Insect Morphology

All arthropods possess:

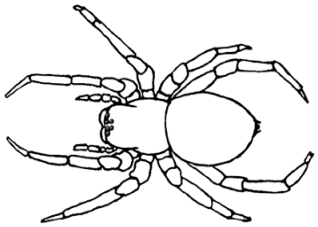
- Exoskeleton - a hard protective covering around the outside of the body (divided by sutures into plates called sclerites)
- Segmented body
- Jointed limbs and jointed mouthparts - that allow extensive specialization
- Bilateral symmetry - whereby a central line can divide the body into two identical halves, left and right
- Ventral nerve cord - as opposed to a vertebrate nerve cord which is dorsal
- Dorsal blood pump

Five important extant classes of Arthropods are arachnids, chilopods, diplopods, crustaceans, and hexapods.

Class Arachnida (arachnids): spiders, scorpions, ticks, mites, etc.

Arachnids possess:

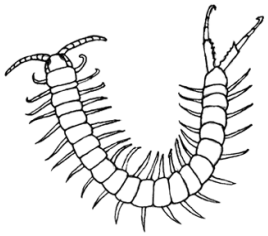
- 2 body segments - cephalothorax and abdomen
- 8 legs
- 1 pair of chelicerae
- no antennae



Class Chilopoda (centipedes)

Chilopods possess:

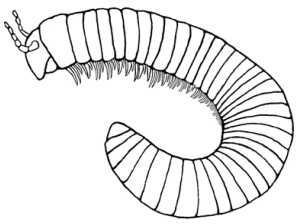
- many body segments
- 1 pair of legs per body segment
- 1 pair of antennae
- 1st pair of legs modified into venomous fangs



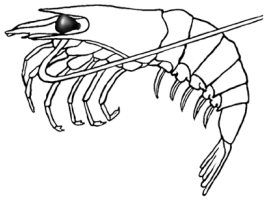
Class Diplopoda (millipedes)

Diplopods possess:

- Many body segments
- 2 pair of legs per body segment
- 1 pair of antennae



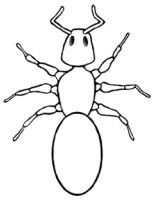
Class Crustacea (crustaceans): Crabs, shrimp, barnacles, sowbugs, etc.



Crustaceans possess:

- Several body segments - head, thorax and abdomen
- Segments may be fused
- Varied number of legs
- 2 pairs of antennae

Class Insecta (Insects); beetles, bugs, wasps, moths, flies, etc.



Insects possess:

- 3 body segments
- 6 legs
- 1 pair of antennae
- Diverse modifications to appendages

Basic Insect Morphology: Head, Thorax, & Abdomen

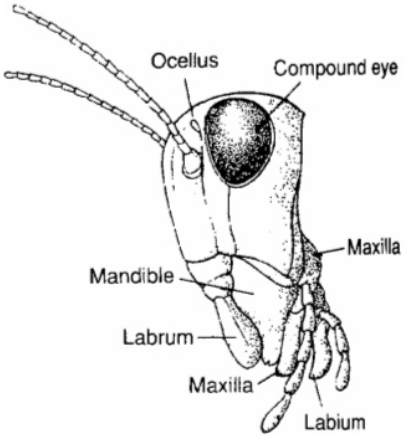
HEAD

The head of an insect is composed of mainly rigid sclerites or sclerotized segments. The insect head is a capsule that contains the compound eyes, simple eyes (ocelli), mouthparts, and antennae.

Compound eyes and ocelli

In most insects there is one pair of large, prominent compound eyes composed of units called ommatidia. There may be up to 30,000 ommatidia in a compound eye. This type of eye gives less resolution than the vertebrate eye, but it gives acute perception of movement. When present, ocelli (either 2 or 3), detect low light or small changes in light intensity.

Horse flies (order Diptera) have spectacular compound eyes.

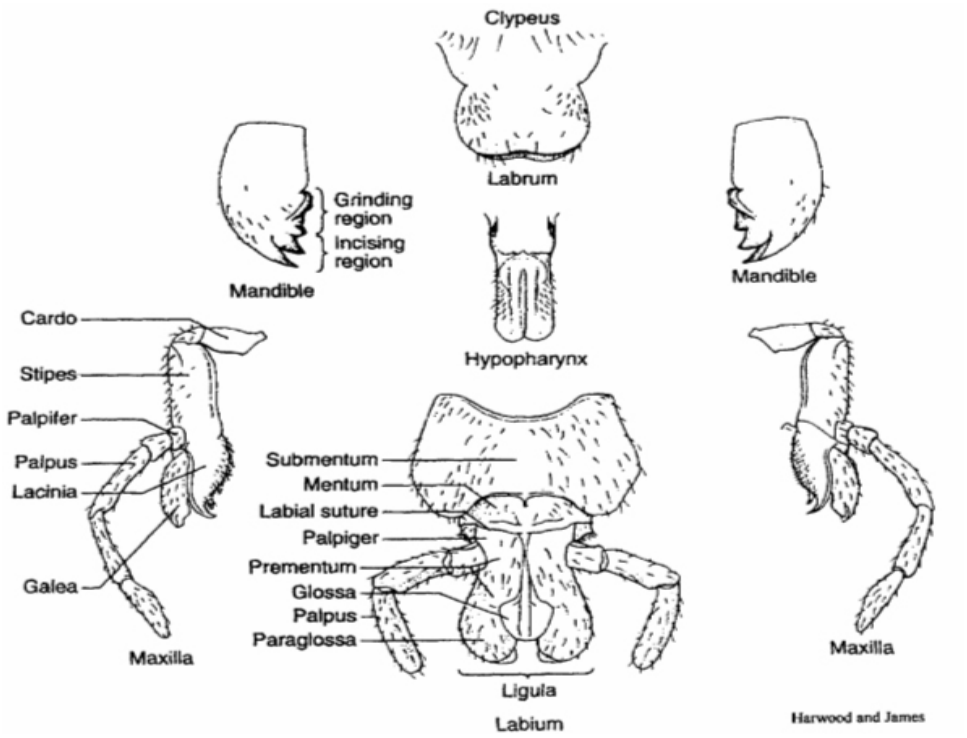


Insect mouthparts (source: University of Florida, https://entnemdept.ufl.edu).

Compound eyes and ocelli on halictid bee (order Hymenoptera) (photo: John Pascarella, Valdosta State University).

Mouthparts

The 4 main mouthparts are the **labrum, mandibles, maxillae (plural maxilla), and labium.** The labrum is a simple fused sclerite, often called the upper lip, and moves longitudinally. It is hinged to the clypeus. The mandibles, or jaws, are highly sclerotized paired structures that move at right angles to the body. They are used for biting, chewing, and severing food. The maxillae are paired structures that can move at right angles to the body and possess segmented palps. The labium (often called the lower lip) is a fused structure that moves longitudinally and possesses a pair of segmented palps. Mouthparts very greatly among insects of different orders but there are two main functional groups: mandibulate and haustellate. Shown above and below are mandibulate (chewing) mouthparts. Haustellate mouthparts can be further classified as piercing-sucking, sponging, and siphoning.



Insect mouthparts (source: University of Florida, https://entnemdept.ufl.edu).

Mandibulate (chewing) mouthparts are used for biting and grinding solid foods (see diagram above). Examples: Dragonflies and damselflies (order Odonata), termites (order Isoptera), adult lacewings (order Neuroptera), beetles (order Coleoptera), ants (order Hymenoptera), cockroaches (order Blattaria), grasshoppers, crickets, and katydids (order Orthoptera), caterpillars (order Lepidoptera). Adult Lepidoptera have siphoning mouthparts.

Order Coleoptera: Stag beetle (source: Jim Occi, BugPics, insectimages.org)

Order Hymenoptera: Carpenter ant, Camponotus sp. (source: Jim Kalisch, Dept. of Entomology, Univ. Nebraska-Lincoln).

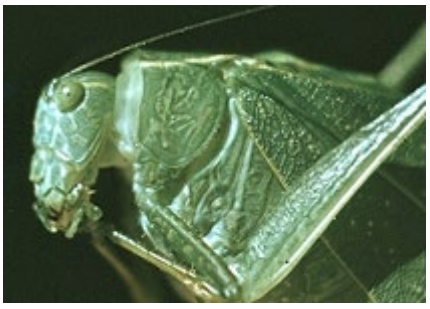
Order Blattaria: Newly molted American cockroach, Periplaneta americana (source: Daniel R. Suiter, University of Georgia, insectimages.org).

Order Neuroptera: Green lacewing adult, Chrysopa oculata (source: John Davidson, The Insects of Cedar Creek, cedarcreek.umn.edu).

Order Coleoptera: Scarab beetle grub (source: Ronald F. Billings, Texas Forest Service, insectimages.org).

Order Odonata: Damselfly eating mosquito (source: Richard Seaman, Nature Wallpaper).

Order Lepidoptera: Saturniid caterpillar, Hyalophora Columbia (source: Connecticut Ag. Experiment Station, insectimages.org).



Order Orthoptera: Katydid (source: Edward L. Manigault, Clemson University Donated Collection, insectimages.org).

Order Isoptera: Termite, Coptotermes formosanus (source: Gerald J. Lenhard, Louisiana State University, insectimages.org).

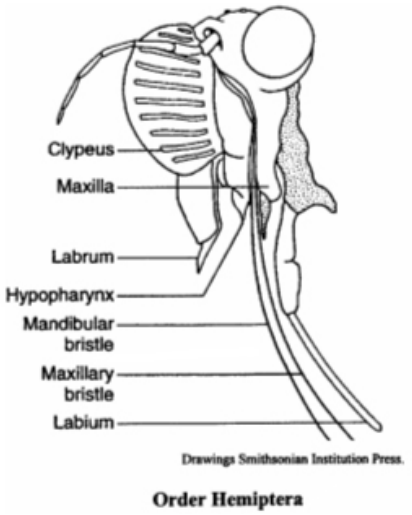
Haustellate mouthparts are primarily used for sucking liquids and can be broken down into two subgroups: those that possess stylets and those that do not.

Stylets are needle-like projections used to penetrate plant and animal tissue. The modified mandibles, maxilla, and hypopharynx form the stylets and the feeding tube. After piercing solid tissue, insects use the modified mouthparts to suck liquids from the host. To the left is a diagram of cicada mouthparts.

Some haustellate mouthparts lack stylets. Unable to pierce tissues, these insects must rely on easily accessible food sources such as nectar at the base of a flower. One example of nonstylate mouthparts are the long siphoning proboscis of butterflies and moths (Lepidoptera). Although the method of liquid transport differs from that of a Lepidopteran proboscis, the rasping-sucking rostrum of some flies are also considered to be haustellate without stylets.

Piercing-sucking mouthparts are used to penetrate solid tissue and then suck up liquid food.

Examples: Cicadas (see diagram), aphids, and other bugs (order Hemiptera), sucking lice (order Phthiraptera), stable flies and mosquitoes (order Diptera).



Haustellate mouthparts (source: University of Florida, https://entnemdept.ufl.edu).

Order Hemiptera: Wheel bug, Arilus cristatus, (source: Edward L. Manigault, Clemson Univ. Donated Collection, insectimages.org).

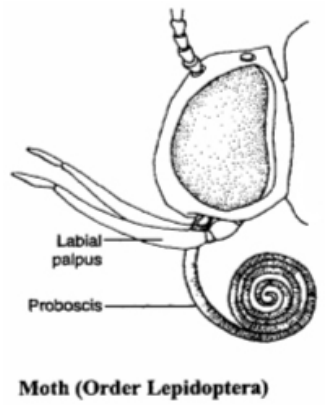
Order Hemiptera: Green peach aphid, Myzus persicae (source: Scott Bauer, USDA ARS, insectimages.org).

Order Diptera: Stable fly, Stomoxys calcitrans (source: North Dakota State University).

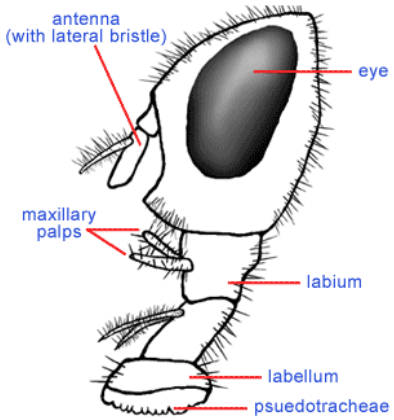
Order Hemiptera: Spined soldier bug, Podisus maculiventris, attacking a caterpillar (source: Russ Ottens, University of Georgia, insectimages.org).

Order Diptera: Mosquito feeding on a human (source: Jim Occi, BugPics, insectimages.org).

Siphoning mouthparts lack stylets and are used to suck liquids.
Examples: Butterflies, moths, and skippers (order Lepidoptera), bees (order Hymenoptera). Larval Lepidoptera have chewing mouthparts.**Sponging** mouthparts are used to sponge and suck liquids.
Examples: House flies and blow flies (order Diptera).



Siphoning mouthparts (source: University of Florida).



Sponging mouthparts (source: University of Sydney).

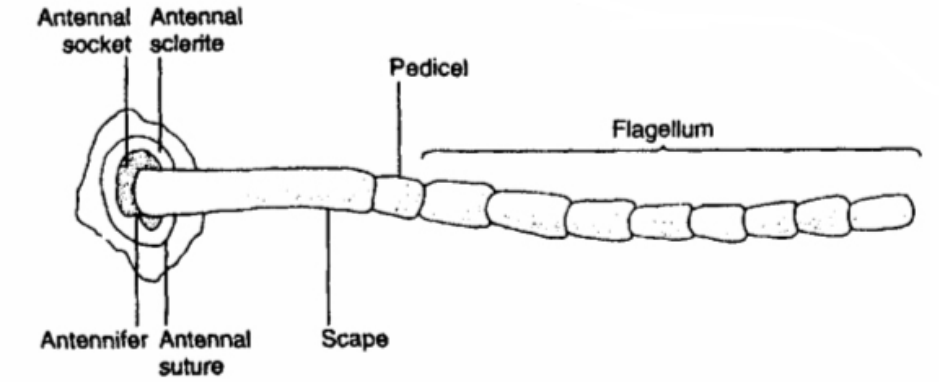
Order Diptera: House fly, Musca domestica (source: L. Clunie, Manaaki Whenua Landcare Research).

Order Diptera: Green bottle fly (blow fly), Phaenicia sericata (source: Joseph Berger, insectimages.org).

Order Diptera: Blue bottle fly (blow fly), Calliphora vomitoria (Stratford Landing Elementary School).

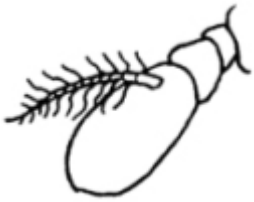
Antennae

Antennae function almost exclusively in sensory perception. Some of the information that can be detected by insect antennae includes: **motion and orientation, odor, sound, humidity, and a variety of chemical cues.** Antennae vary greatly among insects, but all follow a basic plan: segments 1 and 2 are termed the scape and pedicel, respectively. The remaining antennal segments (flagellomeres) are jointly called the flagellum.



Antennae anatomy (source: University of Florida).

Aristate antennae are pouch-like with a lateral bristle.
Examples: House and shore flies (order Diptera).



Aristate antenna (source: University of Sydney).

Order Diptera: House fly, Musca domestica (source: Clemson University - USDA Cooperative Extension Slide Series, insectimages.org).

Order Diptera: Shore fly, Typopsilopa sp. (source: The Insects of Cedar Creek, cedarcreek.umn.edu).

Capitate antennae are abruptly clubbed at the end.
Examples: Butterflies (order Lepidoptera).

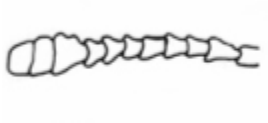
Capitate antenna (source: University of Sydney).

Order Lepidoptera: Painted lady butterfly (source: Vanessa virginiensis, Jerry A. Payne, USDA ARS, insectimages.org).

Order Lepidoptera: Red-banded hairstreak, Calycopis cecrops (source: Jerry A. Payne, USDA ARS, insectimages.org).

Order Lepidoptera: Speckled wood butterfly, Pararge aegeria (source: Peter Wirtz, insectimages.org).

Clavate antennae are gradually clubbed at the end.
Examples: Carrion beetles (order Coleoptera). Adult carrion beetles feed on decaying animal matter or maggots.

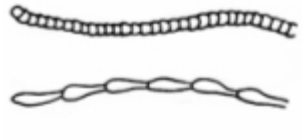


Clavate antenna (source: University of Sydney).

Order Coleoptera: Carrion beetle (source: James L. Castner, University of Florida).

Order Coleoptera: American carrion beetle, Necrophila americana (source: Susan Ellis, Bugwood.org).

Filiform antennae have a thread-like shape.
Examples: Ground and longhorned beetles (order Coleoptera), cockroaches (order Blattaria).



Filiform antennae (source: University of Sydney).

Order Coleoptera: Ground beetle (source: John A. Weidhass, Virginia Tech, insectimages.org).

Order Coleoptera: Asian longhorned beetle, Anoplophora glabripennis (source: Donald Duerr, USDA Forest Service, insectimages.org).

Order Blattaria: American cockroach, Periplaneta americana, Clemson University - USDA Cooperative Extension Slide Series, insectimages.org).

Geniculate antennae are hinged or bent like an elbow.
Examples: Bees and ants (order Hymenoptera).

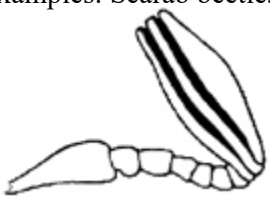
Geniculate antenna (source: University of Sydney).

Order Hymenoptera: Bumble bee, Bombus sp. (source: Russ Ottens, University of Georgia, insectimages.org).

Order Hymenoptera: Blueberry bee, Habropoda laboriosa (source: Jerry A. Payne, USDA ARS, insectimages.org).

Order Hymenoptera: Carpenter ant, Camponotus sp. (source: Jim Kalisch, Dept. Entomology, Univ. Nebraska-Lincoln).

Lamellate or clubbed antennae end in nested plates.
Examples: Scarab beetles (order Coleoptera).



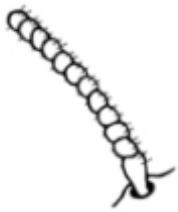
Lamellate antenna (source: NC State University).

Order Coleoptera: Japanese beetle, Popillia japonica (source: Clemson University - USDA Cooperative Extension Slide Series, insectimages.org).

Order Coleoptera: Conifer scarab, Polyphylla occidentalis (source: Gerald J. Lenhard, Louisiana State University, insectimages.org).

Order Coleoptera: Rose chafer, Macrodactylus subspinosus (source: Clemson Univ. - USDA Coop. Ext. Slide Series, insectimages.org).

Moniliform have a beadlike shape.
Examples: Termites (order Isoptera).



Moniliform antenna (source: University of Sydney).

Order Isoptera: Termite, Coptotermes formosanus (source: Gerald J. Lenhard, Louisiana State University, insectimages.org).

Order Isoptera: Termite, Reticulitermes sp. (source: USDA Forest Service - Wood Products Insect Lab Archives, insectimages.org).

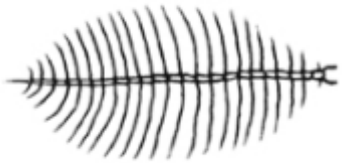
Pectinate antennae have a comb-like shape.
Examples: Fire-colored beetles and fireflies (order Coleoptera).

Pectinate antenna (source: University of Sydney).

Order Coleoptera: Fire-colored beetle, Neopyrochroa flabellata (source: The Insects of Cedar Creek, cedarcreek.umn.edu).

Order Coleoptera: Firefly (source: Thailand's Amazing Insects, Beetles from Thailand, thaibugs.com).

Plumose antennae have a feather-like shape.
Examples: Moths (order Lepidoptera) and mosquitoes (order Diptera).



Plumose antenna (source: University of Sydney).

Order Lepidoptera: Luna moth, Actius luna (source: Gerald J. Lenhard, Louisiana State Univ., insectimages.org).

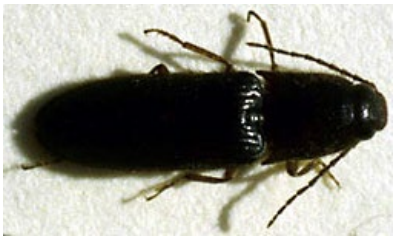
Order Lepidoptera: Cecropia moth male, Hyalophora cecropia, (source: David Keith, Dept. Entomology, Univ. Nebraska-Lincoln).

Order Diptera: Mosquito male, Culex sp. (source: Nikon Digital Eclipse Image Gallery, microscopyu.com).

Serrate antennae have a saw-toothed shape.
Examples: Click beetles (order Coleoptera).

Serrate antenna (source: University of Sydney).

Figure 1Order Coleoptera: Click beetle, Agriotes bicolor (source: Roger S. Key, English Nature, insectimages.org).



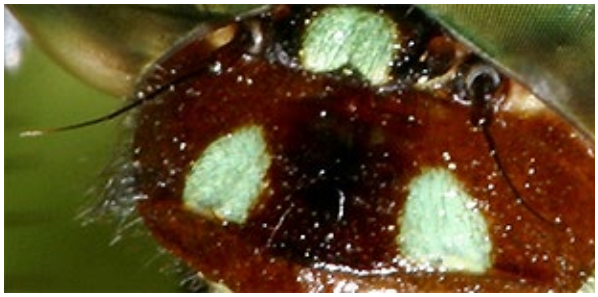
Order Coleoptera: Click beetle (source: Steve L. Brown, University of Georgia, insectimages.org).

Setaceous antennae have a bristle-like shape.
Examples: Dragonflies and damselflies (order Odonata).

Setaceous antenna (source: University of Sydney).

Order Odonata: Damselfly (source: Richard Seaman, Nature Wallpaper, richard-seaman.com).

Order Odonata: Swamp darner (source: Richard Seaman, Nature Wallpaper, richard-seaman.com).

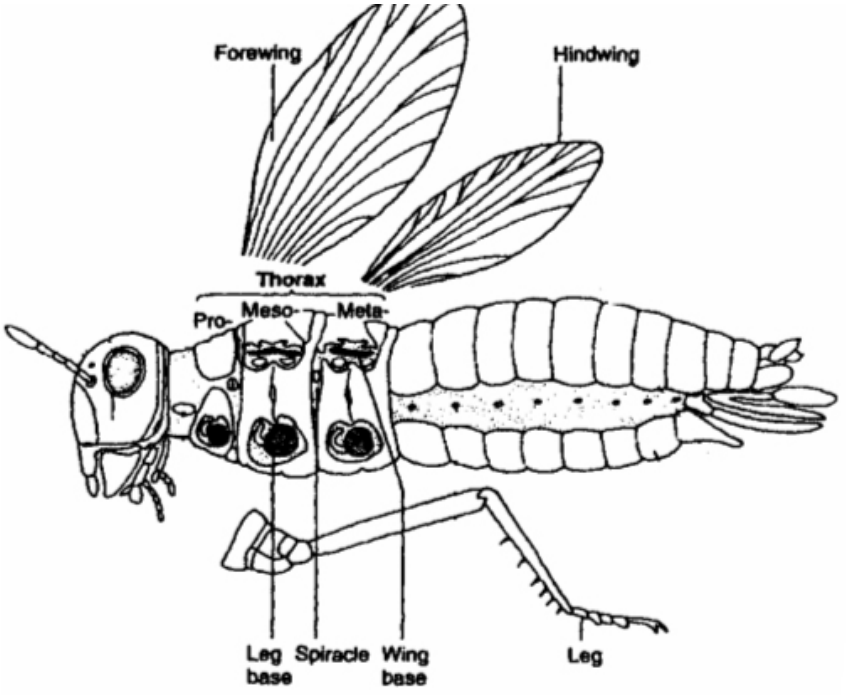


Order Odonata: Close-up of antennae (source: Richard Seaman, Nature Wallpaper, richard-seaman.com).

THORAX

The insect thorax is divided into three parts: the prothorax (pro=first), mesothorax (meso=middle), and metathorax (meta=last). Each segment consists of hardened plates, or sclerites. Dorsal sclerites are called nota (singular notum), lateral sclerites are called pleura (singular pleuron), and ventral sclerites are called sterna (singular sternum). The first segement of the prothorax is the pronotum.

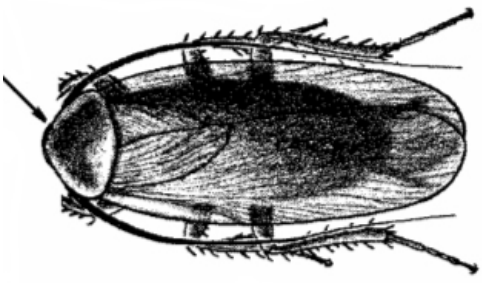
Each of the three thoracic segments contains one pair of legs. Wings are found only on the meso- and metathoracic segments.



Insect anatomy (source: University of Florida).

Pronotum

The pronotum is the dorsal sclerite of the prothorax, which can be highly modified in various orders such as the Hemiptera, Blattaria, and Coleoptera.



Order Blattodea: cockroach (source: University of Florida).

Treehoppers (order Hemiptera) have some of the most bizarre pronotums of all insects.

Cyphonia sp. (source: Membracidae of South America, http://www.ne.jp/asahi/rhyncha/index).

Alchisme sp. (source: Membracidae of South America, http://www.ne.jp/asahi/rhyncha/index).

Bocydium sp. (source: Membracidae of South America, http://www.ne.jp/asahi/rhyncha/index).

Spongophorus ballista (source: Membracidae of South America, http://www.ne.jp/asahi/rhyncha/index).

Spongophorus sp. (source: Membracidae of South America, http://www.ne.jp/asahi/rhyncha/index).

Scarab beetles (order Coleoptera) and other beetles may also have unusual pronotums. In addition, the specimens shown here also have bizarre modifications of the head capsule. Male beetles use horns to fight with other males over females and territory.

Hercules beetle, Dynastes granti (source: Oldrich Jahn, InsectNet.com)

Chalcosoma caucasus, male (source: Oldrich Jahn, Page of the Breeder of Beetles, https://beetlegate.hyperlink.cz/index.htm).

Dung beetle, male (source: Oldrich Jahn, Page of the Breeder of Beetles, https://beetlegate.hyperlink.cz/index.htm).

Cockroaches (order Blattaria) have pronotums that extend forward over the head.

Madagascar hissing cockroach, Gromphadorhina portentosa (source: Flikr.com).

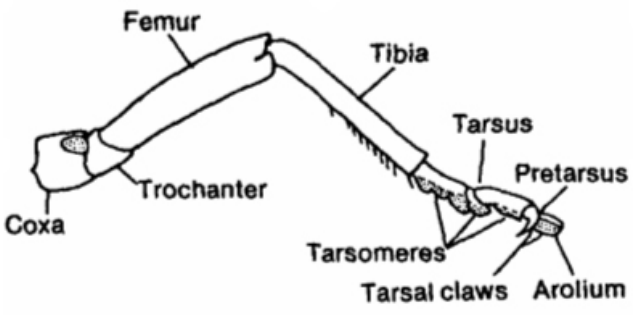
German cockroach (source: Flikr.com).

Orange-headed cockroach, Eublaberus prosticus (source: E. Tenczar).

Legs

The **forelegs** are located on the prothorax, the **mid-legs** on the mesothorax, and **the hind legs** on the metathorax. Each leg has six major components, listed here from proximal to distal: **coxa** (plural coxae), **trochanter**, **femur** (plural femora), **tibia** (plural tibiae), **tarsus** (plural tarsi), **pretarsus**.

The femur and tibia may be modified with spines. The tarsus appears to be divided into one to five "pseudosegments" called **tarsomeres**. Like the mouthparts and antennae, insect legs are highly modified for different functions, depending on the environment and lifestyle of an insect.



Insect leg (source: University of Florida).

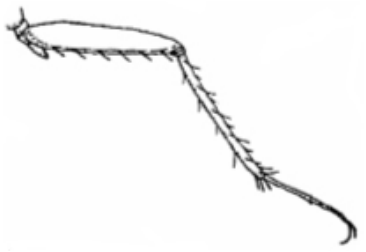
Ambulatory legs are used for walking. The structure is similar to cursorial (running) legs.
Examples: True Bugs (order Hemiptera), and leaf beetles beetles (Coleoptera).

Order Hemiptera: Boxelder bug, Boisea trivittata (source: Clemson University - USDA Cooperative Extension Slide Series, www.insectimages.org).

Order Hemiptera: Tarnished plant bug, Lygus lineolaris (source: Scott Bauer, USDA ARS, www.insectimages.org).

Order Coleoptera: Cottonwood leaf beetle, Chrysomela scripta (source: Lacy L. Hyche, Auburn University, www.insectimages.org).

Cursorial legs are modified for running. Note the long, thin leg segments.
Examples: Cockroaches (order Blattaria), ground and tiger beetles (order Coleoptera).



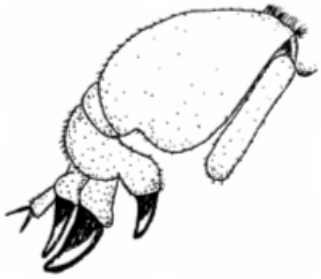
Cursorial leg (source: University of Florida).

Order Blattaria: Oriental cockroach, Blatta orientalis (source: Clemson University - USDA Cooperative Extension Slide Series, insectimages.org).

Order Coleoptera: Ground beetle (source: John A. Weidhass, Virginia Tech, insectimages.org).

Order Coleoptera: Bronze tiger beetle (source: Richard Seaman, Nature Wallpaper, richard-seaman.com).

Fossorial fore legs are modified for digging.
Examples: Ground dwelling insects; mole crickets (order Orthoptera) and cicada nymphs (order Hemiptera).



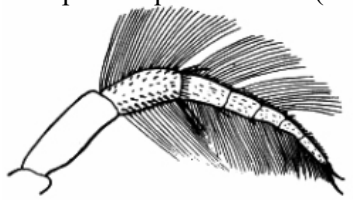
Fossorial leg (source: University of Florida, https://entnemdept.ufl.edu/).

Order Orthoptera: Southern mole cricket, Scapteriscus borellia, Drees, Texas A&M University (source: https://texasinsects.tamu.edu/insects).

Order Orthoptera: Southern mole cricket leg, Scapteriscus borellii (source: University of Florida, https://entnemdept.ufl.edu/).

Order Hemiptera: Cast skin of cicada nymph, Cyclochila australasiae (source: Dave Britton, The Australian Museum).

Natorial legs are modified for swimming. These legs have long setae on the tarsi.
Examples: Aquatic beetles (order Coleoptera) and bugs (order Hemiptera).



Natorial leg (source: University of Florida, https://entnemdept.ufl.edu/).

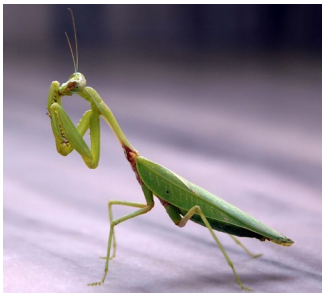
Order Coleoptera: Predaceous diving beetle, Rhantus sp. (source: Dale Parker, AquaTax Consulting, http://www.aquatax.ca/aquatax.html).

Order Coleoptera: Predaceous diving beetle and close up of leg, Acilius sulcatus (source: David Jones, mybitoftheplanet.com).

Order Hemiptera: Backswimmer (source: Dale Parker, AquaTax Consulting, http://www.aquatax.ca/aquatax.html).

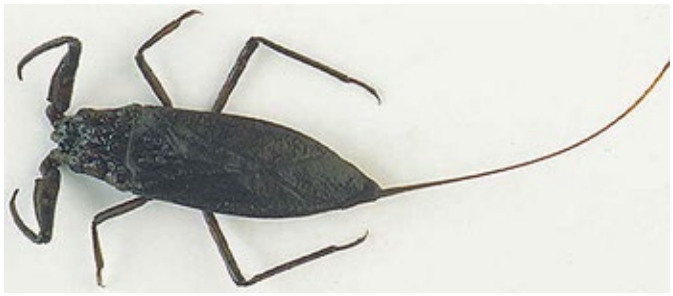
Raptorial fore legs modified for grasping (catching prey).
Examples: Mantids (order Mantodea), ambush bugs, giant water bugs and water scorpions (order Hemiptera).

Raptorial leg (source: University of Florida, https://entnemdept.ufl.edu/).



Order Mantodea: Carolina mantis, Stagomantis Carolina (source: Wikipedia).

Order Hemiptera: Ambush bug, Phymata pennsylvanica, (source: The Insects of Cedar Creek Photo Album, cedarcreek.umn.edu).



Order Hemiptera: Water scorpion (source: Murray Darling Freshwater Research Centre, Wodonga, https://www.mdfrc.org.au/).

Order Hemiptera: Giant water bug, Lethocerus americanus (source: Edward L. Manigault, insectimages.org).

Saltatorial hind legs adapted for jumping. These legs are characterized by an elongated femur and tibia. Examples: Grasshoppers, crickets and katydids (order Orthoptera).

Saltatorial leg (source: University of Florida, https://entnemdept.ufl.edu/).

Order Orthoptera: Redlegged grasshopper, Melanoplus femurrubrum (source: Clemson University - USDA Cooperative Extension Slide Series, insectimages.org).

Order Orthoptera: House cricket, Acheta domestica (source: Joseph Berger, insectimages.org).

Wings

Insects have evolved many variations of the wings, and an individual insect may possess more than one type of wing. Wing venation is a commonly used taxonomic character, especially at the family and species level.

In most living insects (the Neoptera), there are three axillary sclerites that articulate with various parts of the wing. In the Neoptera, a muscle on the third axillary causes it to pivot about the posterior notal wing process and thereby to fold the wing over the back of the insect. In some groups of Neoptera, such as butterflies, the ability to fold the wings over the back has been lost. Two orders of winged insects, the Ephemeroptera and Odonata, have not evolved this wing-flexing mechanism, and their axillary sclerites are arranged in a pattern different from that of the Neoptera; these two orders (together with a number of extinct orders) form the Paleoptera (University of Florida, https://entnemdept.ufl.edu/).

Primitive insects of the **Paleoptera** are unable to fold their wings. Instead, these insects carry their wings vertically or horizontally to their bodies.

Mayfly, Hexagenia sp., order Ephemeroptera (source: Alex Wild, myrmecos.net).

Most modern insects of the **Neoptera** are able to fold their wings over the body. This enables the insects to fit into smaller spaces.

Leaf footed bug, order Hemiptera (source: Clemson University - USDA Cooperative Extension Slide Series, insectimages.org).

Membranous wings are thin and more or less transparent, but some are darkened.
Examples: Dragonfiles and damselflies (order Odonata), lacewings (order Neuroptera), flies (order Diptera), bees and wasps (order Hymenoptera), termites (order Isoptera). Note the paleopterous wing conditions of the damselflies and dragonfly to the right and below and the neopterous wing conditions of the other insects.

Order Odonata, damselfly (source: Richard Seaman, Nature Wallpaper, richard-seaman.com).

Order Odonata, damselfly (source: University of Florida, https://entnemdept.ufl.edu/).

Order Odonata: Dragonfly, Sympetrum corruptum (source: Edward L. Manigault, Clemson University Donated Collection, insectimages.org).

Order Hymenoptera: Bald-faced hornet, Dolichovespula maculata (source: Edward L. Manigault, Clemson University Donated Collection, insectimages.org).

Order Isoptera: Termites, Reticulitermes virginicus (source: Gerald J. Lenhard, Louisiana State University, insectimages.org).

Order Neuroptera: Green lacewing, Chrysoperla sp. (source: David Capaert, bugwood.org).

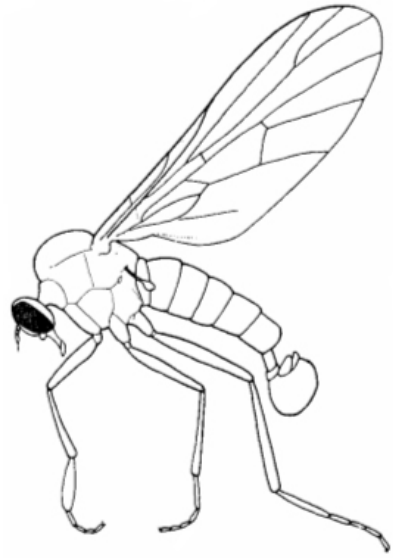
Order Neuroptera: Brown lacewing, Micromus sp. (source: David Capaert, bugwood.org).

Order Diptera: Mydas fly (source: Whitney Cranshaw, bugwood.org).

Halteres are an extreme modification among the order Diptera (true flies), in which the hind wings are reduced to mere nubs used for balance and direction during flight. Examples: All flies (order Diptera).

Order Diptera: Crane fly, Tipula oleracea (source: Janco Tanis, insectimages.org).

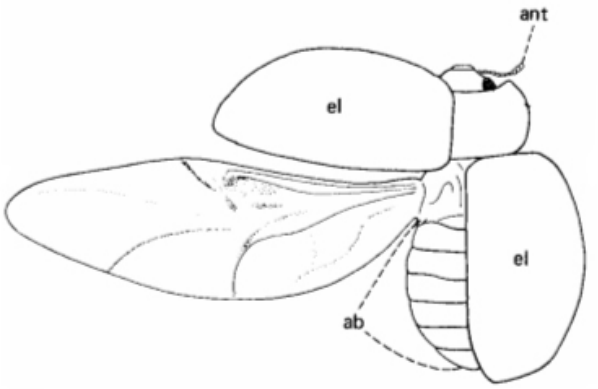
Order Diptera: Xylophagid, Xylophagus sp. (source: The Insects of Cedar Creek, cedarcreek.umn.edu).



Diptera: note halteres (source: University of Florida, https://entnemdept.ufl.edu/).

Elytra (singular elytron) are the hardened, heavily sclerotized forewings of beetles and are modified to protect the hind wings when at rest.
Examples: All beetles (order Coleoptera).

Order Coleoptera: Flatheaded wood borer, Buprestis fasciata (source: William M. Ciesla, Forest Health Management International, insectimages.org).



Elytra (el) of a beetle (source: University of Florida, https://entnemdept.ufl.edu/).

Order Coleoptera: Colorado potato beetle, Leptinotarsa decemlineata (source: Clemson University - USDA Cooperative Extension Slide, insectimages.org).

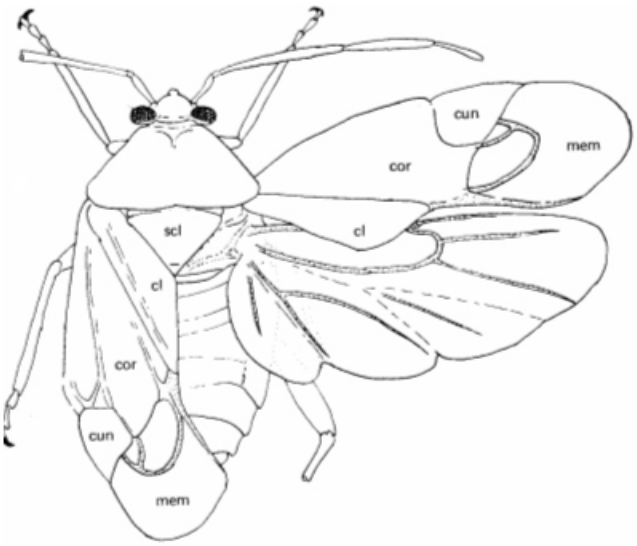
Japanese beetle in flying position (source: Richard Hurd, flickr.com).

Order Coleoptera: Spotted June beetle, Pelidnota punctata (source: Jim Occi, BugPics, insectimages.org).

Order Coleoptera: Margined blister beetle, Epicauta pestifera (source: Clemson University - USDA Cooperative Extension Slide Series, insectimages.org).

A variation of the elytra is the **hemelytra**. The forewings of Hemipterans are said to be hemelytrous because they are hardened throughout the proximal two-thirds, while the distal portion is membranous. Unlike elytra, hemelytra function primarily as flight wings.
Examples: True bugs (order Hemiptera).

Order Hemiptera: Big-eyed bug, Geocoris sp. (source: Bradley Higbee, Paramount Farming, insectimages.org).



Hemelytra (source: University of Florida, https://entnemdept.ufl.edu/).

Order Hemiptera: Four-lined plant bug, Poecilocapsus lineatus (source: Johnny N. Dell, bugwood.org).

Order Hemiptera: Brown stink bug, Euschistus servus (source: Russ Ottens, University of Georgia, insectimages.org).

Order Hemiptera: Leaf footed pine seed bug, Leptoglossus corculus (source: Larry R. Barber, USDA Forest Service, insectimages.org).

Tegmina (singular tegmen) are the leathery forewings of insects in the orders Orthoptera, Blattaria, and Mantodea. Like the elytra on beetles and the hemelytra on bugs, the tegmina help protect the delicate hind wings.
Examples: Grasshoppers, crickets, and katydids (order Orthoptera), Cockroaches (order Blattaria), Mantids (order Mantodea).

Order Orthoptera: Grasshopper, Dissosteira Carolina (source: The Insects of Cedar Creek, cedarcreek.umn.edu). The hind wings fold like a fan under the tegmina.

Order Blattaria: Smokybrown cockroach, Periplaneta fuliginosa (source: Daniel R. Suiter, University of Georgia, insectimages.org).

Order Orthoptera: Grasshopper, Tropidacris dux (source: Ronald F. Billings, Texas Forest Service, insectimages.org).

Order Blattaria: Orange-headed cockroach, Eublaberus prosticus, E. Tenczar).

Order Mantodea: Madagascan marbled mantis, Polyspillota aeruginosa, exotic-pets.co.uk).

Order Orthoptera: Katydid, Pterophylla camellifolia (source: Herbert A. "Joe" Pase III, Texas Forest Service, insectimages.org).

Some insect wings are covered with **scales**. The scales make the wings colorful.
Examples: Butterflies, moths, and skippers (order Lepidoptera), caddisflies (order Trichoptera).

Order Trichoptera: Caddisfly, Nectopsyche utleyorum (source: Gernot Kunz, inaturalist.com).

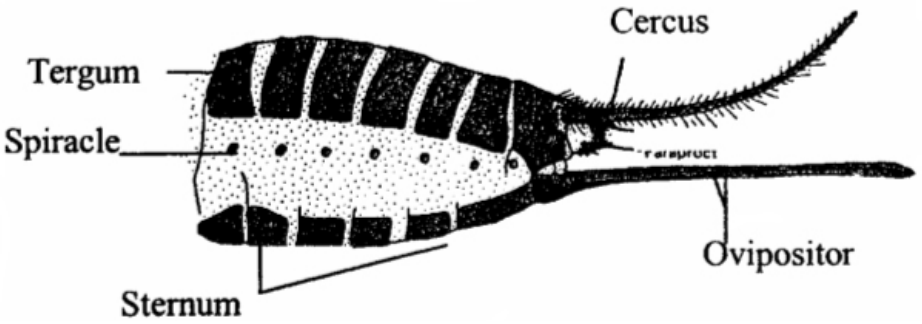
Order Lepidoptera: Tiger swallowtail, Papilio turnus (source: Edward L. Manigault, Clemson University Donated Collection, insectimages.org).

Order Lepidoptera: Io moth, Automeris io (source: Ronald F. Billings, Texas Forest Service, insectimages.org).

Order Lepidoptera: Hoary edge skipper, Achalarus lyciades (source: Jerry A. Payne, USDA ARS, insectimages.org).

ABDOMEN

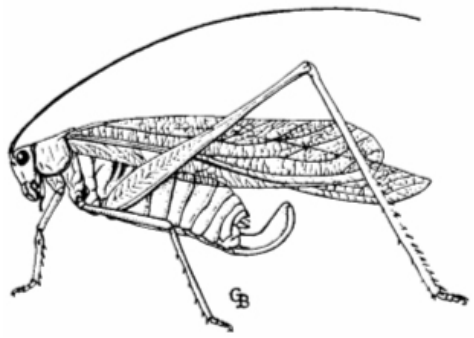
The abdomen contains the reproductive organs and the majority of the organ systems. The dorsal and ventral abdominal segments are termed terga (singular tergum) and sterna (singular sternum), respectively. Spiracles usually can be found in the conjunctive tissue between the terga and sterna of abdominal segments 1-8. Reproductive structures are located on the 9th segment in males (including the aedeagus, or penis, and often a pair of claspers) and on the 8th and 9th abdominal segments in females (female external genitalia copulatory openings and ovipositor).



Abdomen showing ovipositor (source: University of Florida, https://entnemdept.ufl.edu).

Ovipositor

The ovipositor is the egg-laying device found only in female insects. In some insects, the ovipositor is highly modified and conspicuous. In others, the apparatus may be needle or blade-like.



Blade-like ovipositor on katydid, order Orthoptera (source: University of Florida, https://entnemdept.ufl.edu).

Needle-like ovipositor on parasitic ichneumonid wasp, order Hymenoptera (source: University of Florida, https://entnemdept.ufl.edu).

Parasitic wasps (order Hymenoptera) use their ovipositors to insert eggs or small larvae into or onto a host. The stingers of bees and many wasps are modified ovipositors that have lost the egg-laying ability.

Order Hymenoptera: Braconid wasp, female, Spathius pallidus (source: Gerald J. Lenhard, Louisiana State University, insectimages.org).

Order Hymenoptera: Torymid wasp, female, Monodontomerus dentipes (source: Arnold T. Drooz, USDA Forest Service, insectimages.org).

Order Hymenoptera: Ichneumonid wasp, female, Megarhyssa macrurus (source: Jim Occi, BugPics, insectimages.org).

Crickets and **katydids** (order Orthoptera) have needle-like and blade-like ovipositors, respectively.

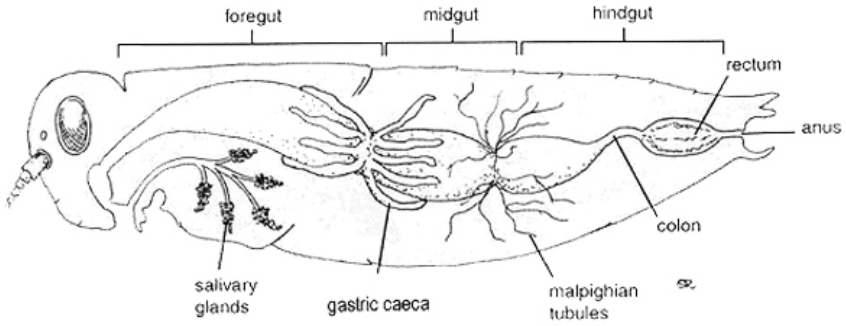
Order Orthoptera: Field cricket, female, Gryllus pennsylvanicus (source: Joseph Berger, insectimages.org).

Order Orthoptera: Katydid, Paracyrtophyllus robustus (source: Herbert A. "Joe" Pase III, Texas Forest Service, insectimages.org).

Internal Anatomy and Metamorphosis

Diagrams and text from University of Florida, University of Florida, https://entnemdept.ufl.edu.

Digestive & Excretory Systems

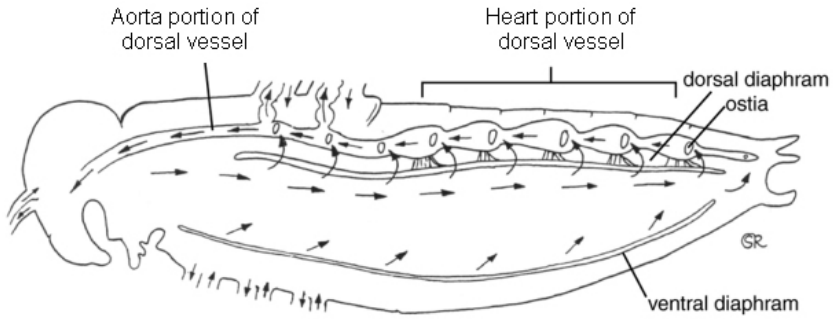


The **digestive system** (sometimes referred to as the **alimentary canal**) is a long tube-like structure that runs from the mouth to the anus and is centrally located within the body cavity, or **hemocoel**. The anterior-most region is called the **foregut** (or **stomodeum**) which includes the Buccal cavity, the esophagus, and the crop. The primary function of the foregut is to begin the breakdown of food particles and transport them to the next region, the **midgut** (or **mesenteron**). The midgut is the major area of digestion and absorption. Undigested food particles then pass into the third region, the **hindgut** (or **proctodeum**), which consists of the ileum, colon, **rectum**, and (often) rectal pads. The hindgut functions in water and solute reabsorption and waste excretion.

The three sections of the digestive tract can be easily identified by structures found at the junction of each region. **Gastric caecae**, for example, mark the end of the foregut and beginning of the midgut. It is believed that the purpose of these structures is to increase surface area for greater nutrient absorption. The constriction at the gastric caecae also marks the spot of the cardiac valve (or sphincter).

Near the junction of the midgut and hindgut are long, thin structures called **Malpighian tubules**. These range in number from a few to hundreds, but only aphids are currently known to have none. Malpighian tubules are creamy to yellow in color and work in conjunction with the ileum to provide the primary site for osmoregulation and excretion.

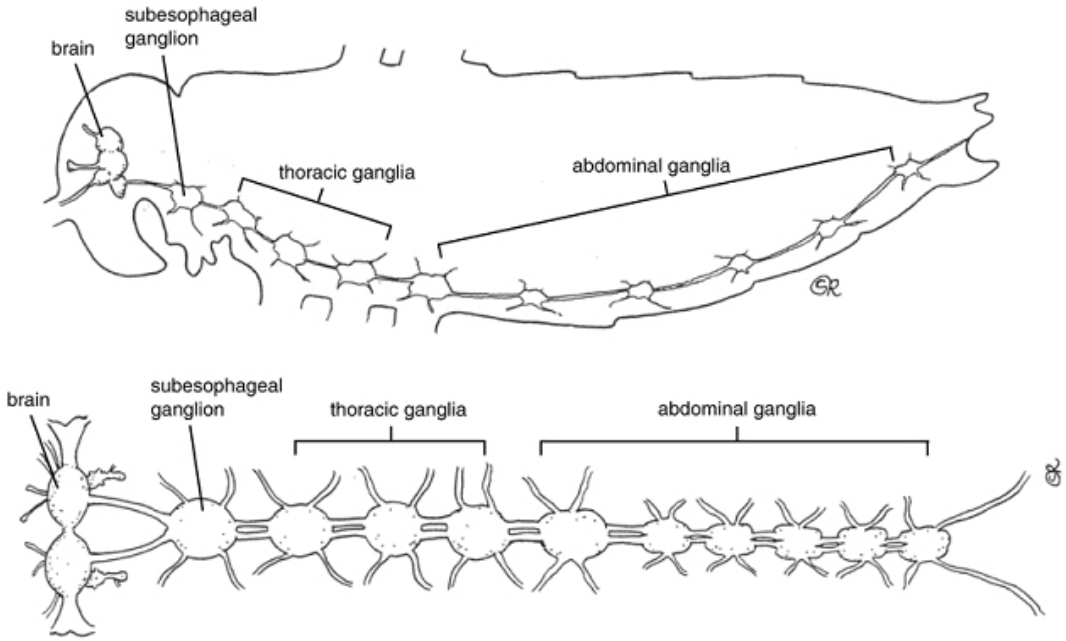
Circulatory System



Unlike the closed circulatory system of humans, insect circulatory systems are said to be open, meaning that they lack a complex network of veins and arteries to help transport blood throughout the body. Instead, insect blood (called **hemolymph**) flows relatively freely throughout the hemocoel.

Only one vessel is present in the insect circulatory system: the **dorsal vessel**. Posteriorly (in the abdominal region), the dorsal vessel acts as the **heart**, pumping hemolymph forward into the anterior region (in the head and thorax), where it acts as the **aorta** and dumps the hemolymph into the head. It flows posteriorly and is returned to the heart via **ostia**, which are small slits in the heart region of the dorsal vessel designed for hemolymph uptake.

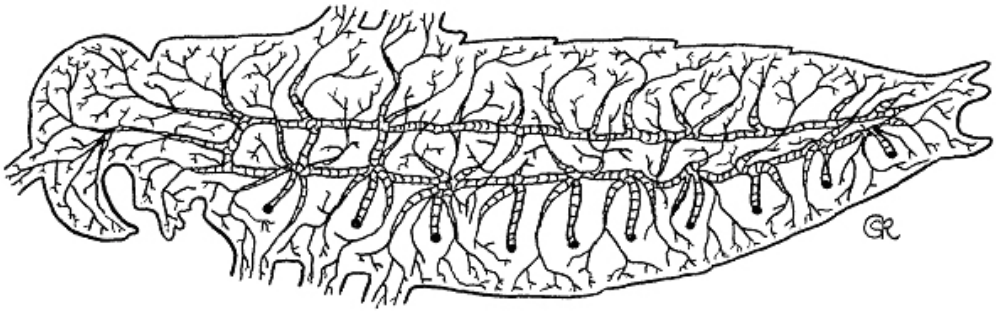
Nervous System



The **ventral nerve cord**, resembles a railroad track running from the head posteriorly to the abdominal region (above, lower diagram). The ventral nerve cord is made up of two nerve cords (**connectives**) that run longitudinally with a series of node-like **ganglia**.

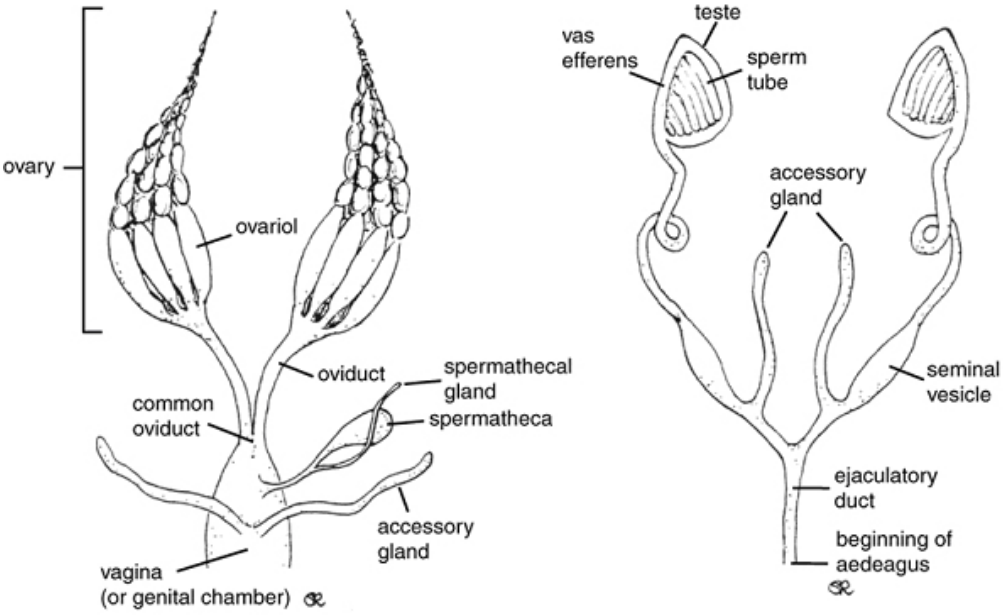
The anterior most region of the ventral nerve cord is called the **subesophageal ganglion**. Just dorsal to that structure is the insect brain (or **supraesophageal ganglion**).

Respiratory System



The insect respiratory system is made up of a series of tubes that originate from **spiracles** (openings of the exoskeleton that allow for gas exchange) and extend throughout the body. Internally, the tubes, or **tracheae**, appear as thin white lines throughout the hemocoel and are particularly noticeable surrounding internal organs. Trachea deliver oxygen to internal organs and tissues.

Reproductive System



The female reproductive system is shown on the left. The male is on the right.

Variation among insect reproductive systems is great. Closely related species are often isolated from one another via small variations in the morphology of reproductive organs that prohibit interspecies mating. However, a generalized system can be constructed that closely represents all sexually reproducing insects. Be familiar with differences in male and female genitalia and be able to identify structures when given a diagram.

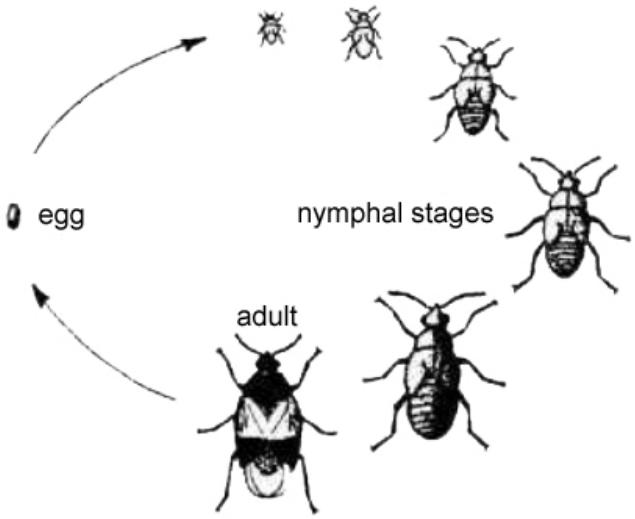
Insect Growth and Development (Metamorphosis)

Information and diagrams are adapted from:
Hoffmann, M.P. and Frodsham, A.C. (1993) Natural Enemies of Vegetable Insect Pests. Cooperative Extension, Cornell University, Ithaca, NY. 63 pp.

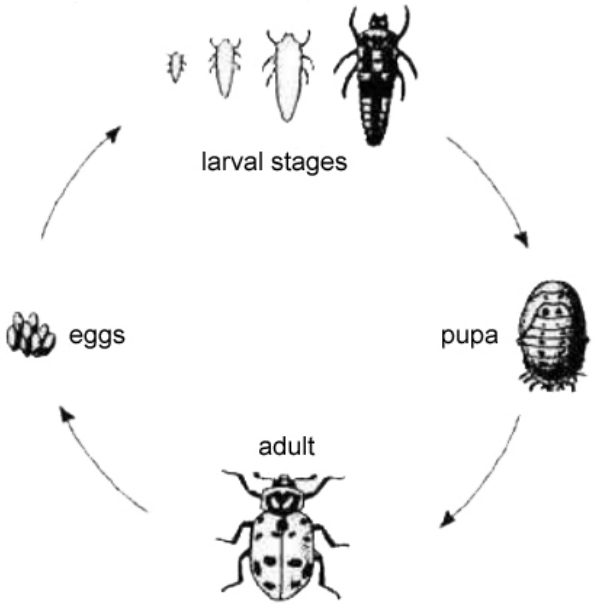
Insects go through several separate life stages: egg, larva or nymph, pupa (complete metamorphosis only), and adult. Eggs are laid one at a time or in masses, in or on plants, or even inside another insect! Eventually a larva or nymph emerges from the egg. There are usually several larval or nymphal stages, called instars. During each stage the nymph grows larger and molts, or sheds its outer skin before the next stage. They grow the most during the last one or two instars, or stages. All the growing happens during the larval or nymphal stages. The eggs, pupae, and adults don't grow in size.

The two types of metamorphosis typical of insects are:

incomplete metamorphosis (egg --> nymph --> adult) and **complete metamorphosis** (egg --> larva --> pupa --> adult).



Order Hemiptera: flower bug, incomplete metamorphosis



Order Coleoptera: lady beetle, complete metamorphosis