Insect Morphology

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• Thorax & Abdomen (part 1)
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• Cockroach dissection

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Department of Biological Sciences
University of Alberta, Edmonton, Alberta, Canada
Insects are strongly cephalized animals, that is, many of the important functions are vested anteriorly with a high degree of pupiposition. The concentrating of segments, sensory structures and neural ganglia. The mouthparts, for producing segmental appendages to the insect head can be found in the mouthpart module. Six or ten segments are conserved to form the head segments. This strong structure provides protection for the brain, support for eyes, ears, antenna and mouthparts. The strong support in the head is seen the mandibles in drawing insects and the sucking pump in getting backing liquids.

The head exoskeleton is a common feature of arthropods, is particularly well illustrated in the head. These normal cuticular supports are also well represented by the cross-bracing tentorium.

The compound eyes are often the most prominent features of the insect head. Insects and arachnids have thousands of more or less equivalent sensory cartridges called ommatidia. Each ommatidium has a hexagonal lens (hundreds, in this picture) and six to eight light-sensitive cells. Single homologous sensory cells from numerous adjacent ommatidia respond to light in their limited field of view and send the information to the same place in the optic lobe of the brain. The image formed in the insect brain is not as detailed as ours but is very rapidly and perceptively sensitive to movement in the visual field.

The insect head can be seen as a single head capsule that is often overlooked - the head capsule. This cleared whole mount reveals another aspect of the head that is often overlooked - the head capsule. The brain contains more than the brain, of course. There are many muscles that operate the various appendages - the mouthparts muscles being particularly complex. The tentorium is the “internal skeleton” which gives strength to the head capsule and provides a place for muscle attachment. It is formed by tube-shaped invaginations of the exoskeleton. The mandibles, maxillary and labial palpi are all visible in this frontal view.

The three most prominent arrangements of the head have been given the names Prognathous, Hypognathous and Opisthognathous.

Hypognathous

The most basic form of the insect head. The suboesophageal ganglion (SOG) is the main mass of nervous tissue. There are dorsal and lateral views respectively. The neurons to nerve connections called the neuropil.

Prognathous

The suboesophageal ganglion (SOG) of all insects serves the major mouthparts and it’s therefore much involved with feeding. It is a typical ganglion (functional concentration of nerve cells) composed of a peripheral region of cell bodies (nerve and glial cells - red) and a region of nerve to nerve connections called the neuropil.

Heads of Insect

The head is a very complex module. The eye is often prominent and the mouthparts are often strong. The evolutionary flexibility of the four mouthpart segmental appendages at the base of the head is often overlooked. The predators in this collage of photos are probably obvious.

Cockroach Brain - dorsal aspect

Drawing of dissected cockroach head showing brain and related nerves. Frontal and hypocerebral ganglia are part of the stomatogastric nervous system, while the corpora cardiaca and corpora allata are part of the hormonal system.

The largest structure in the head-neck region is the brain and suboesophageal ganglion complex. The exoskeleton passes between these two major masses of nervous tissue. These are dorsal and lateral views respectively. The neurons to nerve connections called the neuropil.

HEAD OF INSECT

This section through a compound eye shows some of the features. The lens layer is in red, the retinula layer in blue, and the last two layers of the optic lobe in black and white. The thin layer contains the sensory cells, each retinula cell consists of a retinula layer just under the lens layer contains pigments that help reduce light scattering during the day.

This is a dark adapted eye so the pigments are all at one end. This increases light scattering but it increases sensitivity.

In cockroaches, the head is a somewhat less complex than insects and the sucking pump in getting backing liquids. The strong structure provides protection for the brain, support for eyes, ears, antenna and mouthparts. The strong support in the head is seen the mandibles in drawing insects and the sucking pump in getting backing liquids.

Gallery - See more photos.

The greatest explorers in the insect world were the early entomologists. Insects can be exquisitely sensitive to movement in the visual field. The compound eyes are often the most prominent structures on the insect head. The visual system of an insect is often overlooked - the insect head. The eyes are often used to illustrate the eyes of an insect. The eye is often prominent and the mouthparts are often strong. The evolutionary flexibility of the four mouthpart segmental appendages at the base of the head is often overlooked. The predators in this collage of photos are probably obvious.
Insects owe their great success to their abilities to adapt to a wide variety of habitats. Adaptations have occurred, indeed continue to occur, at every level of organization from the molecular to the ecological. The comparative study of insect mouthparts is first and foremost a study of adaptation. We single out mouthparts and the gross morphological adaptations of organization in introductory courses because the variety of adaptations is so great that we can address vast fundaments of insect evolution by looking at mouthparts alone. Also, they are relatively easy to see and appreciate, and perhaps most important, the mouthparts are anath to insect trophic behavior (food gathering).

The American cockroach (Periplaneta americana) has generalized mouthparts. The insect is omnivorous and its mouthparts are well suited to drawing on a wide variety of foods.

The mouthparts are well developed in cockroaches. Each mouthpart comprises two to three appendages of their segment.

The mouthpart-bearing segments are the labrum, mandibular, maxillary and labial. Two of the segments (mes and lab) have sensory palp as well as other functional parts.

The mouthpart-bearing segments are the labrum, mandibular, maxillary, and labial. The labrum is used for nectar feeding but is greatly modified from the basic plan. The other parts are shown in the photo. All are dark indicating hardened cuticle. These structures are used to manipulate food.

By contrast, the tips of the palp in both appendages are covered with membranous cuticle and, as we will see later, with many sensory palps.

This frontal view of a cockroach head gives a better idea of what the mouthparts look like in situ. The tentorium is also visible (see module on head in this series).

This detailed view of a cockroach mandible clearly shows the scientists that make up this complex mouthpart. The denticles the heaver the sensory and usually the heavier the sclerotization. Thus, the heaviest cuticle is membranous-like and semi-transparent while the darkest cuticle is hard. The blue arrow shows where the maxilla attaches to the head.

This is our review of basic insect mouthparts as found in the American cockroach (Periplaneta americana). Make sure that you understand this basic plan before proceeding.

The rest of this module on mouthparts shows how various insect groups have used the basic mandibulate ground plan to produce highly modified mouthparts adapted to their own way of obtaining food.

REVIEW
Can you recognize the following?

- antennae
- clypeus
- eye
- labial palp
- labrum
- maxillary palp

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Mosquitoes have carried the business of piercing and sucking to a fine art. The stylets are modified labrum, maxillae, hypopharynx and mandibles, just as in horse flies and black flies, but the cross section size is markedly reduced making for a much stealthier approach to feeding.

MAXILLARY PALP

Dipteran mouthpart modifications

Black flies (Simuliidae) are small insects but their mouthparts are relatively large. All of the parts are present in adults but they are greatly modified in females where they are used for piercing and sucking blood. The labrum is used for nectar feeding but the labial, maxillary, and mandibles are modified as piercing structures for blood feeding. The relatively large wound and the anticoagulant properties of the salivary proteins lead to ugly skin reactions.

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Only female mosquitoes take blood. Males do not possess the necessary muscles. The mosquito shows how all muscles in the labium are used for blood feeding. Both sexes suck nectar, and possess the large labellum.

Horse flies (Tabanidae) have the same kinds of mouthpart modifications as black flies but since they are larger, are easier for us to study. Their bite also causes more physical damage. All of the basic parts can be seen here and don’t resemble the mouthparts of the cockroach. Nevertheless these are the appendages of the same segments – the result of the same basic developmental plan.
This SEM (Scanning Electron Microscope) micrograph of a flesh fly labellum shows the sensory hairs that cover the surface of the oral surface of the lobes. These sensory hairs taste sugars, salts, amino acids, water and other chemicals as well as containing a delicate sense of touch on the whole organ.

These two examples of taste hairs were taken from leaf beetle galea. The pore in the tip is where the leaf juice enters in order to be tasted. The sensillum with the little fingers in the right hand picture does not have much of a pore and is probably used to sense temperature and humidity.

Inside the large taste hairs we find the sensory cells, as this electron microscope cross section through the base of the larger sensillum at top right shows. The four numbered cells are chemosensory while the one marked with a yellow arrowhead is mechanosensory. Most taste hairs in insects can also sense movement.

The real thing looks different from the previous drawing of course. For one thing, moths and butterflies are covered with scales (modified cuticular hairs), as seen in this cleared lepidopteran head. The large labial palpi are sensory. In fact, in some specialized nocturnal moths the organs of hearing are also on the palpi. The galeae are separated in this preparation. During feeding, they are held close together to form a sucking tube.

Hymenopteran mouthpart modifications

The sawflies, bees and wasps have various arrangements of mouthparts, the most complex being those of bees (photo at right). Like lepidopterans, bees use a tube to suck nectar but they are modified gloseae (part of the labium). Mandibles are retained primarily for handling wax - in fact, the structure of the mandibles gives rise to the precise hexagonal arrangement of the cells in the honeycomb.

Hemipteran mouthpart modifications

Insects with incomplete metamorphosis also use highly modified mouthparts as shown in the true bugs and their relatives. These are used for piercing and sucking and are similar in some ways to the modifications seen in mosquitoes. The large distal muscles of the sucking pump are the largest muscles in the bug head.

This series of increasing magnifications are taken from the inside of the labrum (epipharynx) of a leaf beetle. The epipharynx forms the anterior surface of the buccal cavity (roof of the mouth so to speak) and it also bears taste-sensitive structures. These sensilla are not hair-like but take the shape of short pegs-in-pits. They too have pores.

The most obvious of the mouthpart sensory structures are the palpi (maxillary and labial). In leaf beetles, the palp tips provide four surfaces that are covered with small sensory pegs - some for taste and some for smell.

Lepidopteran mouthpart modifications

In moths and butterflies the sucking mouthpart is largely the modified maxillary galeae. The area along the food canal is lined with taste papillae. The maxillary palpi are much reduced and mandibles are absent.

This concludes our survey of mouthpart modifications. In several places we mentioned that sensory structures were present on certain mouthparts, such as palp tips. In fact, one of the greatest concentrations of chemosensilla is found on the mouthparts - the other major site being the antennae.

In the next section, we look in detail at some sensory structures and comment briefly on their function. The study of sense organs has major implications for pheromone biology, insect-plant interactions and the chemical modification of feeding by the use of antifeedants.

Digging through plant material, the sawflies, bees and wasps have various arrangements of mouthparts, the most complex being those of bees (photo at right). Like lepidopterans, bees use a tube to suck nectar but they are modified gloseae (part of the labium). Mandibles are retained primarily for handling wax - in fact, the structure of the mandibles gives rise to the precise hexagonal arrangement of the cells in the honeycomb.

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The Insect Thorax and Abdomen

In the simplest terms, the thorax is the locomotory centre of the insect since all its legs and the wings are found there. The largest muscles are also found in the thorax. The thorax is a box-like structure with extensive internal cuticular cross-bracing. It also has numerous cuticular plates (sclerites) that are intimately involved in locomotion. In comparative terms, the brain of the insect is small, in both absolute and relative terms, in the insect thorax. This is true for most insects, including cockroaches for which the thorax is considered to be the most important muscle. This is the area where the insect locomotor muscles are located. The thorax consists of three segments: the prothorax, mesothorax and metathorax. Each segment has a pair of legs and a pair of wings. The thorax is connected to the abdomen by the thoracoabdominal joint. The thorax is also connected to the head by the neck. The thorax is the site of the insect's major sensory organs, including the eyes, antennae, and cerci.

The Wing Base

The wing must move with great dexterity if the insect is to fly properly. The annulus sclerite (red arrow) provides a major part of this complex attachment and the muscles that insert on it are responsible for small but crucial movements of the wing in flight. The coxal-subalar system is also involved in wing folding.

Ventral View of Periplaneta Thorax

1. neck region
2. prothoracic sternum
3. mesothoracic sternum
4. tectum
5. membranous cuticle
6. part of cuticular cross-bracing
7. flight muscle
8. haemocoe with
9. leg muscle
10. ventral nerve cord
11. coxa
12. trochanter muscle
13. basalar muscle (wing pronation)
14. subalar muscle to alary sclerites
15. subalar muscles to alary sclerites
16. subalar muscle (wing suspension)

Most insects have four wings which either beat quite independently as in dragonflies or with varying degrees of unity. The front and hind wings of moths are strongly linked together and the hind wing has a strong structure called the tectum (red arrow) that is part of the winging apparatus. It has a process on the front wing called a supracilia (in the moth in any case).

Grasshoppers are much stronger than cockroaches and this is clearly reflected in the structure of the thorax. Nails the greater part of cuticular plates (sclerites) to form a strong phonotactic flag to support flight.

Meso- and Metathoracic Segments of Periplaneta - ventral view

1. mesosternum
2. metasternum
3. metathoracic trochanter
4. metasternum
5. segmentum

As with most insects, the cockroach abdomen is composed of a series of similar segments until the terminal end where sex complications thin out. The male and female cockroach abdominal tips shown here reveal some obvious differences.

The Odonata the male actually grabs the female by the prothorax (damsel fly) or top of the head (dragonfly) during mating. As they fly or perch, the female reaches around with her abdomen and takes sperm from a specialized holding pouch near the junction of the male thorax and abdomen. These are deformed.
In these views of actual specimens you can identify some of the cuticular parts shown in the drawing of the generalized female abdomen. This specimen is a leafhopper.

Parasitic wasps take the business of ovipositor modification to an extreme but all of the basic parts are there. 50% of all wasps are parasitic on other insects and need to lay their eggs with great precision since many are quite host specific.

Flies, such as this housefly, have a different version of the ovipositor. The last few abdominal segments telescope into the larger anterior abdominal segments except when the fly is laying eggs. Then these segments are extended as shown here.

Many aquatic insects use special adaptations of the last abdominal segments for orienting in the stream or for breathing. Notice how this mayfly nymph uses its caudal filaments for orientation.

Requirements of internal organs also influence the shape of the abdomen. The midgut of this mosquito is so full of blood that the abdomen is swollen to near maximum size (cuticle does not stretch). A large egg load can also swell the abdomen like this.

This drawing shows, in generalized form, the way female abdominal segments 8, 9 and 10 are modified for egg laying. Along with mating, egg laying requires extensive modification of sclerites.

Male and female abdomens are also variously modified, mostly for, in the case of the male, holding the female in position during copulation and in the female accepting the male during copulation and also for oviposition (egg laying).

The entire abdomen can also serve important functions in arthropods. The tail flick that is part of the escape response of the crayfish is perhaps the best known (it’s part of the reason that lobster tails are such good eating). Here is another use of the whole abdomen displayed by black fly larvae. They twist their abdomen 180 degrees so that their feeding fans can be properly oriented in the mainstream water flow.

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This is a section of bending cuticle. As you can see, it is not exactly like the previous drawing. Not all cuticle looks alike. Some is very thick, others thin. Some cuticle has well developed mesocuticle, as shown here. The blue endocuticle is elastic, so this cuticle is highly bendable.

As the functional skeleton of arthropods, the cuticle is the primary place for muscle attachment. This section shows how intimate is the connection between muscle and cuticle. Muscle extensions called tonofibrillae make the actual link. As molting, these connections must remain functional until the last moment when new connections are established with the new cuticle developing beneath the old.

The spectacular picture of a wing base of a moth, shows a top view of bending cuticle. The yellow ovals are the cones of mesocuticle protruding down into the blue endocuticle, so this particular sclerite is very flexible. The large areas of yellow cuticle are exocuticle and are relatively hard.

In bees, the ovipositor function is subsumed by the sting which is served by a poison gland. Oviposition is through a simple opening.
Cockroach Dissection

While it is impossible to choose an insect species that truly represents the morphology of all, the cockroach has gained a commanding position as the insect of choice for illustrating the 'basic' insect body plan. Another strong contender for this role is the grasshopper. Even terms like 'the cockroach' and 'the grasshopper' are terribly misleading, since there are many species of each with sometimes marked differences in various structures. Nevertheless, cockroaches and grasshoppers are good representatives of insects with chewing mandibles and lacking extreme morphological specializations of the major body parts.

Here we address the major external and internal parts of the American cockroach, Periplaneta americana. Some of the terms will be new but many will be strikingly familiar for they are named after their, sometimes very approximate, counterparts in vertebrates.