


## Animals 3: Terrestrial Arthropods

Biology 6A / Sanhita Datta  
Winter 2008

As described in the previous general discussion of Phylum Arthropoda, this extremely successful taxon is characterized by cephalized, bilateral symmetry; a segmented body typically with a pair of specialized jointed appendages on each **somite** (segment); fusion of multiple somites into a functional body region called a **tagma**; and a chitinous true exoskeleton that provides both protection of the internal organs and attachment of muscle bands. Whereas the arthropod class Crustacea dominate the marine environments — and a few crustacean groups such as the pillbug isopods do inhabit the land — the terrestrial world has been thoroughly colonized by three other classes of this phylum:

- I. Arachnida — spiders, scorpions, mites, ticks. Body in two tagmata:
  - a. the prosoma (“forebody”), or **cephalothorax**, with several simple eyes (ocelli), no antenna, and six pairs of appendages (one pair of fanged chelicera, one pair of tactile pedipalps, and four pairs of legs).
  - b. the opisthosoma (“hind body”), or **abdomen**, often without appendages other than ovipositors on females, and web spinnerets on spiders. Scorpion abdomen ends with a segmented tail.
- II. Myriapoda — centipedes, millipedes. Elongated body in two tagmata: the **head** and the highly segmented **trunk** with a pair of legs on each segment.
- III. Insecta — the insects. We will consider this most diverse group of organisms in more detail.

 **Read the description of insects. Carefully observe the pill bugs and spiders. Note at least three observable features from the description that clearly show why these both are not insects.**

## Insects

As measured by diversity, distribution and abundance, insects are considered the most successful group of organisms living on Earth. Almost one million species have been described — more than all other animal species combined — and there may be at least ten times that many yet to be identified. Insects are extraordinarily adaptable creatures, with the physical and behavioral plasticity to live successfully in almost every terrestrial environment on earth, from the desert to the Antarctic. Millions of insects may exist in a single acre of land. They are the main consumers of land plants and constitute a major food source for many other animals.

Insects are directly beneficial to humans by producing honey, silk, wax, and other products. Indirectly, they are important as pollinators of crops, natural enemies of pests, scavengers, and food for other creatures. At the same time, some insects are major pests of humans and domesticated animals because they destroy crops and vector diseases. In reality, less than one percent of insect species are pests, and only a few hundred of these are consistently a problem.

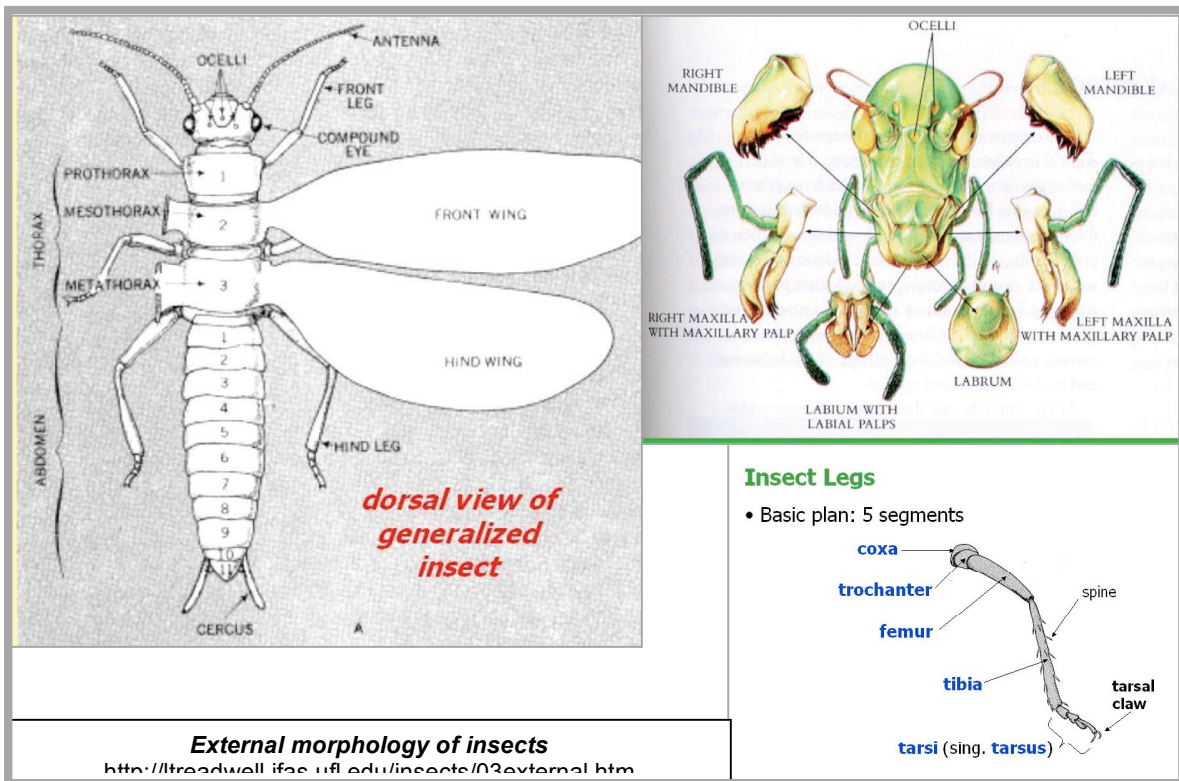
Insects have many characteristics that have been favorable to their success.

1. Waterproof cuticle. As with all arthropods, the epidermis of insects secretes a cuticle (**procuticle**) made of protein and the amino-polysaccharide,  **$\alpha$ -chitin**, that creates a strong, flexible, moldable exoskeleton. In addition, insects (and arachnids) also secrete an outer waxy **epicuticle** that waterproofs their skin to resist desiccation in dry terrestrial environments.

2. Small body size. Insects can exploit small microhabitats and do not require many resources to achieve maturity. Very little food is needed for growth and a greater proportion of their energy can be diverted to reproduction.
3. Winged flight. Most insects have wings at some stage of their life history. Hence, despite their small size, they can range widely for dispersal into favorable habitats and to locate sparse resources. The ability to fly also provides an effective escape from predators.
4. Very high reproductive output. A single female can produce hundreds or thousands of offspring. Any new resource or habitat can be rapidly exploited and a high genetic diversity of young may evolve rapidly in response to environmental challenges.
5. Metamorphic development. Many insects have very different juvenile and adult body forms. Thus adults and juveniles exploit different habitats and food sources without competing with each other.
6. Coevolution with flowering plants. Refer to our Plants 3 & 4 labs. See also Campbell, p. 604.

## INSECT BODY FORMS

Insect bodies are divided into three body regions: **head**, **thorax**, and **abdomen**. Tactile and chemosensory **setal hairs** may occur on any/all tagmata. With so many orders and species, the variability of insect body forms is staggering. But observe these general patterns.






**Head:** The head of an insect develops as a fusion of six or more segments, although in the adult often only five are apparent. The first (anterior) segment bears many sensory structures including the single pair of **antennae** [crustaceans have two pair] with tactile and chemical receptors. Insects with bushy antennae are typically very sensitive to chemical pheromones (moths) or sound vibrations (mosquitoes). There are also here a pair of **compound eyes** — sophisticated visual organs unique to insects and some myriapods. A compound eye is

constructed of multiple facets, each facet having an independent lens and set of photoreceptors, and collectively providing good color vision and excellent detection of motion. Visual hunters like dragonflies have enormous compound eyes. Bees use them like polarized sunglasses to sense sun angles for navigation. In addition to their compound eyes, insects usually have a set (often of three) of simple eyes (**ocelli**) on this segment of their heads.

The remaining head segments and appendages are mostly devoted to feeding. Anterior to the mouth is the **labrum** (upper lip). Posterior to the mouth, on sequential segments, are a pair of jaw-like **mandibles**, a pair of **maxillae**, and the bilobed **labium** (lower lip). These mouthparts occur in an extreme diversity of modifications reflecting the extreme diversity of feeding types among the insects. Some examples include chewing mouthparts in grasshoppers (Orthoptera), a sponge-like fluid collector in flies (Diptera), piercing mouthparts in true bugs (Hemiptera), and a sucking straw-like “tongue” in bees (Hymenoptera) and butterflies (Lepidoptera).

**Thorax:** The insect thorax is its mobility tagma. Fused from three limbed segments, the thorax bear three pairs of walking legs, although in some groups the anterior pair may be used primarily for carrying. Additionally, the second and third thoracic segments of the adult phase usually bear two pairs of wings. Specializations of wing structure are often used to identify insect orders. (Many names of orders end with the suffix *-ptera* = “wings”.) Spiracles opening to the respiratory trachea are usually located above the legs on the second and third segments as well.

**Abdomen:** The abdomen develops from eleven segments (somites) and contains most of the visceral organs, including the digestive, excretory, and reproductive organs. There are no appendages on the abdomen except for the ovipositors on the eleventh segment of females, or structures (e.g., stingers) derived from ovipositors. (Male copulatory organs are retractable. Their terminal abdominal segment generally is more rounded than in females.) In some species, a lateral pair of unsegmented **cerci** may project just anterior to the eleventh somite. The abdomen usually retains a segmented appearance and the sutures between the abdominal sclerites are often flexible, allowing the abdomen to expand when eating or when the ovaries are full of eggs. Most abdominal segments bear a pair of lateral **spiracles**.

-  **Examine the preserved whole specimens of lubber grasshoppers (*Romalea*) using the dissecting microscope. Identify the somites, tagmata, and morphological features described above (all terms in bold). Notice the membrane (tympanum) located on each side of the first abdominal segment. What is this for? Why is it only in grasshoppers?**
-  **Remove the head of the grasshopper and examine at maximum zoom on the dissecting scope or with scanning objective of the compound microscope. Remove the antennae and all mouthparts and arrange them all on a slide to observe under the compound microscope.**
-  **Use the compound microscope to examine the prepared slides of antennae, mouthparts, legs, and stinger from a honeybee (*Apis*). Identify these structures and compare them with the corresponding parts of the grasshopper.**

## **INSECT LIFE HISTORIES**

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Another trait leading to the success of terrestrial arthropods is internal fertilization of eggs, which prevents gametes from drying out. The fertilized eggs generally are then deposited with a waxy coat by means of the ovipositor at the terminus of the female abdomen. A few insect species retain their eggs internally and give live birth. One of the most flexible reproductive systems is found in aphids. During a brief period of the year they reproduce sexually as described above. But for most of the year, the eggs develop asexually without being fertilized (parthenogenesis)

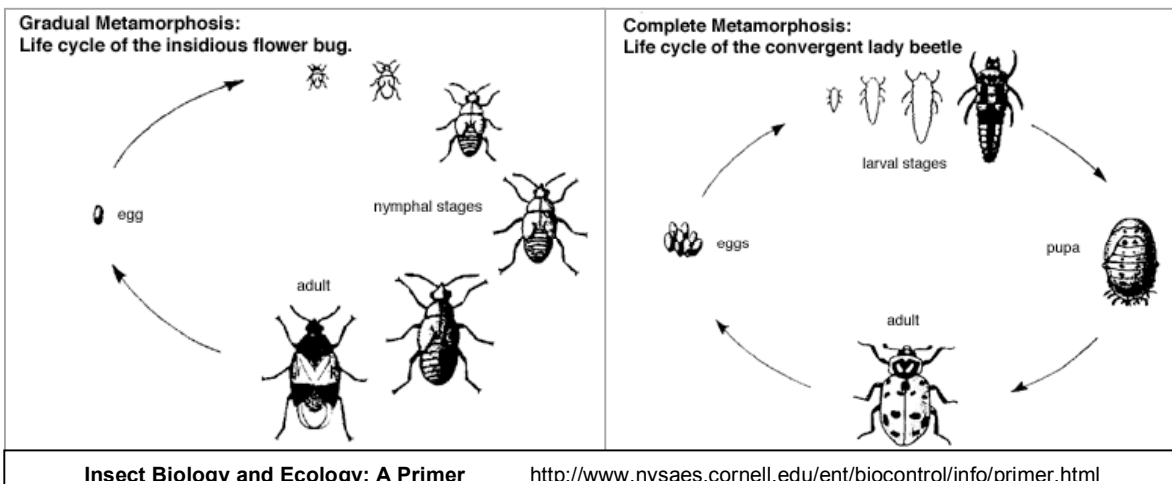
and are retained within the females for live birth. In fact, they have "telescoping generations" with the offspring live-born already pregnant!

Since arthropod bodies are enclosed within an exoskeleton, growth is **discontinuous**. I.e., growth only occurs in spurts when the cuticle is molted (**ecdysis**). At ecdysis, the cuticle becomes thinner and weaker, especially at the sutures between sclerites. The arthropod body swells, usually by taking on water, splitting and shedding the old cuticle. A new cuticle hardens over the swollen body providing room for tissue growth until the next ecdysis. Unlike many crustaceans, in insects only the juvenile forms molt. After hatching from the egg, each immature stage, called an **instar**, eats voraciously and molts frequently into progressively larger size classes. But after the terminal molt into the adult form, the insect no longer will grow and all food energy beyond that needed for maintenance is devoted to reproduction. In many insects, the adults do not feed at all and live off fat stores accumulated as a juvenile to live only long enough to disperse and spawn.

A few insect orders, such as the silverfish (Thysanura) have direct development without metamorphosis (**ametabolous**). The juvenile instars look just like small adult forms.

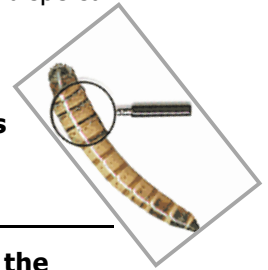
Several other orders have a gradual or incomplete metamorphosis (**hemimetabolous**) over three to five molts becoming more adult-like. These juvenile instars are called **nymphs**, and look like wingless adults with only some differences in proportion or coloration. Common examples of such orders are the grasshoppers and crickets (Orthoptera), earwigs (Dermaptera), cockroaches (Blattaria), "true" bugs (Hemiptera), and aphids (Homoptera). Dragonflies (Odonata) have aquatic nymphs (naiads) that not only are wingless, but have abdominal gills lost upon terminal molt with the opening of the spiracles and emergence from the water to their air-born adult lifestyle.

Insects that undergo complete metamorphosis (**holometabolous**) pass through four basic life stages: egg, **larva**, **pupa**, and adult. Caterpillars, maggots, and grubs are common examples of larvae. During the larval stage there may be three to seven instars, all of which usually are active, and often voracious feeders. As much as 90% of an insect's total weight gain may occur during the last two larval instars. The pupal stage (e.g., cocoon, puparia, chrysalid) is a non-feeding stage that follows the specialized molt from the larval stage. During the pupal stage, many physiological and morphological changes occur. Internally, the insect is going through the process of changing to the adult form. The encased pupal stage may also allow the insect to pass through adverse conditions in protected areas such as leaf litter and soil without exhausting energy. During the final molt, the adult emerges from the hardened exoskeleton of the pupal case. Adults are usually winged and may differ from the larvae in a number of ways including type of legs, mouthparts and feeding habits. Adults of insects undergoing complete metamorphosis are very different in form from the larvae. They may be found in habitats similar



to the larvae, such as some beetles (Coleoptera), or in very different habitats than the larvae, such as bees and wasps (Hymenoptera), butterflies and moths (Lepidoptera), and "true" flies (Diptera). The larval stage tends to specialize in feeding. The adult stage specializes in dispersal and reproduction.

- Observe the live specimens of the hemimetabolous crickets and the holometabolous darkling beetles. Identify each of their respective life stages



**KEY TO THE PRINCIPLE ORDERS OF INSECTS**

- Refer to Figure 33.37 on pp. 662–663 of Campbell. Read the descriptions of the insect orders: **Coleoptera; Dermaptera; Diptera; Hemiptera; Hymenoptera; Lepidoptera; Odonata; Orthoptera.**
- Use the dichotomous key on the following pages to identify the assortment of pinned insects to order. (Use a clothes-pin to hold the pin of the specimen under the dissecting microscope.) Illustrated versions of this key may be found in the available field guides. Key out at least one specimen for each of the above orders. Write out the steps as you progress through the key.
- For each specimen, also describe their respective types of mouth parts (chewing, siphoning, or piercing) and how it relates to their diet or feeding behaviors.
- Take the quiz demonstrating your ability to use the key and to identify unknown representative specimens for the above orders. Record your answers on a standard Scantron form.

<p><b>chewing mouthparts</b></p> <p>Grasshopper (order Orthoptera, Acrididae): mouthparts directed downward and specialized for processing plant materials</p> <p>K.B. Sanford &amp; M.G. Emley ©1978 Viking Penguin</p>		<p><b>Gulf fritillary butterfly (order Lepidoptera, Nymphalidae): coiled mouthparts, adapted for siphoning nectar</b></p> <p><b>Siphoning mouthparts</b></p>		<p style="writing-mode: vertical-rl; transform: rotate(180deg);">External morphology of insects <a href="http://treadwell.ifas.ufl.edu/insects/03external.htm">http://treadwell.ifas.ufl.edu/insects/03external.htm</a></p>
<p><b>piercing-sucking . . .</b></p> <p>The mouthparts of a mosquito</p>		<p><b>Box elder bug (order Hemiptera); mouthparts modified into stylets for piercing plants and sucking out juices</b></p> <p><b>piercing-sucking mouthparts</b></p> <p>K.B. Sanford &amp; M.G. Emley ©1978 Viking Penguin</p>		

## Terms & Concepts to Remember:

- **ametabolous / hemimetabolous / holometabolous**
- **antennae:** Crustaceans have two pair, insects have one pair, arachnids have none.
- **Arthropod = jointed appendages. Classes include Crustacea, Insecta, Myriapoda, & Arachnida**
  - **What features are common to all arthropod classes?**
  - **What features are unique to insects?**
- **cercus (plural: cerci)**
- **compound eyes & ocelli**
- **dichotomous key**
- **ecdysis & discontinuous growth**
- **exoskeleton / chitinous procuticle / waxy epicuticle**
- **cephalothorax**
- **head, thorax, & abdomen**
- **Insecta. Orders include Coleoptera; Dermaptera; Diptera; Hemiptera; Hymenoptera; Lepidoptera; Odonata; Orthoptera**
- **instar**
- **internal fertilization**
- **labrum, mandibles, maxillae, & labium / chewing, siphoning, or piercing**
- **larva & pupa**
- **metamorphosis**
- **nymph**
- **setal hairs**
- **somite**
- **spiracles & tracheae**
- **tagma (plural: tagmata)**
- **wings**

## DICHOTOMOUS KEY TO THE PRINCIPAL ORDERS OF INSECTS

1.	<input type="radio"/> With functional wings.....2 <input type="radio"/> Without functional wings, or with forewings thickened and concealing membranous hindwings .....15
2.	<input type="radio"/> Wings covered with minute scales; mouthparts usually a coiled tube (butterflies, moths) ..... <b>The specimen is Lepidoptera</b> <input type="radio"/> Wings usually clear, not covered with scales; mouthparts not a coiled tube.....3
3.	<input type="radio"/> With one pair of wings (true flies)..... <b>The specimen is Diptera</b> <input type="radio"/> With two pairs of wings.....4
4.	<input type="radio"/> Wings long, narrow, fringed with long hairs, body length 5 mm or less (thrips) ..... <b>The specimen is Thysanoptera</b> <input type="radio"/> Wings not narrow and fringed, body usually longer than 5 mm.....5
5.	<input type="radio"/> Abdomen with two or three threadlike "tails"; hindwings small (mayflies) ..... <b>The specimen is Ephemeroptera</b> <input type="radio"/> Abdomen with only short filaments or none; hindwings larger.....6
6.	<input type="radio"/> Forewings clearly longer and with greater area than hindwings.....7 <input type="radio"/> Forewings not longer, or slightly longer than hindwings, and with same or less area than hindwings.....9
7.	<input type="radio"/> Forewings noticeably hairy; antennae as long or longer than body (caddis flies) ..... <b>The specimen is Trichoptera</b> <input type="radio"/> Wings transparent or translucent, not hairy; antennae shorter than body.....8
8.	<input type="radio"/> Tarsi 2-segmented or 3-segmented; body not wasplike or beelike.....14 <input type="radio"/> Tarsi 5-segmented; usually wasplike or beelike (sawflies, ichneumons, winged ants, wasps, bees) ..... <b>The specimen is Hymenoptera</b>
9.	<input type="radio"/> Head prolonged ventrally into a beaklike structure (scorpionflies) .... <b>The specimen is Mecoptera</b> <input type="radio"/> Head not prolonged ventrally.....10
10.	<input type="radio"/> Antennae very short and bristlelike; eyes large; abdomen long and slender (dragonflies, damselflies) ..... <b>The specimen is Odonata</b> <input type="radio"/> Antennae not short and bristlelike; eyes moderate to small.....11
11.	<input type="radio"/> Hindwings broader than forewings; cerci present(stoneflies) ..... <b>The specimen is Plecoptera</b> <input type="radio"/> Hindwings little if any broader than forewings; cerci absent.....12
12.	<input type="radio"/> Mothlike; wings noticeably hairy and opaque; antennae as long or longer than body (caddis flies) ..... <b>The specimen is Trichoptera</b> <input type="radio"/> Not mothlike; wings not noticeably hairy, usually clear; antennae shorter than body.....13
13.	<input type="radio"/> Wings with few cross veins; tarsi 4-segmented; length to 8 mm (termites) ..... <b>The specimen is Isoptera</b> <input type="radio"/> Wings with numerous cross veins; tarsi 5-segmented; length to 75 mm (fishflies, dobsonflies, lacewings, ant lions) ..... <b>The specimen is Neuroptera</b>
14.	<input type="radio"/> Mouthparts sucking, beak arising from rear of head (cicadas, hoppers, aphids) ..... <b>The specimen is Homoptera</b> <input type="radio"/> Mouthparts chewing, beak absent; body length less than 7 mm (book lice, bar lice) ..... <b>The specimen is Pscoptera</b>

15.	<input type="radio"/> Wings entirely absent.....16 <input type="radio"/> Wings modified, forewings hard and leathery and covering hindwings.....27
16.	<input type="radio"/> Narrow-waisted, antlike (ants, wingless wasps) ..... <b>The specimen is Hymenoptera</b> <input type="radio"/> Not narrow-waisted or antlike.....17
17.	<input type="radio"/> Body rarely flattened laterally; usually do not jump.....18 <input type="radio"/> Body flattened laterally; small jumping insects (fleas) ..... <b>The specimen is Siphonaptera</b>
18.	<input type="radio"/> Parasites of birds and mammals; body nearly always flattened dorsoventrally.....19 <input type="radio"/> Never parasitic; body usually not flattened.....20
19.	<input type="radio"/> Head as wide or wider than thorax (chewing lice)..... <b>The specimen is Mallophaga</b> <input type="radio"/> Head narrower than thorax (sucking lice)..... <b>The specimen is Anoplura</b>
20.	<input type="radio"/> Abdomen with stylelike appendages or threadlike tails (silverfish, bristletails) ..... <b>The specimen is Thysanura</b> <input type="radio"/> Abdomen with neither styles nor tails.....21
21.	<input type="radio"/> Abdomen with a forked tail-like jumping mechanism (springtails).... <b>The specimen is Collembola</b> <input type="radio"/> Abdomen lacking a jumping mechanism.....22
22.	<input type="radio"/> Abdomen usually with two short tubes; small, plump, soft-bodied (aphids, others) ..... <b>The specimen is Homoptera</b> <input type="radio"/> Abdomen without tubes; usually not plump and soft-bodied.....23
23.	<input type="radio"/> Lacking pigment, whitish; soft-bodied.....24 <input type="radio"/> Distinctly pigmented; usually hard-bodied.....25
24.	<input type="radio"/> Antennae long, hairlike; tarsi 2-segmented or 3-segmented (psocids) ..... <b>The specimen is Psocoptera</b> <input type="radio"/> Antennae short, breadlike; tarsi 4-segmented (termites)..... <b>The specimen is Isoptera</b>
25.	<input type="radio"/> Body shape variable; length over 5 mm.....26 <input type="radio"/> Body narrow; length less than 5 mm (thrips)..... <b>The specimen is Thysanoptera</b>
26.	<input type="radio"/> Antennae 4-segmented or 5-segmented; mouthparts sucking (wingless bugs) ..... <b>The specimen is Hemiptera</b> <input type="radio"/> Antennae many-segmented; mouthparts chewing (some cockroaches, walkingsticks) ..... <b>The specimen is Orthoptera</b>
27.	<input type="radio"/> Abdomen with forcepslike cerci (earwings)..... <b>The specimen is Dermaptera</b> <input type="radio"/> Abdomen lacks forcepslike cerci.....28
28.	<input type="radio"/> Mouthparts sucking; beak usually elongate.....29 <input type="radio"/> Mouthparts chewing.....30
29.	<input type="radio"/> Forewings nearly always thickened at base, membranous at tip; beak rises from front or bottom of head (true bugs) ..... <b>The specimen is Hemiptera</b> <input type="radio"/> Forewings of uniform texture throughout; beak arises from hind part of head (hoppers) ..... <b>The specimen is Homoptera</b>
30.	<input type="radio"/> Forewings with veins, at rest held rooflike over abdomen or overlapping (grasshoppers, crickets, cockroaches, mantids)..... <b>The specimen is Orthoptera</b> <input type="radio"/> Forewings without veins, meeting in a straight line down back (beetles) ..... <b>The specimen is Coleoptera</b>