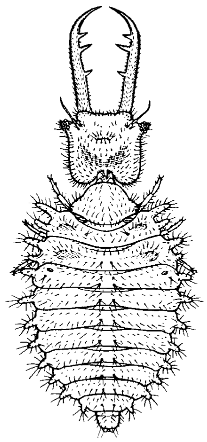


ENTOMOLOGY 322
LABS 13 & 14
Insect Mouthparts

The diversity in insect mouthparts may explain in part why insects are the predominant form of multicellular life on earth (Bernays, 1991). Insects, in one form or another, consume essentially every type of food on the planet, including most terrestrial invertebrates, plant leaves, pollen, fungi, fungal spores, plant fluids (both xylem and phloem), vertebrate blood, detritus, and fecal matter. Mouthparts are often modified for other functions as well, including grooming, fighting, defense, courtship, mating, and egg manipulation. This tremendous morphological diversity can tend to obscure the essential appendiculate nature of insect mouthparts. In the following lab exercises we will track the evolutionary history of insect mouthparts by comparing the mouthparts of a generalized insect (the cricket you studied in the last lab) to a variety of other arthropods, and to the mouthparts of some highly modified insects, such as bees, butterflies, and cicadas.

As mentioned above, the composite nature of the arthropod head has lead to considerable debate as to the true homologies among head segments across the arthropod classes. Table 13.1 is presented below to help provide a framework for examining the mouthparts of arthropods as a whole.

1.

Obtain a specimen of a horseshoe crab (Merostoma: *Limulus*), one of the few extant, primitively marine Chelicerata. From dorsal view, note that the body is divided into two tagmata, the anterior

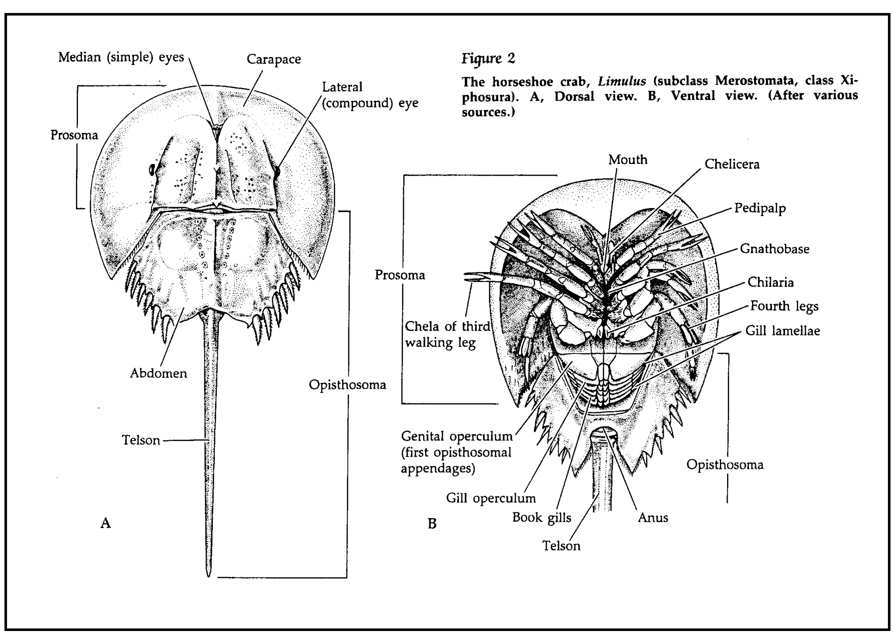


Figure 13.1 (Brusca & Brusca, 1990)

prosoma (cephalothorax) and the posterior opisthosoma (abdomen) with a caudal spine (telson) at its end (Fig. 13.1). In ventral view, note that all locomotory and feeding appendages are located on the prosoma and that all except the last are similar in shape and terminate in pincers. Also note that the appendages of the opisthosoma are modified as gills and gill covers. How many pairs of appendages are there on the prosoma?

The horseshoe crab is a scavenger, feeding on molluscs, etc., by picking them up with its pincers and passing them to the gnathobases, the expanded coxal endites. The endites shred the food and then pass it anteriorly to the mouth. The mouth is directed posteriorly, so that it can intercept the anteriorly-directed stream of food being passed to it by the gnathobases. Note that the anterior pair of appendages are also chelate (pincer-like); these are the chelicerae (Fig. 13.1). The appendages immediately following the chelicerae are the pedipalps, thought to be homologous to the mandibles of myriopods and insects (Table 13.1). How do the pedipalps compare with insect mandibles in structure and plane of movement? What evidence do you think supports the view that pedipalps and mandibles are homologous?

2.

Obtain a specimen of a crayfish (Crustacea: Decapoda), an example of the dominant class of marine arthropods. The body consists of three tagmata, the head and thorax (which are partially fused), and abdomen (Fig. 13.2) Note that the head bears two pairs of pre-oral sensory appendages: the biramous first antennae (1Ant) and the longer second antennae (2Ant). From ventral view, note that the thorax bears five pairs of legs, the first bearing large chelae (pincers; Chpd). In front of these are three pairs of thoracic legs that are modified for feeding, the maxillipeds (Fig. 13.3F,G,H). These in turn do not differ greatly from the two posterior pairs of head appendages, the second maxillae (Fig. 13.3D,E) and first maxillae (or maxillules, Fig. 13.3C). You do not have to make a detailed study of these appendages, but you should note that they are biramous. Anterior to these are the strong jaws or mandibles (Fig. 13.3A). Notice how they articulate with the head and that they are multiarticulate and biramous, bearing a small segmented palp (Plp; telopodite). This is a primitive feature of arthropod mandibles that is lost in insects. The jaw-like part of the mandible thus represents a gnathobase of the coxa. A labrum hangs over the mouth anteriorly.

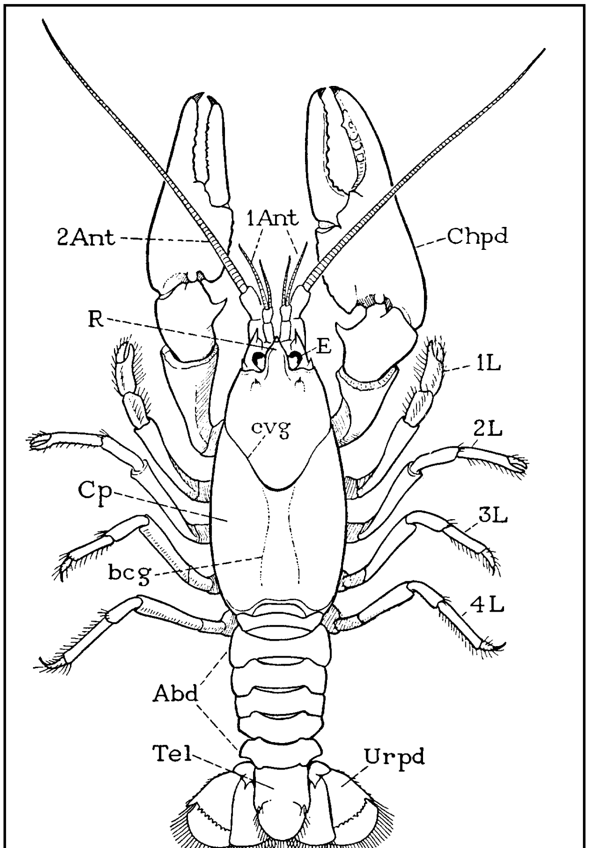


Fig. 40. Crustacea—Decapoda. *Cambarus longulus* Girard, male. *Abd,* abdomen; *1Ant,* first antenna, antennule; *bcg,* branchio-cardiac groove; *cvg,* "cervical" groove; *Chpd,* cheliped; *Cp,* carapace; *E,* compound eye; *1L–4L,* legs, second to fifth pereiopods; *R,* rostrum; *Tel,* telson; *Urpd,* uropod.

Figure 13.2 (Snodgrass, 1952)

Observe a living crayfish and the movement of its legs and two pairs of antennae. Offer it some food (a dead cricket or piece of bread) and observe how the food is handled and brought to the mouth. According to Lochhead, the maxillipeds assist in tearing and manipulating food, while the mandibles serve principally to hold the food and roll it into the mouth.

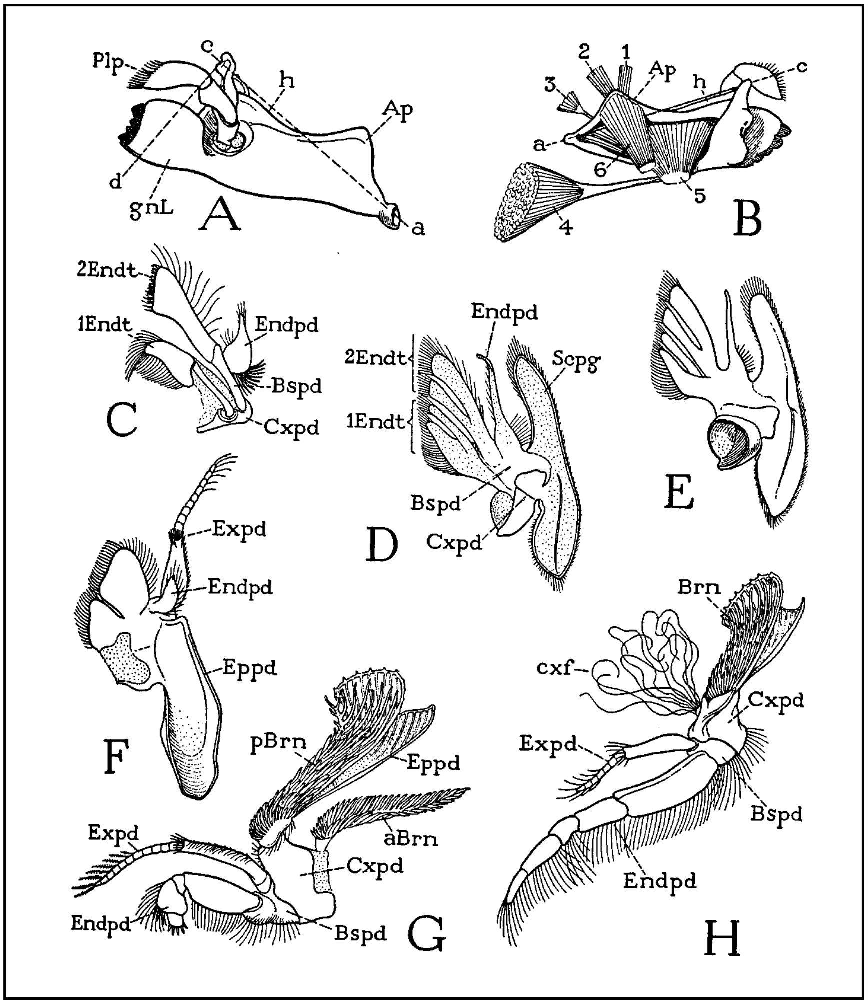


Figure 13.3 (Snodgrass, 1952)

3.

Examine the head of a preserved centipede (Myriapoda: Chilopoda: *Scolopendra* sp.). As in insects, the head is a single solid capsule with only one pair of antennae. The mandible has two segments which are only weakly distinct from each other (Fig. 13.4B). The similarity between crustacean and myriopod mandibles is a bit clearer in millipedes (Myriapoda: Diplopoda) where the distal portion of the mandible (endite lobe) is clearly multiarticulate (Fig. 13.4A). Centipedes have two pairs of maxillae as in crustacea. The second pair of maxillae in myriopods are homologous to the labium of insects (Table 13.1).

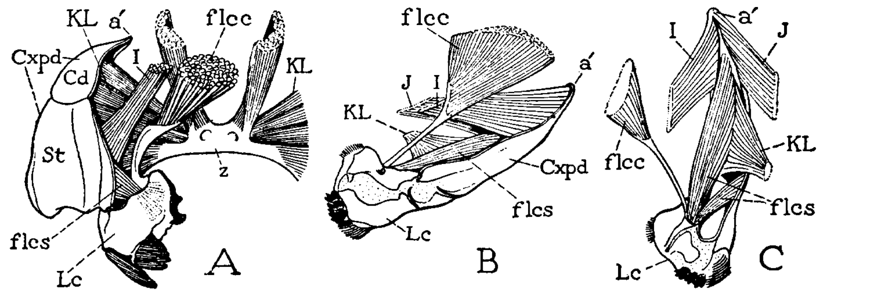


FIG. 73.—Mandibles and mandibular musculature of Myriapoda. A, right mandible of a diplopod, anterior view. B, left mandible of *Scutigera*, anterior view. C, right mandible of same, dorsal view.

Figure 13.4 (Snodgrass, 1935)

Now that you have observed the head appendages in the major classes of Arthropoda, review Table 13.1. Make note of the homologies implied by the table. Notice that the chelicerae of Chelicerata and the 2nd antennae of Crustacea have no corresponding (homologous) appendages in adult myriopods and insects. Only in embryonic development are the limb buds corresponding to these body segments visible in insects and myriopods. Notice also that the Crustacea, Myriopoda, and Insecta all possess mandibles. This is considered a derived trait uniting these groups into a higher taxon called the Mandibulata.

4.

Observe the demonstration of the head of a springtail (Hexapoda: Entognatha: Collembola) (Fig. 13.5). The mouthparts are entognathous, meaning that they are enclosed within the head capsule. The mandibles and maxillae are long, slender, and stylet-like. This is a derived condition (relative to the Arthropoda) even though it is found in the most basal Hexapoda.

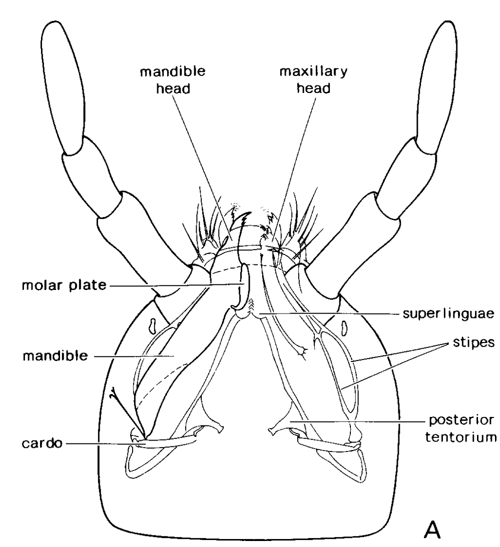


Figure 13.5 (Snodgrass, 1935)

5.

Examine the demonstrations of the mouthparts in bristletails (Archeognatha: Machilidae), the most primitive lineage of Ectognatha. Concentrate on the mandibles (Md in Fig. 13.6). Note the single dorsal articulation with the head capsule (a in Fig. 13.6), and the pointed, distal incisor processes and the median molar lobes.

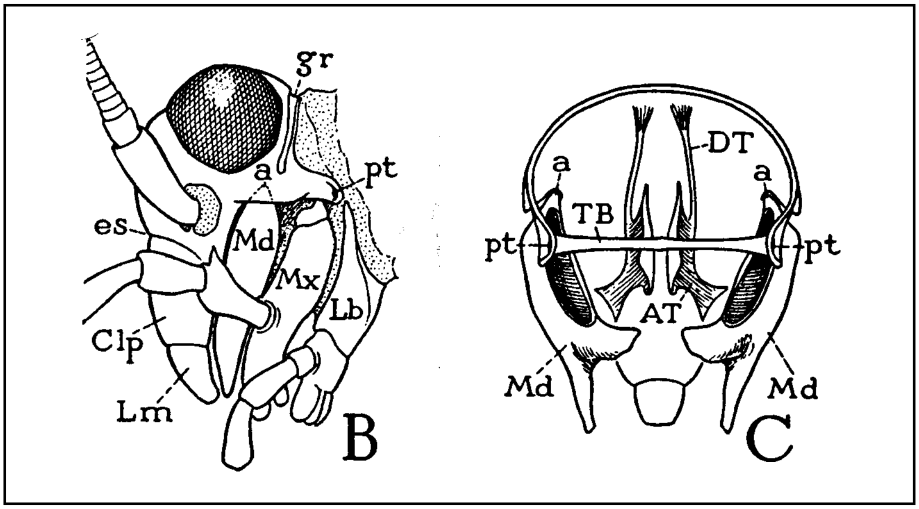


Figure 13.6 (Snodgrass, 1952)

Archaeognatha retain a primitive trait for arthropods: the posession of a monocondylic mandible. As you will remember from the previous lab, the mandibles of crickets (and all other pterygotes for that matter) are dicondylic. The musculature of monocondylic mandibles is actually more complex than that of dicondylic mandibles. In monocondylic mandibles there are four muscles associated with each mandible: anterior rotator (I in Fig. 13.7A), posterior rotator (J in Fig. 13.7A), and two adductors, zygotic adductor (Klz in Fig. 13.7A) and tentorial adductor (Klt in Fig. 13.7A). With the evolution of the dicondylic mandible, the adductors are lost and the anterior rotator becomes the functional abductor (I in Fig. 13.7B) and the posterior rotator becomes the functional adductor (J in Fig. 13.7B).

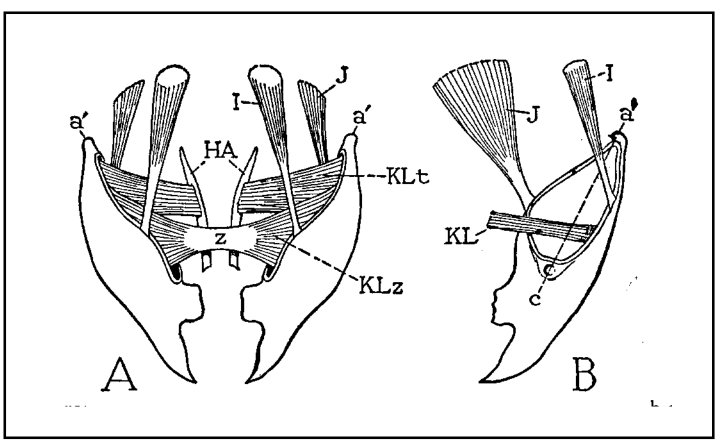


Figure 13.7 (Snodgrass, 1935)

Figure 13.8 gives a phylogenetic interpretation of mandible evolution in insects and myriopods.

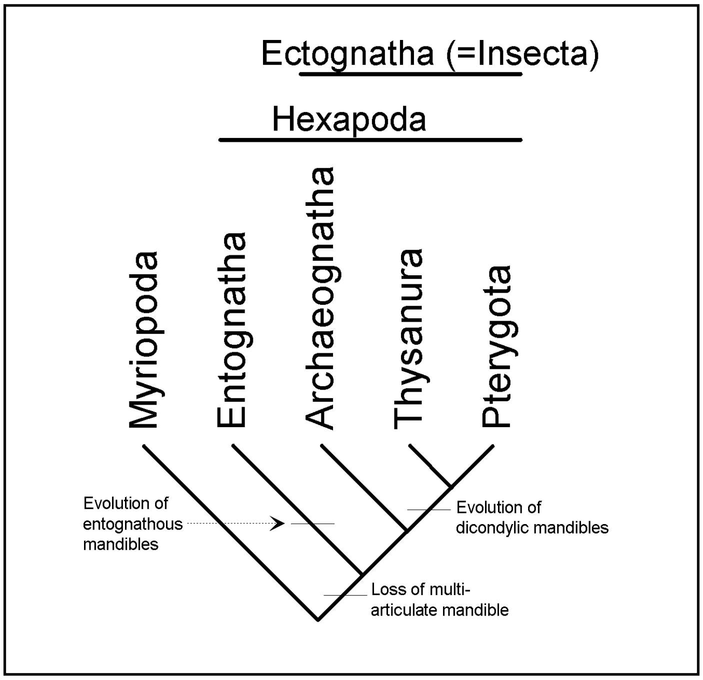


Figure 13.8 Phylogeny of the basal Hexapoda

If a live bristletail is available, observe its head region as it explores its cage. How are the antennae held and moved? How do the mouthparts contact the substrate? Notice especially the maxillary palpi and their movements. Their homology with the thoracic legs should be apparent.

6.

Obtain a live and, hopefully, hungry roach. Observe the movement of the antennae as the roach explores its prison. What portions of the antennae are freely movable? In what positions can the insect move its antennae? Are the antennae used to "feel" the surface of its cage or to "test" the air, or both? Observe the mouthpart region through the glass bottom of its cage. What appendages appear to serve as sensory organs as the insect is walking?

Place a slice of apple or other cafeteria item in the cage. If you have not maltreated your roach, it may be persuaded to eat the food. Observe the action of the mouthparts with a magnifying glass or under the microscope. Which mouthparts guide the food to the mouth? Which mouthparts bite it?

7.

Next, obtain a preserved or freshly killed cockroach. Anchor the roach so that the mouthparts are directed upwards. Observe the relative positions of the mouthparts. With the help of figures 13.9 identify the following structures:

labrum
mandibles
maxilla -- including cardo (Cd), stipes (St), galea (Ga), lacinia (La), maxillary palpus (Plp)
labium -- including prementum (Pmt), submentum (Smt), mentum (Mt), paraglossa (Pgl), glossa (Gl), labial palpus (Plp)
hypopharynx
cibarium
salivarium

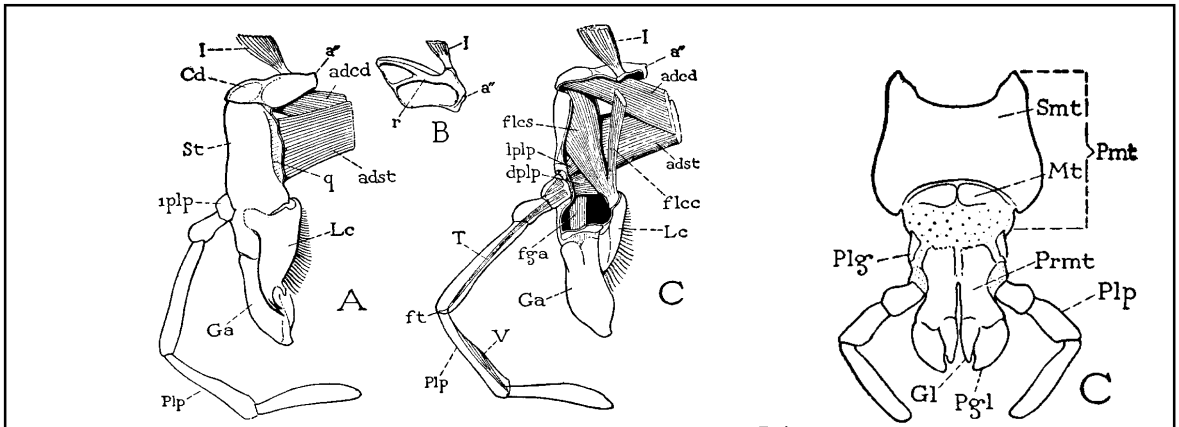


FIG. 80.—Maxillae of *Periplaneta americana*. A, left maxilla, posterior view. B, inner surface of cardo. C, right maxilla, anterior view.

Figure 13.9 (Snodgrass, 1935)

Note the hinging of the labrum to the clypeus. Their common inner wall is the <u>epipharnyx</u> and is the anterior wall of the pre-oral cavity. The <u>tormae</u> are small sclerites at the lateral junctions of the labrum and clypeus, on the inner wall, and are points of muscle attachment.

Examine the morphology of the roach labium and consider how similar it is to the maxillae of myriopods. Is there any doubt in your mind as to whether the labium is homologous to fused second maxillae?

Remove the labrum, clypeus, maxillae, and labium. Observe the mandibles at rest. Note that there are two articulations -- each a ball-and-socket type. Force open the right mandible (why is it so difficult?) and remove it. Are the <u>condyles</u> of both mandibular articulations on the mandible? Note the positions of the two mandibular <u>apodemes</u> relative to the anterior and posterior articulations (indicated by c and a' on Fig. 13.10). The apodeme (9Ap in Fig. 13.10) of the mandibular adductor (9a in Fig. 13.10), which closes the mandibles, is located mediad of the line connecting the two mandibular articulations. The apodeme (8Ap in Fig. 13.10) of the mandibular abductor (9b in Fig. 13.10), which opens the mandibles, is located laterad (or outside) the line connecting the two mandibular articulations.

Which muscle, adductor or abductor, is larger? Why? With a needle, move the other mandible, while viewing the articulations, and movement of the abductor and adductor muscles (you may find it necessary to remove the white membrane in order to see the movement of the adductor muscle).

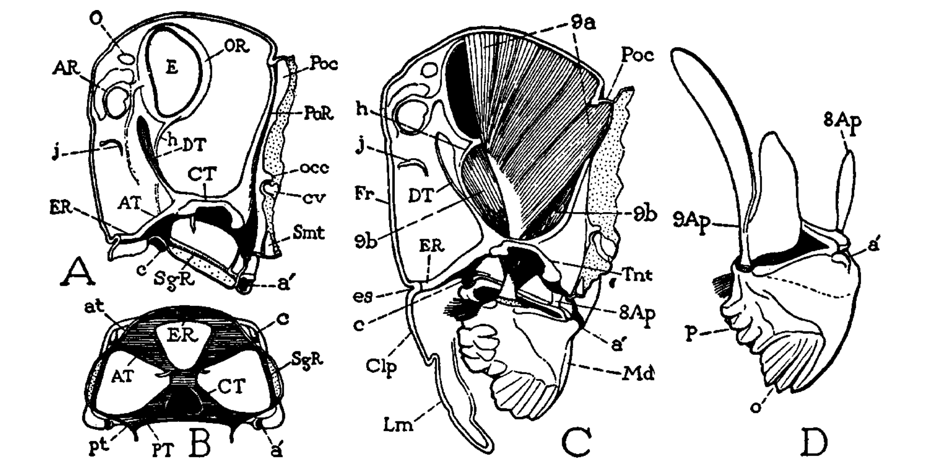


FIG. 76.—Endoskeletal structures of the cranium, and mandibles of a grasshopper, *Dissosteira carolina.* A, interior view of right half of cranium. B, the tentorium, ventral view. C, same as A, but with clypeus, labrum, and right mandible and muscles in place. D, right mandible and its apodemes, posterior view.

Figure 13.10 (Snodgrass, 1935)

Examine the demonstrations of the musculature of the head, especially the adductor muscles of the mandibles. Also examine the cleared tentorium locating the anterior, posterior, and dorsal arms (refer to Figs. 12.5 and 13.10).

8.

Dragonfly nymphs are voracious predators in freshwater ecosystems and have evolved a unique form of prey capture: the labium is modified as a raptorial device which can be rapidly extended to capture prey.

Obtain a preserved dragonfly nymph (Odonata). Identify the mandibles, maxillae, and labium, which forms the "mask" when retracted. Extend the labium and identify the postmentum, prementum, and labial palpi (Fig. 13.11). Note especially the articulation of the postmentum and prementum.

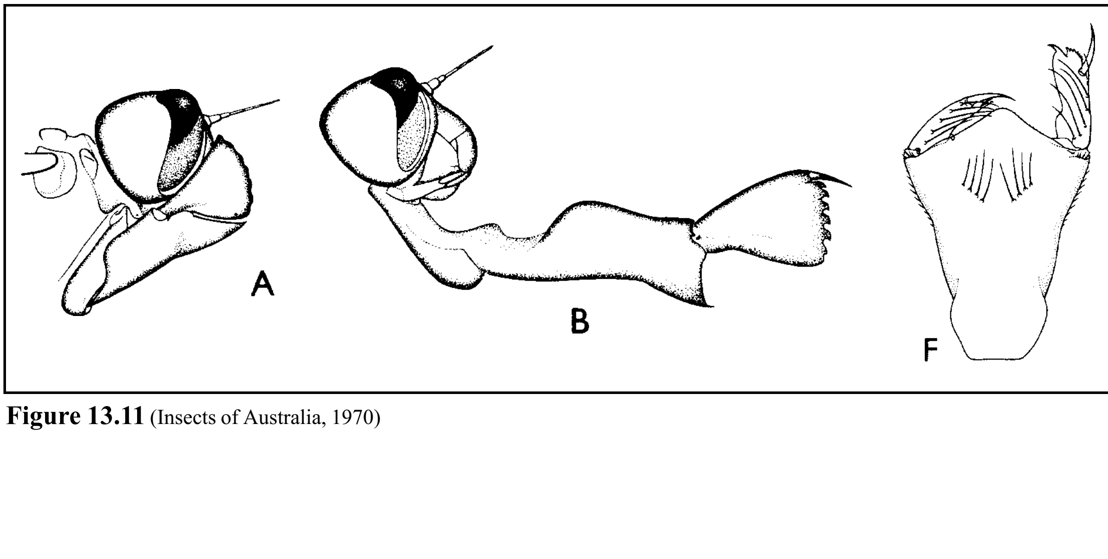


Figure 13.11 (Insects of Australia, 1970)

Obtain a live nymph. Watching its "mask" under the microscope, squeeze its thorax firmly dorso-ventrally. What happens to the mask? Do the labial palpi open? What is the appearance of the premental-postmental joint? Release the thorax. Does the mask return to its resting position? What force propels the strike?

If you have hungry nymphs, place some food (disabled insects) near them. Observe their strike. How is food captured and manipulated?

9.

Obtain a specimen of the honey bee, *Apis mellifera* (Hymenoptera: Apidae) and examine its mouthparts. Note there are functionally two sets: the mandibles, which are used to work wax in the hive, and the labio-maxillary complex (labium plus maxillae), which function as one unit in forming a sucking tube or proboscis to suck nectar from flowers. Extend the proboscis as far as possible. Using Fig. 13.12, identify the following parts:

Mandible
Maxilla:
- **cardo (Cd)**
- **stipes (St)**
- **galea (Ga)**
- **maxillary palpus (MxPlp)**

Labium:
- **mentum (Mt)**
- **submentum (Smt; called the lorum [Lr] in bees)**
- **prementum (Prmt)**
- **labial palpus (lbPlp)**
- **paraglossa (Pgl)**
- **glossa (Gl)**

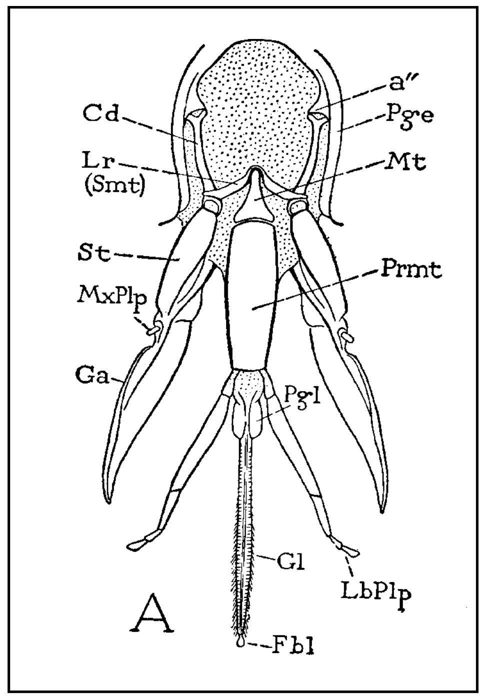


Figure 13.12 (Snodgrass, 1935)

The proboscis can be folded and retracted into a cavity, the proboscidial fossa, on the ventral region of the head. Fold your specimen's mouthparts to convince yourself of this. The proboscidial fossa is sclerotized between the mouthparts and the occipital foramen. The carinae lining the proboscidial fossa are secondary strengthening ridges. In the fossa, lateral postgenal lobes appear to "encroach" on the median, less melanized hypostomal bridge.

Observe a live honey bee and induce it to suck up dilute honey. How is the proboscis used? How are the component parts positioned? How are the mandibles used, if at all?

10.

Obtain a specimen of a cicada (Homoptera: Cicadidae) and examine its mouthparts. The head and mouthparts of the Hemiptera are among the most modified and difficult to understand in the Insecta, but this will not deter us from examining a representative. Hemipteran mouthparts are adapted for piercing tissues (either plant or animal) and sucking them up. In some species proteolytic enzymes are injected with the saliva so that the internal anatomy of the "prey" is liquified before it is withdrawn by the bug.

In the cicada, the beak consists of a sheath formed by the labium (Lb) which encloses two sets of stylets. The outer pair are homologous to mandibles (Mdb) and inner pair are homologous to the maxillae (MxB; Fig. 13.13). The maxillae are grooved on their inner surfaces so as to create food (fc) and salivary (sc) channels (Fig. 13.14B,C). During feeding, the stylets penetrate the plant tissue but the labium remains outside. Identify the following parts of the beak of your cicada, using Figs. 13.13.

labium
stylets (do not attempt to differentiate mandibles and maxillae)
labrum

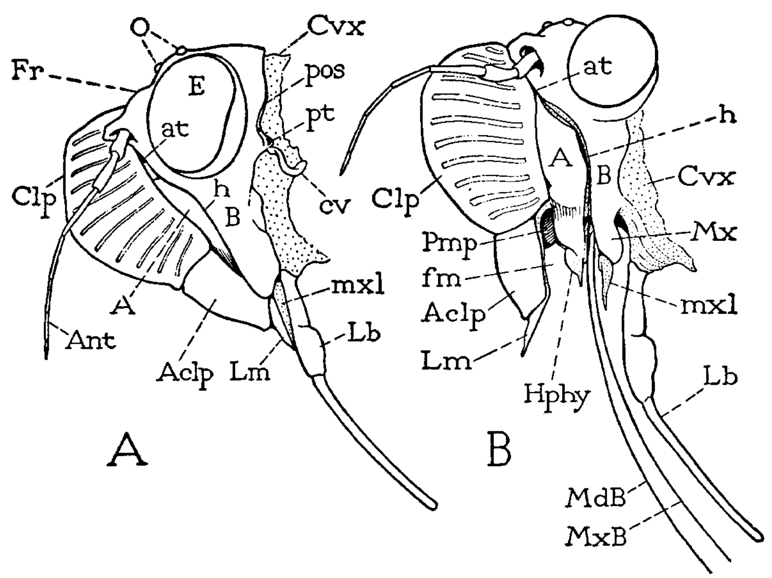


FIG. 178.—Head and beak of *Magicicada septendecim*. A, head of fully matured imago. B, soft head of imago emerging from nymphal skin, with parts separated.

Figure 13.13 (Snodgrass, 1935)

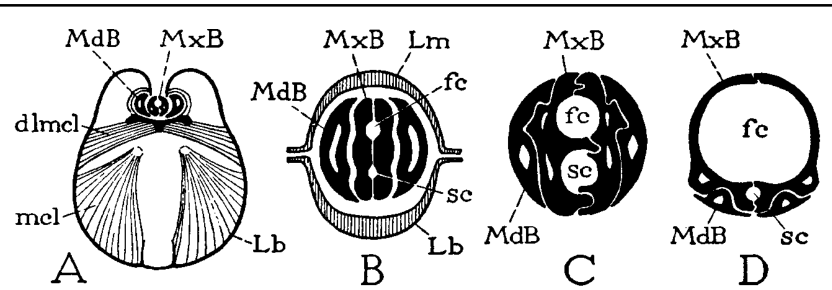


FIG. 182.—Sections of the beak and feeding bristles of Hemiptera. A, *Magicicada septendecim*, labium and bristles. B, *Aphis rumicis*, labrum, labium, and bristles. (*From Davidson*, 1925.) C, *Anasa tristis*, bristle fascicle. (*From D. G. Tower*, 1914.) D, *Cimex lectularius*, bristle fascicle. (*From Kemper*, 1932.)

Figure 13.14 (Snodgrass, 1935)

Examine the demonstrations of the musculature of the head in parasagittal section and identify the following with the aid of Fig. 13.15. A strong cibarial pump (Pmp) is operated by dilator muscles (dlcp) that originate on the expanded fronto-clypeus (Clp) and insert on the epipharnyx, which is strongly sclerotized. When the dilator muscles contract, the cibarium (Pmp) is enlarged and plant juices are sucked up by the vacuum. Try to locate the salivary syringe (Syr), which pumps salivary enzymes from the labial glands through the salivary channel of the stylets into the plant. In section, the well-sclerotized walls of the syringe surround the sclerotized piston, which can be drawn back by dilator muscles (dlsyr) (cut in this section) attached to an apodeme at the piston's base. This action allows saliva to enter the syringe chamber through the gland duct (SlD) opening at its apex. When the dilator muscles relax, an elastic diaphragm pulls the piston forward, closing the gland duct and forcing the saliva into the salivary channel (sc).

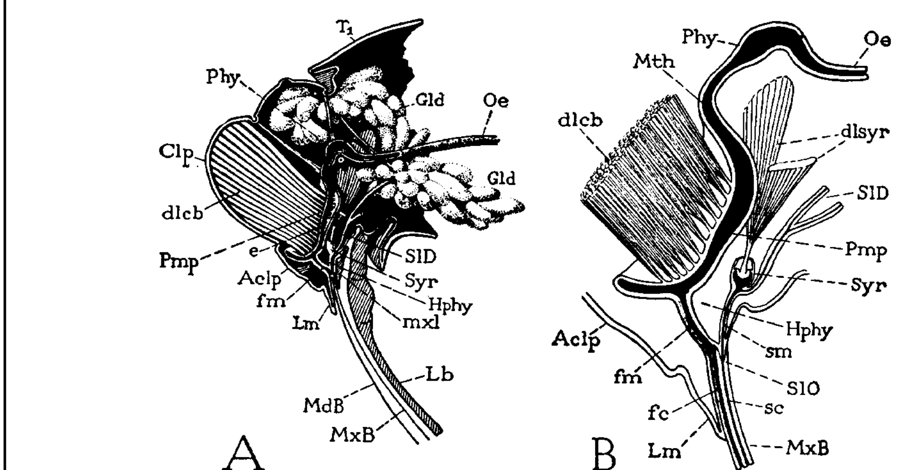


FIG. 179.—The sucking pump and salivary syringe of *Magicicada septendecim.* A, section of the head showing position of the sucking pump (cibarium) with dilator muscles arising on the clypeus. B, section through the mouth region, showing food meatus (*fm*), suck-pump (*Pmp*), and salivary syringe (*Syr*).

Figure 13.15 (Snodgrass, 1935)

11.

Observe the demonstrations of the butterfly head. The proboscis (Prb in Fig. 13.16) in the Lepidoptera is formed from the maxillae -- specifically the galeae. Each galea is a hollow, flexible tube containing muscles and tracheae (mcls and Tra in Fig. 13.17E) that forms a coiled proboscis beneath the head at rest (Prb in Fig. 13.17D). The left and right galeae fit together in a tongue-in-groove fashion and form, between their inner surfaces, a food channel (fc in Fig. 13.17E) through which nectar is drawn. Identify the galea (Prb in Fig. 13.16) and the labial palpus (LbPlp in Fig. 13.16) in lateral view. The galea is extended through hemolymph pressure, and is retracted through elastic recoil and internal muscles. As in cicadas, Lepidoptera have a greatly expanded cibarial pump (Pmp in Fig. 13.17F) powered by huge muscles, called dilators of the cibarium (labelled 1,2,3 in Fig. 13.17F). Identify the dilators of the cibarium in the sagittal section of the butterfly head.

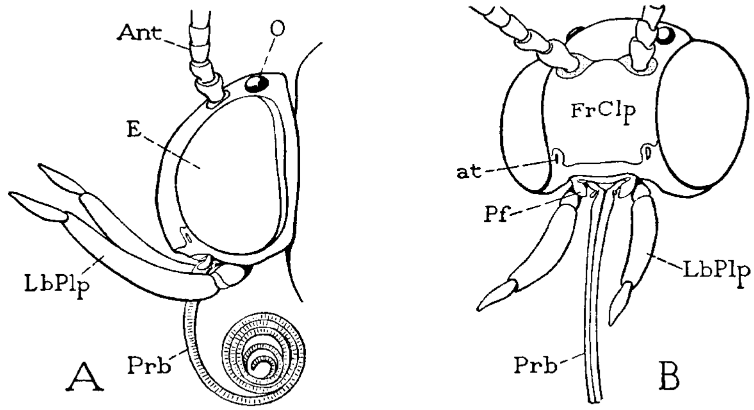


Fig. 168.—Head of peach-tree borer moth, *Synanthedon exitiosa*.

Figure 13.16 (Snodgrass, 1935)

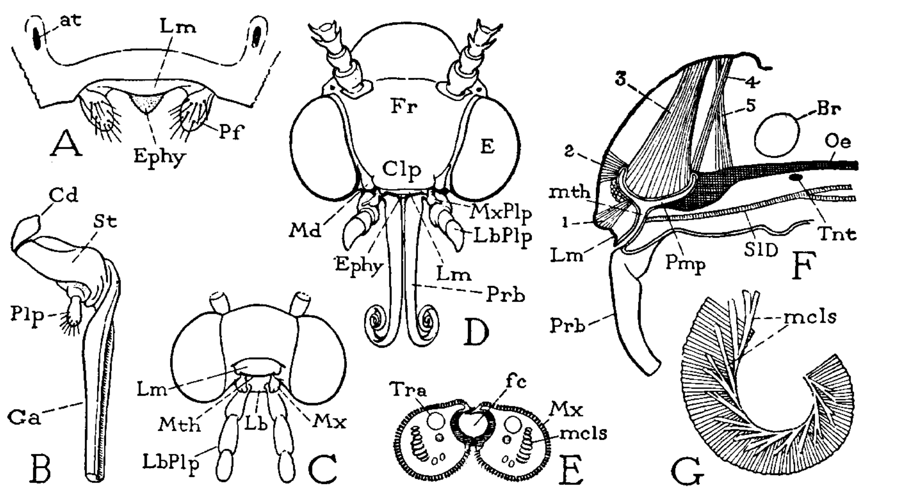


Fig. 169.—Mouth parts and sucking apparatus of adult Lepidoptera. A, *Synanthedon exitiosa*, labrum, epipharynx, and pilifers. B, same, base of maxilla. C, *Malacosoma americana*, showing rudimentary maxillae. D, *Hyphantria cunea*, head and proboscis. E, cross section of proboscis of *Danais archippus*. (*From Burgess*, 1880.) F, section of head of sphinx moth, showing sucking pump, diagrammatic. G, diagram of part of proboscis and its muscles.

Figure 13.17 (Snodgrass, 1935)

Observe a live butterfly and its method of extending its proboscis to feed on honey-water.

12.

Obtain a specimen of a muscoid fly (Diptera: Muscomorpha). The mouthparts of higher Diptera are modified to form a proboscis that is typically a sponging or lapping organ. The mandibles are absent in both sexes, and the only identifiable remnants of the maxillae are the prominant palpi (MxPlp). The proboscis is a composite structure apparently containing parts of the labrum, hypopharynx, and labium, as well as the clypeus. Note that the proboscis is jointed in two places, subdividing it into a basal rostrum (Rst in Fig 13.18), central haustellum (Hstl in Fig. 13.18), and distal lobes, or labella (La in Fig. 13.18). The proboscis may be retracted into a ventral fossa of the head. Extend the proboscis and identify the following parts.

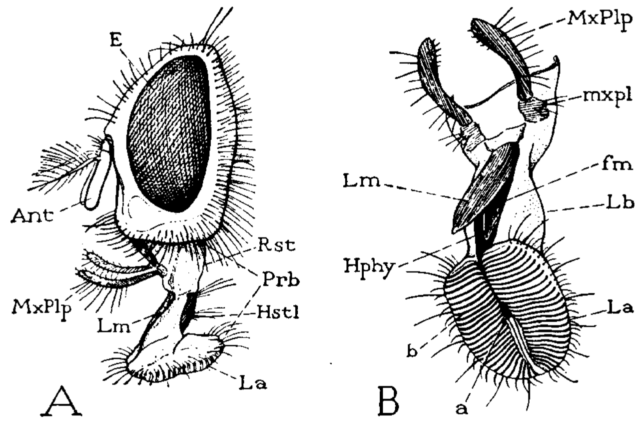


FIG. 173.—Head and proboscis of the house fly, *Musca domestica*. A, lateral view of head with proboscis extended. B, anterodistal view of extended proboscis, showing ventral surfaces of labella with aperture (*a*) leading into food meatus (*fm*) between labrum and hypopharynx.

Figure 13.18 (Snodgrass, 1935)

13.

Obtain 3 heads of "your" insect and examine the external morphology. Identify the principal areas and sutures of the head, including the following:

occipital foramen
occipital sulcus
subgenal sulcus
coronal suture*
ant. and post. tentorial pits
postoccipital suture
epistomal suture
frontal suture*

***Actually, an ecdysial cleavage line**

Examine the mouthparts and identify as many parts as possible without removing them.

Cut 1 head parasagitally into 2 parts, just to the left of the midline. Cut the top of the second head off above the level of the tentorial pits. Boil all parts in KOH. Rinse in distilled water when clear. The heads may be stained in chlorazol black E if desired.

Examine the internal view of the heads, especially the tentorium. Locate the following if present:

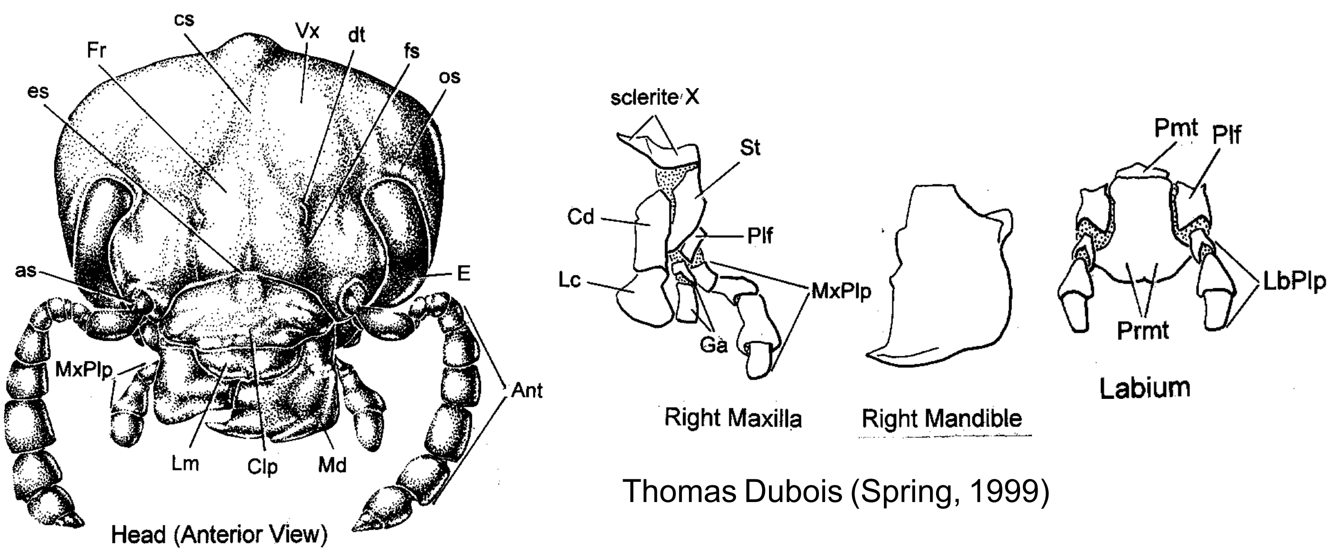
anterior arms - tentorium
posterior arms - tentorium
dorsal arms - tentorium
mandibular apodemes
hypopharyngeal suspensoria
postoccipital ridge
occipital foramen
pharnyx of foregut
tentorial bridge

Cut another head parasagitally into 2 parts, without treating with KOH, and examine the muscles inside the head. Note especially the muscles that move the mandibles and the antennae and those that originate on the tentorium, or in sucking insects, those that originate on the clypeus and frons.

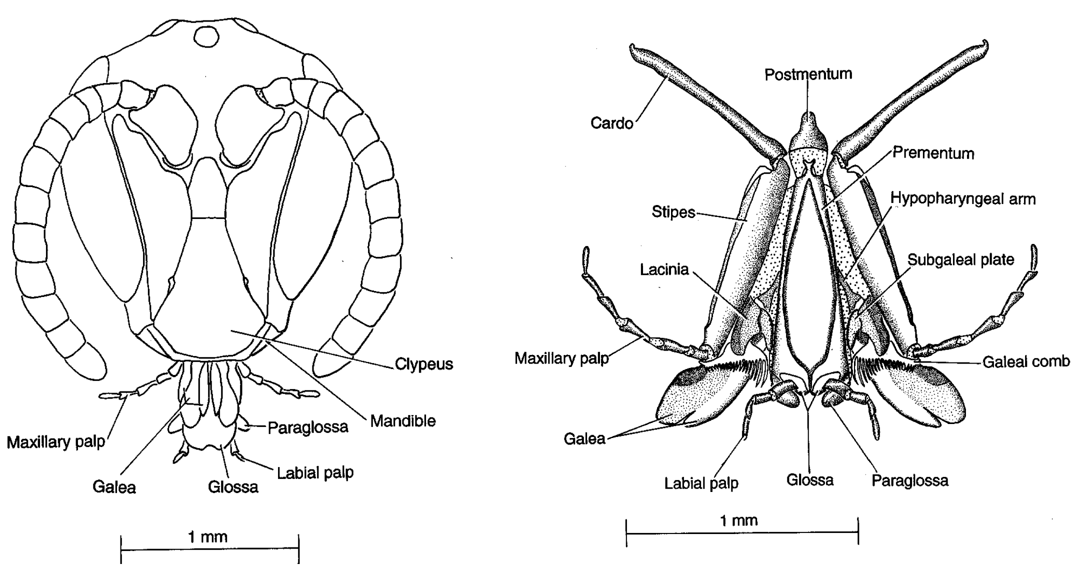
Remove the mouthparts from the cleared specimen whose head top was cut off above, if necessary to identify the mouthpart components. A second set of mouthparts should be examined on an uncleared specimen and removed if necessary. Identify all major parts.

Sketch #4: External structure of the head and mouthparts

Sketch the external structure of the head and mouthparts of your insect, either from anterior, posterior, or lateral view. If in lateral view, position the head facing to the left, as is the convention in most morphological drawings. Mouthparts should be drawn separately in non-sucking insects (Paleoptera, Orthopteroids, Coleoptera, etc.) and need not be shaded (i.e., do line drawings only). For the head capsule, use shading to indicate 3-dimensional structure.



Thomas Dubois (Spring, 1999)



Karl Magnacca (Spring, 1999)