

LABORATORY #1

INTRODUCTION

- **Laboratory introduction: laboratory & field safety, syllabus, schedule**
- **Introduction to insect orders**
- **Introduction to insect morphology and anatomy (external in Laboratory #1, internal in Laboratory #2)**
- **Turn in the last page**

INTRODUCTION TO THE INSECT ORDERS

There are approximately 30 orders of true insects (**ectognathous** hexapods), many of which you are likely already familiar with and many of which even seasoned entomologists are lucky to see in their lifetime (Figure 1). We will be focusing on the orders that you are most likely to encounter in the field. By the end of today you should be able to recognize these orders by sight. You should make drawings of representatives of each order and note their particular characteristics where appropriate. As the course progresses, you will learn commonly encountered groupings (e.g. families) for each of these orders.

- **Odonata:** Dragonflies & Damselflies (Sheet 1).
- **Orthoptera:** Grasshoppers, Locusts, Katydid, Crickets (Sheet 2).
- **Hemiptera:** Bugs, Cicadas, Leafhoppers, Planthoppers, Spittlebugs, Aphids, Scale Insects, Whiteflies (Sheet 3).
- **Coleoptera:** Beetles (Sheet 4).
- **Neuroptera:** Lacewings, Antlions, Owlflies (Sheet 5).
- **Diptera:** True flies (Sheet 6).
- **Lepidoptera:** Butterflies & Moths (Sheet 7).
- **Hymenoptera:** Ants, Bees, Wasps, Sawflies (Sheet 8).

Today you will be examining, identifying, and organizing specimens that have been stored in insect drawers. You will identify them and move them to unit trays for the above orders. You will come across other orders as well (notably Dermaptera, Blattodea, Isoptera, Mantodea, Phasmatodea, and even some Zygentoma). These are listed on Sheet 9. We will examine these in more detail later in the course; you may want to take note of them now.

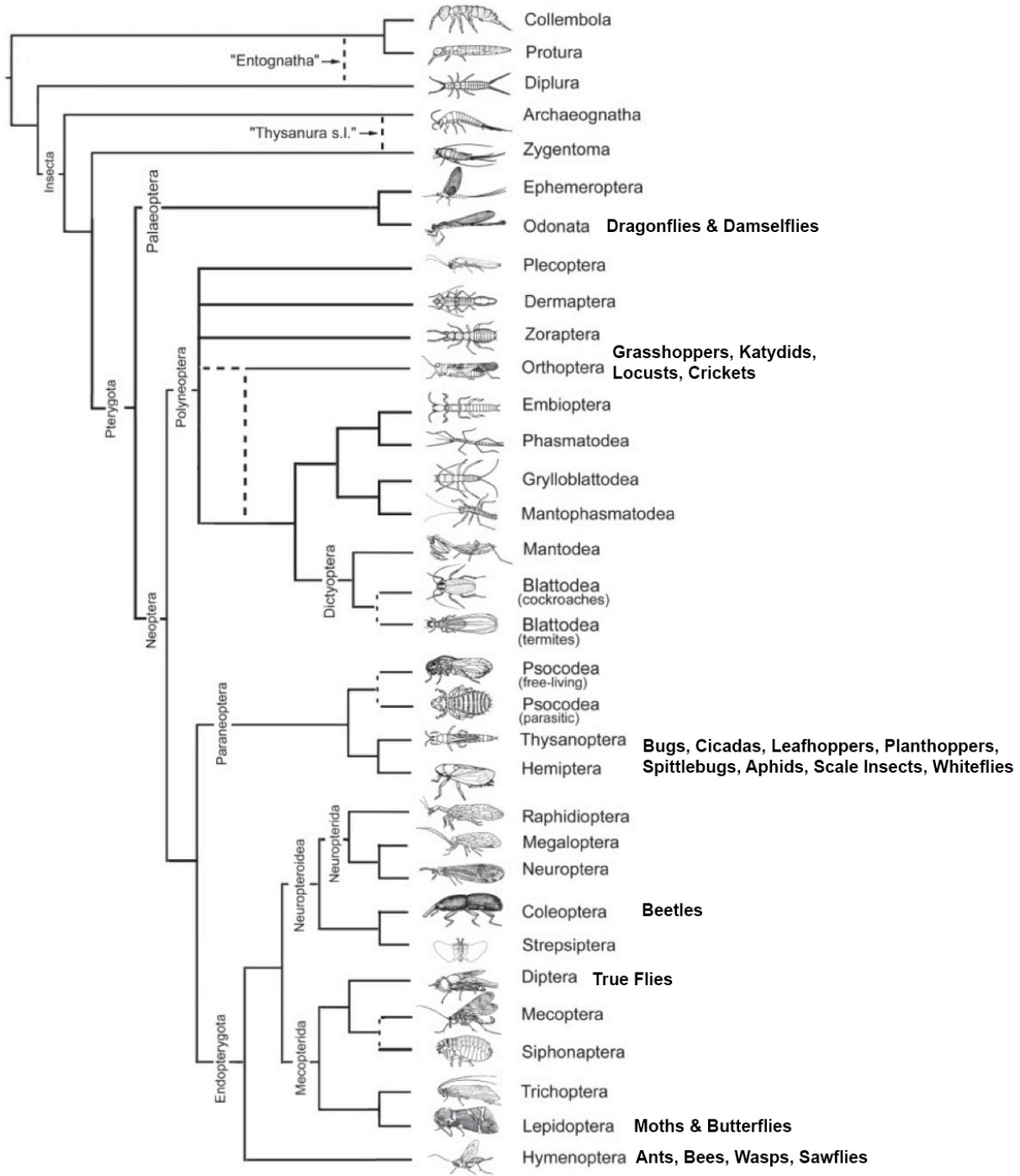


Figure 1: The phylogeny of the insect orders. You will learn how to distinguish the taxa in bold today, and will learn more in depth about their taxonomy and identification later in the semester. You are likely to see or collect many of these taxa. Some of the other orders are seasonal (Ephemeroptera, Plecoptera, Megaloptera, Mecoptera, Trichoptera), rare or absent in California (Grylloblattodea, Mantophasmatodea, Zoraptera), or have habits (Phthiraptera, Strepsiptera, Siphonaptera) that make them unlikely to be encountered in the field. Modified from Figure 7.2 from your textbook.

INTRODUCTION TO INSECT MORPHOLOGY AND ANATOMY

The grasshopper or locust (order Orthoptera) will be used to illustrate basic insect anatomy.

Obtain a large specimen of the lubber grasshopper (*Romalea*), a common species found in the southern United States. Observe the body markings, coloration, and reduced wings that are characteristic of the species. Note that the grasshopper is segmented. What type of segmentation is represented?

As in all insects, the external, protective covering is a tough, nonliving **cuticle** or **exoskeleton** containing chitin. The hardened sclerotized plates of the cuticle are called **sclerites**. The major sclerites are typically separated by membranous areas called sutures that permit movement of body parts. A dorsal sclerite is the **tergum**, a ventral one the **sternum**, and a lateral one the **pleuron**. In areas (e.g., head) where individual segments are fused, the terga (or tergites) are fused as a solid hardened mass. The sclerites may also be divided into subplates. Locate the three tagmata composing the grasshopper's body: (1) anterior head, (2) middle thorax, and (3) posterior abdomen (Fig. 4).

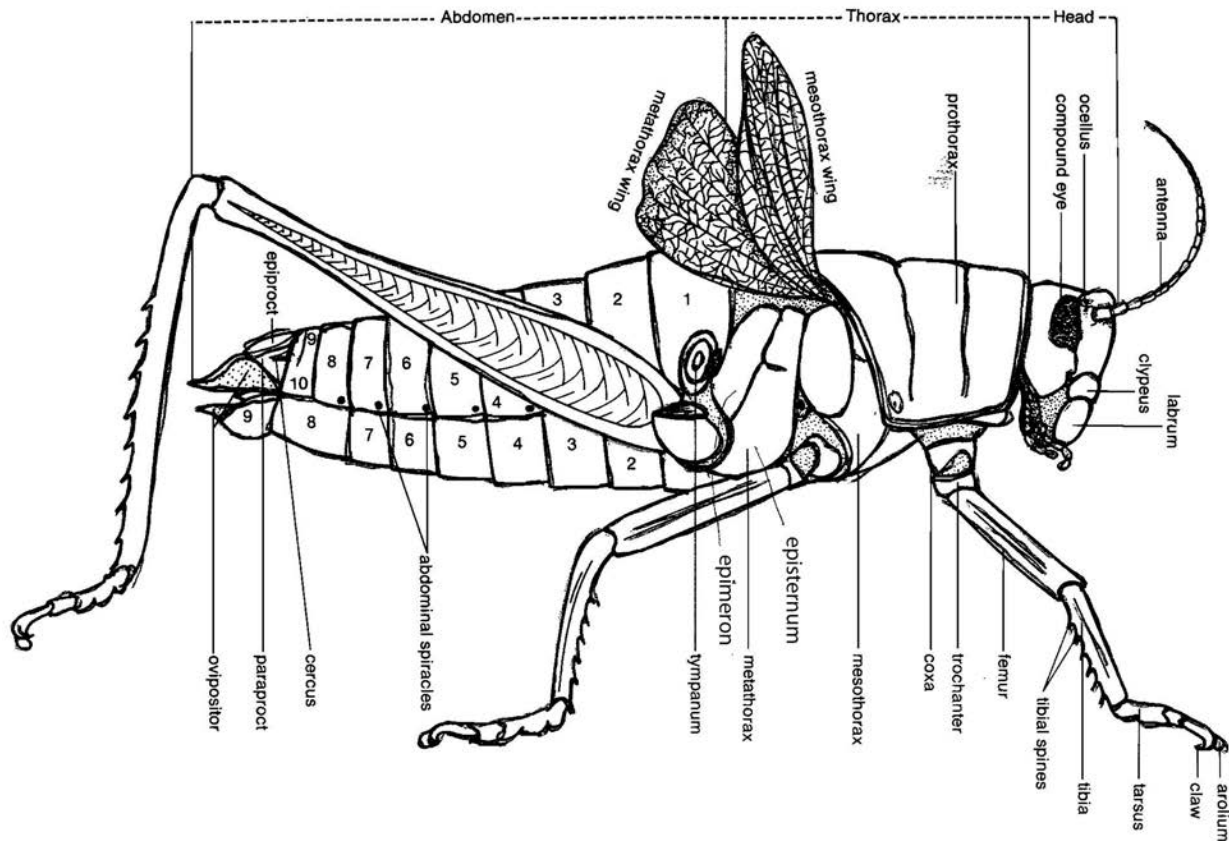


Figure 4: Lateral view of a female lubber grasshopper

Head

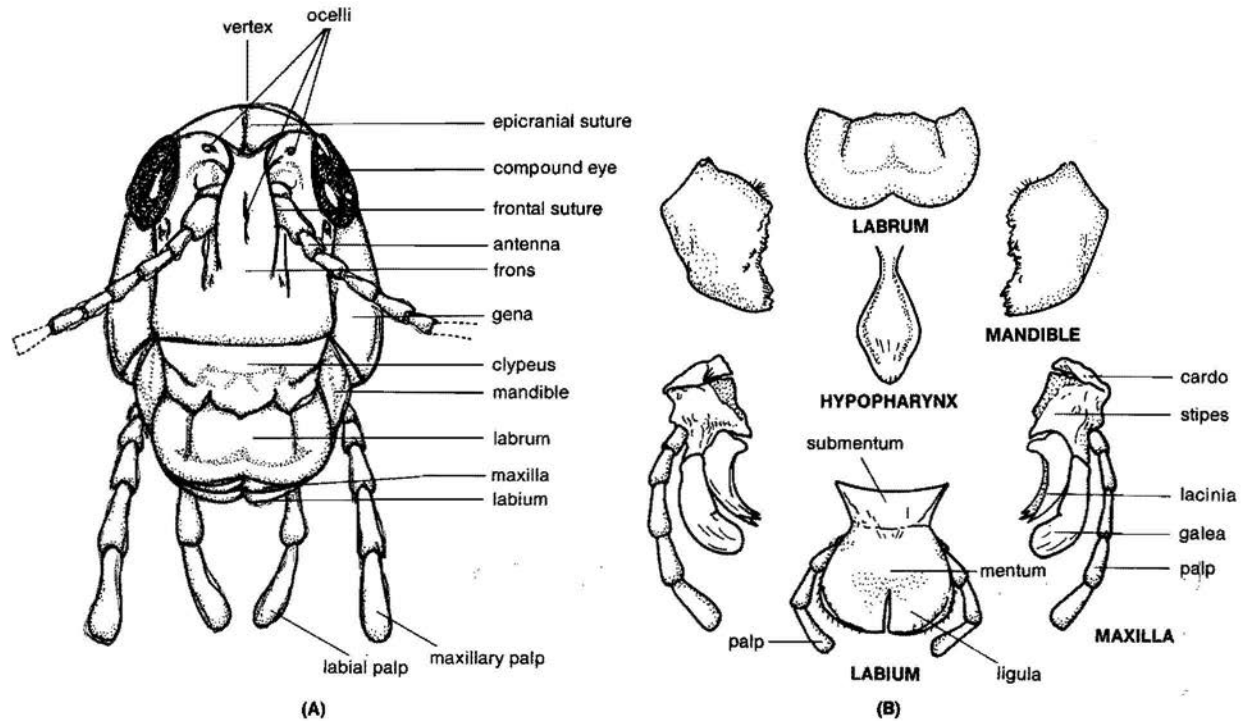
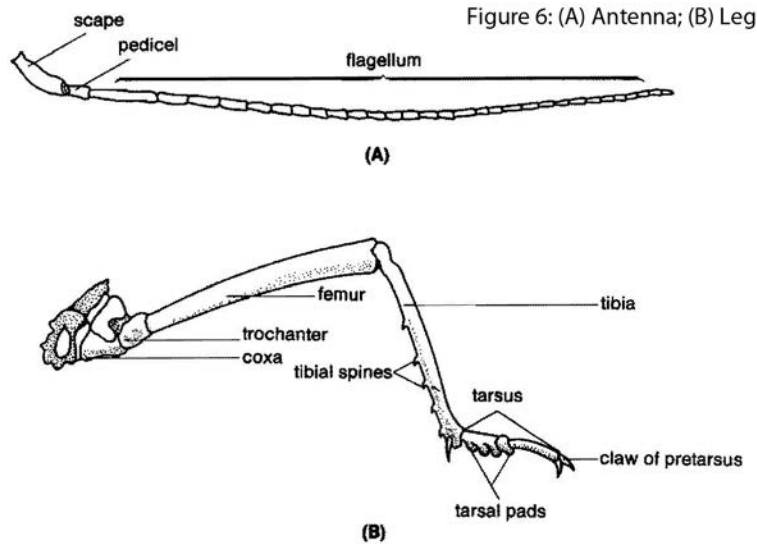


Figure 5. (A) Frontal view of a grasshopper head. (B) Mouthparts of a grasshopper.

1. The head is in form of a capsule (Figs. 4 and 5). The upper part is heavily sclerotized and the ventral area contains the mouth surrounded by several mouthparts used in feeding. Exact agreement by entomologists does not exist as to the number of segments in the insect head. Arguments range from 5 to 7. Current thinking is leaning toward 6. Note the shape of the head and its position in relation to the long axis of the body. The mouthparts of the grasshopper are directed downward, a position called **hypognathous**.
2. The head capsule is divided by sutures into several regions. It is often difficult to discern where one region begins and the other ends. The dorsum of the head between and behind the eyes is the **vertex** (Fig. 5). The **frons** is the anteriofrontal region. Note on the frons the two arms or forks of the Y-shaped **epicranial suture** whose stem begins on the back of the head. The forks are called the **frontal suture** and the stem the **coronal suture**. The epicranial suture represents a line of weakness that splits the head capsule at molting.
3. Locate the **gena** or "cheek," the lateral lower part of the head posterior to the frons and below the eyes. The back of the head is the **occipital** that contains the **occipital foramen** (or foramen magnum).
4. Examine the anterior face of the head (Fig. 5). Locate the liplike sclerite, the **clypeus**, below the frons to which it is attached. Hanging down from the clypeus is the **labrum** or "upper lip."
5. Lift the clypeus with forceps to fully expose the bilobed labrum. Does the labrum articulate directly to the clypeus? A swollen area, the **epipharynx**, is

- prominent in many insects on the ventral or posterior side of the labrum. Does the grasshopper have an epipharynx?
6. Behind the labrum are paired, unsegmented **mandibles**. Lift up the labrum with your forceps to expose these paired, hard mouthparts with teeth used to cut, chew, and grind food. The mandibulate insects include other orthopterans, odonates, isopteran, and coleopterans, so-named because of the type of mandibles present.
 7. Behind the mandibles are the paired **maxillae**. These masticate and manipulate food. Note the antenna-like, segmented **palps** attached on top of the maxillae. How many segments compose a palp? The palps are sensory structures.
 8. Other parts of a maxilla are as follows: the basal **cardo**, the **stipes** with a palp, the outer **galea**, and the inner jawlike **lacinia**. These areas are best observed when the maxillae are dissected out. Although the **labium** is a single structure, it represents fused paired second maxillae. The labium also manipulates food and has paired sensory palps. Note the three regions on the labium: basal **postmentum** (divided into a basal submentum and distal mentum), middle **prementum** with palps, and distal **ligula** with apical lobes.
 9. The labium should be dissected from the grasshopper and observed with the dissecting microscope.
 10. Locate the median, unpaired tonguelike **hypopharynx** that protrudes in the preoral cavity. The hypopharynx is closely associated with the base of the labium. You should dissect out all of the mouthparts and examine them under the dissecting microscope.
 11. Note the shape and position of the two large immovable **compound eyes**. Examine an eye under the dissecting microscope. Note the many hexagonal **facets**. Each facet is a lens to an **ommatidium**, the basic structure of the eye. The number of ommatidia varies; some dragonflies have up to 30,000.
 12. Between the compound eyes and on the frons are three single-faceted simple eyes or **ocelli**. Note that the arrangement of the ocelli forms a triangle. The ocelli apparently perceive changes in light intensity, whereas the compound eyes form images.
 13. Below the two lateral ocelli are two antennae. These movable sensory appendages articulate in antennal sockets. A variety of shapes and sizes of antennae occurs in insects. They function in touch, smell, and hearing. The grasshopper's antennae are threadlike or filiform. Remove an antenna from its socket and examine it under the dissecting microscope. Note the tiny sensory hairs on the antenna. Locate the basal scape, the middle pedicel, and the long flagellum consisting of many segments (Fig. 6). Can you locate Johnston's organ on the pedicel with your dissecting scope?

Cervix or Neck. Connecting the head and thorax is a membranous region called the cervix or neck. It is not a separate body segment, but a contribution from the labial segment and the prothoracic segment. The cervix allows flexibility of movement between the head and thorax regions.



Thorax

1. All insects have three segments to the thorax: anterior **prothorax**, middle **mesothorax**, and posterior **metathorax** (Fig. 4). Each bears a pair of legs. The parchment-like forewings (or **tegmina**) are attached to the mesothorax and the hind wings are attached to the metathorax.
2. Observe the wing coloration and the folded shape of the hind wings. Flight is primarily by the hind wings. Note the many veins in the wings. What function might they perform? The venation pattern is important in insect taxonomy. Both wings are outgrowths of the body wall and lack internal muscles.
3. Examine the sclerites of the thorax. Each tergum or dorsal plate on the thorax is called a **notum**. The wings are attached to the lateral margins of the nota.
4. Note the greatly sclerotized sternum. The different specialized plates and sutures of the notum and sternum will not be discussed.
5. Each pleuron is divided by a suture forming two sclerites. The anterior sclerite is the **episternum** and the posterior one the **epimeron**. Observe these with the dissecting microscope.
6. Two pairs of **spiracles**, external openings to the tracheal respiratory system, occur on the thorax above the attachments of the second and third pairs of legs. You will observe that these locations are between the prothorax and mesothorax and between the mesothorax and metathorax, respectively.
7. Observe the legs. Each leg consists of six parts: **coxa**, **trochanter**, **femur**, **tibia**, **tarsus**, and **pretarsus** (Fig. 6). The short basal coxa articulates with the body.
8. Note the shape of the greatly enlarged femur of the last pair of legs. What adaptation might this enlarged part serve?
9. Note the two rows of spines on the tibia. Are the spines of both rows equal in size and number? Why are the spines located on the dorsal surface of the tibia instead of the ventral surface?
10. Count the segments of the tarsus. Note the tarsal pads or **pulvilli**. How many are there and what function might the pads serve? The short pretarsus also has an adhesive pad, the **arolium**, and a pair of **claws**.

Abdomen

1. Observe that the abdomen is distinctly segmented and lacks jointed appendages (Figs. 4 and 7). Count the abdominal segments. The first segment bears a **tympanum**, an oval membrane covering the organ of hearing. The last pair of segments is reduced and limited to a tergite, the **epiproct**, below which lies the **anus**.
2. Observe the tergite and anus under the dissecting microscope. Note the small spine or **cercus** projecting behind the tenth segment. The plate below the cercus is the **paraproct**. Although reduced in size, the cercus is one of the few appendages found on the abdomen. The other appendages on the abdomen are reproductive in function.
3. At the end of the abdomen in female grasshoppers is a pincer-shaped **ovipositor** for digging a hole in the ground for deposition of eggs. Observe the bladelike structures (**valvulae**) that compose the ovipositor (Fig. 7).
4. Male grasshoppers lack the ovipositor. Note that the expanded sternum of segment 9 (the **subgenital plate**) encloses the male copulatory organs.
5. Observe the terga and sternal plates of the abdominal segments. Note their arrangement. Are pleural sclerites present?
6. On the lower anterior edge of each abdominal tergite of segments 1 to 8 is a small oval spiracle that leads to an internal trachea of the respiratory system. Observe the spiracles with the dissecting microscope. Some may be situated in a pigmented area and be difficult to see. Counting those on the thorax and those on the abdomen, the grasshopper has ten pairs of spiracles. The first four pairs are used in inspiration and the remaining pairs function in expiration.

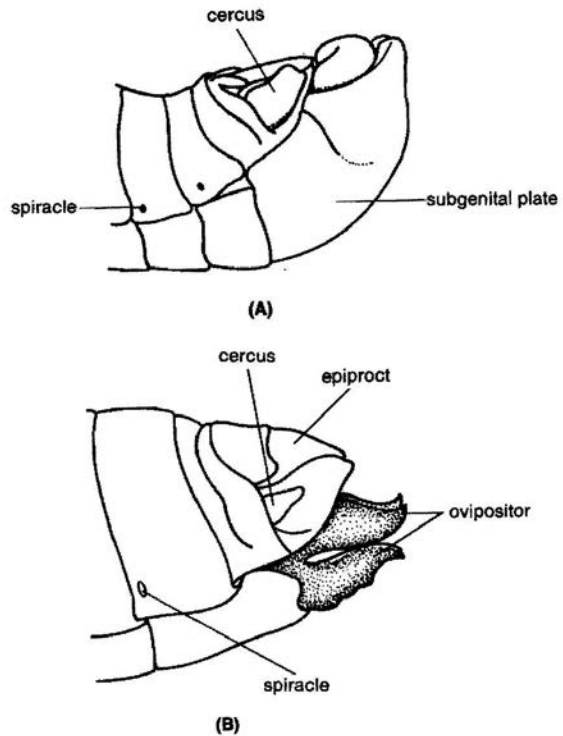


Figure 7: Posterior ends of (A) male and (B) female grasshoppers

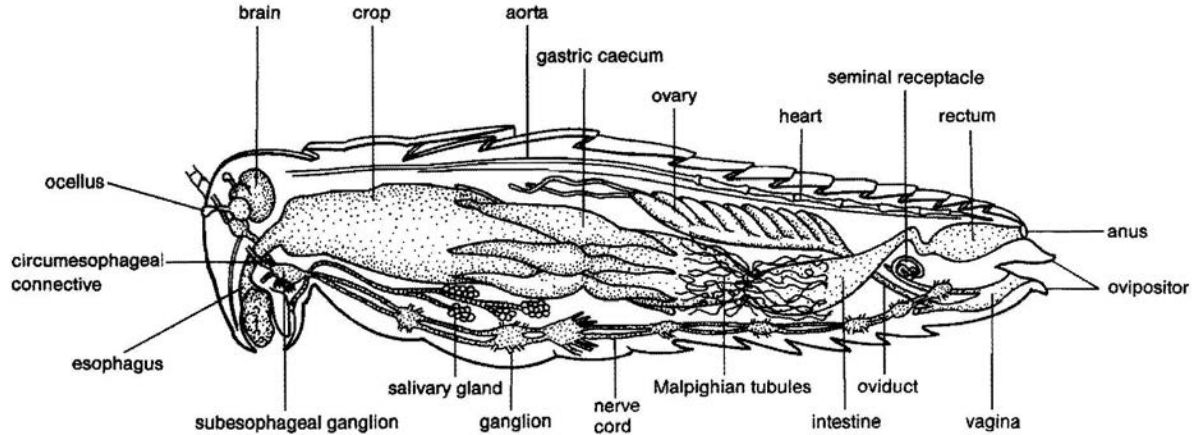


Figure 8: Internal anatomy of a female grasshopper.

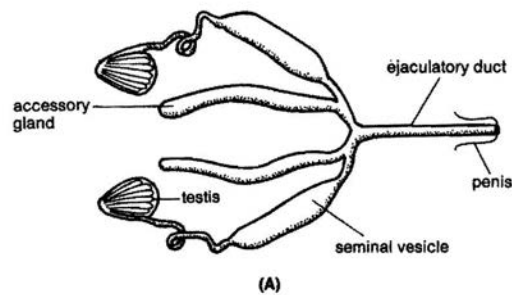
Internal Anatomy. Much of the internal anatomy of the grasshopper will be difficult to observe. Therefore, exercise care in dissection and observation.

1. With a pair of fine-pointed scissors, clip off the wings close to the body. Make a very shallow **midsagittal** cut through the dorsal body wall beginning at the head and ending at the posterior end. Pin down the two halves of the body wall to the dissection tray.
2. The large cavity exposed and containing the internal organs is the **hemocoel** (Fig. 8). This is not a true body cavity or coelom but part of the **open (lacunar)** circulatory system. The hemocoel is filled with blood or **hemolymph**. The **heart** is an elongated slender tube in the dorsal part of the abdomen. It extends anteriorly as an **aorta**. Although the heart is difficult to see, make an attempt to locate it.
3. Note the muscles along the body wall, especially those in the thorax associated with the legs and wings. The muscles of the grasshopper are in bands.
4. Note the whitish, delicate tubes extending from the body wall to the viscera. These are **tracheae**. Prepare a wet mount of a piece of a trachea and examine it under low and high powers of a compound microscope. Describe the appearance of the tracheae.
5. Components of the digestive system are the most conspicuous of the internal organs. Much of the hemocoel is filled with the digestive system (Fig. 8). Locate the tube-shaped **esophagus** leading from a short **pharynx** that connects to the mouth. The esophagus enlarges posteriorly as a thin-walled **crop** in the thorax. The **crop** leads to a narrow **proventriculus** (or **gizzard**) with internal gastric teeth for shredding food.
6. You may see salivary or labial glands below the crop, with a duct opening in the preoral cavity between the labium and hypopharynx. The components above compose the foregut (or stomodeum) of the grasshopper's digestive system.
7. Posteriorly the proventriculus leads to an elongated **stomach** or **ventriculus**. Much of the stomach is concealed by finger-shaped **gastric caecae**. These are involved in nutrient absorption. How many are present? The stomach and gastric caecae constitute the midgut (mesenteron).
8. Connecting to the stomach posteriorly is an **intestine**, with an enlarged anterior component and a slender posterior component, an enlarged **rectum**, and the

anus. The intestine, rectum, and anus constitute the hindgut (proctodeum).

9. The many threadlike excretory organs called **Malpighian tubules** and other organs such as those originating from the reproductive system may conceal parts of the hindgut. Care must be exercised not to destroy these structures.
10. Grasshoppers are dioecious. Females possess the egg-laying ovipositor, whereas males lack this structure and thus have a rounded posterior end (Fig. 7). Females lay their eggs in the ground in late summer or early fall. In the following spring, the eggs hatch into immature grasshoppers (or nymphs). They undergo several molts before attaining the adult form.

11. Examine a male grasshopper and locate as many of the following parts as possible (Fig. 9). The two fused **testes** of the male lie dorsal to the intestine. A slender tube, the **vas deferens**, extends from each testis. The tube passes posteroventrally and becomes enlarged as a reservoir, the **seminal vesicle**, before uniting to form a common **ejaculatory duct** that enters the **penis**. Two **accessory glands** that secrete a fluid join the ejaculatory duct.



12. Examine a female grasshopper (Fig. 9). Several tapering **ovarioles** or egg tubes where eggs are produced form an **ovary**. Extending from each ovary is an **oviduct**. The two oviducts join to form the **vagina**, an egg-holding chamber located under the intestine. Two **accessory glands** and a **seminal receptacle** (or **spermatheca**) enter the vagina separately.

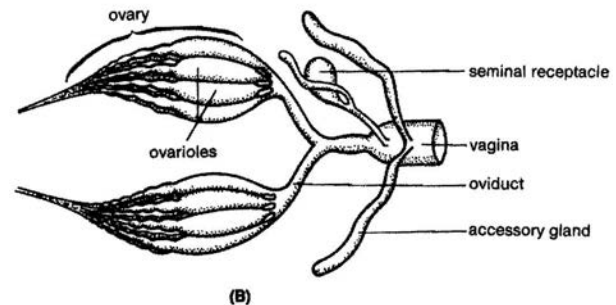


Figure 9: Reproductive systems of (A) male and (B) female insects.

Sperm received from the male during copulation are stored in the receptacle.

13. Insects possess a highly developed nervous system (Fig. 8). It is similar to that of the crayfish and for the most part, the system lies below the digestive system. Attempt to observe the following components of the grasshopper's nervous system. The central nervous system consists of a **trilobed brain** located in the head above the esophagus. Extending off the brain is a pair of **circumesophageal connectives** that connect to a **subesophageal ganglion**. The ganglion innervates the mandibles, maxillae, and labium. Extending posteriorly in the insect is the paired **ventral nerve cord** with one pair of ganglia per segment.

Sheet 1: ORDER ODONATA: Dragonflies & Damselflies

Identification: Two pairs of long, narrow, membranous wings that are roughly equal in size. They also have large eyes and extremely long, narrow abdomens. Potential is confusion with Neuroptera, which hold wings differently when at rest. They undergo incomplete metamorphosis.

Diagnosis:

- **Nymphs aquatic**, with highly **modified labium**.
- Adults and nymphs highly predaceous.
- Pterothorax large, well developed for powerful flight.
- Mate in tandem flight.
- Colorful.
- Adult antennae bristlelike, short.
- Long, narrow, membranous wings, profusely veined.
- Legs long with long spines and spurs for forming basket to hold prey captured in flight; adults cannot walk.
- Abdomen long and slender.

Zygoptera: Damselflies. Slender bodied. Eyes large and widely separated. Wings, when at rest, are usually held above body. Forewing = Hindwing.

Anisoptera: Dragonflies. Stouter bodied. Eyes large, but close together. Wings at rest are held outspread laterally from the body. Forewing similar to hindwing but venation is not identical.

Habitat & Habits:

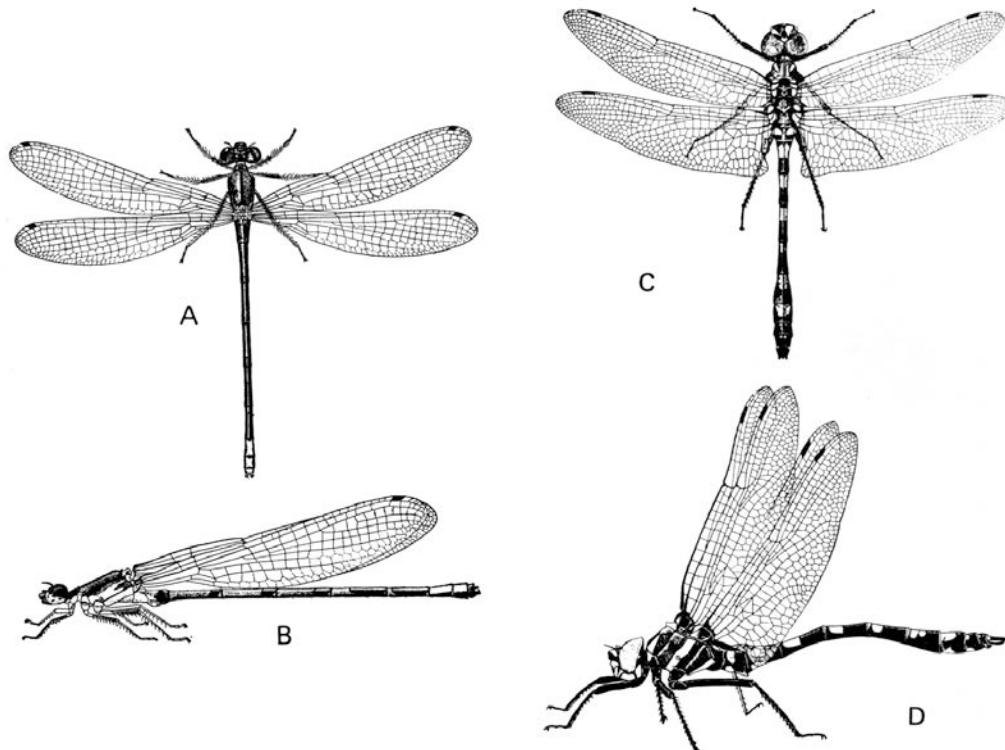
- Incomplete metamorphosis.
- Larvae 10-12 instars, in 1 year to 4 years (!).
- Overwinter as larvae or eggs.
- Last instar crawls out of water to emerge.
- Adult lives few weeks to a few months. Newly emerged adults are soft and silvery, chitin not yet hardened or colored = **teneral**.
- All stages are predators (carnivorous, cannibalistic).
- Tandem mating: Male deposits sperm in secondary genitalia under his abdominal segment 2. Male grasps female behind her head (Anisops) or in groove of pro- and mesothorax (Zygops) with specialized primary genitalic appendages at end of his abdomen = the tandem position. Female loops her abdomen down and forward and engages male's secondary genitalia = wheel position. Some males have secondary genitalia that can remove sperm from previously mated females.
- Oviposition
 - Damselflies and primitive dragonflies: female punctures vegetation or debris with ovipositor and inserts eggs (above or below water). Some species become fully submerged. Often done while in tandem.

- Advanced dragonflies: (a) Female (sometimes in tandem) repeatedly strikes surface of water in rhythmic fashion, depositing eggs; (b) Directly into substrate in shallow water; (c) Plants in dry land.
- Mass flights, migration—not well understood.
- Males defend territories and partition flying space for reproduction and feeding.
- Larvae lie-in-wait predators: clingers and sprawlers on aquatic vegetation, burrowers. Most common in standing water or slower areas of stream.
- Anal area of larval abdomen especially well adapted for respiration and osmoregulation. Anisoptera able to pump water in and out of rectal chamber—jet propulsion. Caudal lamellae of Zygops increase available surface area.
- Adults elusive, aerial, diurnal predators. Generally fly only when sunny.

Collecting & Preserving: Adults are very good flyers—capture with nets in flight or when perched, green netting better. Kill jars with ethyl acetate or cyanide (or let specimens starve in paper envelopes to evacuate gut), then place specimens in acetone for a few hours to leach out fats—preserves color better. Store permanently in “odonate envelopes”. Collect larvae in Kahle’s preservative, pierce base of abdomen of large specimens or inject with Kahle’s.

Distribution: 6,500 species in 600 genera. Worldwide, most tropical, approximately 460 species in USA and Canada.

A & B: Typical Zygoptera. C & D: Typical Anisoptera.



Sheet 2: ORDER ORTHOPTERA: Grasshoppers, Locusts, Katydid, Crickets

Identification: Usually have long back legs, hop high in the air, and often make rhythmic sounds. Leathery forewings that cover larger hind wings that are folded like a fan when at rest. They undergo incomplete metamorphosis.

Suborder Caelifera: Short-horned grasshoppers
Diagnosis (see Figure 1 to the right):

- Hind legs with femora thickened and modified for jumping.
- Fore wings, when present, in form of thickened tegmina.
- Antennae shorter than body, thick, fewer than 30 segments.
- Sides of base of abdomen with tympanal organs.
- Stridulatory organs, when present, involve rubbing edge of tegmen with ridge on inside of hind femur.
- Ovipositor short.

Habitat and habits:

- Largely diurnal. Practically exclusively phytophagous. Eggs are laid in “pods” held together by foamy secretions and buried in ground. Gregarious behavior and sustained migration common. Many are injurious to crops.

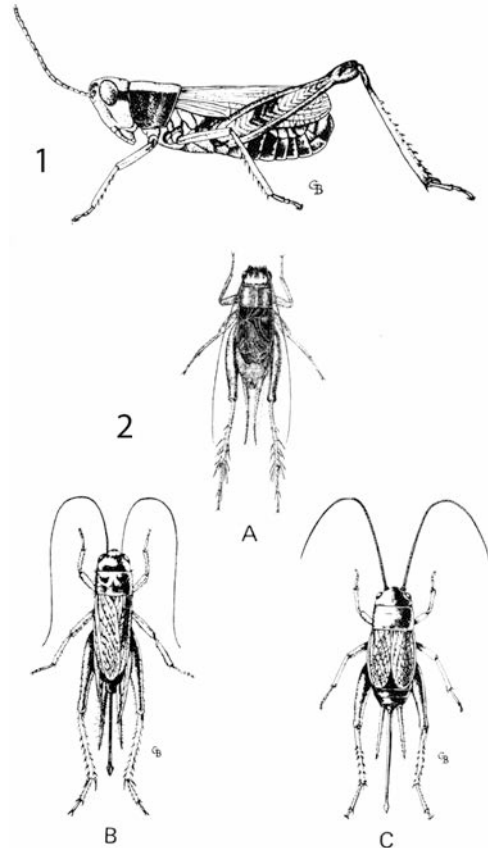
Suborder Ensifera: Long-horned grasshoppers, katydids, and crickets
Diagnosis (see Figure 2 to the right):

- Hind legs with femora thickened and modified for jumping.
- Fore wings, when present, in form of thickened tegmina.
- Antennae longer than body, thin, with many more than 30 segments.
- Fore tibiae usually with basal, oval, or slitlike tympanal organ.
- Bases of tegmina modified for stridulation—“scraper/file” system.
- Ovipositor long, sword-, dagger-, sickle-, or needle-like.

Habitat and habits:

- Largely nocturnal. Phytophagous, detritivorous, carnivorous. Arboreal, subterranean, and cave-dwellers. Eggs generally deposited separately, frequently in living plant tissue.

Collecting and preserving: Sweep-netting or set out oatmeal bait and collect at night. Pin with left wing spread. Eviscerate abdomens of large specimens.



Distribution: 20,000 species worldwide. About 1350 in USA and Canada.

Sheet 3: ORDER HEMIPTERA: Bugs, Cicadas, Leafhoppers, Planthoppers, Spittlebugs, Aphids, Scale Insects, Whiteflies

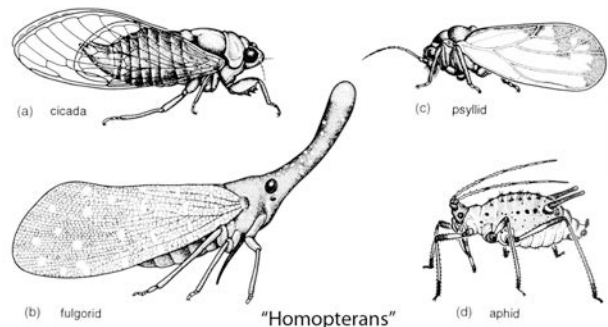
Identification: Highly diverse morphologically. All have piercing, sucking mouthparts that lie in a beak-like grooved labium. Most hold their head horizontally with the mouthparts directed backwards (opisthognathous). All but the true bugs (Heteroptera) have two pairs of membranous wings that are held in a tentlike or rooftop position over the body when at rest. Heteropterans have a triangle on the back just behind the head. This is formed by the way the insects fold their forewings when at rest. They have two pairs of wings: the hind wings are all membranous, while the basal half of the forewings is hardened. Some bugs look similar to beetles, but you can distinguish them by seeing that the wings form a triangle on the back instead of meeting in a straight line. They undergo incomplete metamorphosis.

Diagnosis:

- Forewing a hemelytron in Heteroptera, completely membranous in remaining (paraphyletic grade sometimes called “Homoptera”).
- Wings folded flat over abdomen or rooflike.
- Piercing-sucking mouthparts with beaklike labium—in Heteroptera beak arises in front of head, in “Homoptera” beak arises in back of head, appearing to arise from between forelegs in some groups.
- Palps absent.
- Antennae long and conspicuous or short, bristlelike, and concealed.
- Tarsi 1 to 3-segmented.
- Scutellum generally triangular.

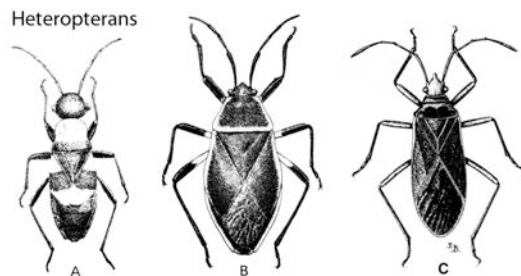
Habitats and Habits:

- Terrestrial and aquatic. Feed on plant juices, many host specific; some are predatory, including bloodsuckers. Many Heteroptera with scent glands on metathorax. Some “Homoptera” with complex life cycles.



Collecting and Preserving: Beating, sweeping vegetation on land and in water; **UV lights.** Pin large hard-bodied forms. Aphids and scale insects must be slide mounted, record identity of host plant.

Distribution: Largest order of non-holometabolous insects. 90,000 species in 140 families worldwide. About 12,000 species in USA and Canada.

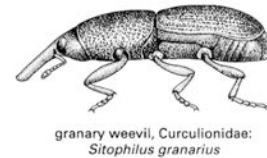
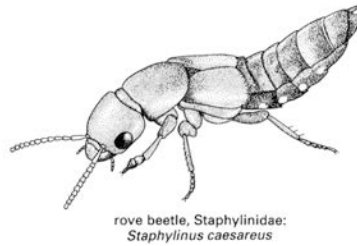
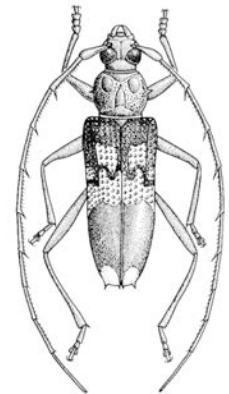
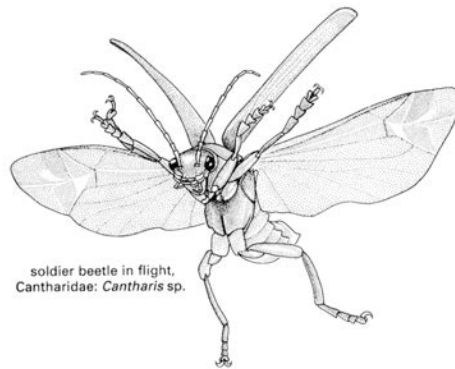


Sheet 4: COLEOPTERA: Beetles

Identification: The main clue to beetles is a pair of hardened wings covering the top of the body and meeting in a straight line down the back. Beetles have two pairs of wings, but you do not often see both pairs since, when at rest, the membranous flying hind wings are folded under the tough front ones. They undergo complete metamorphosis.

Diagnosis:

- Very large and diverse group—1 in every 4 animals is a beetle.
- Terrestrial and aquatic.
- 0.0025mm (feather-winged beetles) to 150mm (rhinoceros and Hercules beetles).
- Dull to brightly colored
- Generally 11-segmented antennae.
- Elytra (forewings) sclerotized, with longitudinal ridges and pits, venation unrecognizable, cover HW and abdomen—sometimes shortened.
- No cerci
- External genitalia withdrawn in abdomen.



Habitat and habits:

- Beetles are found in just about every environment doing just about everything. There are even beetles that are ectoparasites on beavers and otters! They reach their peak diversity in the phytophagous (plant-feeding) lineages, but are also carnivores, fungivores, detritivores, coprophages (dung-feeders), and ectoparasites.

Collecting and Preserving: Collected almost anywhere. UV lights, beating sweeping, numerous trapping methods. Pin or point, never on slides.

Distribution: More than 350,000 species already described worldwide. About 30,000 species in USA and Canada. Perhaps the most famous quote about beetles comes from the great population geneticist J.B.S. Haldane, who was asked what might be learned about a Creator by examining the world. His response: "an inordinate fondness for beetles".

Sheet 5: NEUROPTERA: Lacewings, Antlions, Owlflies

Identification: The adults of this order possess four membranous wings, with the forewings and hindwings about the same size, and with many veins and crossveins. They have chewing mouthparts, and undergo complete metamorphosis.

Diagnosis:

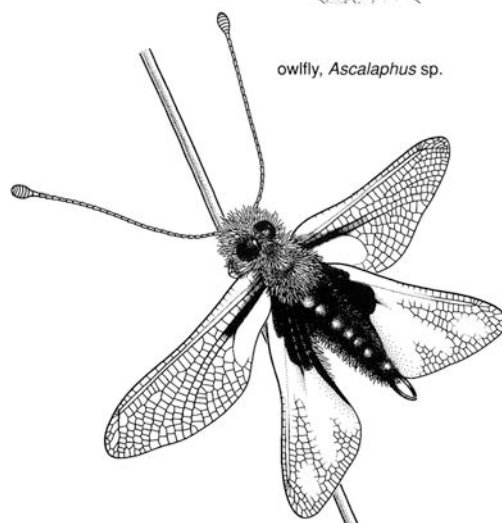
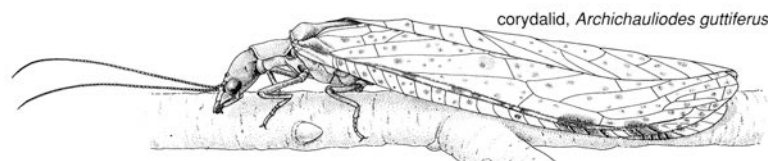
- Forewings and hindwings similar in size and shape, with many veins and crossveins, hindwing anal area not folded.
- Larvae with grooved elongate mandibles covered by elongate maxillary lobe, forming piercing-sucking tubes.
- If prothorax lengthened then forelegs are raptorial and arise from anterior end (mantisflies).

Habitat and habits:

- Predaceous in the larval stage, particularly on "Homoptera" especially aphids; some feed on insect eggs. Adult and larvae found most often on vegetation. Sisyridae (spongillaflies) have aquatic larvae that feed on freshwater sponges. Mantispidae (mantisflies) are parasitic on spider egg masses. Myrmeleontidae (antlion) larvae live in dry sand where they construct conical pits used to capture insect prey. Brown lacewing larvae carry debris on hooked spines and bristles on back for concealment. Green lacewings have stalked eggs and larvae feed on aphids.

Collecting and Preserving: UV lights best for adults, also beating. Pin, can spread wings.

Distribution: About 5,000 species worldwide; about 400 in USA and Canada.

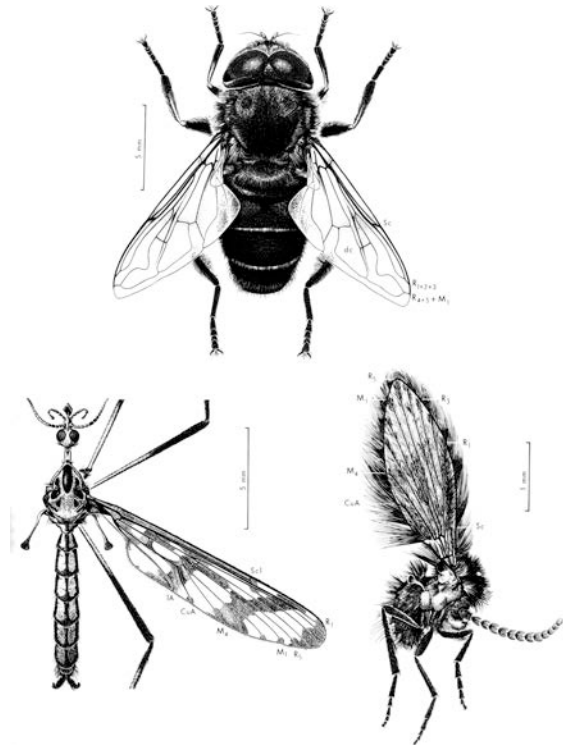


Sheet 6: DIPTERA: True flies

Identification: If you find an insect with just one pair of wings, then it is most likely a fly of some kind (some scale insect males have one set of wings, as do twisted-winged parasites). Not all flies look like houseflies: some are delicate, such as mosquitoes, some look like bees or wasps (check for one pair of wings!), and some are extremely small, such as gnats. Metamorphosis is complete.

Diagnosis:

- Overall shape surprisingly uniform: head more or less globular; thorax oval or hump-backed; abdomen elongate, cylindrical, or oval.
- Usually dull in color—black, brown, pale; few brightly colored forms.
- Body with spines, setae, and often scales—arranged in definitive patterns and very important taxonomically—chaetotaxy.
- Head with many features used in identification—setae, ocelli, ptilinal fissure (allows emergence from pupal stage), lunule, antennae.
- Mouthparts highly modified, but derived from common groundplan: piercing sucking (mosquitoes), sponging (houseflies), stabbing (horseflies), nonfunctional.
- Thorax, especially mesothorax, and wing venation very important taxonomically.



Habits and habitats:

- Very diverse, especially larvae. Most larvae are detritus feeders and include fully aquatic species (most diverse group of aquatic insects), including those found in brine and oil; stem, leaf and fruit borers; gall formers, flower and sap feeders; carrion, feces, and garbage feeders; mucus feeders; parasitoids and predators (biocontrol); endo- and ectoparasites. Adults, especially primitive species occur in moist, shady areas and are primarily crepuscular or nocturnal. Others are diurnal. Most adult Diptera feed on honeydew, nectar, or pollen, while others are bloodsuckers.

Collecting and Preserving: Netting and light trapping, especially New Jersey traps; also rearing. Pin, point, or minuten immediately. Try not to collect in ethanol.

Distribution: 150,000 species described worldwide, about 25,000 in over 2,200 genera in Nearctic.

Sheet 7: LEPIDOPTERA: Moths & Butterflies

Identification: These insects are easy to know, for their two pairs of wings are covered with small scales that rub off easily.

Diagnosis:

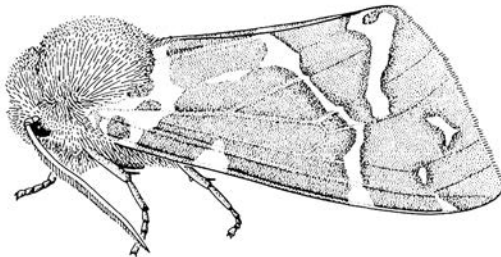
- Size minute to very large
- Body and wings covered with scales, often very colorful.
- Siphoning mouthparts, coiled beneath head.
- Antennae plumose or clavate

Habits and habitats:

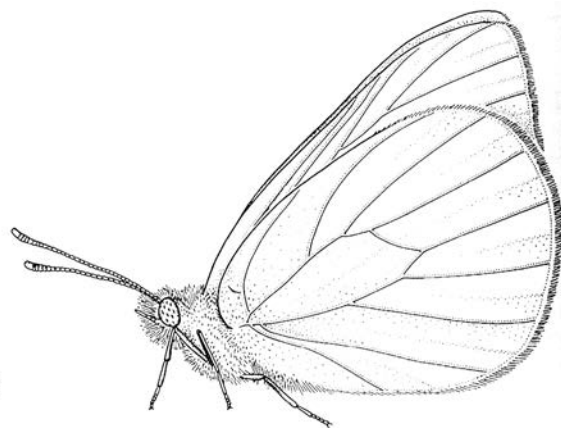
- Adult moths generally nocturnal, butterflies and skippers diurnal. Adults suck nectar or feed on pollen; some noctuids suck blood. Habits and habitats of the larvae are very diverse and include external leaf feeders; leaf, woody stem, and fruit and nut borers; stored products and detritus feeders; fungus and lichen feeders; few parasites and predators; some feed on decomposing plant and animal matter. Many are of great economic importance.

Collecting and Preserving: Collect adult moths at lights, butterflies during day with aerial nets. Can also set out baits or other attractants. Minimize handling of specimens and use cyanide kill jars for rapid killing—avoid rubbing off scales. Pinch thorax or inject with alcohol with hypodermic syringe. Paper specimens and keep them moist. Wings must be spread. Collect larvae live, record host plant, can attempt to rear. Kill larvae by boiling first in water or FAA solution for a minute or so; preserve permanently in 80%EtOH. Never place live larvae directly in alcohol.

Distribution: 180,000 species worldwide, about 13,000 in USA and Canada.



garden tiger moth, Arctiidae: *Arctia caja*



cabbage white butterfly, Pieridae: *Pieris rapae*

Sheet 8: Hymenoptera: Ants, Bees, Wasps, Sawflies

Identification: All of these insects have two pairs of thin, clear, membranous wings, with the forewing a little larger than the hindwing. In the females, the abdomen ends in a well-developed egg-laying organ and/or stinger. Metamorphosis is complete.

Diagnosis:

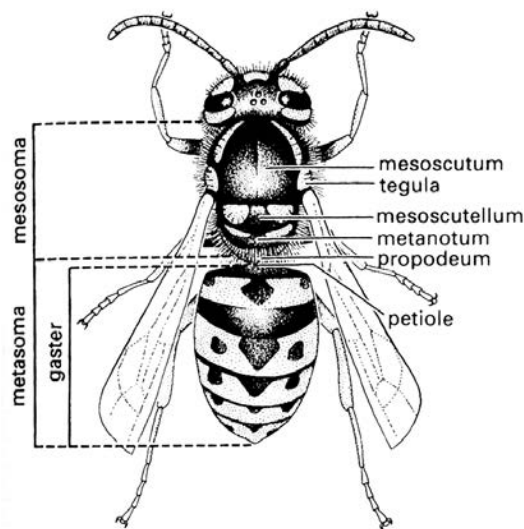
- Minute to very large
- Usually dark brown or black, but often marked yellow, red, white, metallic blue or green.
- Mandibulate mouthparts, but with lapping tongue—maxillo-labial complex.
- Wings membranous, hindwings smaller than forewings; sometimes wingless.
- Forewings usually attached to hindwings by a row of hooks called hamuli.
- First abdominal segment fused with thorax (propodeum).

Habitat and habits:

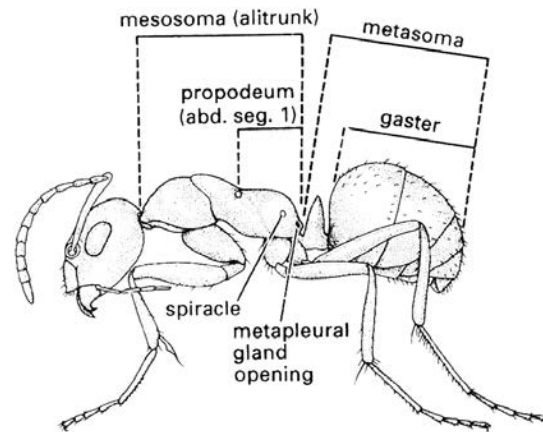
- Very diverse biology. Leaf feeders, miners, gall formers, parasites, predators, pollen and nectar gatherers, fungus gardeners, and insect farmers, but few scavengers except among the ants. Three major groups: “Symphyta”—sawflies, plant feeders; “Parasitica”—parasitoids of other arthropods; Aculeata—bees, ants, wasps, hunt arthropod prey or gather pollen and nectar on which to feed. Many display sociality to one degree or another.

Collecting and Preserving: Collect from flowers and nests; rear parasitic species from hosts; black Malaise traps for Ichneumonidae; netting. Pin and point or minuten, larvae in 80% EtOH.

Distribution: 200,000 species described worldwide; 17,500 in USA and Canada. Likely massively gross underestimate for both.



worker of the European wasp, *Vespula germanica*



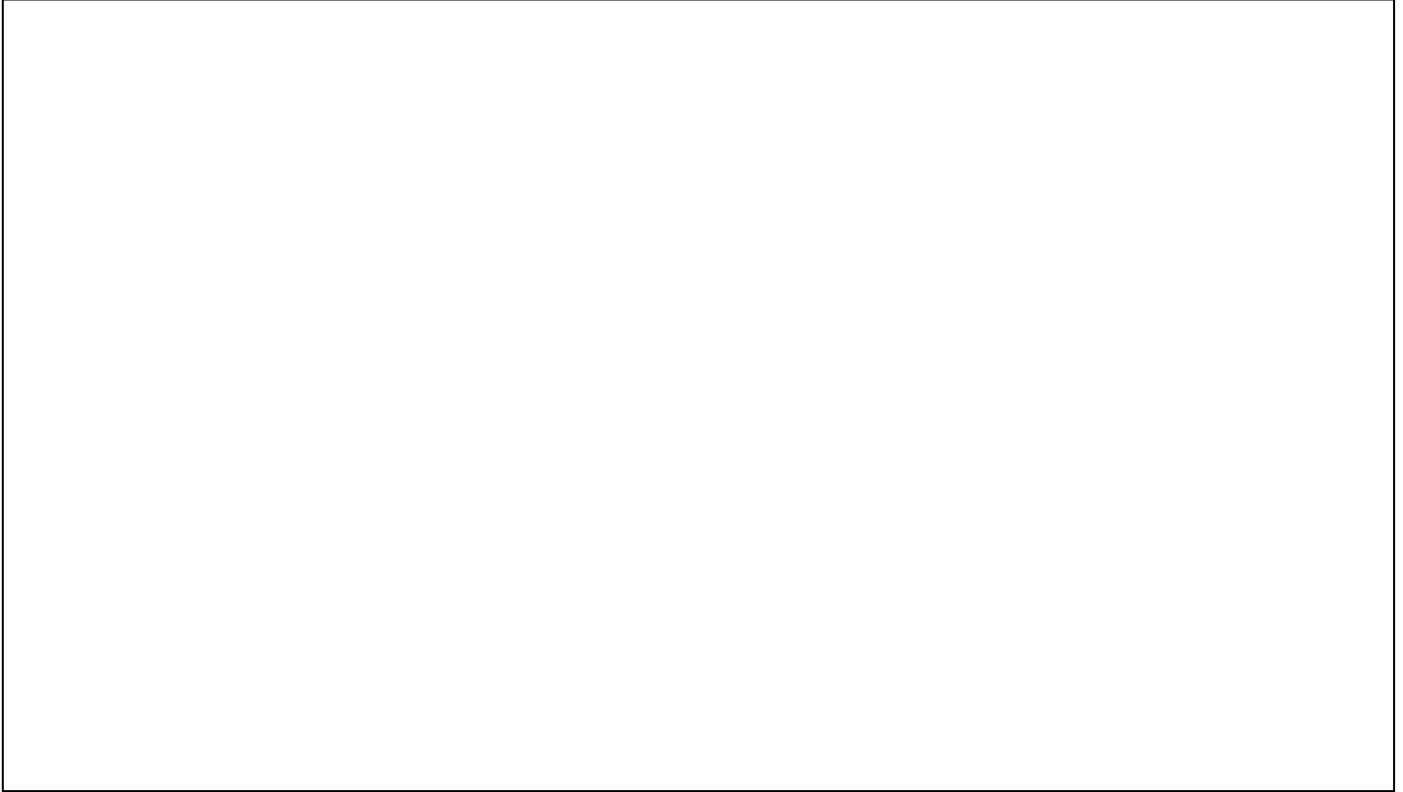
worker ant of *Formica subsericea*

COMMONLY ENCOUNTERED MINOR ORDERS

1. Order **ARCHAEOGNATHA** (Bristletails) and **ZYGENTOMA** (Silverfish). Fast-moving insects with styliform appendages on the abdomen; chewing mouthparts; destructive to clothing and books; primitively wingless; metamorphosis lacking.
2. Order **EPHEMEROPTERA** (Mayflies). First pair of net-veined wings larger than second pair; two or three caudal appendages; vestigial chewing mouthparts of short-lived adults; metamorphosis incomplete.
3. Order **PLECOPTERA** (Stoneflies). Medium-sized or small, somewhat flattened, soft-bodied, rather drab-colored insects found near streams or rocky lake shores; they are poor fliers and are seldom found far from water; most species have four membranous wings; the front wings are elongate and rather narrow and usually have a series of cross veins between M and Cu₁ and between Cu₁ and Cu₂; the hind wings are slightly shorter than the front wings and usually have a well-developed anal lobe that is folded fanwise when the wings are at rest; metamorphosis incomplete.
4. Order **ISOPTERA** (Termites). Abdomen broadly joined to the thorax; bodies soft and often whitish; these colonial, social insects have winged and wingless individuals; wings are equal in length; chewing mouthparts; metamorphosis incomplete.
5. Order **BLATTODEA** (Cockroaches). Cursorial insects with five-segmented tarsi and none of the legs modified for digging or grasping; the body is oval and flattened and the head is concealed above from the pronotum; cerci are one- to many-segmented and usually fairly long; the antennae are long and filiform; metamorphosis incomplete.
6. Order **MANTODEA** (Mantises). Often large, elongate, rather slow-moving insects that are striking in appearance because of their peculiarly modified raptorial front legs; prothorax is greatly lengthened and movably attached to the pterothorax; the front coxae are very long and mobile; and the front femora and tibiae are armed with strong spines and fitted for grasping prey; the head is freely movable; metamorphosis incomplete.
7. Order **PHASMATODEA** (Walking sticks). Body elongated and sticklike; wings are often much reduced or entirely absent; cerci are short and one-segmented; metamorphosis incomplete.
8. Order **DERMAPTERA** (Earwigs). Elongate, slender, somewhat flattened insects that resemblerove beetles but have forceps-like cerci; if winged, the front wings are short, leathery, and veinless; and the wings are membranous and rounded with radiating veins.
9. Order **THYSANOPTERA** (Thrips). Minute, slender-bodied insects; wings when fully developed are four in number, very long and narrow with few or no veins, and fringed with long hairs; metamorphosis incomplete.
10. Order **TRICHOPTERA** (Caddisflies). Four membranous wings are rather hairy and are usually held rooflike over the abdomen at rest; the antennae are long and slender; metamorphosis complete.

Make a rough sketch of representative from the following orders. **Annotate your sketches to note the unique traits for *each particular order*.**

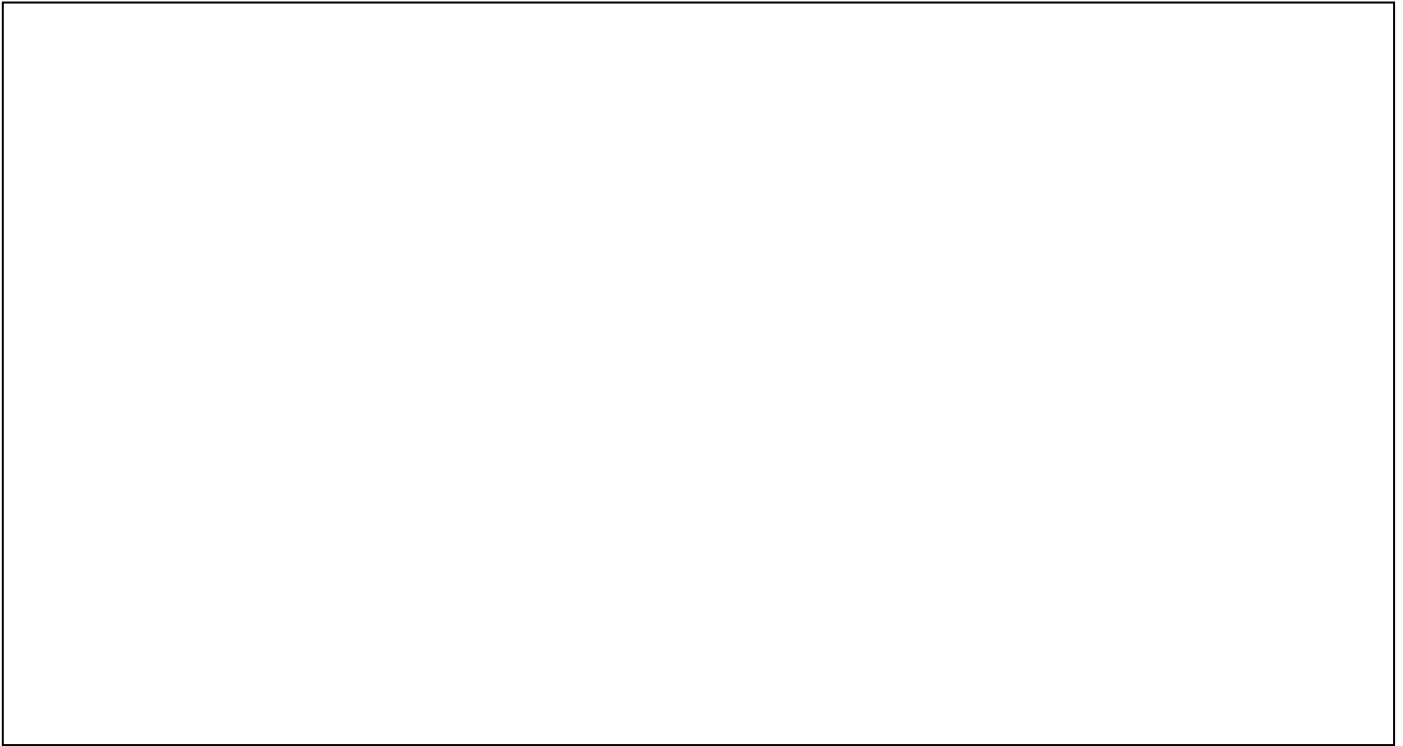
1. Odonata



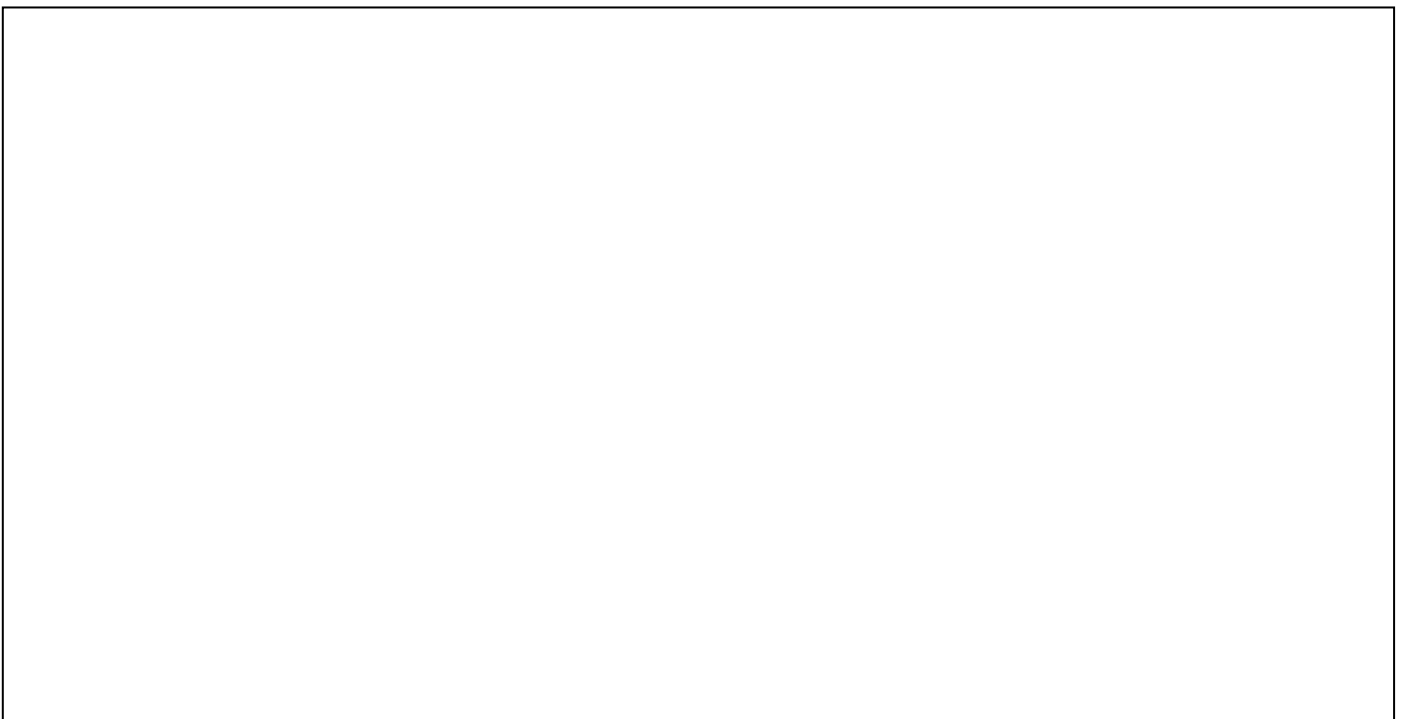
How does this **differ** from a Neuroptera?



2. Hemiptera (make sure you sketch EITHER a Heteroptera or a Hopper—ask Dr. Morse about this if unclear). Look closely at the **mouthparts**, **antennae**, and **wing position/structure**. Note how these differ from a Coleoptera or Orthoptera.



3. Coleoptera. Make sure that you can recognize the **elytra** and the **mandibulate mouthparts**.



4. Diptera. Pay close to attention to recognizing the **halteres**. These are easy in some but VERY difficult in things like house flies or *Drosophila*.



5. Lepidoptera. Notice especially the scales on the wings and the haustellate mouthparts.



6. Hymenoptera. Look at either a bee or a wasp. Make sure you annotate the narrowed waste and the **propodeum**.

