Thorax

The skeleton of the thoracic segments is modified to give efficient support for the legs and wings, and the musculature is adapted to produce the movements of these appendages.

THORAX: is composed of three segments: the prothorax, mesothorax, and metathorax. The thoracic segments can be divided into three major sclerites that have their own special names: dorsal body plate tergum or nota, ventral body plate sternum and lateral plate pleuron. In most insects all three segments bear a pair of legs, but this is not the case in larval Diptera, larval Hymenoptera Apocrita, some larval Coleoptera and a small number of adult insects which are apodous. In addition, winged insects have a pair of wings on the meso- and meta-thoracic segments and these two segments are then collectively known as the **pterothorax**.

Morphology of the thorax:

Thoracic nota: Dorsal body plate of each thoracic segment is called as pronotum, mesonotum and metanotum respectively. The pterothoracic nota each have two main divisions – the anterior wing-bearing alinotum and the posterior phragma-bearing postnotum. These are firmly supported on the pleural sclerotization by means of the pre alar and post alar arms, respectively. Lateral margins of the alinotum are constructed for articulation of the wing. Pterothoracic notum have 3 transverse sutures (antecostal, prescutal and scuto-scutellar) and 5 tergites (acrotergite, prescutum, scutum, scutellum and post-scutellum)(Fig.7.2)). The antecostae of the primitive segments become greatly enlarged forming phragmata,to which the large dorsal longitudinal muscles are attached.

Thoracic sterna: the primary sclerotizations on the ventral side are segmental and inter segmental plates which often remain separate in the thorax, the inter segmental sclerite is produced internally into spine and is called spinasternum , while the segmental sclerite is called the eusternum. Each eusternum may be simple or divided into separate sclerites – typically the presternum, basisternum and sternellum (Fig.7.3). The eusternum may be fused laterally with one of the pleural sclerites and is then called the laterosternite. Fusion of the sternal and pleural plates may form precoxal and postcoxal bridges. Arising from the eusternum is pair of apophysis, the so- called sternal apophysis, the origin of these on the sternum is marked externally by pits joined by a sulcus.In the higher pterygotes these apophyses are borne on a median internal ridge and form a Y-shaped furca (Fig.7.4).

Thoracic pleura: The lateral wall of a thorathic segment between the notum and sternum is the pleura. In the pterothorax, the pleuron is divided into two main areas the anterior episternum and the posterior epimeron – by an internal pleural ridge, which is visible externally as the pleural suture (Fig.7.3). The pleural ridge runs from the pleural coxal process (which articulates with the coxa) to the pleural wing process (which articulates with the wing), providing reinforcement for these articulation points. Extending between the two pleural processes is a strong internal plural ridge. The ridge may be invaginated at on pointed to form an intern alarm, or pleural apophysis (Fig. 7.4). As noted earlier, these apophyses combine with the pleural arms to form a rigid internal support. The latter provides attachment for the major longitudinal ventral muscles and certain muscles of the leg. The epipleurites are small sclerites beneath the wing and consist of the basalaria anterior to the pleural wing process and the posterior subalaria, but are often reduced to just one basalare and one subalare, which serve as attachment points for some direct flight muscles. The trochantinis the small sclerite anterior to the coxa. Pterothoracic pleuron provides space for articulation of wings and legs. Thoracic appendages are three pairs of legs and two pairs of wings. Two pairs of spiracles are also present in the mesopleuron and metapleuron. Functions of thorax mainly concerned with locomotion.

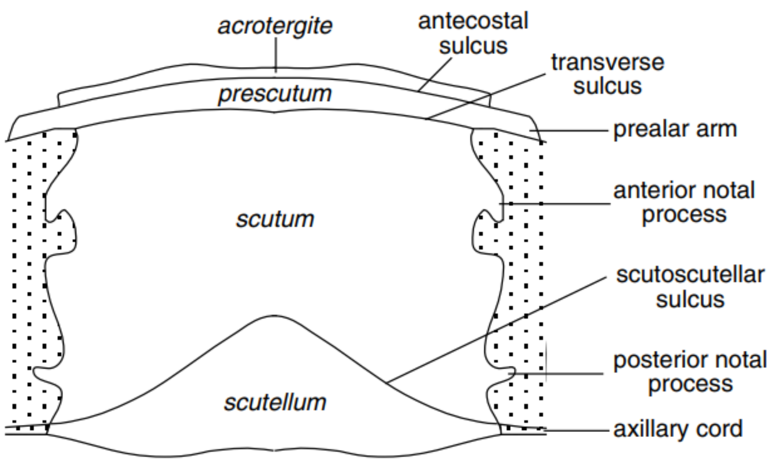


Fig. 7.2. Notum of a wing-bearing segment. Stippled areas are membrane at base of wing (axillary sclerites not shown). Names of sclerites ir

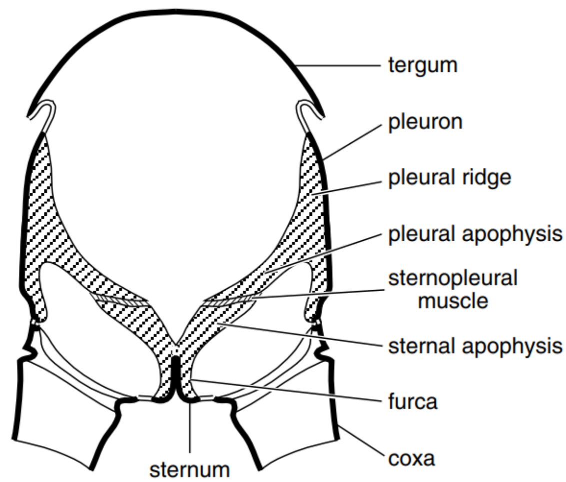


Fig. 7.4. Cross-section of a thoracic segment showing the pleural ridges and sternal apophyses (after Snodgrass, 1935).

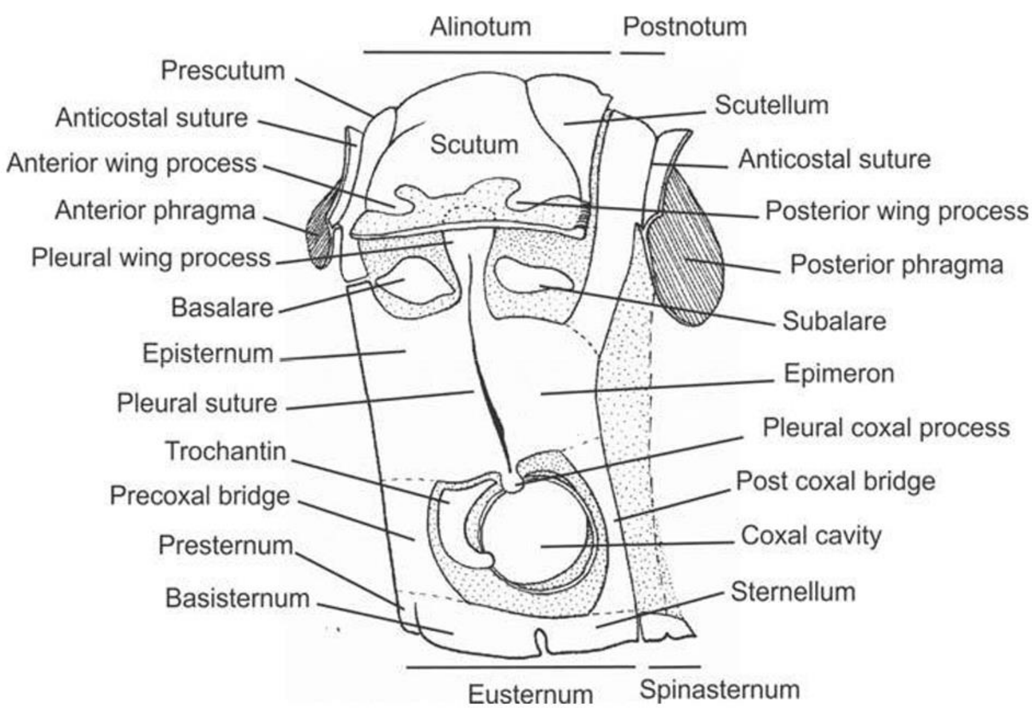


Fig.7.3 lateral view of a typical wing-bearing segment (Pterothorax).

LEGS

STRUCTURE OF LEGS: Insects typically have three pairs of legs, one pair on each of the thoracic segments. From this, the alternative name for insects, the 'hexapods', is derived, although not all hexapods are now regarded as insects. Each **leg** consists typically of six segments, articulating with each other by mono- or di-condylic articulations set in a membrane, the corium. The six basic segments are coxa, trochanter, femur, tibia, tarsus and pretarsus (Fig. 7.6 A).

Coxa: It is the functional basal segment and it is rigidly fixed to thorax or weakly articulated. **Trochanter** : It is very small and the second segment. It is articulated with coxa and more or less fixed to femur. **Femur:** It is the largest, strongest segment and is articulated with the tibia. **Tibia** : It is equal or more than the length of the femur, articulated with tarsus. **Tarsus:** it is the largest segment of the leg and usually divided into subsegments tarsomeres. The number of tarsomeres vary from 1-5 and are movable one on the other In Protura, some Collembola and the larvae of most holometabolous insects, the tarsus is unsegmented. Among the 5 segments, 1st segment is large, big or broad in size known as basitarsus. The tarsus at its end consists of **pretarsus** which is in the form of a pair of claws and cushion like pulvilli. In between the claws, if there is lobe like structure, it is known as "**aroleum**" (Fig. 7.6 B) as in Orthoptera (grasshopper) and if it is bristle like structure, it is called "**Empodium**"(Fig. 7.6 C) as in Diptera.

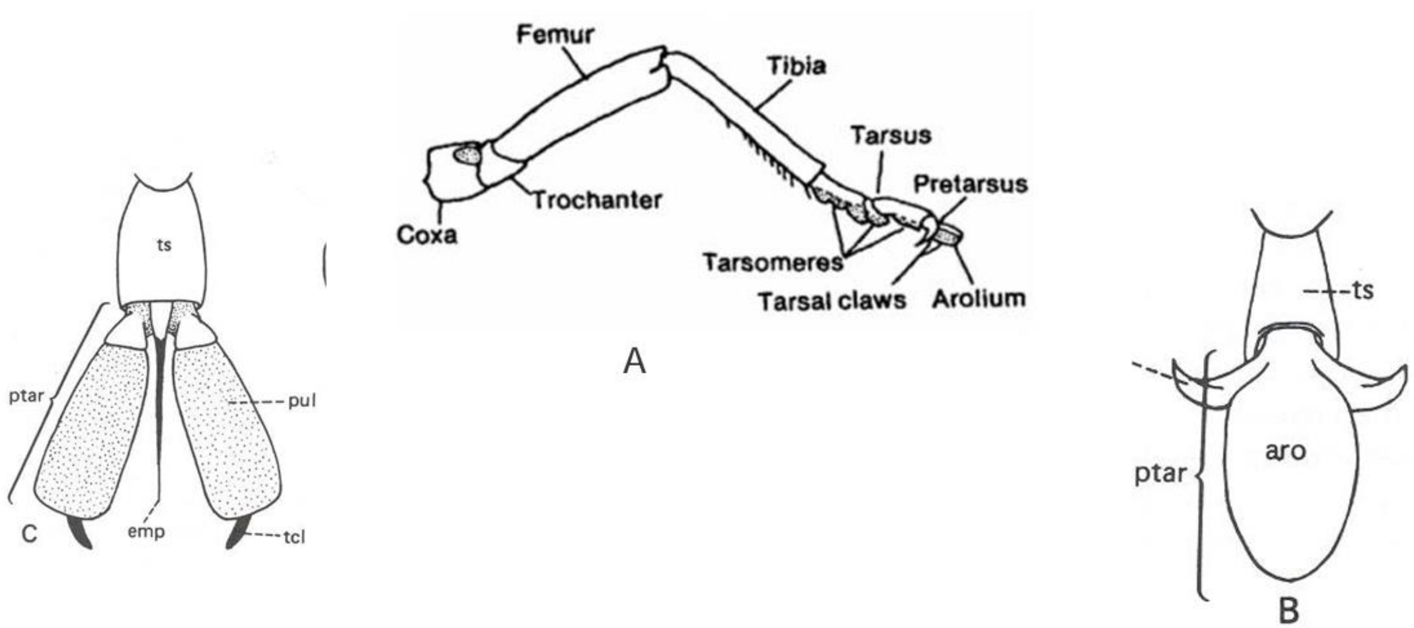


Fig 7.6.A-Structure of typical insect leg; B-Arolium; C-Empodium

MODIFICATIONS OF THE BASIC LEG STRUCTURE: The basic insect walking leg may be modified in various ways to serve a number of functions. Amongst these are jumping, swimming, digging, grasping, grooming and stridulation.

Digging Legs modified for digging are best known in the Scarabaeoidea and the mole cricket, Gryllotalpa. In Gryllotalpa, the forelimb is very short and broad, the tibia and tarsomeres bearing stout lobes which are used in excavation. In the scarab beetles, the femora are short, the tibiae are again strong and toothed, but the tarsi are often weakly developed. Larval cicadas are also burrowing insects. They have large, toothed fore femora, the principal digging organs, and strong tibiae which may serve to loosen the soil (Fig. 8.9a).

Grasping Modifications of the legs for grasping are frequent in predatory insects. Often pincers are formed by the apposition of the tibia on the femur. This occurs in the forelegs of mantids (see Fig. 2.9) and mantispids (Neuroptera), in some Heteroptera such as Phymatidae and Nepidae, and in some Empididae and Ephydridae amongst the Diptera.

Clinging leg. The ability to hold on is important in ectoparasitic insects. These usually have well-developed claws and the legs are frequently stout and short as in Hippoboscidae, Ischnocera and Anoplura. In the latter two groups, the tarsi are only one or two segmented and often there is only a single claw which folds against a projection of the tibia to form a grasping organ (Fig. 8.9b).

Grooming Insects commonly use the legs or mandibles to groom parts of the body, removing particles of detritus in the process. The eyes and antennae are often groomed, and so are the wings. Cockroaches clean their antennae by passing them through the mandibles, which chew lightly at the surface, but many insects use the forelegs for this purpose, then cleaning the legs with the mandibles. Neuroptera and Diptera hold an antenna between the two forelegs, which are drawn forwards together towards its tip. Mosquitoes have a comb, consisting of several rows of setae, at the distal end of the fore tibia. The combs are scraped along the proboscis or antennae in rapid strokes. In many other insects each antenna is cleaned by the ipsilateral foreleg which is often modified as a toilet organ. Schistocerca (Orthoptera) has a cleaning groove between the first and second pads of the first tarsomere. This is fitted over the lowered antenna and then drawn slowly along it by an upward movement of the head and extension of the leg. In Apis and other Hymenoptera there is a basal notch in the basitarsus lined with spinelike hairs forming a comb. A flattened spur extends down from the tip of the tibia in such a way that when the metatarsus is flexed against the tibia the spur closes off the notch to form a complete ring (Fig. 8.9c). This ring is used to clean the antenna. First it is closed round the base of the flagellum and then the antenna is drawn through it so that the comb cleans the outer surface and the spines on the spur scrape the inner surface. A similar, though less well-developed organ, occurs in Coleoptera of the families Staphylinidae and Carabidae. Lepidoptera have a mobile lobe called the strigil on the ventral surface of the fore tibia. It is often armed with a brush of hairs and is used to clean the antenna and possibly the proboscis. The hind legs of Apoidea are modified to **collect pollen** from the hairs of the body and accumulate it in the pollen basket. Pollen collecting is facilitated by pectinate hairs which are characteristic of the Apoidea. In the honeybee, Apis, pollen collected on the head region is brushed off with the forelegs and moistened with regurgitated nectar before being passed back to the hind legs which also collect pollen from the abdomen using the comb on the basitarsus (Fig. 8.9d). The pollen on the combs of one side is then removed by the rake of the opposite hind leg and collects in the pollen press between the tibia and basitarsus. By closure of the press, pollen is forced outwards and upwards on to the outside of the tibia and is held in place by the hairs of the pollen basket. On returning to the nest, the pollen is kicked off into a cell by the middle legs.

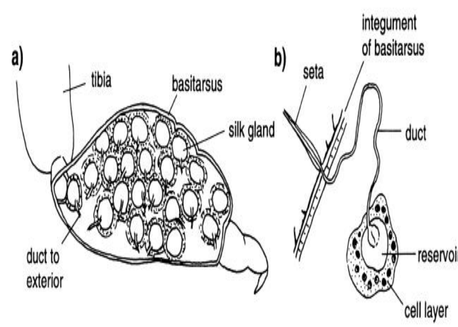
Silk production Insects in the order Embioptera are unique in having silk glands in the basitarsus of the front legs in all stages of development of both sexes. The basal tarsomere is greatly swollen, and within it are numerous silk glands each with a single layer of cells surrounding a reservoir (Fig. 8.10). There may be as many as 200 glands within the tarsomere, each connected by a duct to its own seta with a pore at the tip through which the silk is extruded.

Adhesion. Many insects are able to climb and hold on to smooth sur faces. Different insects use different structures and probably different mechanisms for adhesion, but many use adhesive setae, also sometimes called tenent hairs. These setae are grouped together to form adhesive pads which occur on various parts of the legs. Rhodnius and some other Reduviidae have adhesive pads at the distal ends of the tibiae of the front and middle legs. Amongst the flies, the pulvilli have adhesive properties, and many beetles have pads of setae on the underside of the tarsomeres. In each of these cases the adhesive structures are areas of membranous cuticle covered by large numbers of small setae. For example in the lady beetle, Epilachna, there are two pads on the underside of each tarsus. Each pad carries about 800 setae which are 70–120 m long. Many of the setae are expanded at the tip to form flattened, foot-like structures 5–10 m in diameter (Fig. 8.8a). In the fly, Calliphora, the adhesive setae are also on the tarsi. They are much smaller than those in the beetle, only 9–15 m high with a 'foot' about 1 m in diameter. The fly has about 42 000 adhesive hairs altogether. The flexibility of the setae enables them to make contact with irregular surfaces much more efficiently than would be true of a single, larger structure. This greatly increases the power of adhesion. The males of many species of beetle have more adhesive setae than the females. These additional setae are used by the male to grasp the female during mating. Hairless adhesive pads occur in a number of insects. The arolia of cockroaches and grasshoppers can function as adhesive organs, and in the latter group they are bigger in habitually climbing species. In male dytiscid beetles a different mechanism of adhesion occurs. The first three tarsomeres of the foreleg of male Dytiscus are enlarged to form a circular disc. On the inside, this disc is set with stalked cuticular cups, most of which are only about 0.1 mm in diameter, but two of which are much larger than the rest, one being about 1 mm across (Fig. 8.8b). It seems that these cups act as true suckers, although it is not certain how the suction is created. The suckers are used by the male to grasp the female, but may also be used occasionally to grasp prey.

Jumping: In Orthoptera, Siphonaptera, Homoptera and some beetles, jumping is produced by the hind legs, but the ant, Harpegnathos, uses both the middle and hind pairs of legs. In Orthoptera, Alticini (flea beetles) and Orchestes (a weevil) the hind femora are greatly enlarged, housing the large extensor tibiae muscles which provide the power for the jump. In all these insects, the jump results from the sudden straightening of the femoro-tibial joint extending the tibia, which is also elongate, so that the tarsus is pushed against the substratum with great force. The structure of the hind leg, and especially of the femoro-tibial joint, is adapted to permit the development of maximum force by the extensor tibiae muscle, the storage of the energy they produce, and its rapid release resulting in the sudden extension of the tibia. The extensor tibiae muscle consists of a series of short fibers inserted obliquely into a long, flat apodeme (Fig. 8.21).

Free-swimming insects Larval and pupal Diptera, larval and adult Heteroptera and adult Coleoptera form the bulk of free-swimming insects and, apart from the Diptera, most of them use the hind legs, sometimes together with the middle legs, in swimming. The point of attachment of the hind legs is displaced posteriorly compared with terrestrial insects and in dytiscids and gyrinids, the coxae are immovably fused to the thorax. The thrust which a leg exerts in water is proportional to its area and the square of the velocity with which it moves. Hence to produce the most efficient forward movement a leg should present a large surface area and move rapidly on the backstroke, while presenting only a small surface and moving relatively slowly on the recovery stroke. Higher speeds will be produced if the greatest surface area is furthest from the body. To achieve a large surface area the hind tibiae and tarsi, and sometimes also those of the middle legs, are flattened antero-posteriorly to form a paddle, which, in Acilius and Dytiscus, is increased in area by inflexible hairs and, in Gyrinus (Coleoptera), by cuticular blades 1 m thick and 30–40 m wide (Fig. 8.32). In Acilius (Coleoptera) the hairs constitute 69% of the total area of the hind tibiae and 83% of the area of the tarsi. The hind legs of these insects are relatively shorter than the hind legs of related terrestrial insects, but the tarsi are relatively longer.

Fig. 8.10. Silk production in the foreleg of an embiid. (a) Basitarsus seen in transparency to show the silk glands. (b) A single silk gland showing its connection to a seta.



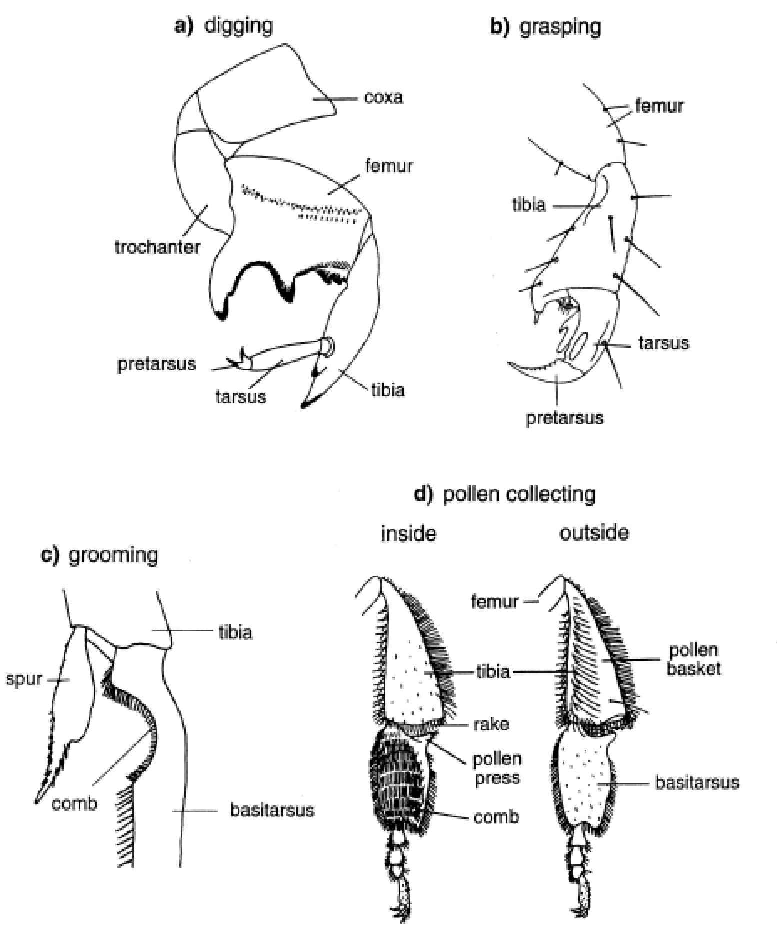


Fig. 8.9. Adaptations of legs. (a) Digging. Foreleg of a larval cicada (after Pesson, 1951). (b) Grasping. Leg of *Haematopinus* (Phthiraptera) (after Séguy, 1951). (c) Grooming. Foreleg of a mutillid (Hymenoptera) (after Schönitzer & Lawitzky, 1987). (d) Hind tibia and tarsus of a worker honeybee showing the pollen-collecting apparatus (partly after Snodgrass, 1956).

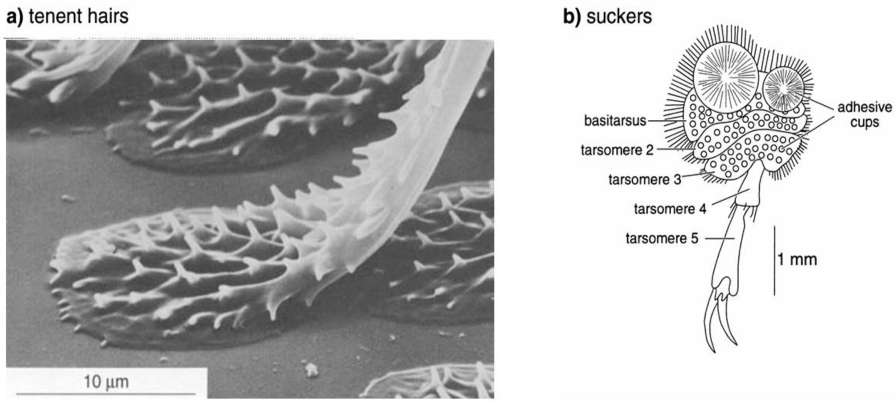
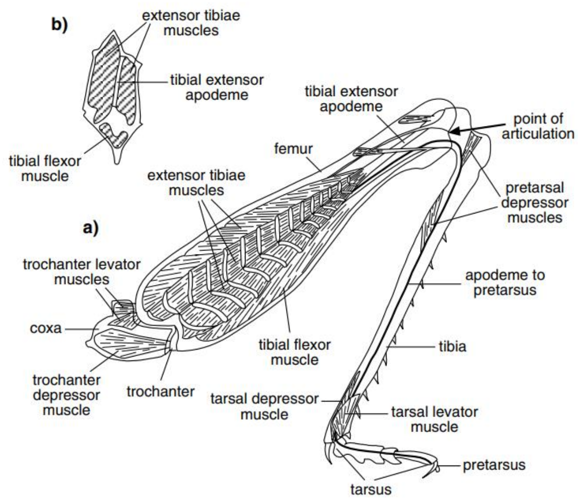


Fig. 8.8. Adhesive pads. **(a)** Tip of tenent hair of *Philonthus* (Coleoptera, Staphylinidae) (after Stork, 1983). **(b)** Suckers on the foreleg of male *Dytiscus* (Coleoptera, Dytiscidae) (after Miall, 1922).

Fig. 8.21. Jumping. Hind leg of a grasshopper (after Snodgrass, 1935). **(a)** Leg seen in transparency to show the musculature. **(b)** Transverse section of the femur.



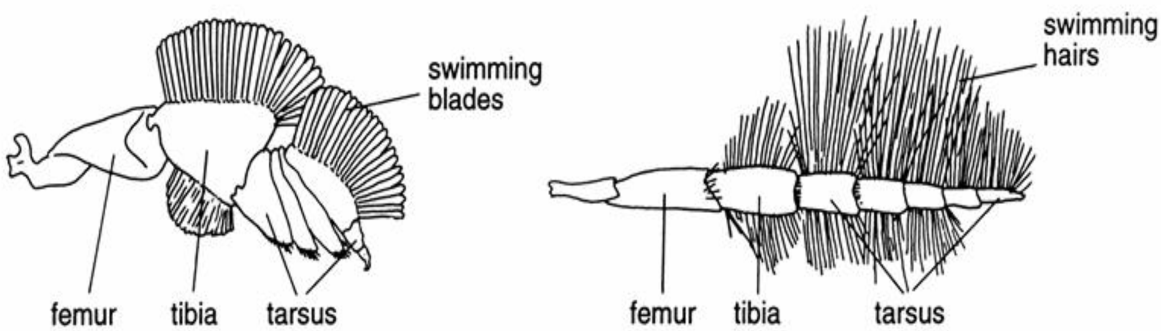


Fig. 8.32. Hind leg modifications of aquatic beetles. Structural adaptations and surface area of each part of the leg (after Nachtigall, 1962). **(a)** *Gyrinus*, **(b)** *Acilius*.

WINGS

STRUCTURE OF WINGS: Fully developed and functional wings occur only in adult insects although the developing wings are present in larvae. In hemimetabolous larvae they are visible as external pads, but they develop internally in holometabolous species. The Ephemeroptera are exceptional in having two fully winged stages. The final larval stage molts to a subimago, which resembles the adult except for having fringed and slightly translucent wings and rather shorter legs. It is able to make a short flight, after which it molts and the adult stage emerges. In the course of this molt the cuticle of the wings is shed with the rest of the cuticle. The fully developed wings of all insects appear as thin, rigid flaps arising dorsolaterally from between the pleura and nota of the meso- and meta-thoracic segments.

Each wing consists of a thin membrane supported by a system of veins. The membrane is formed by two layers of integument closely apposed, while the veins are formed where the two layers remain separate and the cuticle may be thicker and more heavily sclerotized (Fig. 9.1). Within each of the major veins is a nerve and a trachea, and, since the cavities of the veins are connected with the hemocoel, hemolymph can flow into the wings.

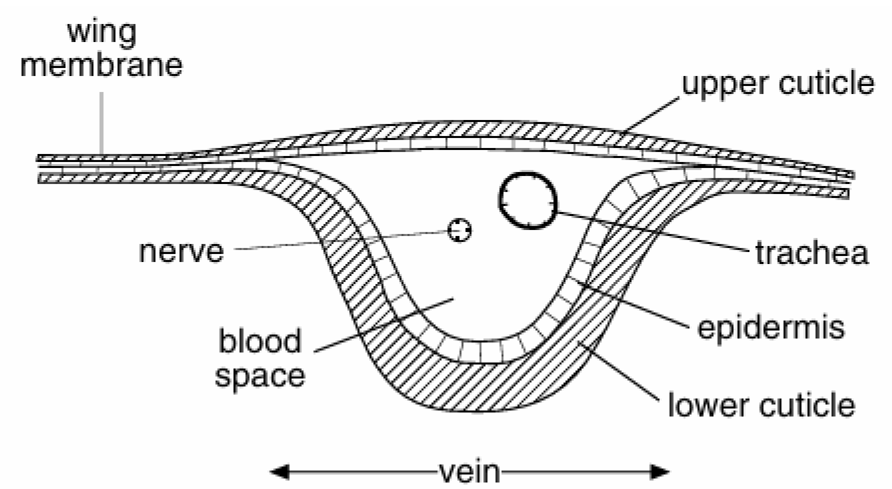


Fig. 9.1. Diagrammatic section through part of a wing including a transverse section of a vein.

Basic structure of the wing: The structure of the wing is determined primarily by the need to optimize the production of favorable aerodynamic forces during flight. In addition, in many insects, the structure allows the wing to fold when the insect is not flying.

A typical insect wing is triangular with three margins and three angles. Three margins are: costal or anterior, Apical or outer and Anal or inner. Three angles are: Humeral angle: between body wall and costal margin, Apical or outer angle: between costal and apical margin, Anal angle:

between apical and anal margin. The surface area of typical insect wing is divided into two portions ie. Remegium and Vannal Area. The anterior (upper) part of the wing towards coastal margin where more no of longitudinal veins are present is called remigium. The posterior part of the wing where veins are sparsely distributed is known as vannal area, which is called as clavus in forewings and vanus in hindwings. Jugum is the inner most portion of the wing that is cutoff from the main wing by jugal fold (Fig.9.3).

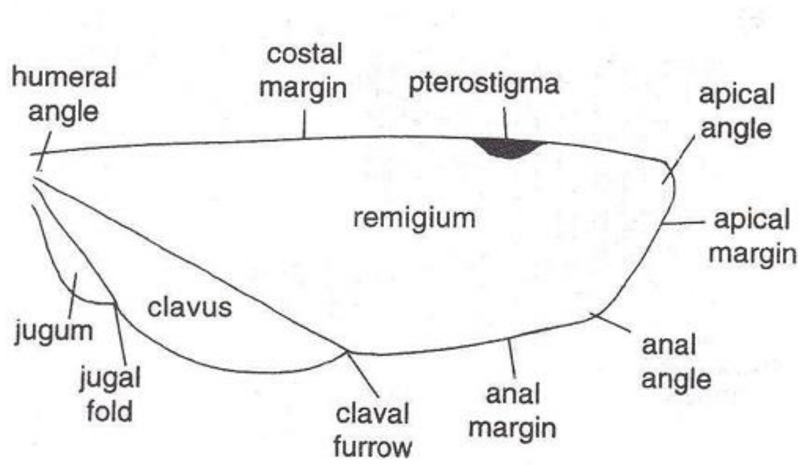


Fig. 9.3 Insect Wing Area

Hair of two types occurs on the wings, larger hairs known as **macrotrichia**: are Socketed and may be restricted to veins, the scales of Lepidoptera and Trichoptera are highly modified macrotrichia, and **microtrichia**: Small and irregularly scattered fixed hairs that lack the basal articulation characteristic of setae. These are found onthe wings of some Mecoptera and Diptera.

Veins and venation The principal support of the wing membrane is provided by a number of well-marked veins running along the length of the wing and connected to each other by a variable number of cross-veins. There is a tendency for the wings of lower orders of insects to be pleated in a fan-like manner with the longitudinal veins alternately on the crests or in the troughs of folds (Fig. 9.2). A vein on a crest is called convex (Fig. 9.2a), while a vein in a trough is called concave (in Fig. 9.2a).

Arrangement of veins on wing surface is known as **Wing venation**, which consists of two types of veins, Longitudinal veins and Cross veins.

Longitudinal veins:

1. Costa (C) : It forms the thickened anterior margin of the wing (costal) and is un branched. and is convex

2. Sub costa (Sc) : It runs immediately below the costa always in the bottom of a trough between C and R . It is forked distally .The two branches of SC are Sc1 and Sc2 and is concave

3. Radial vein (R): It is the next main vein , stout and connects at the base with second auxillary sclerite , it divided in to two branches R1 and Rs (Radial sector). R1 goes directly towards apical margin and is convex; Rs is concave and divided in to 4 branches, R2, R3,R4, R5.

4. Media (M) It is one of the two veins articulating with some of the small median seclerites. It is divided in two branches 1. Media anterior (MA) which is convex and 2.Media posterior(MP) and is concave. Media anterior is again divided into MA1 and MA2. Median posterior is again divided in to MP1, MP2, MP3, MP4.

5. Cubitus (Cu): It articulates with median auxillary sclerite. Cubitus is divided into convex CU1 and concave CU2. CU1 is again divided into CU1a and CU1b.

6. Anal veins (A) : These veins are convex. They are individual un-branched, 1-3 in number. 1 or 2 jugal veins (unbranched) are present in the jugal lobe of the forewing.

Cross veins

Humeral cross vein (**h**): between costa and subcostal

Radial cross vein (**r**): between radius and radial sector

Sectorial cross veins (**s**): between sub branches of radial sector

Radio medial cross vein (**r-m**): between

radius and media Medical cross veins: between branches of media

Medio-cubital veins: between media and cubitus

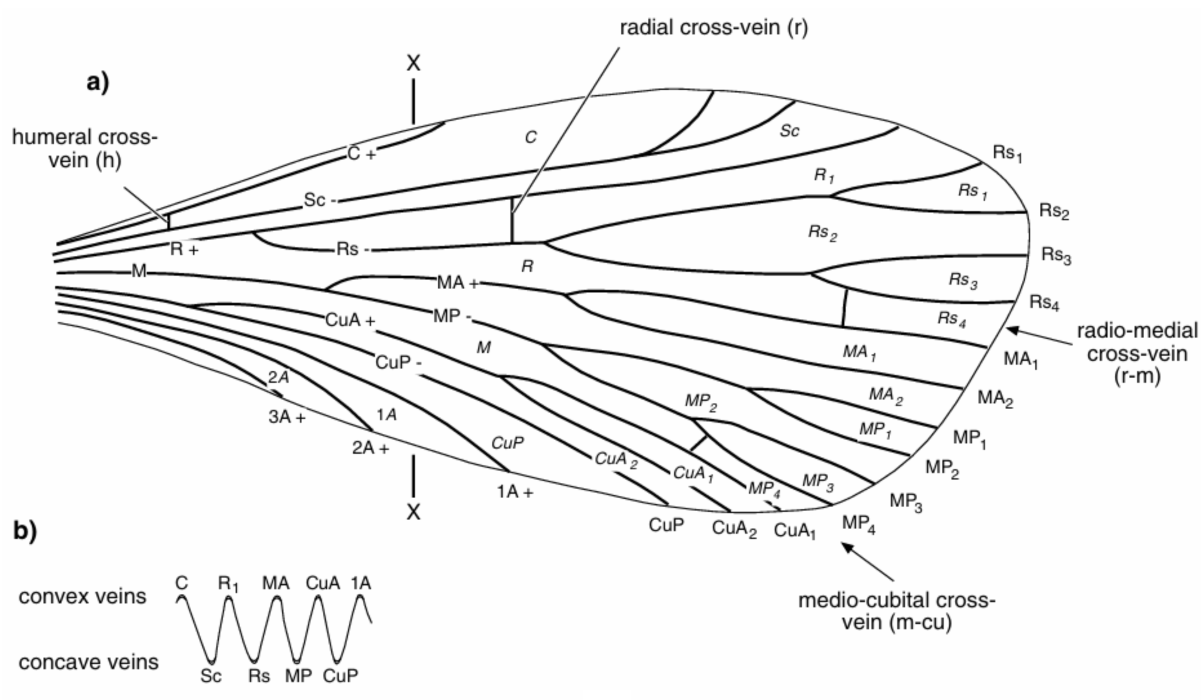


Fig. 9.2. Wing venation. **(a)** Diagram of wing venation showing the main cross veins and the names of the cells (italicized) enclosed by the veins. See text for abbreviations. **(b)** Section at X–X in (a) showing the concave and convex veins with the depth of pleating greatly exaggerated.

Insects are the only invertebrates possessing wings and capable of true flight. Based on the presence or absence of wings, class insecta is divided into two subclasses.

1. Apterygota: The primitive apterygotes are wingless eg. Silver fish and Spring tails.

2. Pterygota: among the pterygotes, wings arise from meso and meta thoracic segments, front pair of wings is known as forewings and back pair of wings is known as hindwings. In the heterometabola their wing- buds develop as external outgrowths which are visible from outside throughout most of the nymphal instars till they expand to their full size after the last molt (hence also called **Exopterygota**). In the holometabola their wing- buds develop inside invaginated sacs of the body wall, so they are not invisible from outside throughout the whole larval period (hence also called **Endopterygota**).

Sometimes wings may be **reduced** among pterygotes e.g. Mallophaga and Siphunculata . In coccids, only males are winged; and aphids may or may not have the wings. Based on the degree of development of wings the insects may be classified into three forms **Macropterous** (large-winged), **Brachypterous** (with short wings that donot cover the abdomen), and **Apterous** (wingless).

Cells are areas of the wing delimited by veins, and may be open (extending to the wing margin) or closed (surrounded by veins). They are named usually according to the longitudinal veins or vein branches that they lie behind, except that certain cells are known by special names, such as the discal cell in Lepidoptera and the triangle in Odonata.

Pterostigma. is an opaque or pigmented spot anteriorly near the apex of the wing, on forewing in Hymenoptera, Pscoptera, Megaloptera and Mecoptera and on both wings in Odonata. Functions as inertial mass in flight. Reduces wing flutter during gliding in odonates, thereby increasing flight efficiency. Provides passive control of angle of attack in small insects, which enhances efficiency during flapping flight.

MODIFICATIONS OF THE WINGS

The **wing membrane:** The wing membrane is typically semitransparent and often exhibits iridescence as a result of its structure. Sometimes, in addition, the wings are patterned by pigments contained in the epidermal cells. This is true in some Mecoptera and Tephritidae, while in many insects which have hardened forewings, such as Orthoptera and Coleoptera, the whole forewing is pigmented. The surface of the wing membrane is often set with small non-innervated spines called microtrichia. In Trichoptera, larger macrotrichia clothe the whole of the wing membrane giving it a hairy appearance.

In Lepidoptera, the wings are clothed in scales which vary in form from hair-like to flat plates. They usually cover the body as well as the wings. The scales are set in sockets in the wing membrane and are inclined to the surface, overlapping each other to form a complete covering. In primitive Lepidoptera, the scales are randomly distributed on the wings, but in butterflies (Papilionoidea) and some other groups they are arranged in rows. Pigments in the scales are responsible for the colors of many Lepidoptera, the pigment being in the wall or the cavity of the scale. In other instances, physical colors result from the structure of the scale. Some specialized scales are associated with glands , while scales may also be important in smoothing the air-flow over the wings and body. On the body they are also important as an insulating layer helping to maintain high thoracic temperatures. Scales also occur on the wing veins and body of mosquitoes (Culicidae) and on the wings of some Psocoptera and a few Trichoptera and Coleoptera. Scales and hairs on the wing membrane are not innervated, but mechano- and chemosensitive hairs are often present on the veins.

Wings with narrow, petiolate bases are found in relatively slow-flying insects, such as some damselflies (Zygoptera) and antlions (Myrmeleontidae) (Fig. 9.8a). This shape probably minimizes drag on the body due to the downwash of air from the flapping wings. Wings with broad bases, on the other hand, are associated with the capacity for rapid flight. They occur in Orthoptera, many Hemiptera and Lepidoptera (Fig. 9.8b), as well as in dragonflies (Anisoptera) and ascalaphids (Neuroptera, Ascalaphidae).

In Odonata, Isoptera, Mecoptera and male Embioptera the two pairs of wings are roughly elliptical in shape and similar in form, but in most other groups of insects the fore and hindwings differ from each other. Sometimes the hindwings are small, relative to the forewings, as in Ephemeroptera, Hymenoptera (Fig. 9.8c,f) and male coccids, while in some Ephemeroptera, such as Cloeon, and some male coccids they are absent altogether. In Diptera, the hindwings are modified to form halteres. In other insects, most of the power for flight is provided by the hindwings which have a much bigger area than the forewings (Fig. 9.8d). This is the case in Blattodeea, Mantodea, Orthoptera, Dermaptera and most Plecoptera and Coleoptera and in male Strepsiptera where the forewings are dumb-bell shaped.

The wings of very small insects are often reduced to straps with one or two supporting veins and long fringes of hairs (Fig. 9.8e). These forms occur in Thysanoptera, in Trichogrammatidae and Mymaridae amongst the Hymenoptera, and in some of the small Staphylinoidea amongst the Coleoptera. The wings of plume moths, Pterophoridae and Orneodidae, are deeply cleft and fringed with scales (Fig. 9.8g). Wing fringes are common in Lepidoptera and Culicidae, and in some Tinaeoidea they are so extensive as to greatly increase the effective area of the wing. In other cases, particular wing forms are presumed to have some ecological significance apart from the production of aerodynamic forces, although their real significance is not always certain. The forewings of many insects are thicker than the hindwings and serve to protect the latter when they are folded at rest (Fig. 9.9). Forewings modified in this way are known as elytra or tegmina. Leathery tegmina occur in Blattodeea, Mantodea, Orthoptera and Dermaptera, while in Heteroptera only the basal part of the wing is hardened, such wings being known as **hemelytra** (Fig. 9.10a). The basal part of the hemelytron may be subdivided into regions by well-marked veins and, in mirids, where the development is most complete, the anterior part of the wing is cut off as a proximal embolium and distal cuneus, the center of the wing is the corium, and the anal region is cut off as the clavus. In lygaeids only the corium and the clavus are differentiated. The **elytra** of Coleoptera are usually very heavily sclerotized and the basic wing venation is lost, although it may be indicated internally by the arrangement of tracheae. The two surfaces of the elytron are separated by a blood space (Fig. 9.10b) across which run cuticular columns, the trabeculae, arranged in longitudinal rows and marked externally by striations. There are usually nine or ten such striae, although the number may be as high as 25 in some Carabidae. The elytra of beetles do not overlap in the midline, but meet and are held together by a tongued and grooved joint, while in some Carabidae, Curculionidae and Ptinidae they are fused together so that they cannot open and in these species the hindwings are also reduced. At the sides, the elytra are often reflexed downwards, the vertical part being called the epipleuron and the horizontal part the disc. In Orthoptera, the forewings are often modified for sound production and they may be retained for this function in species in which they are no longer used in flight. The shape of the wings may also have significance not directly related to flight. Swallow-tailed butterflies and some Lycaenidae have a projection from the hind margin of the hindwing, while in the Nemopteridae and some Zygaenidae the hindwings are slender ribbons trailing out behind the insect. This probably tends to divert the attention of a predator away from the head and thorax, at least in some of these insects. An irregular outline to the wings, such as occurs in some butterflies, serves to break up the outline of a resting insect and presumably has a camouflage function.

Some insects have both pairs of wings reduced and they are said to be **brachypterous or micropterous**. This occurs, for instance, in some Orthoptera and Hemiptera. The completely wingless, or **apterous**, condition is also widespread. **Winglessness occurs** as a primitive condition in the Apterygota, while the ectoparasitic orders Phthiraptera and Siphonaptera are **secondarily wingless**. Wingless species are also widespread in most other orders, but apparently do not occur in Odonata or Ephemeroptera. Sometimes both sexes are wingless, but frequently the male is winged and only the female is apterous. This is the case in coccids, Embioptera, Strepsiptera, Mutillidae and some Chalcididae. In the ants and termites, only the reproductive caste is winged and here the wings are shed after the nuptial flight, breaking off by a basal suture so that only a wing scale remains. The break is achieved in different ways, but termites frequently rest the wing on the ground and then break it off by twisting the wing base. After loss of the wings, the flight muscles degenerate. Commonly the development of the wings varies within a species either geographically or seasonally. The extent to which this is genetically determined is often unclear, but in many species environmental factors have a dominant effect. Such wing **polyphenism** occurs in various groups. Within a species of the grasshopper, Chrotogonus, the tegmina and hindwings may vary in length from fully developed to very short. In many other insects, however, and notably in Hemiptera, species may either be apterous or macropterous (with fully developed wings), without any intermediates.

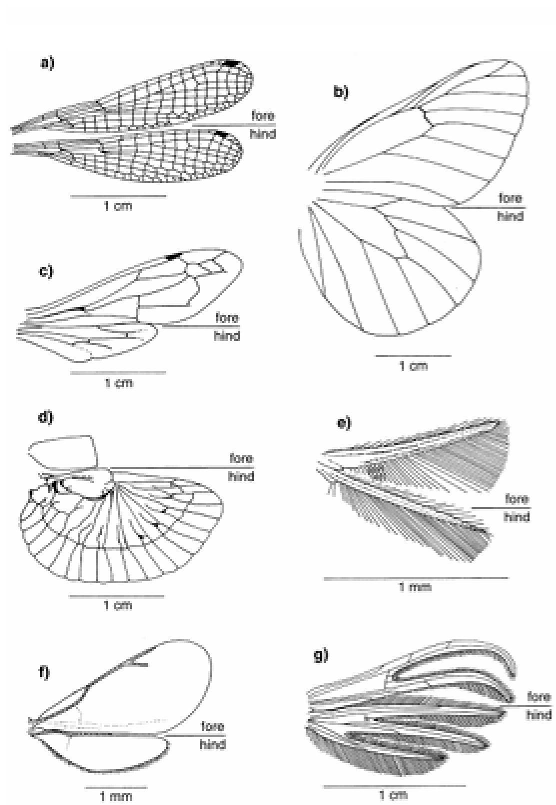


Fig. 9.8. Wing forms. **(a)** Both wings power-producing. Petiolate wings of a damsel fly. Not anatomically coupled (Zygoptera, *Ischnura*). **(b)** Both wings power-producing. Broad-based wings with amplexiform coupling (Lepidoptera, *Aporia*). **(c)** Forewing power-producing. Hindwing reduced and coupled to the forewing by hamuli in a hornet (Hymenoptera, *Vespa*). **(d)** Hindwing power-producing. Forewing reduced to a short tegmen in an earwig. Not anatomically coupled (Dermaptera, *Echinosoma*). **(e)** Fringed wings and reduced venation of a thrips. Frenate-type wing coupling (Thysanoptera, *Thrips*). Notice the small size. **(f)** Reduced venation of a chalcid wasp. Hindwing coupled to forewing by hamuli (Hymenoptera, *Eulophus*). Notice the small size. **(g)** Deeply divided wings of a plume moth. Frenate wing coupling (Lepidoptera, *Alucita*).

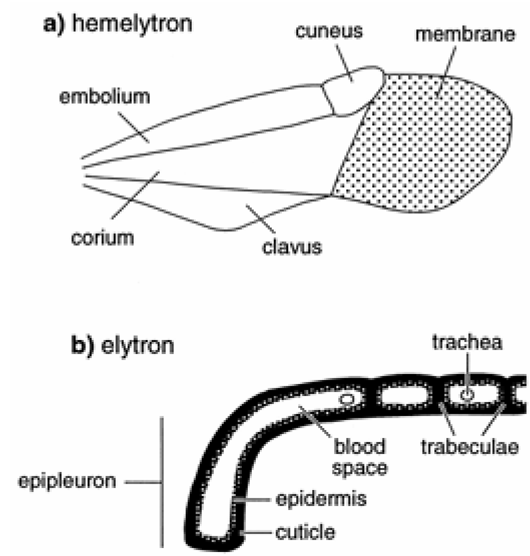


Fig. 9.10. Protective forewings. **(a)** Hemelytron of a mirid (Heteroptera) (after Comstock, 1918). **(b)** Diagrammatic transverse section through part of an elytron of a beetle.

Wing coupling apparatus. For taking flight, insect need to keep both the fore and hindwings together as a single unit. The structures in the form of lobes, bristles, hairs or spines that help thewings to be together are known as wing coupling organs. Orthoptera and Odonata wings are not anatomically coupled. Observe the following types of wing couplingin different insects. The commonest coupling mechanism (seen clearly in Hymenoptera and some Trichoptera) is a row of small hooks, or hamuli, alongthe anterior margin of the hind wing that engages with a fold along the posterior margin of the fore wing (hamulate coupling) (fig.5 a). In some other insects (e.g. Mecoptera, Lepidoptera and some Trichoptera), a jugal lobe of the fore wing overlaps the anterior hind wing (jugate coupling) (fig.5b). , eg. Primitive lepidopterans of the family Hepialidae, or the margins of the fore and hind wing overlap broadly (amplexiform coupling) (fig.5c), eg. butterfly, or one or more hind-wing bristles (the frenulum) hook under a retaining structure (the retinaculum) on the fore wing (frenate coupling) (fig.5d) eg. Family Sphingidae of the order lepidoptera.

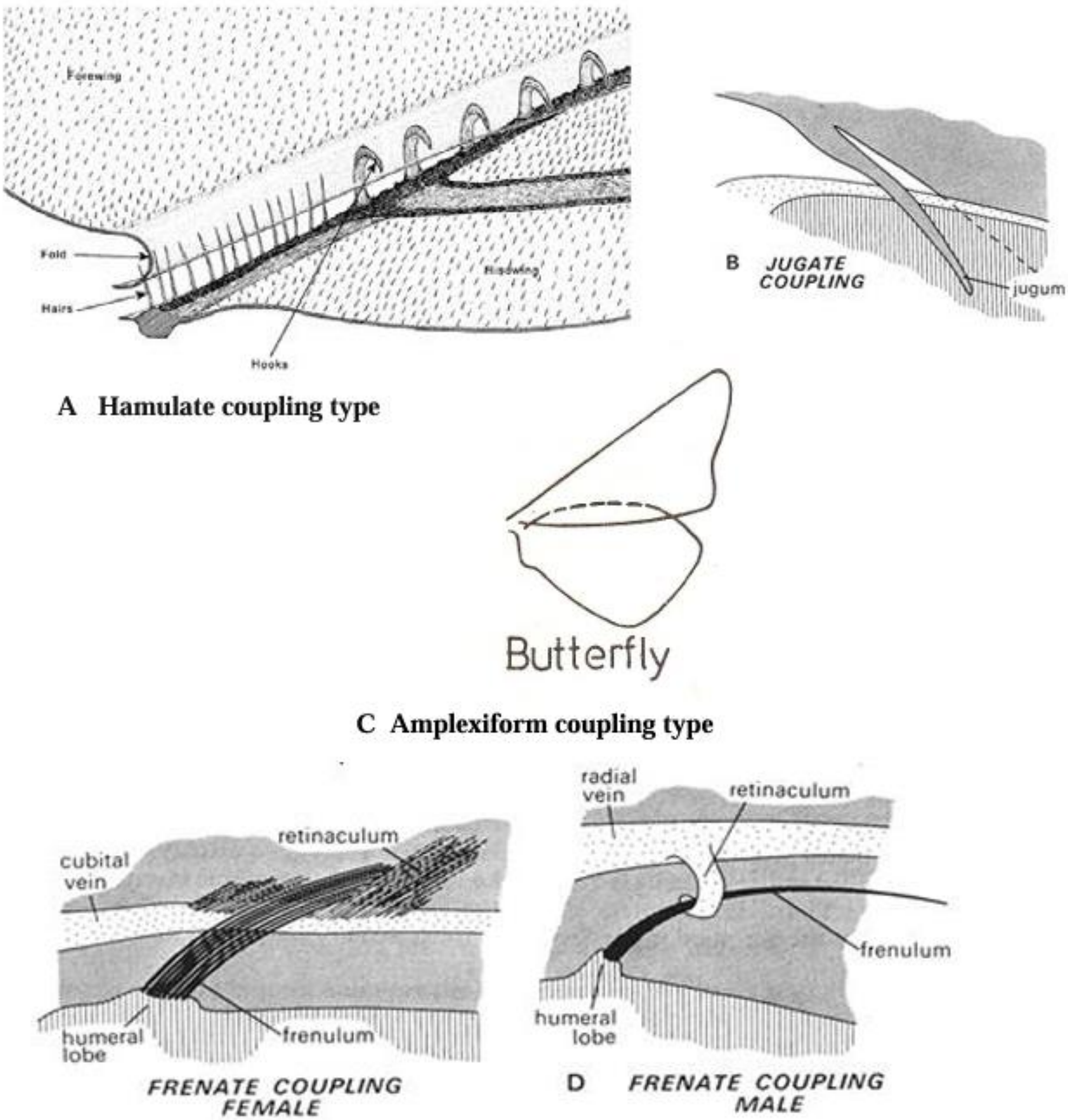


Fig.5 Wing coupling mechanism.