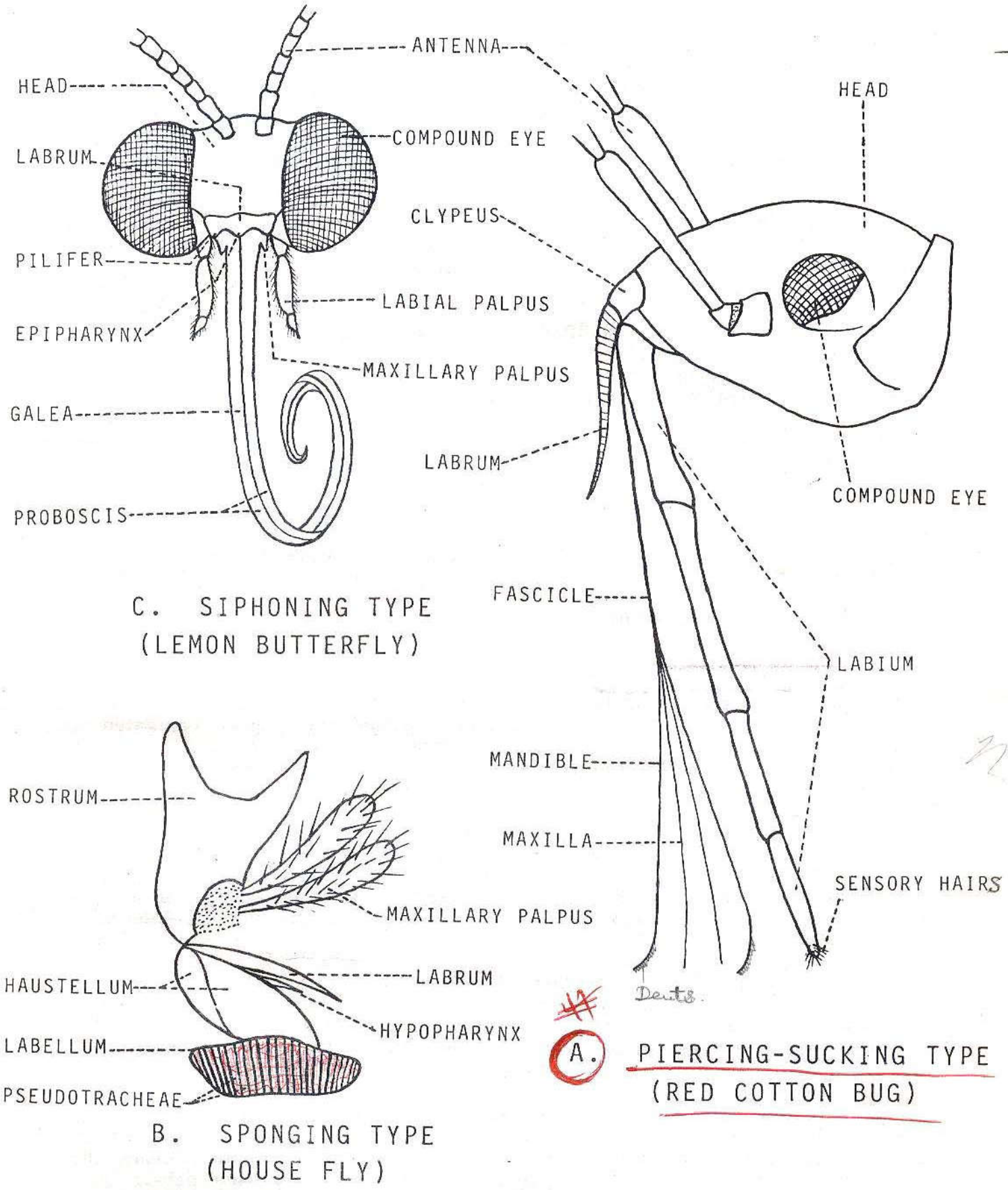


FIG.20. SUCKING TYPE OF MOUTHPARTS

and labrum. The former lies at the bottom of the groove and forms the salivary channel because it has a canal within it. The latter is ventrally grooved and lies on the hypopharynx and thus forms the food channel by closing its groove from below by the hypopharynx. Normally these two structures are not visible outside. Press the haustellum gently, you will see that they become easily visible.

Labellum: It is the terminal portion of the proboscis which has a pair of large, sponge-like, fleshy lobes, the labella. They contain numerous fine tubes, the pseudotracheae which open outside.

IV. Siphoning type: e.g. lemon butterfly *(Papilio demoleus)*(Fig. 20C): The mouthparts are highly modified and visible in the form of a long but coiled proboscis below the head. It is straightened only at the time of feeding. Many parts are either absent or greatly reduced and thus not visible. Examine the KOH treated head and note that only the following parts are visible.

Labrum: It is a narrow, transverse sclerite which is provided with a median triangular lobe, the epipharynx and two prominent lateral lobes, the pilifers.

Maxillae: The galeae of the maxillae are greatly elongated to form the suctorial proboscis. They are grooved on their inner sides and hooked together to form a sucking tube. The maxillary palpi are greatly reduced and appear as small knobs.

Labium: It is represented only by the large, 3-segmented, hairy labial palpi.

V. Chewing-lapping type: e.g. honeybee *(Apis florea)*(Fig. 21): This is a combination of two types, i.e., the labrum and mandibles are similar to those of the chewing type but the labium and maxillae are greatly elongated and modified to form the lapping or licking proboscis. First locate the parts and then dissect them out by the following method. Take the head in your hand and remove the labrum and mandibles one by one with a dissecting needle. Then for dissecting out the labium and maxillae, press the head forward with a needle against some hard surface (preferably on a slide). In this way the mouthparts are taken out easily. Now study them in the following order.

Labrum (Fig. 21A): It is a narrow, transverse flap with the anterior border slightly excavated. Its base is attached to the clypeus and its free border contains small hair.

Mandibles (Fig. 21B): These are paired, dumb-bell-shaped sclerotised structures lying on sides and partly concealed by the labrum. The outer surface is provided with long hair which gradually shorten towards anterior end. They are not used for feeding but for moulding wax into hexagonal cells in the hive.

Maxillae (Fig. 21C): These are paired lateral structures lying below mandibles. Each maxilla consists of a long, narrow, basal sclerite, the cardo. It contains on it an elongate and broad sclerite, the stipes. This, in turn, bears three structures on it, i.e., a minute peg-like 2-segmented maxillary palpus on the outer side of its apex, a very large blade-like galea on the inner side of its apex and a reduced, narrow lacinia on its inner side.

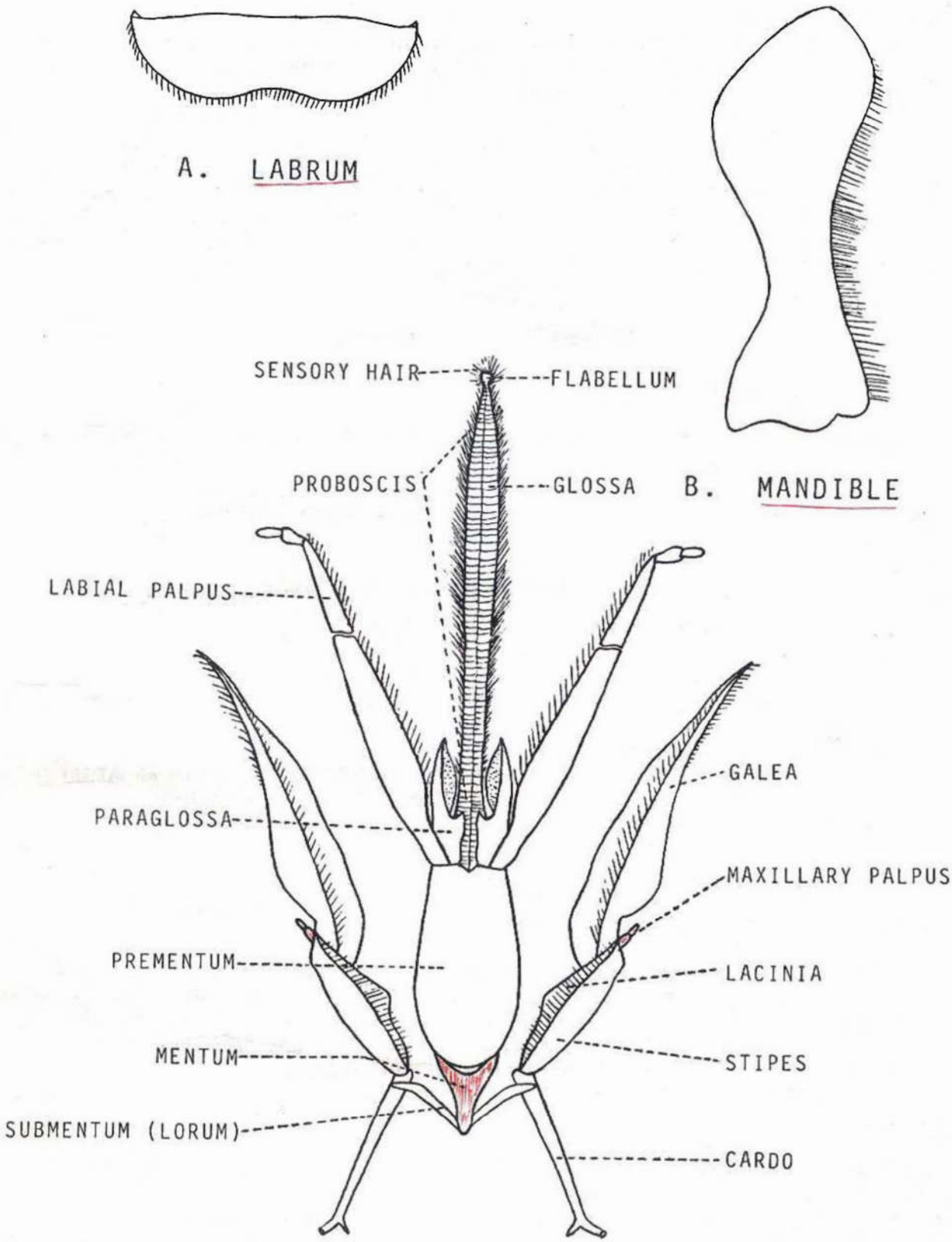


FIG.21. CHEWING-LAPPING TYPE OF MOUTHPARTS (HONEYBEE)

Labium (Fig. 21C): It lies between the maxillae on the lower side of the mouth. It consists of a flexible, V-shaped, basal sclerite, the submentum (lorum). Its extremities are connected with the distal ends of the cardines. In its middle articulates a small triangular sclerite, the mentum which carries on it a large sclerotised prementum. On each side of the apex of the prementum is an elongate, 4-segmented, hairy structure, the labial palpus. Inner to the labial palpi are two small lobes, the paraglossae. Each one is apically divided into two processes, the inner very small and the outer large and spoon-shaped. Between the paraglossae lies an elongate spindle-shaped flexible proboscis which is formed by the fusion of two glossae. It has transverse ridges and long hair on it. Its apex is expanded to form a small knob-like lobe, the flabellum.

APPENDAGES OF THORAX

These consist of the wings and legs.

A. Wings: These are the membranous, paired appendages of flight which are located dorsolaterally on the thorax.

(a) Occurrence of wings: The insects have either no wings or a pair of wings (on the mesothorax) or two pairs of wings (first on the mesothorax and second on the metathorax). Examine these conditions in a silverfish (Fig. 8A), house fly (Fig. 7E) and grasshopper (Fig. 4) respectively. Note that the prothorax never bears wings.

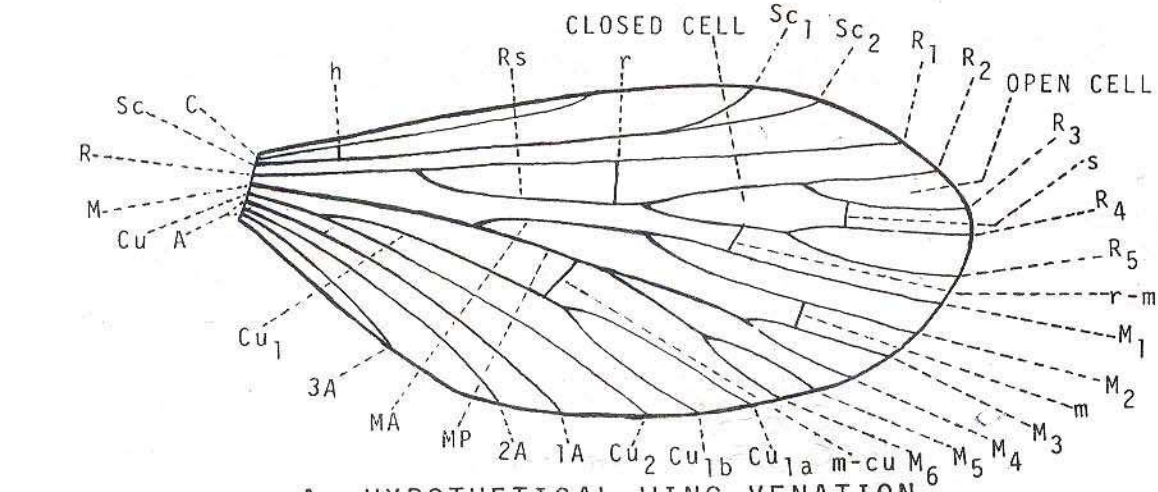
(b) Development of wings: The wingless insects are called the apterous, with reduced wings the brachypterous and with complete wings the macropterous. The undeveloped wings of nymphs and naiads are called wing pads (Fig. 9C).

The insects which are supposed primitively wingless are known as Apterygota, e.g., silverfish (Fig. 8A), doubletails, telsontails and springtails. The insects which are winged or secondarily wingless are called the Pterygota. It has further two types. The insects which develop their wings outside the body are called Exopterygota, e.g., grasshoppers (Fig. 8B), bugs, etc. The insects which develop their wings inside the body are known as Endopterygota, e.g., flies, wasps, moths (Fig. 9A), butterflies, beetles, etc.

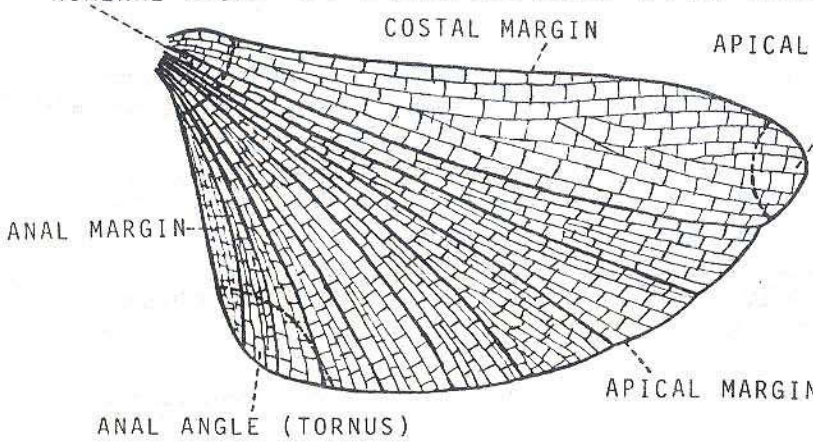
(c) Wing margins and angles: Place the hind wing of an ak grasshopper (Fig. 22H) between two slides under a microscope and note the following: It is almost triangular in shape. Its anterior border is called the costal margin, outer border the apical margin and inner border the anal margin. The following three angles are also defined: the humeral angle between the costal and anal margins, the apical angle between the costal and apical margins, and the anal angle (tornus) between the anal and apical margins.

(d) Wing venation (Fig. 22A): The wings of most insects are membranous. They are supported by a framework of hollow ribs or thickened ridges, the veins. Most of these veins extend lengthwise in the wing and are called longitudinal veins. A few of them connect the longitudinal veins and are called cross veins. The arrangement of veins in a wing is called venation or neuration.

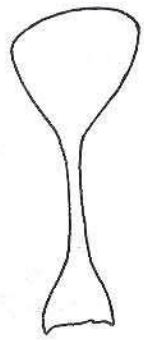
In the wings of certain insects, the areas between the longitudinal veins contain an irregular network of veins called archedictyon, e.g., dragonflies, mayflies, stoneflies and ant-lions. The wings of these insects are also called net-veined.



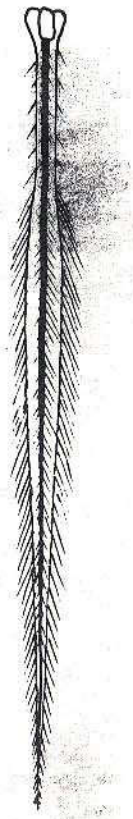
A. HYPOTHETICAL WING VENATION



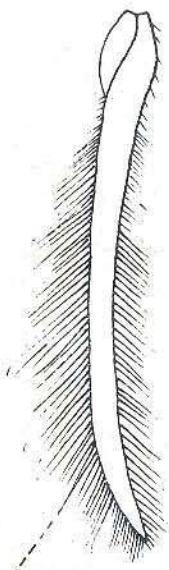
H. MEMBRANOUS (AK GRASSHOPPER)



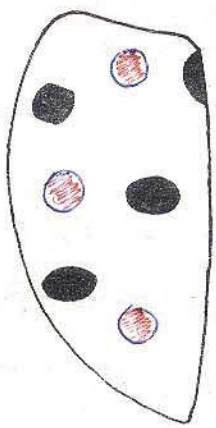
E. HALTERE (HOUSE FLY)



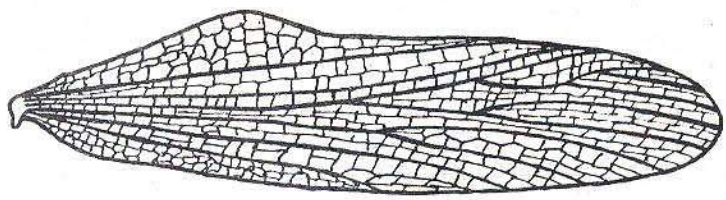
F. FILOHALTERE (CROCE SP.)



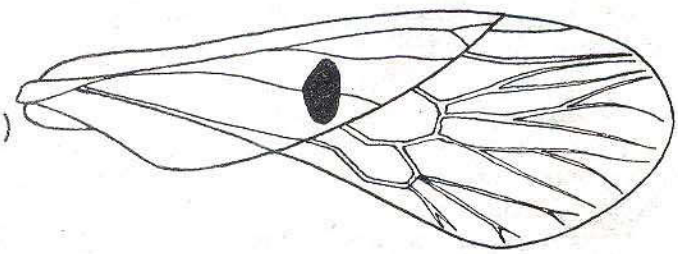
G. STRIPPY (THRIPS)



C. ELYTRON (BEETLE)



B. TEGMEN (AK GRASSHOPPER)



D. HEMELYTRON (RED COTTON BUG)

FIG.22. STRUCTURE AND TYPES OF WINGS

The longitudinal veins and most of the cross veins bear names. These names (from the anterior to the posterior) with their abbreviations are as follows:

Longitudinal veins	Cross veins
1. Costa (C)	1. Humeral (h)
2. Subcosta (Sc)	2. Radial (r)
3. Radius (R)	3. Sectorial (s)
4. Media (M)	4. Radiomedial (r-m)
5. Cubitus (Cu)	5. Medial (m)
6. Anals (A)	6. Mediocubital (m-cu)
	7- Cubital vein (cu)
	8- Cubital anal (cu-a)

Note the abbreviations of longitudinal veins are always in capital letters and those of cross veins always in small letters.

The longitudinal veins may be simple or branched in varying degrees in different insects. But the basic hypothetical or primitive arrangement is as follows: The costa is unbranched. It forms either the anterior margin or lies along the anterior margin. The subcosta is 2-branched distally. The radius is divided into two branches: R1 and the radial sector (Rs). The radial sector divides into two branches and each branch further divides into two. The radius is thus 5-branched. The media is divided into two branches: anterior media (MA) and posterior media (MP). The anterior media divides into two branches. Similarly the posterior media divides into two branches and each branch divides again into two. The media is thus 6-branched. The cubitus is 2-branched, with its first branch further divided into two. There are 3 or 4 anals which are typically unbranched.

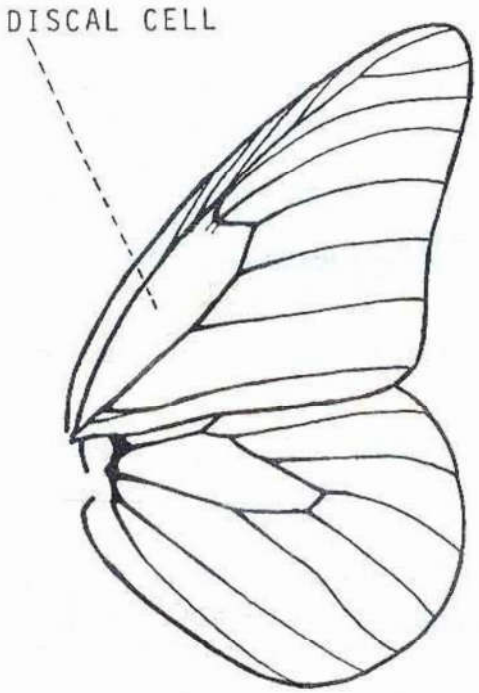
It must be remembered that the abbreviations of the main longitudinal veins are generally written at their bases. But their final branches are indicated at the wing margin (Fig. 22A).

The most important cross veins are: the humeral connects the costa and subcosta near the base of the wing. The radial connects R1 and radial sector (Rs). The sectorial connects R3 and R4. The radiomedial connects radius and media, usually near the middle of the wing. The medial connects M2 and M3. The mediocubital connects media and cubitus.

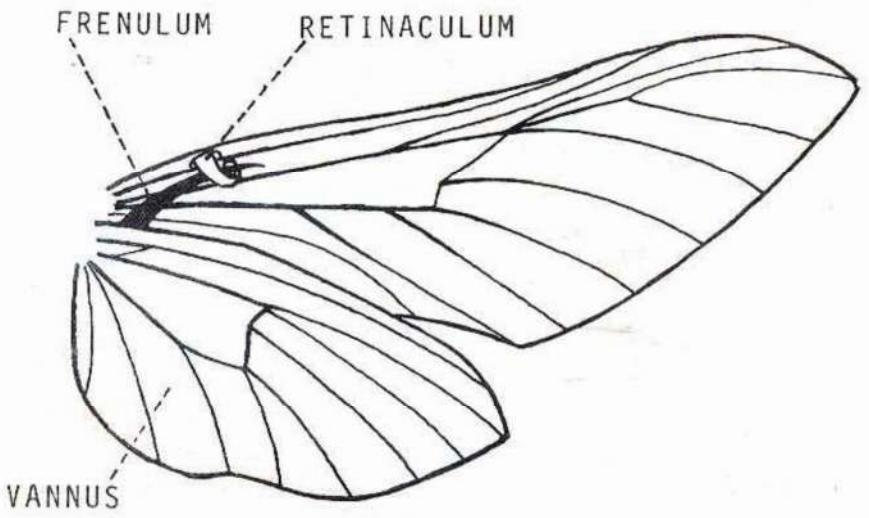
This hypothetical or primitive wing venation can not be seen in any wing at present because some veins or their branches have either lost or fused together. The fusion of two branches (e.g. R4 and R5) is written as R4+5.

(e) Cells of wings: The longitudinal and cross veins surround the areas of various shapes which are called cells. There are two types of cells. If the area is entirely surrounded by veins, it is a closed cell (Fig. 22A). If the area extends to the wing margin, it is an open cell (Fig. 22A). A cell is named after the vein which forms its anterior border. In some insects certain cells have special names, e.g., discal cell of butterflies and moths (Fig. 23A).

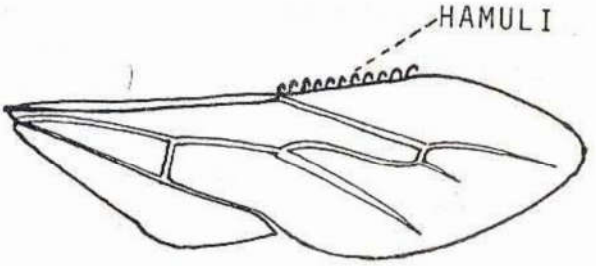
(f) Areas of wings: The central area of the wing is called the disc. The area of the wing having the maximum number of veins is called remigium (Fig. 23B). The area containing only the anal veins is termed the annal or vannal area (Fig. 23C).



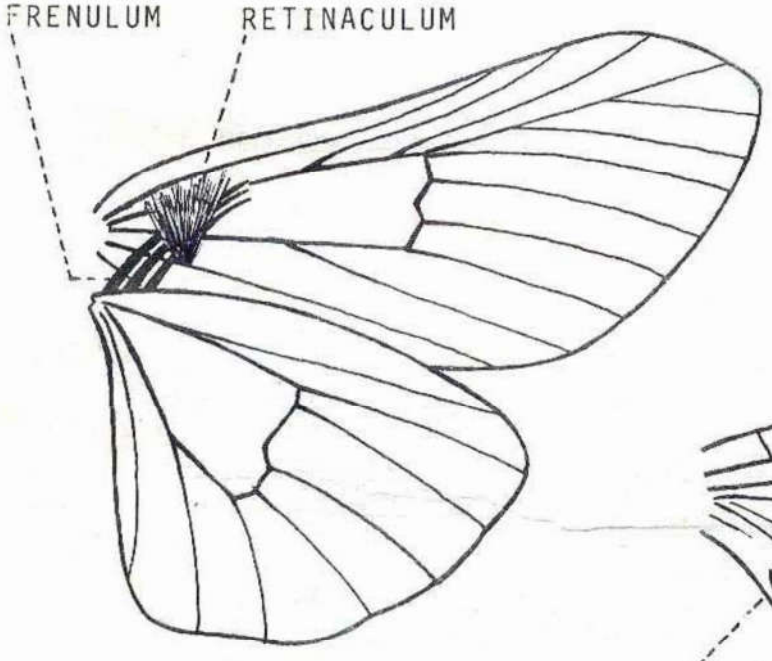
A. OVERLAPPING (BUTTERFLY)



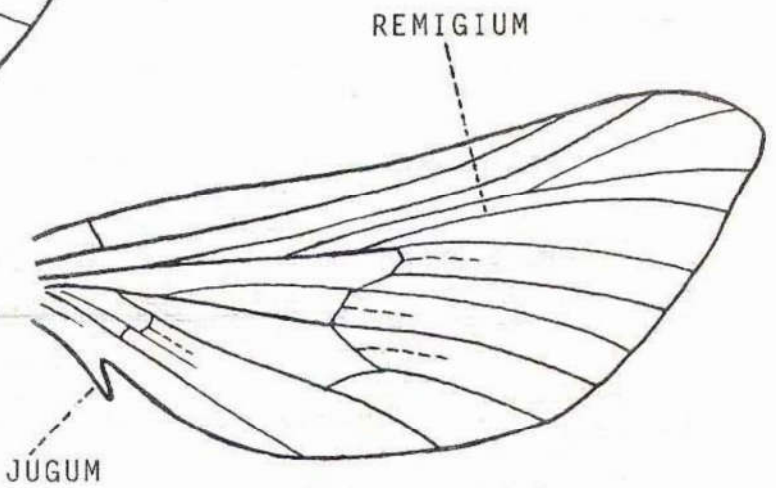
C. FRENULUM AND RETINACULUM
(MALE GEOMETRID MOTH)



E. HAMULI (HONEYBEE)



D. FRENULUM AND RETINACULUM
(FEMALE GEOMETRID MOTH)



B. JUGUM (JUGATE MOTH)

FIG.23. WING COUPLING APPARATUS

(g) Special structures of wings: Some insects have a thick pigmented spot along the costal border near the apex of the wing which is called Pterostigma, e.g., dragonflies, damselflies, most hymenopterous insects, etc. A thick, short, cross vein descends from the middle of the anterior border which is called nodus in dragonflies. The border appears to be broken and jointed at this point. The wings of butterflies and moths are covered with scales of various shapes. The rod-like wings of thrips have fringes of long hair which are called marginal setae (Fig. 22G).

(h) Types of wings: Some important types or modifications of wings are as follows:

1. **Tegmina** (Fig. 22B): The fore wings are modified into long, narrow, hard and slightly thick structures, the tegmina (sing. tegmen), e.g., grasshoppers, cockroaches, mantids, crickets, etc.

2. **Elytra** (Fig. 22C): The fore wings are modified into very thick and hard structures, the elytra (sing. elytron), e.g., beetles, weevils and earwigs. They form a protective covering for hind wings when the insect is in rest.

3. **Hemelytra** (Fig. 22D): The basal part of the fore wing is thick and hard while the apical part is thin and membranous. Such wings are called hemelytra (sing. hemelytron), e.g., true bugs (like red cotton bug).

4. **Halteres** (Fig. 22E): The hind wings are modified into tiny, knobbed structures, the halteres, e.g., flies (like house fly), male coccids (like mango mealybug).

5. **Pseudohalteres:** When the fore wings are modified into halteres, they are known as pseudohalteres, e.g., male stylopids.

6. **Filohalteres** (Fig. 22F): When the hind wings are modified into very long, thread-like structures, they are termed filohalteres, e.g., some lacewings *(Croce sp.)*.

7. **Strippy (Fig. 22G):** The wings are modified into strips or rod-like structures and fringed with long hair, e.g., thrips.

8. **Membranous** (Fig. 22H): The hind wings are very thin and broad like a membrane, e.g., grasshoppers, locusts, crickets, earwigs, beetles, etc.

(i) Wing coupling apparatus: The mechanism by which the two wings of one side are linked together and act as a unit during the flight is called wing coupling apparatus. ~~Study the following devices:~~ mechanism; and the linking structure is known as wing coupling apparatus

1. **Overlapping** (Fig. 23A): This is the simplest method in which the fore wing overlaps the anterior border of the hind wing, e.g., butterflies.

2. **Jugum** (Fig. 23B): This is a finger-like process at the base of the posterior border of the front wing which projects under the hind wing, e.g., jugate moths.

3. **Frenulum** (Fig. 23C, D): This is a single stout spine (in males) or several spines (in females) on the humeral angle of the hind wing, e.g., geometrid moths.

4. **Retinaculum** (Fig. 23C, D): It is a strong curved process (in males) or a group of strong hair (in females) on the lower side of the fore wing. The frenulum is held by the retinaculum, e.g., geometrid moths.

5. **Hamuli** (Fig. 23E): These consist of a row of minute hooks on the anterior border of the hind wing that catch into the uprolled hind border of the fore wing, e.g., honeybees.

B. Legs: These are paired, jointed, primarily locomotary appendages which are articulated on the ventral side of the thorax.

The adult insects normally have three pairs of legs. The first pair is on the prothorax, the second on the mesothorax and the third on the metathorax. Now pull out the metaleg of an ak grasshopper (Fig. 24B), which is considered to be a typical or generalised leg, and study its parts.

(a) **Parts of leg:** A typical leg consists of the following parts:

1. **Coxa:** It is the first or basal segment which is large, elongated and more or less triangular in shape. It is attached with the body by a membrane, the coxal corium.

2. **Trochanter:** It is a small, triangular segment which is rigidly fixed to the femur, but articulates with coxa.

3. **Femur:** It is a very long and thick segment which is provided with fishbone-shaped leaping muscles. It has a ventral groove, the femasulcus to accommodate tibia in it. The femasulcus contains a small tubercle, the Brunner's organ on its inner margin near the proximal end. The femur narrows toward its apex which is expanded to form the lateral genicular lobes. These are separated by a deep groove which allows free movement of tibia.

4. **Tibia:** It is very long and slender segment armed with two rows of spines on its dorsal surface. Its apex contains an outer and an inner pair of strong, curved spurs.

5. **Tarsus:** It consists of three segments. The first segment is longer than the second while the third one is the longest. The first segment bears three pairs of small pad-like structures, the plantulae, on its lower surface. The second segment contains a single pair, while the third segment has a single elongated pair of these structures. The tarsus ends in a pair of hair-like, strong, curved claws or ungues, which contain a bladder-like lobe, the arolium between them. The claws and arolium together are called the pretarsus by some morphologists.

Also examine the tarsus of a robber fly (Fig. 24C). It also ends in two long, strong, curved claws. Below them is a pair of long and broad pads, the pulvilli (sing. pulvillus). Between the claws is a strong bristle-like structure, the empodium.

(b) **Types of legs:** The legs of insects are greatly modified for performing different functions. Some important modifications or types are as follows:

1. **Cursorial** (ambulatory or walking) (Fig. 24A): The femur is normal and not thickened, e.g., metaleg of cockroach.

2. **Saltatorial** (leaping or jumping)(Fig. 24B): The femur contains powerful muscles and is greatly thickened, e.g., metaleg of grasshopper.

3. **Raptorial** (catching or grasping)(Fig. 25A): The coxa is very long. The femur is long, thick, with double row of spines and a groove on the lower side. The tibia is shorter, spiny and fits into the groove of the femur, e.g., proleg of a mantid. (Praying insect)

4. **Fossorial** (digging)(Fig. 25B): The parts are reduced and flattened to become strong for digging. The tibia has finger-like projections on its apex. The tarsus is also produced into three finger-like processes which are seen below those of the tibia, e.g., proleg of mole cricket.

5. **Natatorial** (swimming)(Fig. 25C): All parts are flattened and tarsus, in addition, has long hair, e.g., metaleg of giant water bug and water beetle.

6. **Clinging** (Fig. 25D): The tibia has a small process at its apex. The tarsus is 1-segmented and bears a claw that fits against the tibial process for clinging to the hair of the host, e.g., louse.

7. **Silk secreting** (Fig. 25E): The first segment of the fore tarsus is greatly swollen and contains silk glands, e.g., proleg of female webspinner.

8. **Antenna cleaner** (Fig. 24D): There is a large spur on the apex of the tibia which fits into a semicircular notch on the proximal end of the tarsus. This notch also contains fine hair. The antennae are drawn through this structure so that the pollens, etc., clinging to them are removed, e.g., proleg of worker honeybee.

9. **Pollen collecting** (Fig. 24E): This type has a polliniferous apparatus. The tibia is greatly dilated. Its outer surface is smooth, bordered on each side with a fringe of long curved hair, which is called corbicula or pollen basket. On the distal end of tibia is a row of hair, the pecten or pollen rake. The basitarsus (first or basal segment of tarsus) on its base has a small ear-like lobe that contains a row of small hair. This lobe is called auricle. The basitarsus is greatly enlarged. It bears on its inner surface several transverse rows of short stiff hair which form scopa, pollen comb or pollen brush, e.g., metaleg of worker honeybee.

10. **Basket-like:** There is no morphological modification in this type of leg. But during flight, all legs come together to form a basket below the mouth for catching and eating insects. Note, the trochanter is 2-segmented, e.g., dragonfly and damselfly.

APPENDAGES OF ABDOMEN

The most common appendages are styli, cerci and ovipositor in the adult insects and abdominal prolegs and gills in the young insects.

1. **Styli** (Fig. 8A): These are paired, short, slender, unsegmented, finger-like appendages which arise from the lower side of the abdominal segments, e.g., bristletails, doubletails, cockroaches and mantids.

2. **Cerci** (Figs. 4, 17A): They are a pair of short to very long, segmented or unsegmented, needle-like appendages which arise from the side of 11th abdominal segment, e.g., grasshoppers, crickets, cockroaches, mantids, bristletails,

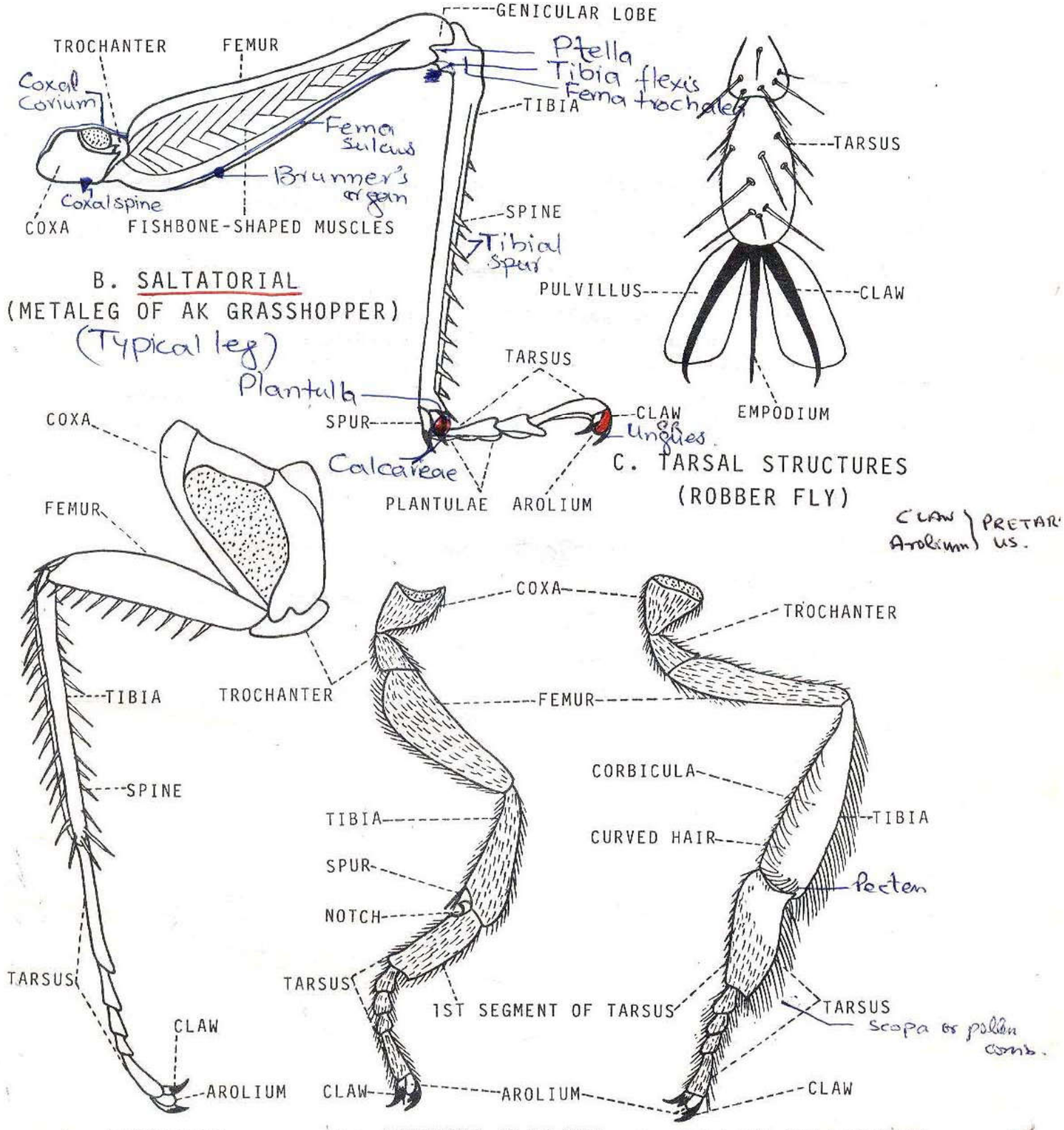


FIG. 24. STRUCTURE AND TYPES OF LEGS

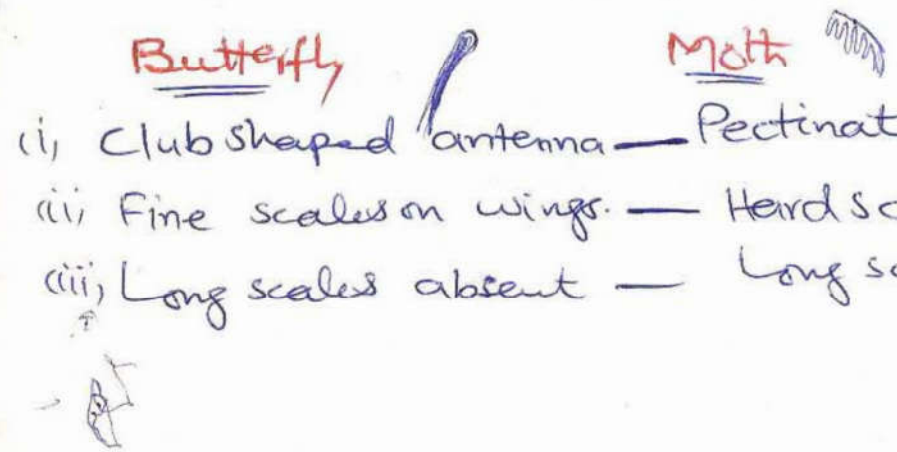
mayflies, stoneflies, etc. They may be in the form of forceps such as earwigs.

3. Ovipositor (Fig. 4): It is the egg-laying apparatus or external genitalia of the female that is present at the end of abdomen. It may be short (having different shapes) to very long and needle-like, e.g., grasshoppers, crickets, leafhoppers, planthoppers, etc.

4. Abdominal prolegs (9A): These are paired, fleshy, more or less conical, leg-like appendages present on the lower side of the abdomen of larvae, e.g., butterflies, moths, sawflies, scorpionflies, etc.

5. Gills (Fig. 9C): These are paired, thin-walled, respiratory appendages of the young ones of many aquatic insects. They are more frequently present on the abdomen and may have a lateral, dorsal or ventral position. They may be of different shapes such as plate-like, leaf-like, finger-like or spine-like, e.g., mayflies, stoneflies dragonflies, damselflies, caddisflies, some beetles, etc.

Some less common appendages are the median caudal filament (bristletails and mayflies), a pair of cornicles on the upper side of 5th abdominal segment (aphids), urogomphi at the end of abdomen (some beetles), ventral tube, retinaculum and furcula (springtails), etc.



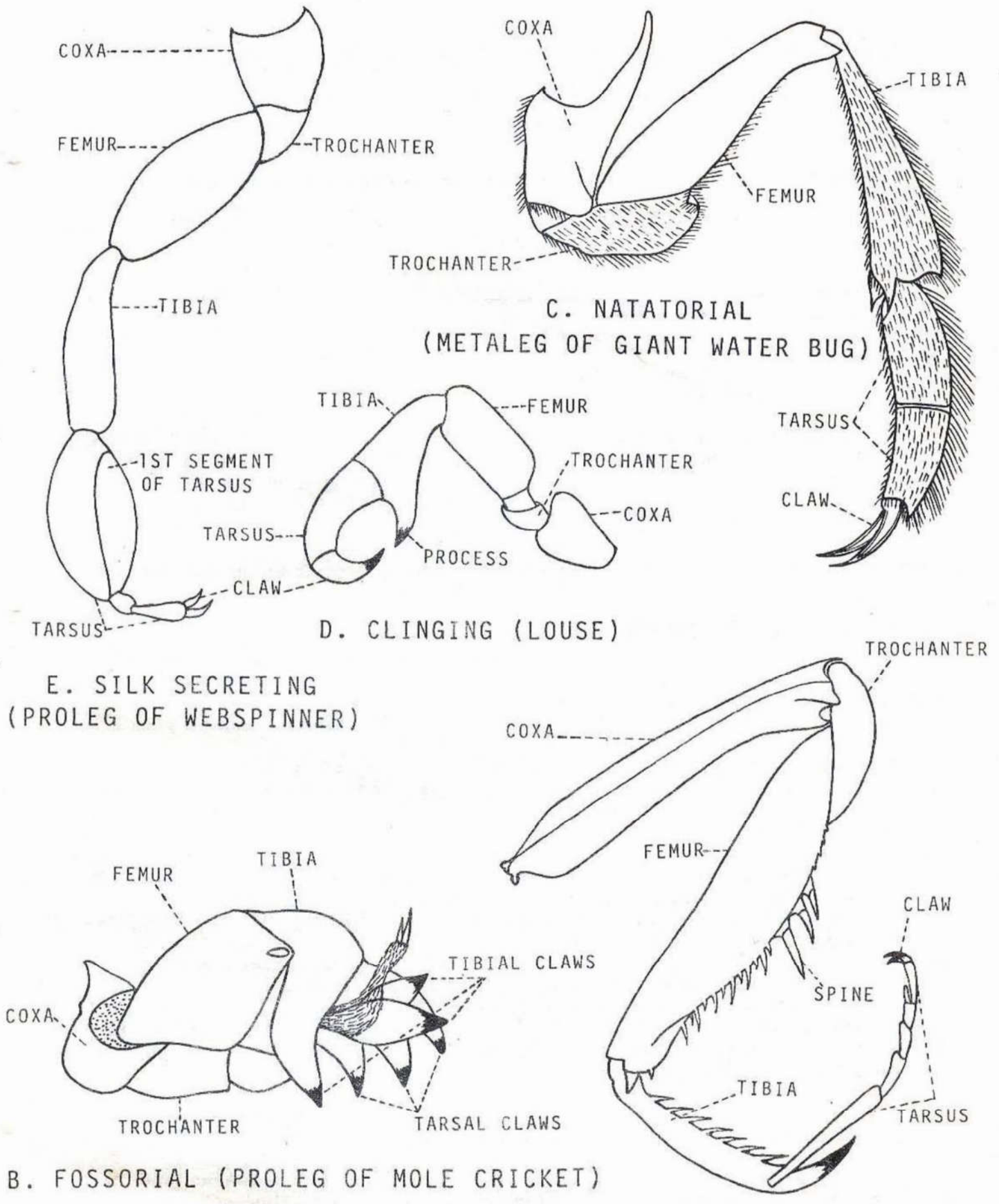


FIG. 25. TYPES OF LEGS