4-H Entomology Manual

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(Updated October 2009, revised June 2013)
Orders follow *Introduction to the Study of Insects*, *7th Edition* by Triplehorn and Johnson, 2005.

Introduction

As a 4-H member there are a lot of different projects you may consider. Why pick entomology? If you try it, you will soon find out there are *many* good reasons.

Entomology (en-teh-moll'-o-gee') is the study of insects, and insects are everywhere. They are, by far, the most numerous and diverse kinds of animals. For example, there are more kinds (species) of weevils—just one kind of beetle—than there are different kinds of birds, fish, mammals, amphibians, and reptiles found in the world.

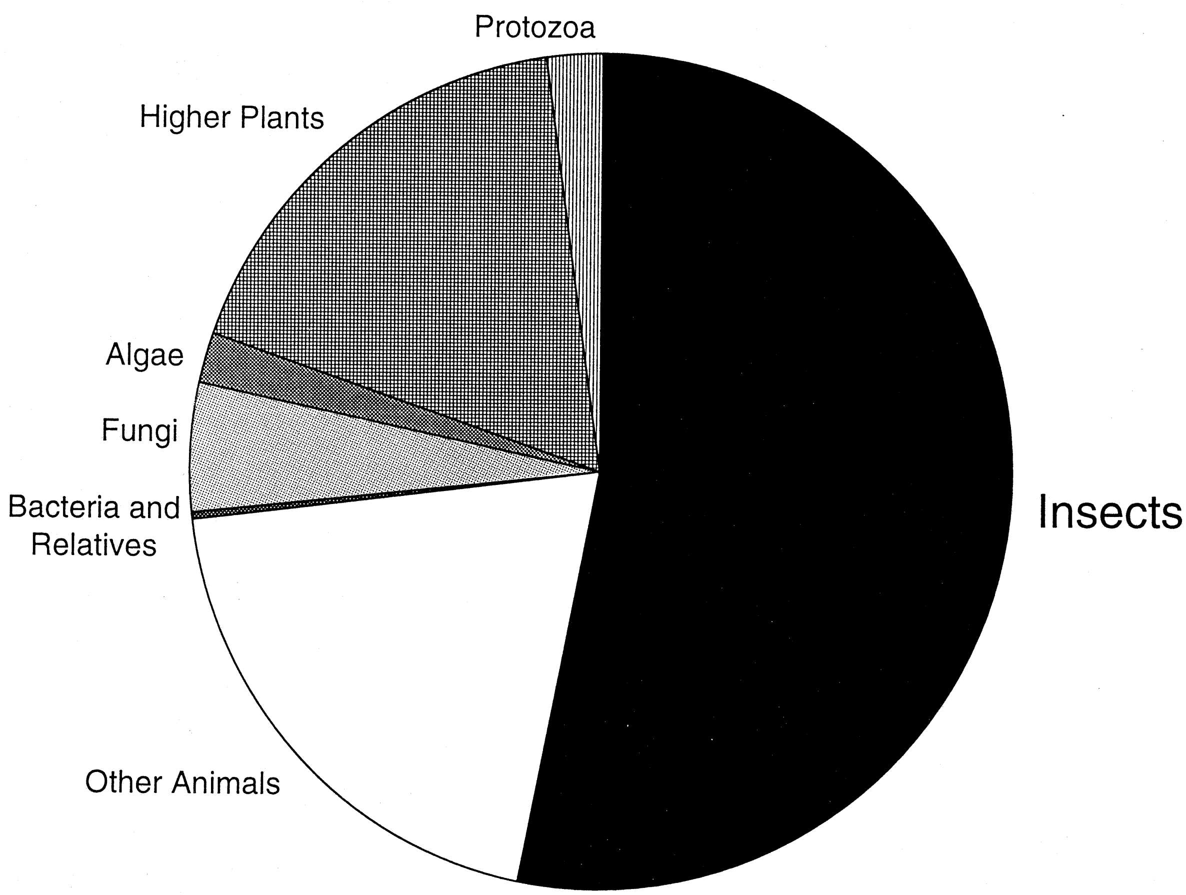
It shouldn't be hard to find material for your project. Insects occur in almost every environment—all around your yard, in fields, streams and ponds, and even in your home.

Despite their small size, insects are very interesting. If you have a chance to observe them closely, both their appearance and their habits may well fascinate you. No made-up, blockbuster Hollywood movie has ever truly come close to how amazing insects can be in everyday life.

The pest insects come to mind first, i.e., those that eat our crops, bite us or otherwise distress us. Combined, insects cause billions of dollars of damage in the United States every year, and they can be even more important in warmer, tropical areas. However, insects also are invaluable to our well-being. They help to pollinate plants, many of which are totally dependent on insects for their survival. Insects have also been in the recycling business for millions of years. They feed on dead plants and animals, and this activity releases nutrients for the growth of new plants. Most fish, many birds, and other animals dine primarily on insects. Insects do a pretty good job of keeping most of the pest insects in line, feeding on them as important biological controls.

Insects and Their Relatives

Insects are the most abundant and diverse form of life found on earth. Over three-quarters-of-a-million species are known to exist, more than the number of all kinds of other animals *and* plants put together. Only in the oceans are they outnumbered, by their close relatives the crustaceans.

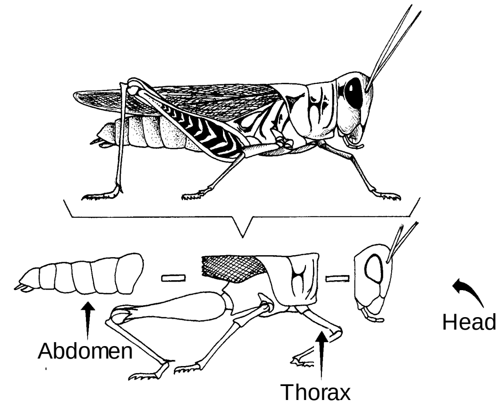


Relative number of different species among all life forms.

Insects have several important relatives. The insects, together with centipedes, crustaceans, spiders, mites and many other animals, belong to an even larger group (**phylum**) of animals—the **arthropods**. The word arthropod means "jointed foot," a description that captures one of the most prominent features of all these types of animals. All of their appendages (legs, mouthparts, antennae, etc.) are divided into segments.

More specifically, all arthropods possess the following *combination of characteristics* that make them distinctive within the world of animals:

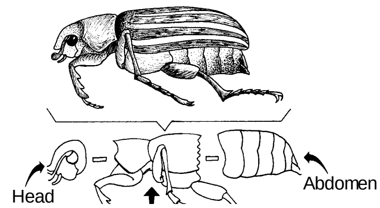
- a body that is segmented
- appendages that are jointed
- a hard skeleton on the *outside* of the body (called an **exoskeleton**)
- the need to periodically shed and regrow the external skeleton (molt) in order to grow



Body parts of a typical adult insect: grasshopper.

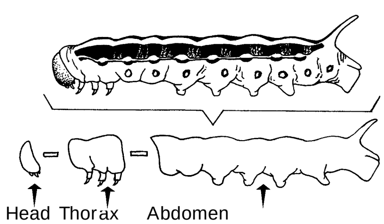
The arthropods are subdivided into smaller groups, each with its own additional unique features. Each of these is known as a **Class**, the largest of which is Insecta (or Hexapoda), which includes all the insects. As a distinct class, insects possess the following combination of characteristics:

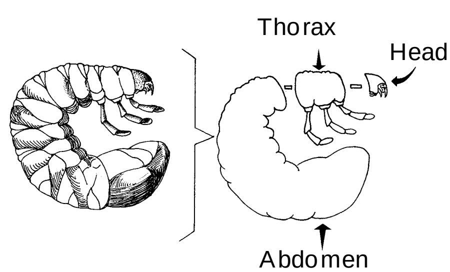
- 3 body regions, known (from front to back) as the **head**, **thorax**, and **abdomen**
- 3 pairs of legs, all of which are attached to the center part of the body, the thorax
- only a single pair of antennae



Body parts of a typical adult insect: beetle.

In addition, *most insects have wings when they reach the adult stage*, a unique feature among the arthropods. They are the only type of arthropod that can fly by actively moving wings. Spiders, mites and smaller stages of many other arthropods often are blown long distances in the wind.

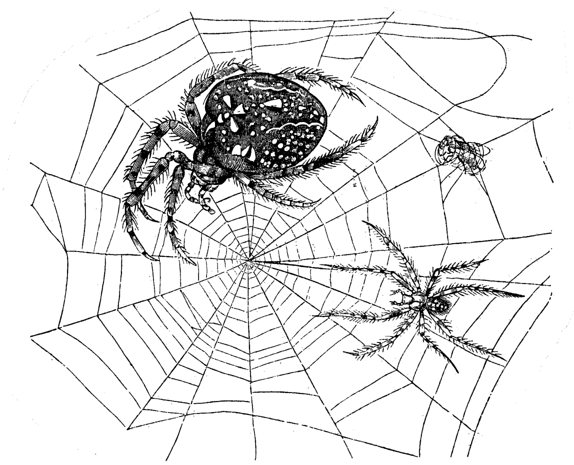




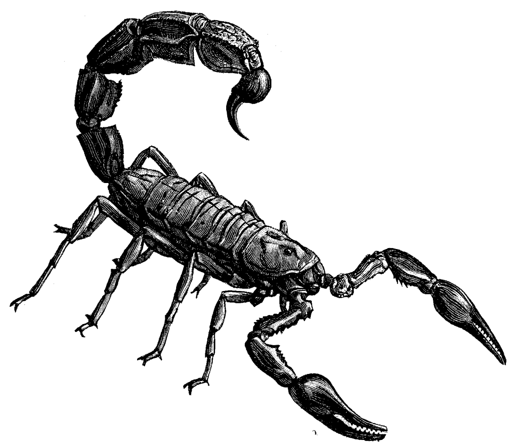
Body parts of two typical insect larvae: a caterpillar and a white grub.

Several other types of arthropods are commonly encountered. Most familiar are the members of the class **Arachnida**. Spiders, mites, ticks, and scorpions are examples of arachnids that might be found while "bug hunting." These animals possess only two body regions. The head and the area of the body containing the legs are fused together into the **cephalothorax**. They also possess a large **abdomen** on the hind end that contains most of the organs needed to digest food and to reproduce.

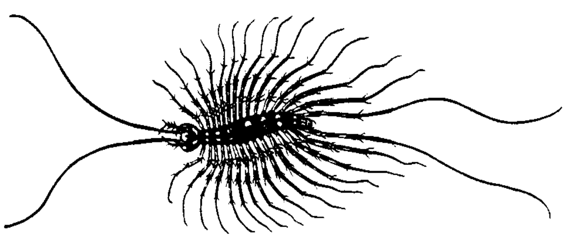
Perhaps the most distinctive features on arachnids are their four pairs of legs. Arachnids are a very important group of arthropods (second only to the insects). Some occur as pests: spider mites attack plants and ticks feed on blood and transmit diseases. However, other arachnids are highly beneficial. Most spiders feed only on other arthropods, including many insect pests.



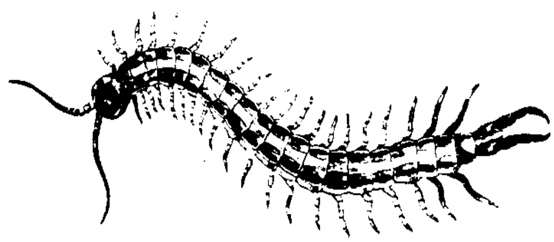
Spider



Scorpion

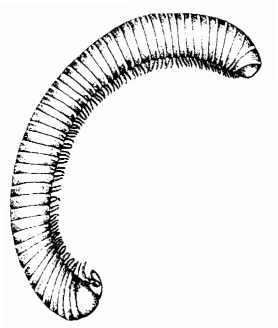


Centipede



Centipede

Centipedes, members of the class **Chilopoda**, also are arthropods. Most centipedes have a long, rather flattened body. Prominent along the sides is a pair of legs on each body segment, from which they get their name the "hundred leggers." (Centipedes actually only have about 40–50 legs.) Most centipedes are fast-moving animals and all are hunters of insects and other small prey.

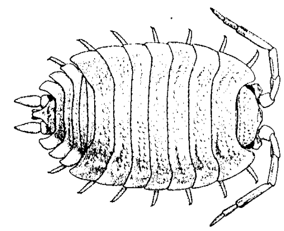


Millipede

Another group of worm-like arthropods is the millipedes, the class **Diplopoda**. Millipedes possess a great many small legs, usually two per body segment. These "thousand leggers" are often found under rocks or in other damp areas, emerging at night to feed on soft or decaying plant matter.

The crustaceans (class **Crustacea**) include such animals as crayfish, shrimp, and crabs. Most occur in water, although a few familiar land crustaceans exist, i.e., the sowbugs and the pillbugs ('roly-polys').

Crustaceans have five to seven pairs of legs and two body regions (cephalothorax and abdomen).



Sowbug

Features of the Five Principal Arthropod Classes

Insecta (Hexapoda) (Insects and Entognaths)
Three body regions (head, thorax, abdomen); three pairs of legs (all attached to the thorax); one pair of antennae; wings (usually) in the adult stage, typically two pairs.

Crustacea (Crustaceans: Crayfish, Shrimp, Sowbugs, Pillbugs, etc.)
Five to seven pairs of legs; two body regions (cephalothorax and abdomen); two pair of antennae.

Diplopoda (Diplopods: Millipedes)
Elongated, usually rounded bodies; numerous body segments (typically around 50); on most segments there are two pairs of small legs.

Chilopoda (Chilopods: Centipedes)
Elongated, flattened bodies; 14 to 20 body segments; on most segments there is one pair of legs.

Arachnida (Arachnids: Spiders, Ticks, Mites, Scorpions, Daddy-longlegs)
Four pairs of legs; two body regions (cephalothorax and abdomen); no antennae.

How Insects Grow and Develop (Metamorphosis)

One of the most amazing things about insects is the tremendous changes they must undergo as they grow and develop to the adult stage. These changes in form are known as **metamorphosis**. Humans often think it can be tough at times growing up—but it's nothing compared to what insects have to go through!

Almost all insects begin as eggs, although in a few cases the eggs have already hatched within the mother, so they are born alive. Regardless, the newborn insect, frail as it may be, must begin to make it on its own. With the notable exception of the social insects—such as ants, termites, and certain bees and wasps—a young insect must immediately begin to find the food and shelter it needs.

As the young insects develop, they grow in a series of distinct stages, not gradually as do humans. This is because of the hard, external skeleton (**exoskeleton**) that insects possess. In order to grow larger, the exoskeleton must be shed and regrown—a process known as **molting**. During molting, a whole new exoskeleton is produced that is larger than the previous one. This can take several hours or even days to happen. Even after the old exoskeleton has been shed, it then must harden, a period during which the insect is very vulnerable. After this process is completed, there can be no further change in body size until the following molt.

Tough as it sounds, insects must go through the process of molting several times (typically 3 to 7 molts) before they are full grown. After the final molt as they transform to the adult stage, growth ceases. It is at this stage that the insects are sexually mature, and also this is when the wings develop in winged forms.

As insects develop, they may go through various patterns of change. The kinds of changes vary among different insect groups, but three general types of development predominate**—no metamorphosis, simple (gradual) metamorphosis** and **complete metamorphosis**. Some of the more primitive orders (i.e., silverfish, springtails, firebrats) do not undergo distinctive changes as they grow. Although external differences are gradual and are not readily noticed in these types of developing insects, only the final adult form can reproduce—they are known as **ametabolous** insects having no metamorphosis. Ametabolous insects are generally wingless.

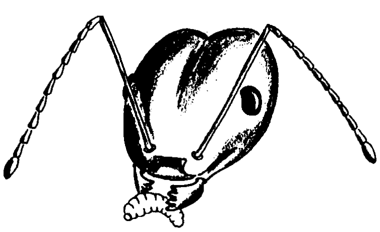
Insects that have a pattern of simple (or gradual) metamorphosis go through three basic life stages—**egg**, **nymph** and **adult**. The immature nymphs typically pass through three to five stages (**instars**) and sometimes many more, molting between each stage. Nymphs and adults often live in the same habitat, with the principal changes during metamorphosis being body proportions, sexual maturity and the development of wings. Examples of insects that undergo simple metamorphosis include grasshoppers and crickets (Orthoptera), earwigs (Dermaptera), cockroaches (Blattodea), the "true" bugs (Hemiptera), aphids and related insects (Homoptera).

Insects that undergo complete metamorphosis pass through four basic life stages—the **egg**, **larva**, **pupa** and **adult**. Caterpillars, maggots, and grubs are typical examples of immature insect forms, known as larvae. Larval insects typically molt between three and seven times, continuously growing and feeding in between the molts. The pupal stage (e.g., cocoon, puparium, chrysalid) is the next non-feeding stage, during which the insect changes to the adult form. It is only the adults that have wings. Often, even the legs, mouthparts, and antennae change between the immature and adult stages of these insects. With these types of insects, it can be difficult to match the young and adult stages of the same insect. They look different, often feed on different things and may be found in very different areas. However, complete metamorphosis is very common and is shared by the most abundant kinds of insects, such as butterflies and moths, beetles, flies, and lacewings.

How Insects Feed—Mouthparts

Because insects feed on such a wide variety of materials, the mouthparts that allow them to feed are similarly diverse. Most common are mouthparts that allow the insects to chew. Grasshoppers are good examples of insects with **chewing mouthparts** that prominently feature a pair of strong *mandibles*. Other important parts of the mouth are the *maxillae*, located behind the mandibles of the grasshopper, which aid in holding and manipulating the food. At the base of the mouthparts is the *labium*, and on top is the plate-like *labrum*.

Many other insects have mouthparts designed to chew: beetles, earwigs, caterpillars and mantids, for example. Insects that feed on wood, such as roundheaded borers, have stout, strong jaws that make up much of their head. However, there are slight differences in the design of "chewing" mouthparts used by insects. For example, the lacewings and antlions (Neuroptera) have prominent hooked mandibles designed to capture prey. They have a "blood-groove" running along the inside edge to allow it to feed. Many beetles that prey on other insects similarly have hooked jaws (mandibles).



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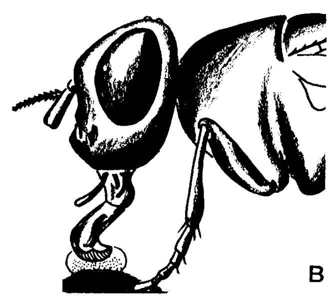
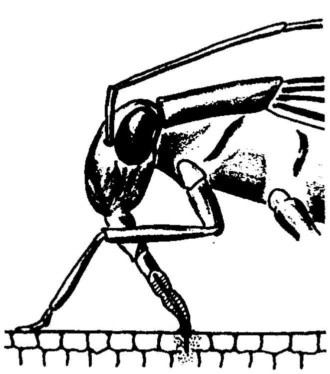


B

Types of insect mouthparts: (A) chewing mouthparts showing mandibles, (B) sponging mouthparts of certain kinds of flies, (C) piercing-sucking mouthparts, and (D) siphoning mouth tube of butterflies (arrows point to extended and retracted proboscis).



C

D

Some other insects combine chewing mouthparts with other features. Honeybees have chewing mouthparts used primarily to mold and form the wax of their colony. They also possess a tongue-like proboscis used to suck nectar. Mouthparts of horse flies and stable flies are designed to slash the skin to produce oozing blood that can then be sucked up quickly.

Another common type of mouthpart is designed to pierce tissues and suck fluids. **Piercing-sucking mouthparts** are used by all the true bugs as well as cicadas, aphids, and leafhoppers (Order: Hemiptera). With these insects, the mandibles and the maxillae are very drawn out, forming a long, hair-thin tube, or *proboscis*. The mandibles penetrate the plants while the maxillae form a channel through which the plant sap can be withdrawn. Although many insects with mouthparts designed for piercing and sucking fluids feed on plants, others prefer blood. Mosquitoes, buffalo gnats and other annoying biting flies feed in this manner.

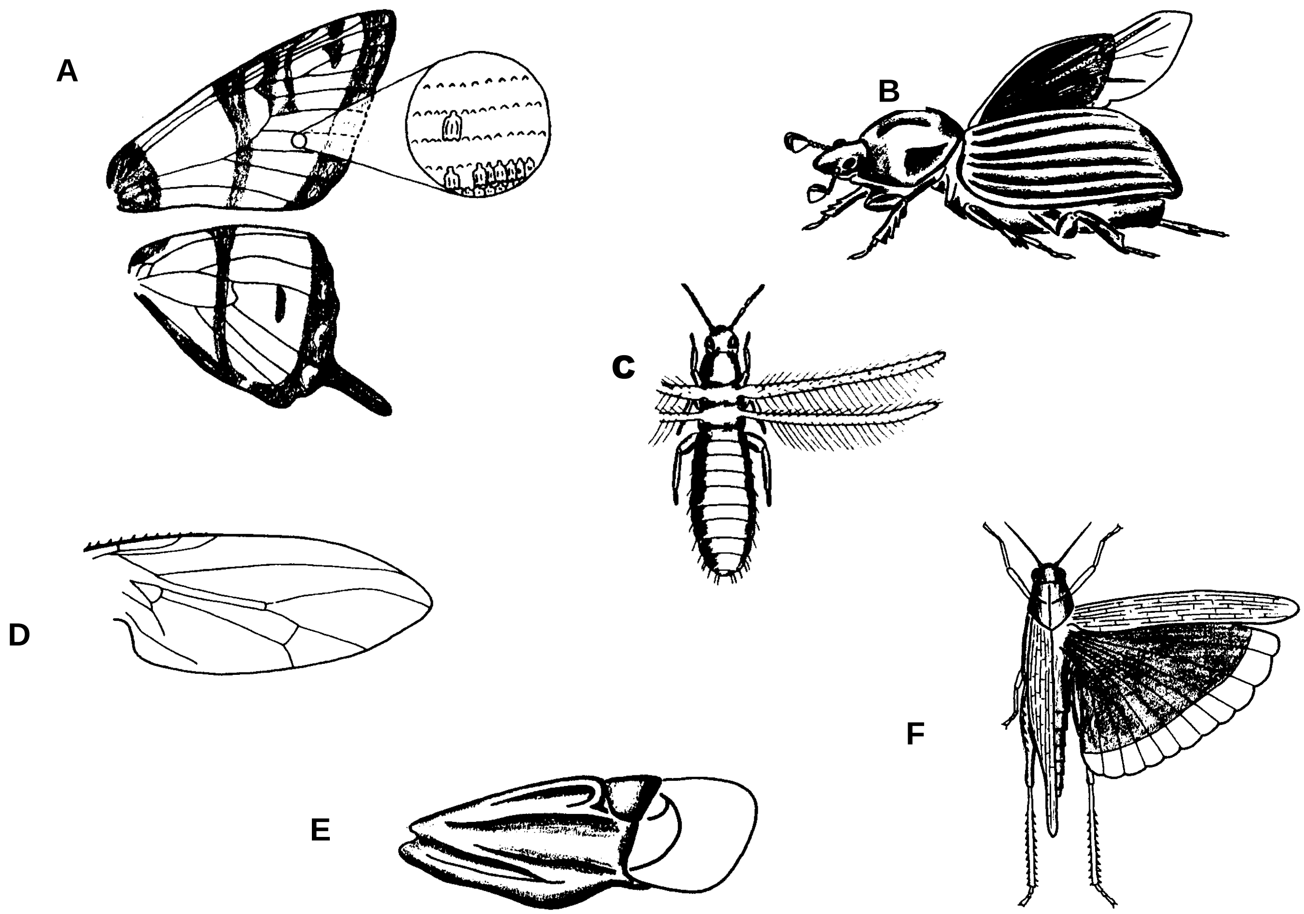
A unique way of feeding is found among the thrips (Order: Thysanoptera). With these insects, only a single mandible is present, greatly enlarged into a single "tooth" that they use to break through the surface of (epidermal cells) leaves and flowers. Long, thin stylets (maxillae) that fit closely together along their length forming a 'sucking tube' are then inserted into the cell through the hole made by the mandible. The thrips then suck the fluids from the plant cell. This type of feeding is sometimes described as rasping-sucking, but might be more accurately described as piercing-sucking.

Many other insects feed on fluids, but do not cause injury as they feed. Most butterflies and moths feed on nectar, which they extract from flowers with **siphoning mouthparts**. These form a long tube (called a **proboscis**) that normally is curled under the head at rest but which may extend an inch or more as they feed. Many flies lap their food with **sponging mouthparts**.

Adults of some insects do not feed at all, having gotten all their nourishment during earlier stages in their development. The large silk moths, such as the cecropia moth, do not feed after they emerge from their cocoon. The whole order of Ephemeroptera, the mayflies, are well known for their brief adult life, as they live little more than a few days, during which they do not feed. Such insects are said to have **reduced** or **vestigial mouthparts**.

Other Important Features—Wings and Antennae

Other features that can be useful in identifying insects are the types of wings they possess and their antennae. Most, but not all, insects possess wings in the adult stage, a feature that separates insects from other arthropods, such as millipedes, pillbugs, and spiders. Most insects have two pairs of wings, attached to the second and third segments of their 3-part thorax. The notable exceptions are flies, members of the order Diptera (meaning "two-wing"), that lack hind wings. Mosquitoes, blowflies, houseflies and robberflies all are members of this common insect group.



Types of insect wings: (A) scaly wing of moths and butterflies, (B) armor-like (elytron) and membranous wings of beetles, (C) feathery wings of thrips, (D) membranous wing of a fly, (E) half-leathery/half-membranous wing (hemelytron) of true bugs, and (F) leathery wings of grasshoppers

Wing features can be used to distinguish many groups (orders) of insects.

Lepidoptera (moths, butterflies)—wings are covered with fine scales ("dust").
Trichoptera (caddisflies)—wings are covered with fine hairs.
Coleoptera (beetles)—front wings are hardened (called elytra) and cover the membranous hind wings.
Neuroptera (lacewings, snakeflies, etc.)—the "nerve-wing" insects, a reference to the very large number of veins on their wings.
Thysanoptera (thrips)—edges of the wings are bordered by long hairs, making these the "fringe-winged"

insects.
Diptera (flies, midges, mosquitoes)—only possess a single pair of wings, the forewings.
Isoptera (termites)—in reproductive king and queen stages that possess wings—both the forewing and the hindwing are of equal length.
Hemiptera (true bugs)—the forewings are patterned with two different designs. The base of the wings are thickened while towards the tip they become more membranous. A V-pattern typically forms behind the head when the wings are folded.
Dermaptera (earwigs)—the very short wing covers are distinctive with this order, although the rove beetles (Coleoptera: Staphylinidae) also share this character. (Only earwigs have the combination of short wings and distinctive cerci on the hind end.)
Siphonaptera (fleas)—no wings occur with this group in any life stage.

Antennae are used by insects to sense odors and vibrations in their environment—functioning somewhat as does the human nose. However, insects have antennae of various, and sometimes fantastic, design. These can also be used to separate the adult insects of many different insect groups.

Lepidoptera (butterflies)—long, thin antennae that end with a knob.
Lepidoptera (skippers)—long, thin antennae that end with a hook.
Lepidoptera (moths)—variable, but often feathery and large. Males typically have larger antennae than females.
Diptera—variable. Many of the most common flies (suborder: Cyclorrapha), such as house flies and blowflies, have antennae that appear as a small lobe on the front of their head with a hair sticking out of it. These are called **aristate** antennae. Mosquitoes, midges, craneflies and related flies (suborder: Nematocera) have antennae that appear as filaments or plumes.
Orthoptera (grasshoppers, crickets), **Blattodea** (roaches), **Mantodea** (mantids)—very long filament-like antennae characterize these orders.
Coleoptera (beetles)—no order has such a wide range of antennae as do the beetles. Some families have long thin antennae—the extreme being the wood borers known as longhorned beetles, which may have antennae almost twice as long as the body. Scarab beetles have peculiar clubbed antennae, while those of other species may be feathery.
Neuroptera (ant-lions, lacewings, etc.)—long antennae with a club-like tip.
Odonata (dragonflies and damselflies)—small, hair-like antennae between the eyes.
Isoptera—antennae appearing as a string of beads.
Hymenoptera (ants, hunting wasps)—antennae are elbowed, with an extended first segment and smaller segments towards the tip.
Hymenoptera (parasitic wasps)—antennae very long and made of many tiny segments, producing a long filament.

Importance of Insects

Often, people focus their attention on those insects that damage plants, bite or sting, or otherwise cause annoyance or loss—the *pest* insects. However, only a very small fraction of all the kinds of insects can be described in this way. Instead, most insects (including some pests) are essential in ecosystems, and many others provide direct benefits to humans.

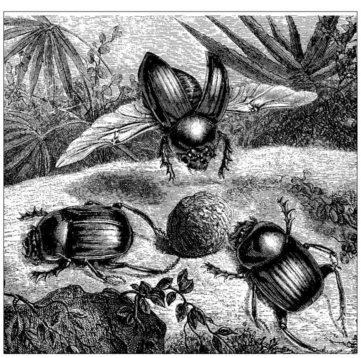
The importance of insects is well stated by the words of the noted biologist E.O. Wilson:

> *If all mankind were to disappear tomorrow the world would regenerate to the rich state of equilibrium that existed 10,000 years ago. If insects were to vanish the terrestrial ecosystems would collapse into chaos.*

Insects in the Natural Recycling of Nutrients

One of the most important (but overlooked) roles of insects is their involvement in the recycling of nutrients in natural systems. Many insects are **macrodecomposers**, which help break down organic matter they scavenge. For example the manure of cattle and other animals would not break down without the help of such insects as dung beetles. The decay of dead animals is greatly accelerated by hide beetles and flies that feed on them. The decay of wood is often dependent on termites, carpenter ants, and various other insects that tunnel into it.

Many scavenging insects also pull organic matter into the soil as they live and breed, further helping to build soil. Dung beetles often roll small balls of manure and bury them in the soil as a place to lay eggs. The burying beetles (Silphidae family) do the same with small dead rodents. Ants bring large amounts of dead insects and other materials into their colony. In addition, the tunneling of ants aerates and mixes soils, providing an essential task that earthworms provide elsewhere.



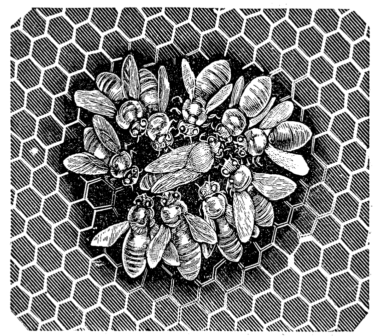
Dung beetles at work.

Insects as Pollinators

Insects provide a tremendous benefit in the pollination of plants. Many flowers require a visiting insect to transfer the pollen needed to fertilize and set seed. Bees, including the introduced honey bee, are the best known pollinators. However, many other insects such as flies, moths, butterflies and wasps also can be important.

Insect pollination is essential to the production of many crops. Crops like apples, cherries, cantaloupes and peaches are almost entirely dependent on insect pollinators, like honeybees. Without the insects, these crops could not be grown. The pollination activity of bees annually provides services that are worth tens of millions of dollars to agriculture. Additionally, many crops, such as row crops, vegetables, fruit and legumes, require insect pollination to provide the seeds that are used by farmers. Many of the native wildflowers also are dependent on insect pollination for their survival. About 1/3 of all seed plants require insect pollination.

One side benefit of pollination by honey bees is the hive products they produce, i.e. honey and beeswax. These materials are worth over $40 million dollars annually to beekeepers in the Mid-South, many of whom make their living working with these insects.



Beehive activity

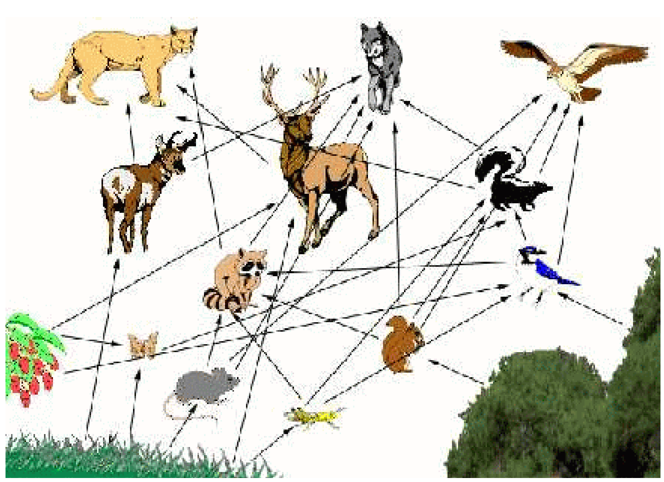
Bees and Beekeeping

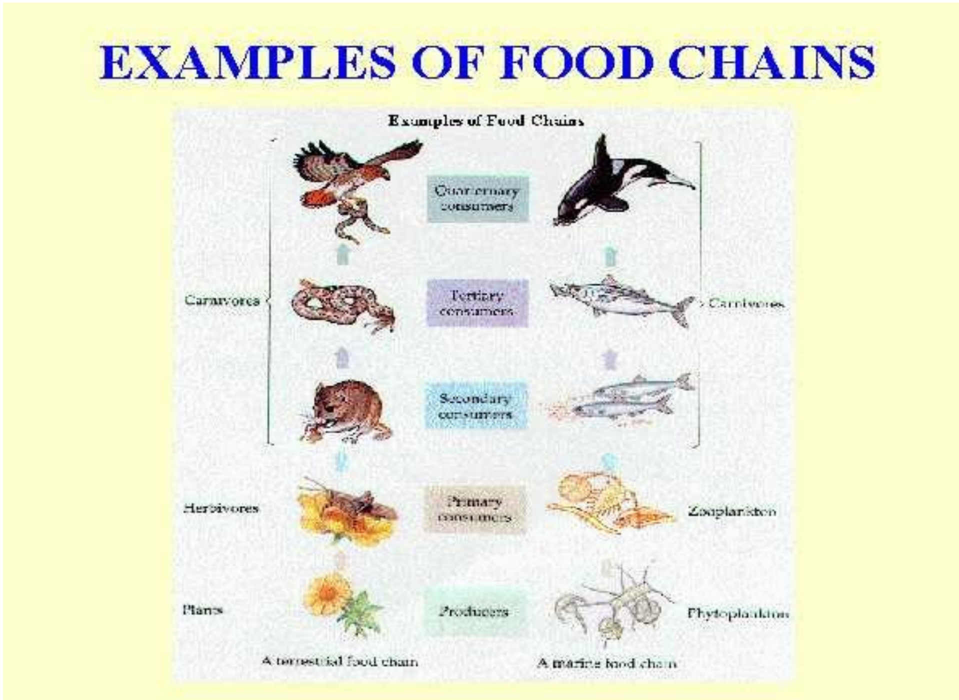
See pp. 78–80 for a short treatise on honey bees and beekeeping. This exciting project can prepare a 4-Her for a lifelong hobby, a supplemental income, or even a full-time profession. It also affords the beekeeper an opportunity to study a unique society of creatures which is both beneficial and profitable to man.

Insects in Food Webs of Wildlife

Insects are central to the food webs that support other wildlife. Most game fish, such as bass, crappie, trout, and others use insects as a major part of their diet. Insects are central to the diet of many songbirds, especially during the time of year when they rear their young. Many birds feed on insects throughout their life. Insects also make up a large part of the diet of many small mammals, like shrews and kangaroo rats. In turn, these mammals are prey for hawks, foxes, and other predators.

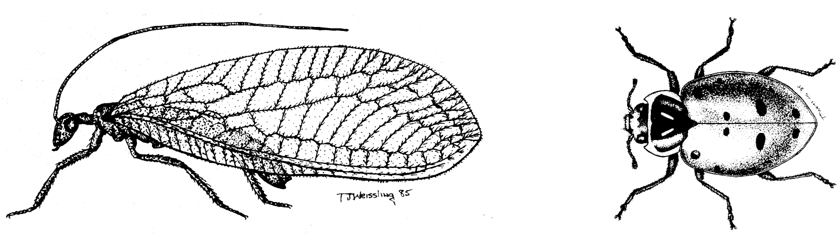
Food Web





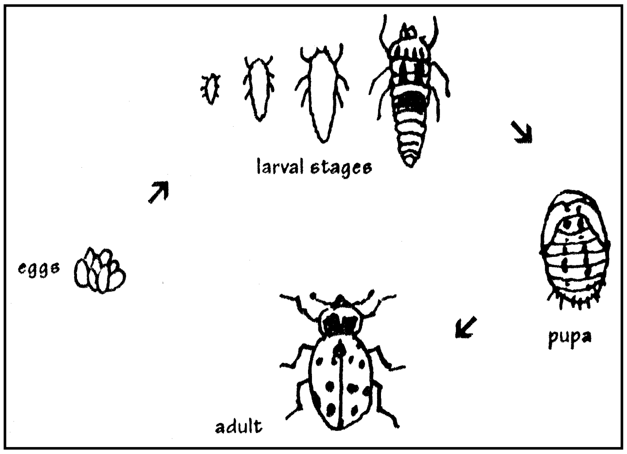
Insects as Biological Controls of Pests

For many pest insects, the most important factor keeping their populations in check is the activities of other insects: **biological controls**. Some insects develop as predators of other insects. Developing insect predators actively hunt and feed on several other insects as prey. Adult stages also may be predators, although some (green lacewings and flower flies, for example) feed on pollen.

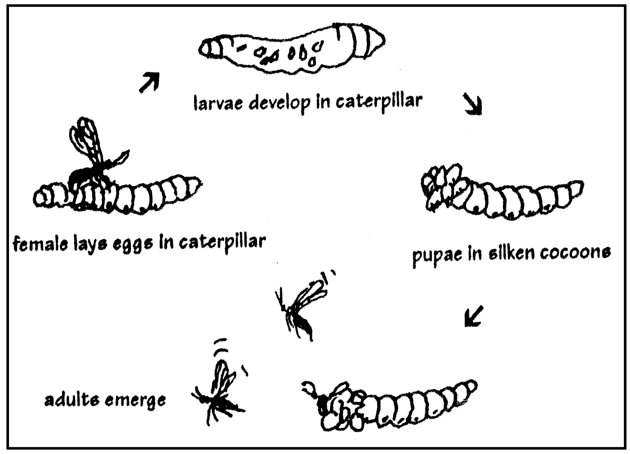


Insect predators: lacewing (left) and lady beetle (right).

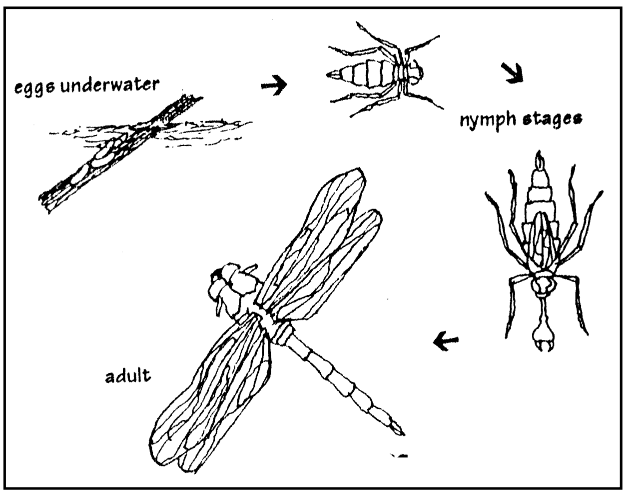
Other insects develop as **parasites** of pests. Usually, these are flies or wasps that lay eggs on certain kinds of insects. Their young usually feed inside the insect host, killing it and emerging in the adult parasite form. Parasitic wasps may lay dozens of eggs, each developing into an insect that kills a pest. A new generation may occur every three weeks, allowing them to become very abundant in a short period.



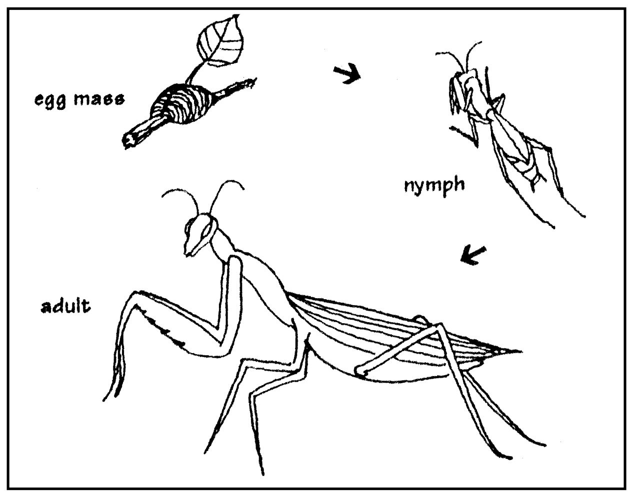
LADY BEETLE LIFE CYCLE
The lady beetle life cycle is typical of most insects.



PARASITIC WASP
The parasitic wasp has the 4 common life cycle stages of an insect, but the larval stage usually occurs inside a host.



DRAGONFLIES
Dragonflies are a bit different from other insects. The larval stage of their life cycle is lived underwater. In this underwater stage they are called nymphs.



MANTID
Even though it is an insect, the mantid has a more gradual life cycle–egg to wingless nymph to mature adult. The nymph stage looks like a small adult.

Life cycles of some insects useful in biological control.

Another important group is **hunting wasps**. These wasps capture, paralyze, and take insects to their nests, which may be dug in the ground, cut into wood, or constructed of wood, paper, or mud.

Hunting Wasps

Hymenoptera

Sphecid wasps (Family Sphecidae)
Spider wasps (Family Pompilidae)
Mud daubers (Family Specidae)

Hunting wasps

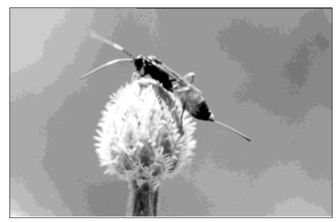
Insects that are Parasites of Pests

Diptera

Tachinid flies (Family Tachinidae)
Robber flies (Family Asilidae)

Hymenoptera

Braconid wasps (Family Braconidae)
Ichneumonid wasps (Family Ichneumonidae)
Chalcid wasps (Superfamily Chalcidoidea)



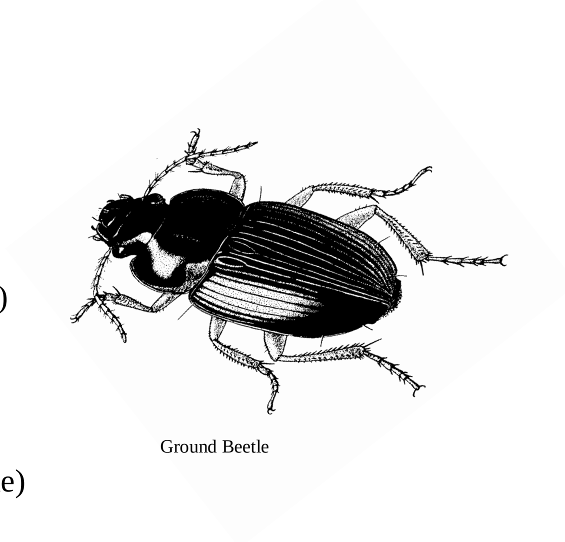
Braconid wasp

Insects can be very important in controlling plant pests. For example, lady beetles may eat several hundred aphids during the two or three weeks they are larvae, and then many more as adults. Often, the benefit of these useful insects is not realized until their activity is disrupted by use of insecticides. Insecticides are chemicals used to control pest insects, but they often harm beneficial insects as well. The use of predators and parasites of insect pests is known as **biological control.**

Although some insects damage desirable plants, others feed on plants we consider to be weeds. In this role, these insects provide a very useful function by helping to keep some weeds in check. Government agencies, such as state departments of agriculture, state universities, and the USDA usually coordinate the release of new insects to control weeds and ensure the insects will not hurt other plants. Currently, programs are being conducted to use insects to control weeds like leafy spurge, musk thistle, and larkspur.

Common Predators of Insect and Mite Pests

Coleoptera
- Lady beetles (Family Coccinellidae)
- Ground beetles (Family Carabidae)
- Tiger beetles (Family Cicindelidae)
- Checkered beetles (Family Cleridae)


Ground Beetle

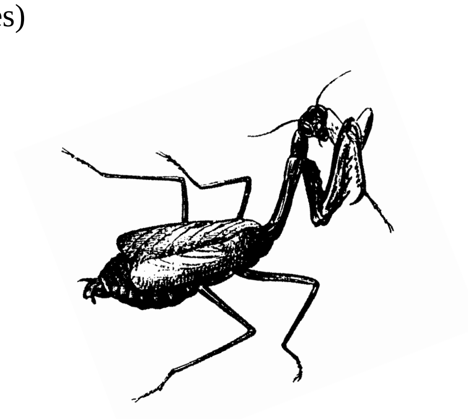
Diptera
- Syrphid/flower flies (Family Syrphidae)
- Robber flies (Family Asilidae)

Neuroptera
- Green lacewings (Family Chrysopidae)
- Brown lacewings (Family Hemerobiidae)
- Antlions (Family Myrmeleontidae)

Thysanoptera
- Bandedwinged thrips (Aeolothripidae)

Odonata
- Dragonflies and Damselflies (various families)

Mantodea
- Mantids (Family Mantidae)


Mantid

Hemiptera
- Stink bugs (Family Pentatomidae)
- Damsel bugs (Family Nabidae)
- Assassin bugs (Family Reduviidae)
- Minute pirate bugs (Family Anthocoridae)
- Big-eyed bugs (Family Lygaeidae)

Arachnida
- All spiders (Order Araneae)

Although spiders are not insects, entomologists most often deal with questions and problems relating to this group of arthropods, which is closely related to insects. We have included a short discussion on spiders in this section.

Spiders

Spiders! Mention this name and many thoughts might come to mind. If the name is said real slow, it has an almost scarey sound. Some might think of the venom glands associated with spiders, adding to the mystery that surrounds these creatures. Some think all spider venoms are harmful to humans. Some might think of the large circular webs that are often seen in fields, at wood edges or along the edges of shady country lanes. These webs are used to trap insects, a major source of food for spiders. Let's briefly explore the lives of spiders and see what can be learned.

The fear often associated with spiders might be handed down from generation to generation. It might have started because some family member in the past was frightened by a spider, so a dire warning was passed on to other family members. Legend has it that a certain species of spider in Italy causes its victims to go into uncontrolled periods of dancing to the point of exhaustion. Several variations on this story exist, adding to the mystery surrounding spiders. Finally, consider the nursery rhyme "Little Miss Muffet." In this story Little Miss Muffet would have nothing to do with the spider that "sat down beside her." Youngsters hearing this story for the first time might decide that spiders are to be feared. Do not let stories frighten you or keep you from studying or observing these fascinating animals.

Spiders and insects belong to the same phylum, Arthropoda, as do a number of other animals. Examples are spiders, insects, millipedes, centipedes, crabs, scorpions, mites, ticks, harvestmen (daddy-long legs), etc. Some common body characteristics shared by these animals are jointed appendages (legs, antenna), an exoskeleton, segmented bodies (two or three body regions), and a bilaterally symmetric body (the right half mirrors the left half). "How do spiders differ from insects?" The most obvious answer is the number of legs. Insects have three pair of legs and the spiders have four. One other body characteristic is the number of major body parts. The insects have three major body parts (head, thorax and abdomen) and the spiders have only two (cephalothorax, a combination of the head and thorax, and abdomen).

Harvestmen (order Opiliones) have tremendously long legs and look similar to spiders. One difference is in the number of body regions. The spiders, in most cases, have two distinct body regions, while in the harvestmen there is no distinct separation between the cephalothorax and abdomen, and it appears that there is only one body region.

Harvestmen can be found in shady areas around homes. They may be on the ground or on plants. In the fall, large numbers of these animals can be found clumped together. The name "harvestmen" may have come from finding these groups in the fall, the time for the harvest of various crops. Harvestmen feed on small insects such as springtails (Collembola). They will also feed on mites and decaying organic matter.

A story periodically circulates that says the harvestmen have a very toxic venom and they should be avoided. The only problem with this story is that it's just a story—there is no factual information that supports this story. Texts always point out the dangers associated with spider venoms such as the black widow or the brown recluse, and with certain species of scorpions; however, no mention is ever made of harvestmen venom. There is always the possibility of being bitten by a wild creature, so care should be taken when dealing with any of them.

Define the following terms:

Prey—an animal that is attacked by another and is most often eaten as food.
Predator—an animal that attacks and feeds on other animals. (adj., predatory)

Since spiders are predatory creatures, they must have a way of subduing their prey once it is caught or entangled within a web of silk. This is done with venom that is delivered through the hollow jaw-like structures called **chelicera**.

The misconception is that all spider venom is dangerous to humans. First things first: Most spiders are capable of biting if one handles them roughly or one comes into contact with the spider by accident. The vast majority of spider venoms are not harmful to people. However, if one is bitten, proper first aid should be administered just as one would do if a knee is scratched in a bike accident. Two spiders do have toxic venom, and you should be able to recognize them—the brown recluse and the black widow.

Brown Recluse. The length of the body is between 10 and 12 millimeters and it is about 5 millimeters wide (practice your conversion from the metric system to the English system: one inch equals 25.4 millimeters or one millimeter equals 0.039 inches). The legs are very long and slender, and this makes the body appear larger, but a recluse is about the size of a quarter (25-cent piece), legs and all. The color of the spider is brown to yellowish brown, with the abdomen darker than the front part of the body. This spider is sometimes called the "fiddle back or violin spider" because it has the outline of a fiddle or a violin on the front part of the body. The brown recluse is usually found in little used parts of houses and storage buildings. The venomous bite of this spider causes localized tissues to die around the area of the bite. It is very painful and slow to heal.

Brown Recluse Spider

Black Widow. The female black widow is the one most often seen. It is a shiny black color with a red hourglass mark on the underside of the abdomen. The abdomen is also very large and round. It is so large that it appears out of proportion to the front part of the body. This spider can be found in homes, but it is usually found in outside areas. Watch for it around wood piles, stacks of bricks, under items such as tin laying on the ground, in water meter boxes, in stumps or hollow logs and similar locations.

Webbing is very important to some spiders as it is used to catch insects. The garden spider is a very large spider with black and yellow markings, and it is one of the web-making spiders. These spiders make very large orb like webs with some silk strands that go in circles and others that run out from the center of the web like spokes. As one would expect, this family of spiders (Araneidae) is known as the orb weavers. Some spiders in this group use the web continuously and make necessary repairs on it each day. Others build a new web for each night's use. These spiders can be large like the garden spider or so small that one has to look very closely to see them in the center of the web. Some can even have small projections on the abdomen. This is a very diverse group of spiders, so don't let size or body shape fool you.

The **orb weavers** are very dependent on silk, but there are other groups that have very little use for silk. Collectively, these spiders are known as "hunting spiders," and they use very little silk in their day to day activities. Three families of spiders in this group are the typical crab spiders (Thomisidae), the wolf spiders (Lycosidae), and the lynx spiders (Oxyopidae).

The **crab spiders** are small, with the females ranging in size from 3 to 11 millimeters. The males are smaller than the females. They get their name "crab" from their movements. They can move sideways as well as move forward or backward. This movement is similar to the movement of the crabs one would see at the beach. Crab spiders feed by ambushing insects and other small animals. Some of these spiders live on the ground with colors varying from dull grays to browns to blacks. They may be found under loose bark on fallen trees or in leaf litter on the forest floor. Their dull coloring allows them to wait patiently for some unsuspecting insect to venture close enough for the spider to catch it. Other spiders in this group are brightly colored and live on vegetation. Colors vary from green to white to yellow. Some can even change their coloration from white to yellow or reverse this process depending on the background color. This bright coloration again allows the spider to remain hidden while it waits for its prey to venture within range. It uses no silk in the catching of its prey.

Wolf spiders are another group of hunting spiders; however, some species still use silk to some degree. In some situations, they use silk as lining for their resting places, and some species make a web called a sheet web. Although there is some reliance on silk, the majority of these spiders hunt for prey, and they hunt in the true sense of the word. They don't use concealment or stealth. They simply find and overpower their prey. Once caught, the prey is crushed with the spider's strong chelicera. A number of spiders hunt at night, but the wolf spiders hunt as much during the day as they do at night. Size can vary greatly in the wolf spiders. They can be as small as 4 to 5 millimeters long, to as much as 25 to 35 millimeters long. The larger ones are the most obvious. The body of these spiders is very hairy, and this condition is very obvious on the larger spiders. Wolf spiders are mostly ground inhabiting but will occasionally get into houses. Their colors are shades of brown, black, and gray.

If crab spiders ambush their prey like leopards and wolf spiders overpower their prey like lions, then the **lynx spiders** are the cheetahs of the spider world. The lynx spiders are long-legged, agile spiders that are found almost exclusively on low-growing plants. They move from limb to limb or from plant to plant using their keen eyesight to find prey. Once an insect is seen, they chase it down. Silk does not play a role in the catching of prey. Lynx spiders are often brightly colored, and a common spider in the group is the green lynx. This spider has a bright green cephalothorax with red and yellow markings on the abdomen. A red area is also present just below the eyes. It is 18 to 20 millimeters long.

This is a brief look at the world of spiders and one should not think that these are the only spiders that exist. There are many more families than the few that have been mentioned here. In closing, remember:

- Most spiders can bite, but not all spiders are venomous to humans.
- The brown recluse and black widow have venoms that are harmful to humans.
- All spiders are predators.
- Some spiders use silk to catch their prey, but not all spiders use silk for this purpose.
- Some spiders ambush their prey.
- Some spiders overpower their prey.
- Some spiders use speed to catch their prey.

Insects as Pests

A small (less than one percent) but very important fraction of insects are pests—and can be very expensive ones. Pest insects can damage crop plants, livestock, and man in a variety of ways.

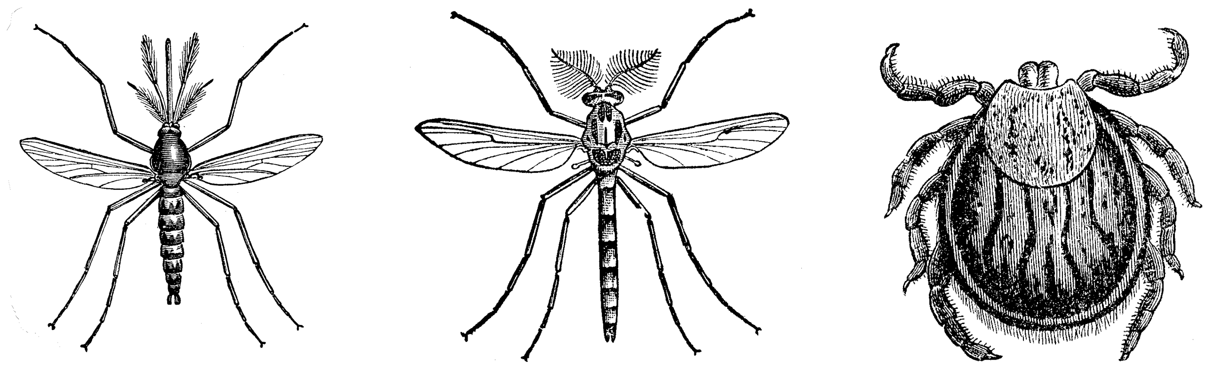
Insects chew leaves and needles. This type of injury may weaken a plant and cause it to be less productive. Some pests, like grasshoppers, will chew a wide variety of plants. Others limit their feeding to only a few types of plants. Cabbageworms feed primarily on cabbage-family plants. Tomato hornworms feed on tomato leaves and fruit. Insects that chew young plants, such as cutworms and flea beetles, may kill the plant.

Insects suck the sap from plants. Aphids, whiteflies, leafhoppers, plant bugs and scale insects feed on the sap from plants. In the process, they may damage plant cells or remove valuable nutrients. Aphids may cause young leaves to curl or distort and to be smaller than normal. They also produce honeydew which promotes sooty mold, thus interfering with photosynthesis. Plant bugs inject enzymes into the plant disrupting nutrient flow.

Insects produce galls on plants. Unusual growths on plants are caused by many insects, certain mites, and some plant disease organisms. These abnormal growths are known as galls and result from the way the insect feeds on the plant. Some common galls are ball-like growths on leaves and swellings of stems and twigs. The cone-like gall on the tips of spruce trees is produced by the Cooley spruce gall aphid. Pecan phylloxera produce galls on the leaves and stems of pecan and other related trees.

Insects destroy fruit and seeds. Some insects feed directly on the fruit or seeds of plants. A worm in an apple probably is the larva of a codling moth. The ear of sweet corn is often inhabited by corn earworms. Even after harvest, various insects thrive on stored foods in warehouses, grain storage bins, and pantries. Flour beetles, sawtoothed grain beetle, and Indianmeal moth are all pests that can be found in most homes.

Insects transmit plant diseases. Often, the insect itself causes little damage when it pauses to feed on a plant. However, many insects can pick up viruses, bacteria, and other disease organisms as they feed. Then, they transmit them to healthy plants, resulting in severe damage and even death of the plant. For example, aphids transmit viruses that cause disease in wheat and barley; bark beetles move fungi that cause Dutch elm disease, which kills American elm; the aster leafhopper can inject the bacteria causing aster yellows (a common problem for lettuce, carrots, and many flowers); and western flower thrips transmit spotted wilt virus to tomatoes, peanuts, and other crops.



Biting arthropods such as mosquitoes (left and center) and ticks (right), transmit diseases to humans to animals.

Insects transmit diseases to humans and animals. Insects and other arthropods can transmit diseases to people and to other animals. Perhaps best known are mosquitoes, which spread malaria, yellow fever, dog heartworm, and many other very important diseases. Mosquitoes are also vectors of a number of different kinds of encephalitis, which can be very serious to horses and occasionally infects humans. Even more important in disease transmission are ticks, which may transmit Lyme disease, Rocky Mountain spotted fever, tularemia, and other diseases.

Insects sting, bite, or otherwise create annoyance. Many insects feed on the blood of animals. Fleas, ticks, sucking lice and mange mites require an animal host to survive. Various biting flies, such as mosquitoes, blackflies, and deerflies, need a blood meal to produce young. Yellowjackets, bees, and ants can sting, usually in an effort to protect and defend their colony. The bites and stings of these insects often harm humans and livestock.

Managing Pest Insects

Although only a very small percentage of insects have habits that make them "pests," finding ways to effectively manage those that are is an important task of entomologists. However, insect management can be difficult, as insects are greatly adaptable and controls must not only be effective but also avoid damaging beneficial organisms. The general goal of insect pest management is to use strategies that result in the suppression of the target organism (pest) without disturbing nontarget organisms (natural enemies, pollinators, wildlife).

Several types of controls are available for managing insect pests. Often more than one type is appropriate and they are employed in combination.

Biological control consists of the action of natural enemies (e.g., parasitoids, predators, and insect diseases/pathogens). Biological control can involve the use of naturally occurring biological controls, those that already exist in the area. These can sometimes be encouraged by diversifying crop environments, or avoiding practices that may harm the natural controls. For example, normal cultural practices that are part of growing a crop, such as plowing or timing of cutting hay have impacts on beneficial insects as well as pests. Chemicals used for pest management (pesticides) vary widely in how they affect biological controls.

In a few cases, biological control involves releasing beneficial insects. Several companies raise and/or ship various beneficial insects to control pests. This approach has been successful in greenhouses for whiteflies, mealybugs, and other damaging species, but is often very expensive.

In addition, new insects are occasionally introduced into the U.S. by government agencies. This is usually done to help control some previously introduced pest insect or weed. Because of the need to ensure that a released insect will do no harm, this type of biological control is almost always managed by state departments of agriculture or federal agencies.

The Asian lady beetle is an example of a release made by the USDA. Its normal distribution is Asiatic and it is found in southern Siberia, Manchuria, China, Formosa, Korea, Japan, etc. Researchers were looking for a beneficial species that would feed more on pest species in trees, such as pecan, walnut, apple, and peach. Circumstantial evidence indicates that this insect is in fact doing what it was intended to do—reduce aphid and other pest species in trees. Releases were made during 1916, 1964, and 1965 in California. Additional releases were made in Nova Scotia, Connecticut, District of Columbia, Delaware, Georgia, Louisiana, Maine, Maryland, Mississippi, Ohio, Pennsylvania and Washington from 1978 to 1982. Connecticut received another release in 1985. Eight Mississippi releases were made between July and October 1980. Total insects released were 3,781. This 'beneficial insect' has increased until it now is the predominant species of lady beetle in many areas. In some areas, because of its tendency to congregate on the walls of houses, it has become an annual fall and spring nuisance to homeowners.

Cultural control consists of trying to reduce pest insect populations by the utilization of agricultural practices. One type of cultural control is to grow varieties of plants that are resistant to pests, such as sorghum that is resistant to greenbug (aphid) and weevil-resistant alfalfa. Short season cotton varieties greatly reduce their susceptibility to pests, which build high populations in the late season.

Planting dates can often be used to greatly reduce or even eliminate pest problems. Uniform early planting of grain sorghum so that it heads early is often the only control technique needed for sorghum midge. Planting crops at their optimum growing potential is very important in reducing susceptibility to pests. Cotton should always be planted into warm soils so that it emerges and grows as quickly as possible to reduce susceptibility to thrips and cutworm damage. Later-planted cotton has a greater susceptibility to boll weevils, bollworms, tobacco budworms, and pink bollworms in the Western U.S., while delayed planting in the rolling plains of Texas and other states often allows a suicidal emergence of boll weevils in the spring.

Rotating crops helps manage insects such as rootworms in corn and plowing crop residues helps with problems associated with corn borers. Planting sweet potatoes after cotton leads to fewer soil-borne insect and disease problems than when planting them following corn or other grass crops. Planting cotton, corn, soybeans and grain sorghum in rotation helps to reduce pest populations for all the crops.

Plant populations and seeding rate impact insect populations, as do nutrients that are applied. All of these factors tend to affect the growth and development of plants, accelerating maturity of crops, making them more or less susceptible to pests.

Stalk destruction in both corn and cotton is important in reducing pest populations. Southwestern cornborers and other borers may be eliminated by timely corn stalk destruction in the fall to prevent overwintering of these corn pests. Cotton stalk destruction has been shown to greatly reduce the number of boll weevils available for hibernation.

Site selection can help greatly in reducing pest populations. Cotton should be planted away from optimum overwintering sites of boll weevils. Planting corn and cotton close together often causes problems with bollworms moving from the corn into cotton.

The destruction of overwintering sites and early tillage or herbicide burn down helps to control many pests. Cutworm infestations can often be completely eliminated by removing cover 3 to 4 weeks ahead of planting.

Mechanical or **physical control** involves the use of machines, implements, or other practices purposefully for control of insects. Handpicking the pest insects in a garden is an obvious example. Traps of all types (color-based, light traps, bait/odor lure traps) are mechanical controls. Exclusion of insects from your home by using screens is a mechanical control tactic. Building barriers that insects cannot scale is another method of mechanical control. Insect pests may also be affected by heat or cold. Freezing foods—or your carpet beetle–infested insect collection—is a physical control. The addition or removal of humidity from an area may also mechanically impact insect populations. Blister beetles can be driven from a garden by beating on a bucket or pan. Thus, sound can be used as a management technique.

Chemical control, the use of insecticides or miticides to control pest arthropods, is an important management tactic. There are a great many different types of chemicals used for control of insects. Some are derived from plants, such as pyrethrins extracted from certain chrysanthemum daisies and neem seed oils. Most insecticides are synthetically produced and have a very wide range of uses and effects. One of the greatest advantages of insecticides is that their effects are usually rapid, allowing immediate control of a pest problem that was not managed by other methods. Insecticides are often relatively inexpensive and easy to use. Some of the ways that insecticides can be applied are as direct sprays or dusts, systemic treatments applied to soil that are then taken up by roots and moved throughout a plant, or foggers, which place an aerosol vapor in the air. Some insecticides may affect many different types of insects and are known as *broad spectrum insecticides*. Others affect only a few kinds of closely related insects and are considered *selective insecticides*.

As with other types of pesticides there can be certain hazards associated with the use of insecticides, however when used properly and in strict accordance with label directions, potential problems can be prevented. Therefore it is always very important to read and follow all directions for the use of any pesticide.

Integrated Pest Management (IPM) is a philosophical approach to pest management problems. At its core, it recognizes that a variety of management approaches are required to achieve the best means of managing a pest. Furthermore the techniques employed in pest management should be used in a coordinated (integrated) manner. For example, IPM tries to use cultural or chemical control practices that can avoid damaging biological controls. A common benefit of IPM practice is important environmental protection and reduced human health risks.

For More Information about Local Insects

Although there are a lot of books about insects and in developing your 4-H project, you will want to learn more about those that are important in your area. One good source is the local Extension office. County agents and associates, such as Master Gardeners, often are very familiar with the more important insects in your area. Also, several insect fact sheets are available which can be an important source of information and help to build your 4-H entomology resource files.

Fact sheets and other Extension publications are also available through the state land grant university.

Try Out Your Own Insect Control Experiments

As part of your 4-H project, you may wish to conduct an experiment to test an insect management idea. To determine how effective a practice might be, set out a well-planned experiment that will give conclusive results.

If management trials are poorly conducted they produce unconvincing results.

Tests should be set up using a control (or check). The control is a part of the experiment that is treated, in every way, in the same way as is that part receiving your experimental treatment. The reason for this is that insect populations vary greatly from year to year and even during short periods within the growing season. Without a control you have nothing with which to compare the effectiveness of the experimental treatment. It may have worked, or the insects may naturally not have been as abundant. With the control as a reference you can quantify its effectiveness, allowing you to make statements such as “this spray controlled 80 percent of the aphids.”

Furthermore, it is a very good idea to *replicate* your results. Insects are rarely distributed uniformly in an area, often being more abundant on certain plants or along edges of fields. Typical field experiments usually involve at least 3 or 4 replications for the researcher to begin to have good confidence that the results are real and repeatable. So, for example, if you were to test the effects of a soap spray on a garden insect you might want to first divide the area into eight plots, 4 that would receive the soap spray and 4 that would serve as the untreated control for comparison.

Then you are ready to “reap your results” and see how things turned out. For insect control trials this will require taking some measurement of how well the treatments worked. For example, you may observe how many insects are left on a leaf, how many mosquitoes are biting, or how much damage was done to the plant. By your careful measurements, and a well-designed experiment, you come up with results that you will have confidence in and can share with others.

Classification of Insects

Classification for Your 4-H Project

Because there are so many different kinds of insects, identifying them can be very difficult. Don't get discouraged—even professional entomologists don't know them all. As you work your way through your 4-H units, just try to make some progress in what you know. As you work at it, you will be surprised how much you have learned. Try to work through the following stages in your study of entomology:

Early Learning Objectives. Learn the features of insects and what separates them from their Arthropod relatives: spiders, scorpions, ticks, pillbugs, etc. Learn the features of the various insect orders.

Advancing Into Entomology. Learn the features that characterize the adult insects of the most important insect orders. Expect to make mistakes, but you should be able to get 90 percent correct if you work on it. Adult leaders and professional entomologists are often willing to help. Don't hesitate to learn to use "keys" and other publications and to ask for help.

After You Have Gained Some Experience. Expand your collection and experiences to include other insects. Try to correct past mistakes on identification of insect orders—shoot for a level of 95–100 percent correct identifications of insects to the order level. Start to learn the features of immature stages of moths/butterflies (Lepidoptera), beetles/grubs (Coleoptera), flies (Diptera), and other insects. By this time you should also be starting to learn further sub-groupings of insects, the families.

Expanding Your Knowledge Base after a Few Years. Continue to learn immature stages of insects at the order level and adult insects to the family level. Few individuals have the expertise to identify insects to genus and species. Therefore, most 4-H collectors concentrate on **order and common name**.

Although these are some general learning objectives, always refer to your local and state fair books for exhibit information.

Once you have identified something as being an insect (from the Class Insecta), the next breakdown is the **ORDER**. For example, butterflies and moths, which have scale-covered wings, are in the order *Lepidoptera*. Beetles, characterized by having hard wing covers, are in the order *Coleoptera*. Flies are unique in having only a single pair of wings, the hind wings being reduced to an almost invisible knob, and are classified in the order *Diptera*, meaning "two-wing."

Because of differences in how scientists classify the insects, you may see some differences in the number of orders and in their name. Perhaps the most widely used classification system in the

Classification of Two Common Insects

Common Name: **Honeybee**
Scientific Name: *Apis mellifera*

KINGDOM: Animal (animals)
  PHYLUM: Arthropoda (arthropods)
    CLASS: Insecta/Hexapoda (insects)
      ORDER: Hymenoptera (bees, wasps, ants, etc.)
        FAMILY: Apidae (bees)
          GENUS: *Apis*
            SPECIES: *mellifera*

Common Name: **Colorado potato beetle**
Scientific Name: *Leptinotarsa decemlineata*

KINGDOM: Animal (animals)
  PHYLUM: Arthropoda (arthropods)
    CLASS: Insecta/Hexapoda (insects)
      ORDER: Coleoptera (beetles)
        FAMILY: Chrysomelidae (leaf beetles)
          GENUS: *Leptinotarsa*
            SPECIES: *decemlineata*

United States is that used in the textbook, *Introduction to the Study of Insects,* which lists 31 insect orders. For most 4-H collections, you will only be asked to correctly identify insects to their proper order and to assign a common name.

Orders are subdivided into **families**. The family names usually end in "dae" (pronounced "dee"). For example, the beetles (Order Coleoptera) are divided into many dozens of families, including lady beetles (Coccinellidae), weevils or snout beetles (Curculionidae), and leaf beetles (Chrysomelidae).

Furthermore, each family of animals is divided into **genera** (singular **genus**), and each genus is divided into various species. All types (species) of insects, as well as all other life forms, have their own **scientific name** (sometimes called the "Latin name"), made by combining the genus and species name.

When written, the genus name is capitalized and in italics. If it cannot be italicized, it is underlined. For example, the scientific name of the house fly is *Musca domestica*; and that of the tomato hornworm is *Manduca quinquemaculata*. The idea of giving each species a universally recognized scientific name came from Carolus Linnaeus, a Swedish botanist (1707–1778), who developed this system. (For a discussion on Carolus Linnaeus and other famous entomologists see the History of Entomology section.)

Since each scientific name has two parts, it is described as **binomial nomenclature**, and it is considered to be the international standard for discussing the identity of different plants and animals. Although scientific names may seem a bit awkward to pronounce, they do serve a very useful purpose, allowing people throughout the world to know which insect is being discussed.

Although this may be a bit confusing, consider how we identify ourselves. A similar system might be used to find William Smith or Patty Jones, two imaginary 4-H members.

Postal Classification of a 4-H Member

COUNTRY: United States of America
STATE: Mississippi
CITY: Greenwood
STREET: Leflore Ave.
NUMBER: 1776
SURNAME: Smith
FIRST NAME: William

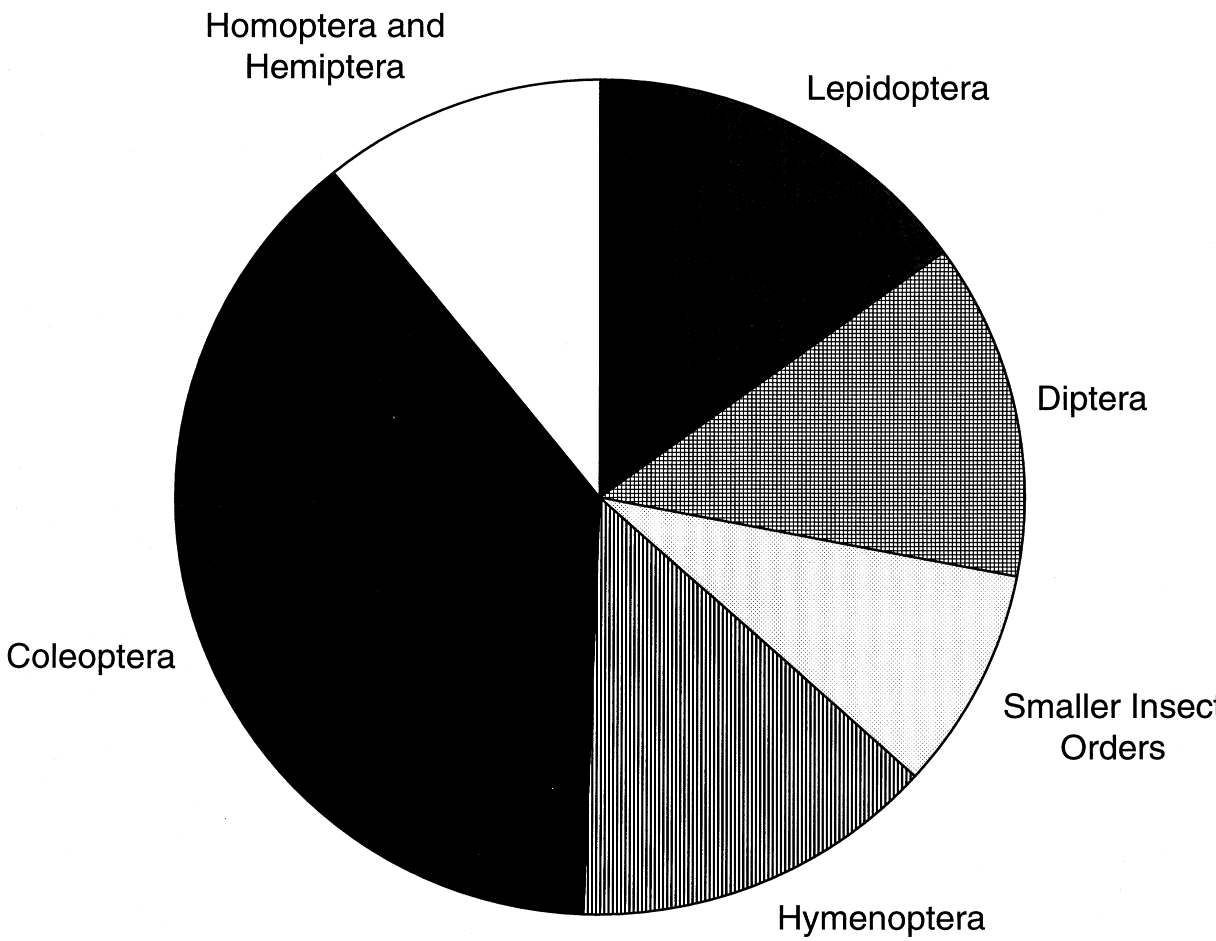
COUNTRY: United States of America
STATE: Tennessee
CITY: Gatlinburg
STREET: Bent St.
NUMBER: 429
SURNAME: Jones
FIRST NAME: Patty

Common Name or Scientific Name?

All insect orders and families—and many individual species of insects—have a **common name**. This is the familiar insect name in English, in contrast to the more formal **scientific name**. For example, “beetles” is the common name for the order Coleoptera; “swallowtails” is the common name for the family Papilionidae; and “house fly” is the common name for the insect *Musca domestica*.

Scientific names are universal; they are the same in every country, and that is their appeal. However, most people find it easier to learn and use the common names when discussing local insects. As long as they are used consistently, common names can be just as useful and are acceptable for 4-H collections and study.

The common names used in the United States are standardized by the Entomological Society of America. Periodically, they produce a publication entitled *Common Names of Insects and Related Organisms*. Canada and Mexico produce similar publications.



Relative number of species in the different insect orders.

Standard 4-H collections in the southern states use the order and common names for identification of insects and in general accept the common name given in the Peterson's Field Guide to Insects of America North of Mexico.

The Insect Orders

Currently, most entomologists recognize 31 separate orders of insects found in North America. This includes the Protura, Collembola and Diplura, which are placed in a different class, the class Entognatha, by some authors. Some are extremely abundant and are commonly observed, e.g., beetles (Coleoptera), moths and butterflies (Lepidoptera), and the "true bugs" (Hemiptera). Others are rarely found, such as the rockcrawlers (Grylloblattaria) and webspinners (Embiidina). Some are just too small to attract our attention, although they may be extremely abundant. For example, a square-foot patch of rich garden soil or grass field may host thousands of tiny springtails (Collembola). The 31 insect orders listed in *Introduction to the Study of Insects, 7th edition* by Triplehorn and Johnson, copyright 2005, are listed below. This is the standard entomology text used for insect identification in most college entomology classes and by most professional entomologists. However, this text is costly (around $150) and too technical for most 4-Hers. The National Wildlife Federation's Field Guide to Insects and Spiders of North America by Arthur V. Evans, Copyright 2007, is the standard reference recommended for 4-Hers. It is more affordable (around $25) but closely follows the order classification used in the 7th edition of *Introduction to the Study of Insects*. The main difference is that the Evans reference breaks the order Neuroptera into three orders: Neuroptera, Megaloptera, and Raphidioptera.

Outline of the Insect Orders

(based on classification scheme of Triplehorn and Johnson, 2005)

Order (common name)	*Type of metamorphosis*
(These first three orders are sometimes placed in a different class – Entognatha)	
Protura (proturans)	No distinct metamorphosis
Collembola (springtails)	No distinct metamorphosis
Diplura (diplurans)	No distinct metamorphosis
Microcoryphia (bristletails)	No distinct metamorphosis
Thysanura (silverfish, firebrats)	No distinct metamorphosis
Orthoptera (grasshoppers, crickets)	Simple/Gradual
Grylloblattodea (rockcrawlers)	Simple/Gradual
Phasmatodea (walkingsticks)	Simple/Gradual
Mantodea (mantids)	Simple/Gradual
Mantophasmatodea	Simple/Gradual
Blattodea (cockroaches)	Simple/Gradual
Isoptera (termites)	Simple/Gradual

Outline of the Insect Orders (continued)

Order (common name)	*Type of metamorphosis*
Dermaptera (earwigs)	Simple/Gradual
Embiidina (webspinners)	Simple/Gradual
Psocoptera (psocids)	Simple/Gradual
Phthiraptera (lice)	Simple/Gradual
Zoraptera (zorapterans)	Simple/Gradual
Hemiptera (true bugs, cicadas, hoppers, aphids, scale, whiteflies)	Simple/Gradual
Plecoptera (stoneflies)	Incomplete (A variation on simple metamorphosis with immature, aquatic forms)
Ephemeroptera (mayflies)	Incomplete
Odonata (dragonflies and damselflies)	Incomplete
Thysanoptera (thrips)	Complete
Neuroptera (alderflies, dobsonflies, lacewings, antlions)	Complete
Coleoptera (beetles)	Complete
Strepsiptera (twisted-wing parasites)	Complete
Mecoptera (scorpionflies)	Complete
Siphonaptera (fleas)	Complete
Diptera (flies, gnats, mosquitoes, etc.)	Complete
Trichoptera (caddisflies)	Complete
Lepidoptera (butterflies, moths)	Complete
Hymenoptera (sawflies, ichneumons, ants, wasps and bees)	Complete

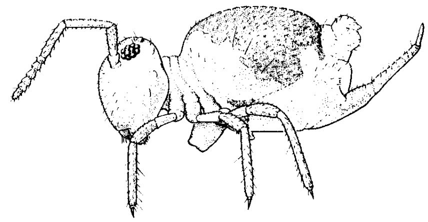
Several different features are used when identifying the different orders of insects. Each order of insects has some combination of these features that makes it distinctive.

- **Mouthparts.** What type of mouthpart does the insect have and how does it feed? Does the insect chew or have some altered mouth type that allows it to suck fluids?
- **Wings.** Are wings present in the adult? Are there one or two pairs? Does the wing have any special features, such as being covered by scales?
- **Legs.** Are there any unusual features of the insect's legs? Do immature stages have temporary *prolegs* on the abdomen, such as caterpillars?
- **Antennae.** Are the antennae characteristic? Are they thread-like, bead-like, or elbowed?
- **Metamorphosis.** What types of growth stages does the insect go through as it develops? Is it gradual (simple) metamorphosis, complete metamorphosis, or something intermediate? This will also determine how different the immature stages (caterpillars, grubs) are from the adult forms (butterflies, beetles).

Summary of Features of the Most Common Insect Orders

Features that may be particularly useful for identification are listed with each order.

Insects with No Apparent Metamorphosis



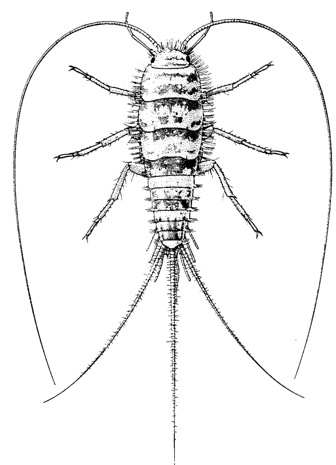
Springtail

Order: **COLLEMBOLA** (Springtails)
Pronunciation: kol-lem'-boh-luh
Metamorphosis—None

Adult features
- Wingless
- Very small size and almost always associated with soil
- Chewing mouthparts
- “Springtail” (furcula) often present
- Most jump

Immature (nymph) features
- Same as adult only smaller in size

Habits—In many areas, the springtails are the most numerous insect, as tens of millions may occur in an acre of soil. However, they are so tiny they rarely are noticed. Most springtails feed on decaying plant matter, although some are predators of other insects and mites found in soil.



Silverfish

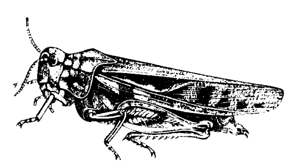
Order: **THYSANURA** (Silverfish, firebrats)
Pronunciation: thy-san-urr'-uh
Metamorphosis—None

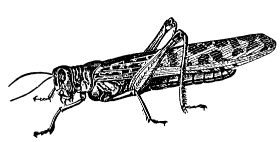
Adult features
- Wingless
- Chewing mouthparts
- Pair of long, tail-like cerci
- Active, fast-moving

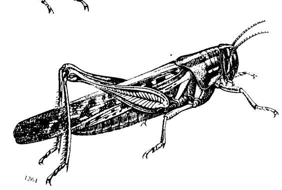
Immature (nymph) features
- Same as adult only smaller in size

Insects with Simple Types of Metamorphosis

Grasshoppers

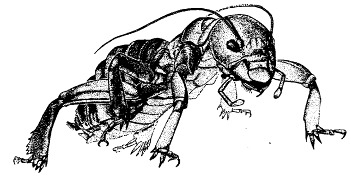






Order: **ORTHOPTERA** (Grasshoppers, crickets, katydids)
Pronunciation: or-thop'-terr-uh
Derivation: Orthoptera is greek for

“straight wing,” a reference to the generally straight forewings of these insects.
Metamorphosis—Simple/gradual

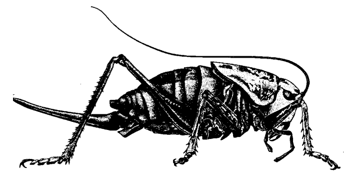


Jerusalem Cricket

Adult features

A familiar order that perhaps is best recognized by knowing the associated insect groups-grasshoppers, crickets, etc.

- Legs designed for jumping
- Chewing mouthparts
- Thread-like antennae
- Forewings, if present, are thickened slightly (leathery)

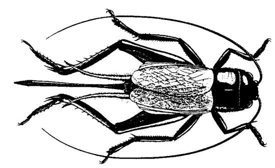


Mormon Cricket

Immature (nymph) features

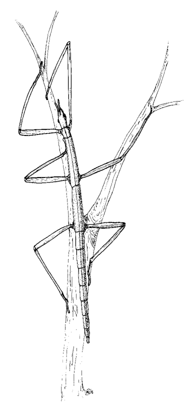
- Chewing mouthparts, antennae similar to adult
- No wings, but wing pads usually are visible in older nymphs
- Legs designed for jumping

Habits—Almost all members of this order feed on plants. (A few are predators or scavengers.) The most familiar members of this order are the grasshoppers, some of which can be serious pests of agricultural plants during outbreaks. Crickets and katydids include some of the best known “insect songsters.”



Field Cricket

Order: **PHASMATODEA** (Walkingsticks) *Pronunciation*: phas-ma-toe'-dee-uh
(Note: Some older books include this order with Orthoptera)
Metamorphosis—Simple/gradual



Walkingstick

Adult features

- Very elongated body
- Chewing mouthparts
- Wings absent

Immature (nymph) features

- Chewing mouthparts
- General form similar to adult

Habits—The walkingsticks feed on plants, chewing the leaves. Their unusual stick-like form provides them with great camouflage.

Order: **MANTODEA** (Mantids) *Pronunciation*: man-toe'-dee-uh
(**Note**: Several books include this order with Orthoptera, or combine it with walkingsticks into the order Dictyoptera)
Metamorphosis—Simple/gradual

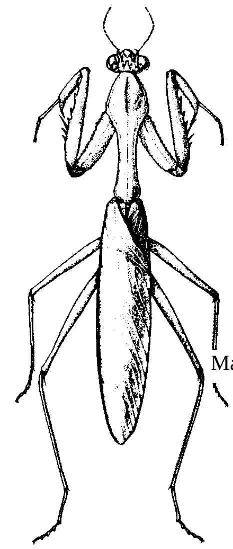
Adult features

- Forelegs designed for grasping and holding prey

- Elongated body
- Chewing mouthparts
- Long, thread-like antennae
- Wings (if present) are leathery and cover the abdomen

Immature (nymph) features

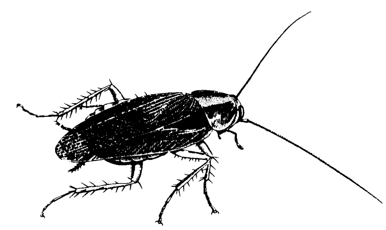
- General form similar to adult
- Wings absent



Mantid

Habits—Mantids develop as predators of other insects, which they capture with their grasping forelegs and eat. Several native species of mantids occur, but the largest and best recognized species are the Chinese mantid and European or "praying" mantid. Winter is spent in the egg stage within a mass covered with a tough styrofoam-like covering.

Order: **Blattodea** (Roaches) *Pronunciation*: blat-toe'-dee-uh
(**Note**: Several books include this order with Orthoptera; a few lump them with Isoptera, the termites)
Metamorphosis—Simple/gradual



Cockroach

Adult features

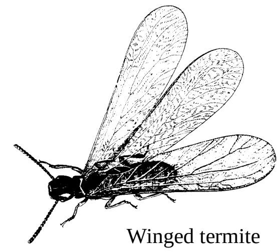
- Body generally flattened (top to bottom)
- Long, thread-like antennae
- Chewing mouthparts
- Wings (if present) are leathery and cover the abdomen

Immature (nymph) features

- Chewing mouthparts
- General form similar to adult
- Wings absent

Habits—Most species of roaches are found in warmer subtropical and tropical areas of the world. Only a few wood roaches, found feeding on decaying bark and other debris, are native to the region. However, a few kinds of roaches are well-adapted to indoor life and have been widely spread by humans, such as the German cockroach, Oriental cockroach, and American cockroach and most often are found co-existing with people.

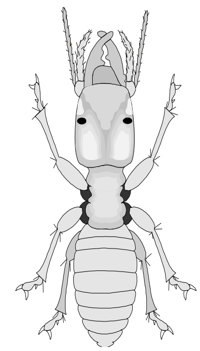
Order: **ISOPTERA** (Termites) *Pronunciation*: eye-sop'-terr-uh
Metamorphosis—Simple/gradual



Winged termite

Adult features
- Most are pale colored and found only in colonies
- Winged stages dark, with two pairs of wings that are equal in size
- Antennae appear to be made of a series of small beads
- Chewing mouthparts

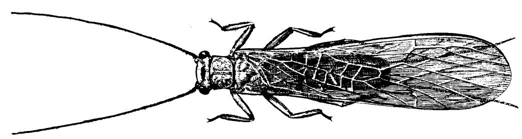
Immature (nymph) features
- Chewing mouthparts
- General form similar to adult



Termite

Habits—Termites are true social insects that live in colonies. Essentially, all regional species have colonies below ground. Only the winged reproductive stages leave the colony. Termites are capable of digesting cellulose, often through the aid of protozoa in their digestive system.

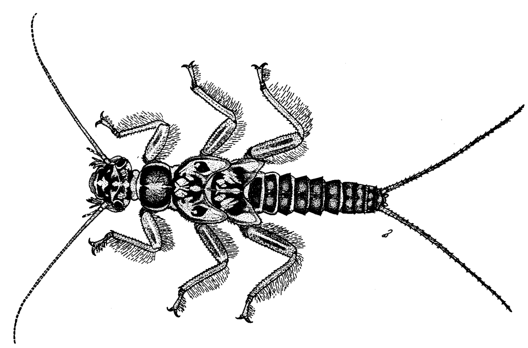
Order: **PLECOPTERA** (Stoneflies) *Pronunciation*: plee-cop'-terr-uh
Derivation: Plecoptera is Greek for "folded wing," a reference to how they fold their wings flat over their backs when at rest
Metamorphosis—Incomplete



Plecoptera adult

Adult features
- Elongated wings that fold flat over the body when at rest
- Long, filament-like antennae
- Two, tail-like filaments
- Almost always found near rivers and streams

Immature (nymph) features
- Two tail-like filaments at end of abdomen
- Generally flattened body shape (top to bottom)
- Aquatic, found in cooler water, particularly streams and rivers



Plecoptera larva

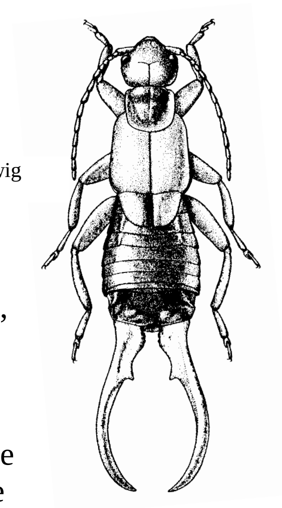
Order: **DERMAPTERA** (Earwigs) *Pronunciation*: dur-map'-terr-uh
Derivation: Greek for "skin wing," referring to the texture of the forewing
Metamorphosis—Simple/gradual

Adult features

- Chewing mouthparts
- Forewings are very short and leathery
- Cerci (pincers) present at tip of abdomen

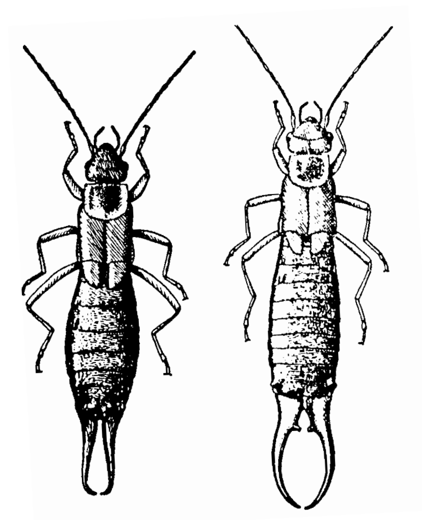
Immature (nymph) features

- Chewing mouthparts
- Cerci similar to adult



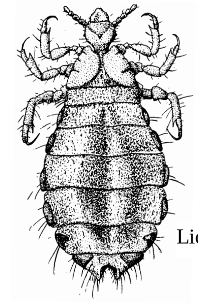
Earwig

Habits—The only common earwig in the region is the European earwig, an introduced species. They overwinter as adults, laying eggs in early winter. Females stay with the eggs and young nymphs for the early part of their lives. During the day, earwigs like to hide in dark, moist areas. Sexes can be separated by the cerci: those of the males are bowed; of the females straight. They can pinch with their mouthparts, but the cerci are weak and cannot produce a painful pinch.



European earwig: left, female; right, male

Order: **PHTHIRAPTERA** (Lice) *Pronunciation*: thur-ap'-terr-uh



Lice

Note: Many books and older 4-H materials separate this group into two orders: sucking lice (*Anoplura*) and chewing or bird lice (*Mallophaga*). Because of the many similarities in appearance and habit, these two groups now are usually combined into the lice, order Phthiraptera.

Metamorphosis—Simple/gradual

Adult features

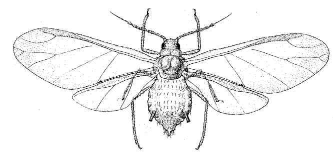
- Legs, particularly forelegs, designed to grasp hair or feathers
- Mouthparts variable. Some suck blood, others chew.
- Wingless
- Flattened body (top-bottom)

Immature (nymph) features

- Similar to adult

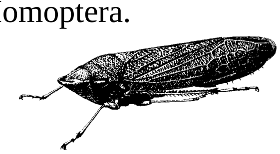
Habits—All members of this order are parasites of animals. The sucking lice suck blood from mammals and include such pests as the head louse and hog louse. Most chewing lice feed on skin and feathers of birds. As true parasites, they are almost always found on the body of the host animal on which they feed.

Order: **HEMIPTERA** True bugs, aphids, scales, whiteflies, leaf hoppers, cicadas, and others. *Pronunciation*: hem-ip'-terr-uh



Metamorphosis—Simple/gradual

Note: Older references divide this group into two orders: Hemiptera and Homoptera.

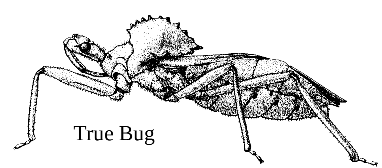


Adult features:

- Highly variable in form
- Piercing, sucking mouthparts
- Prominent V-shaped area (scutellum) behind head, between the folded wings

Immature (nymph) features:

- Piercing-sucking mouthparts similar to adult
- No wings, but wing pads are usually visible in older nymphs



Some problem features with Order:

- Females of many families are always wingless (e.g., scales) or often wingless (e.g., aphids)
- Female scales have most features obscured by the scale covering. However, they can be distinguished as homopterans behaviorally because they are extremely immobile, a feature largely limited among plant pests to the homopterans (a result of phloem-feeding habit).
- Whiteflies, a family that is primarily found in the subtropical and tropical areas of the world, produce nymphal stages that are very different in form from the adult and include a non-feeding 'pupal' stage.

Order: **EPHEMEROPTERA** (Mayflies) *Pronunciation*: eff-em-err-op'-terr-uh

Ephemeroptera is Greek for "short-lived" and "winged," a reference to the very short life of the winged adult stages.

Metamorphosis—Incomplete

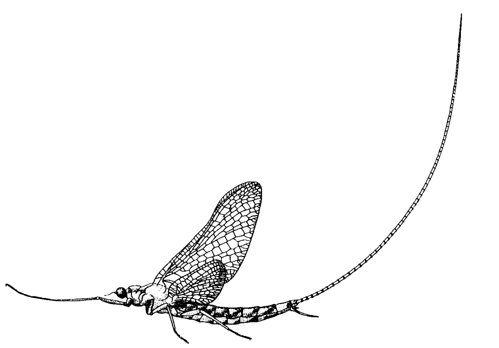
Adult features:

- Forewing large and triangular; hind wing small and rounded
- Wings held vertically over the body
- Small, bristle-like antennae
- Two, very long tail-like filaments
- No functional mouthparts (vestigial)

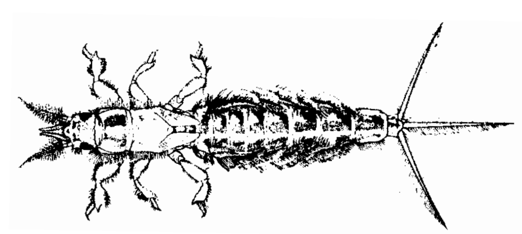
Immature (nymph) features:

- Feathery or plate-like gills along the abdomen
- General elongated form
- Found only in water, particularly rivers and streams
- Three (occasionally two) tail-like filaments

Habits—Immature stages (naiads) develop in water, where they feed on algae and particles of organic matter. After becoming full grown, they transform to a winged form that is generally dark in color, known as the subimago or "dun" stage to fisherman. Within hours to two days, the insect again molts to the final adult form. Mayflies are the only insects that molt after winged forms have been produced. Although the larvae may take one to two years to develop, the adult stage—which does not feed—survives at most only a couple of days, during which mating and egg laying occur.



Mayfly adult



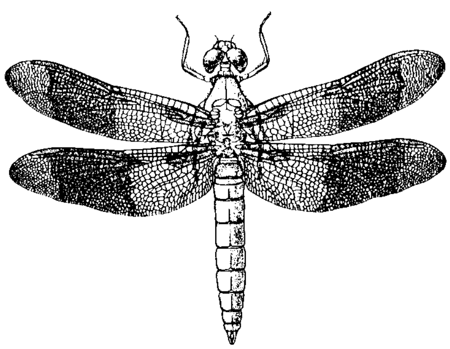
Mayfly larva

Order: **ODONATA** (Dragonflies and damselflies) *Pronunciation*: o-don-ate'-uh
Metamorphosis—Incomplete

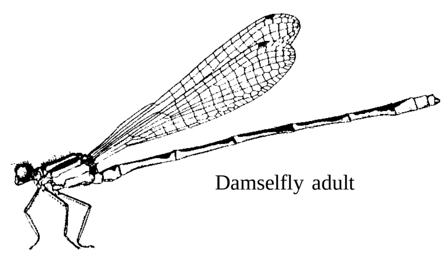
Adult features:
- Large insects with elongated body form, very narrow abdomen
- Very large eyes, which may cover much of the head
- Prominent, chewing mouthparts used to capture and consume winged prey
- Small, bristle-like antennae
- Large elongated wings that are highly veined

Immature (nymph) features:
- Restricted to water
- Large eyes
- Three leaf-like gills at end of abdomen (damselflies only)
- Unique, hinged jaw that can project forward to capture prey

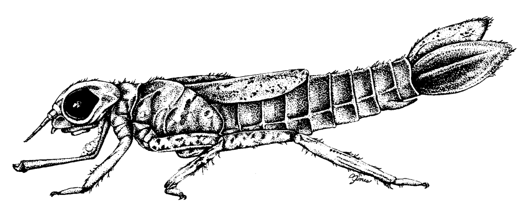
Habits—Both adult and immature stages develop as predators of other insects. The nymphs (naiads) are found in water and possess a unique, extensible mouthpart that can rapidly extend forward to grab prey. Adults are excellent fliers that capture other insects in flight. The dragonflies hold their wings horizontally when at rest, while the more slender-bodied damselflies have wings that project backward.



Dragonfly adult



Damselfly adult



Damselfly larva with jaw extended

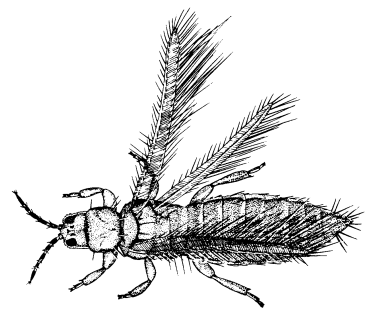
Order: **THYSANOPTERA** (Thrips) *Pronunciation*: thy-san-op'-terr-uh

Derivation: Greek for "fringe wing," a reference to the characteristic fringing of the wings

Metamorphosis—A hybrid between simple (gradual) and complete

Adult features:

- Extremely small (typically less than 1/16 inch)
- Fringing of the wings is unique, but difficult to use as identification character, since the insects are very small and often fold their wings over their backs
- Generally elongated body shape
- Mouthparts cone-like in side view
- Plant-feeding species typically cause scarring wounds.



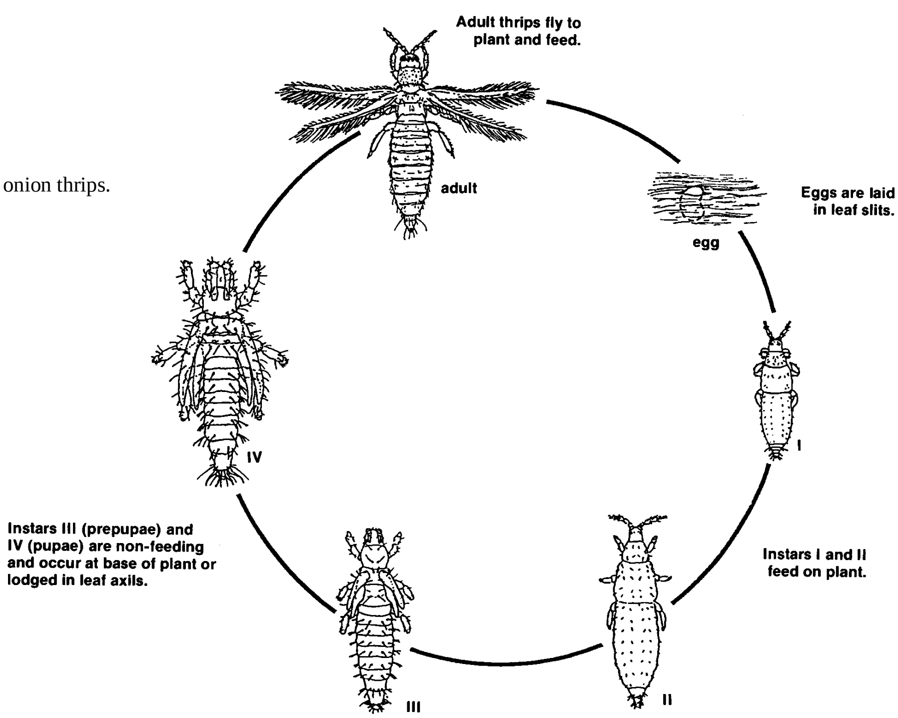
Thrips

Immature (nymph) features:

- Feeding habits similar to adult
- Generally similar to adult in form, but wingless and usually pale colored

Habits—Thrips are very common insects but, because of their small size, are rarely observed. The most abundant species feed on leaves and/or flowers. A few are predators of insects and mites. Plant-feeding thrips feed by gashing cells of plants, inserting their tube-like maxillae, and sucking the released fluids, a habit sometimes described as "piercing-sucking."

Life cycle of the onion thrips.



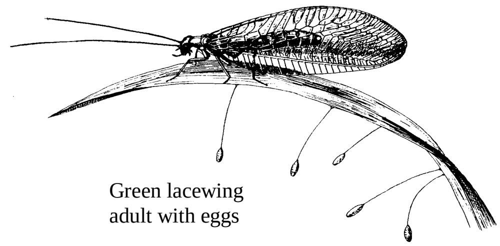
Insects with Complete Metamorphosis

Order: **NEUROPTERA** (Lacewings, antlions, snakeflies, dobsonflies, etc.)

Pronunciation: new-rop'-terr-uh

Derivation: Greek for "nerve wing," a reference to the highly veined wings

Metamorphosis—Complete



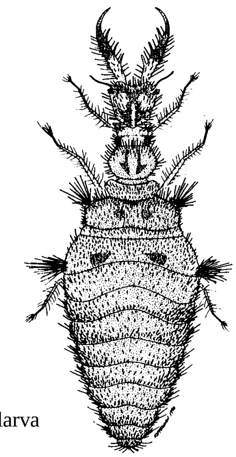
Green lacewing adult with eggs

Adult features:

- Highly veined, membranous wings (front of forewing with multiple cells)
- Chewing mouthparts
- Adults often predators, although many feed on nectar, pollen

Immature (larva) features:

- Forward-projecting, curved, pointed jaws
- Often elongated body shape
- Three pairs of legs, no prolegs



Antlion larva

Habits—Immature stages of this order are predators of other insects, or in the case of the mantispids, eggs of spiders. They possess an unusual mouthpart, designed to grasp and crush prey, and then suck the blood. Adults of some members also are insect predators, while others feed on nectar or pollen.

Order: **COLEOPTERA** (Beetles)

Pronunciation: cole-ee-op'-terr-uh

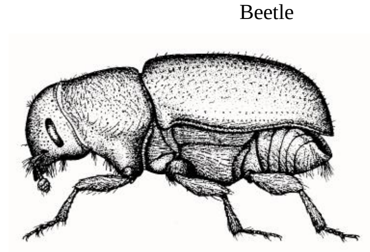
Derivation: Greek for "sheath wing," a reference to the characteristic hardened forewings of this group of insects

Metamorphosis—Complete

Adult features:

- Two pairs of wings
- Front pair of wings hardened into wing coverings (elytra)
- Mouthparts designed to chew

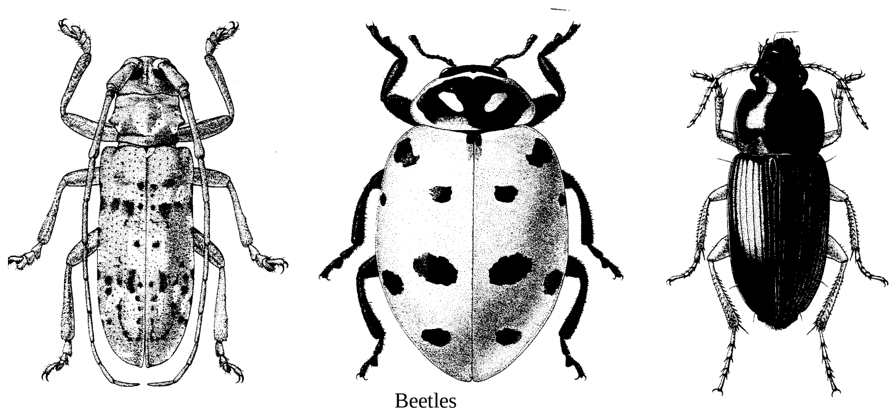
Beetle



Immature (larva) features:

- Larvae known as "grubs"
- Head capsule is distinct
- Larvae that feed on outside of plants usually have true legs, but no prolegs
- Larvae that feed internally in plants (e.g., bark beetles, weevils, wood borers) have no true legs, as well as no prolegs

Habits—The beetles are, by far, the largest and most diverse order of insects. A great many develop by feeding on plants. Several beetles are important crop pests. The Mexican bean beetle, Colorado potato beetle, boll weevil, and pine beetle are just a few of the commonly known plant pests. Other beetles are important in biological control; these include ground beetles and the familiar lady beetles. Some of the most important scavenger insects are in this order. These include the scarab beetles and hide beetles. Many types of beetles are also adapted to life in water. These include predaceous diving beetles, whirlygig, and others.

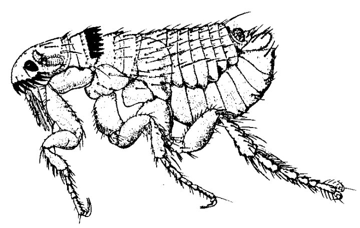


Beetles

Order: **SIPHONAPTERA** (Fleas)

Pronunciation: si-fon-ap'-terr-uh

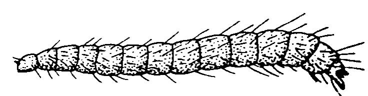
Metamorphosis—Complete



Flea adult

Adult features:

- Wingless
- Body flattened (side to side)
- Large hind leg designed for jumping
- Dark colored
- Parasites of mammals, occasionally of birds
- Mouthparts designed to pierce skin, suck blood
- Small size (less than ⅛ inch)
- Body is covered with bristles that project backwards



Flea larva

Immature (larva) features:

- Typical form is worm-like, legless
- Pale colored except for dark head
- Associated with nest/resting area of the host on which adult feeds

Habits—Adult stages of fleas feed on the blood of mammals or birds. However, the worm-like larvae are scavengers, feeding instead on skin flakes, dried or excreted blood from the adults, or other debris. A few species of fleas are important in the spread of diseases. Fleas are a vector of the disease bubonic plague.

Order: **DIPTERA** (Flies, mosquitoes, midges, gnats, etc.)

Pronunciation: dip'-terr-uh

Derivation: Greek for "two-wing," a reference to the characteristic that these insects have only a single pair of wings

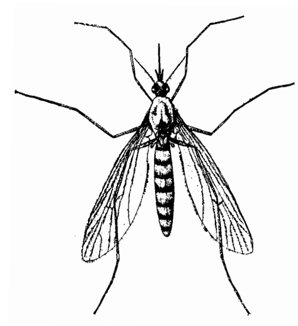
Metamorphosis—Complete

Adult features:

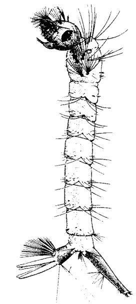
- Two wings (one pair)
- Hind wings reduced to a knob-like **haltere**
- Mouthparts highly variable
- Sponge fluids (e.g., house flies)
- Cut and lap fluids (e.g., horse flies)
- Pierce and suck (e.g., mosquitoes)

Immature (larva) features:

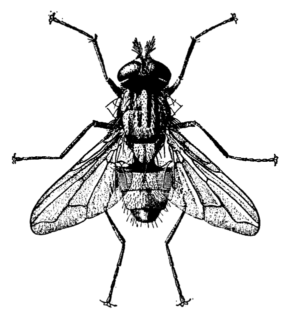
- Often called maggots
- No legs
- Elongated, often tapered form
- Often no visible head capsule common
- Some have small head, but remain legless (e.g., mosquitoes, gnats)



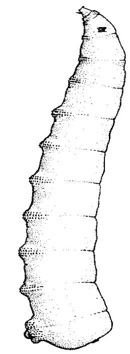
Mosquito adult



Mosquito larva



House fly adult

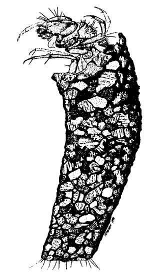


House fly larva

Habits—Second only to beetles in number, members of this order can be found in almost any environment. Some of the better known species, such as house flies and blow flies, develop as scavengers. Adult stages of several families bite and feed on blood (the mosquitoes being most notorious). The gall midges and others damage plants, but many others feed on plant pests (flower flies, robber flies). Many of the midges are among the most abundant insects found in ponds and streams. These fill niches in the food chain, providing food for fish and other small animals.

Order: **TRICHOPTERA** (Caddisflies) *Pronunciation*: tri-cop'-terr-uh
Derivation: Greek for "hair wing," a reference to the fine covering of hairs on the wing
Metamorphosis—Complete

Caddisfly adult



Caddisfly larva

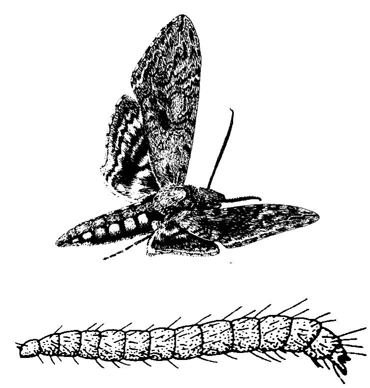
Adult features:
- Two pairs of wings
- Wings with fine hairs
- Wings held roof-like over the body when at rest
- Mouthparts are non-functional; vestigial

Immature (larva) features:
- Larvae live in water, particularly flowing streams
- Some live within cases they construct of silk and pebbles, sticks or small leaves
- Many construct small silken nets, others are free living and actively hunt other insects

Habits—Caddisflies develop in water, particularly permanently flowing streams and rivers. Often, the larvae live inside a case of pebbles, sand, small leaves, or other debris they carry around as they feed on algae, other organic matter, and sometimes, other insects. Some caddisflies construct silken nets that catch floating particles on which they feed. The adult insects are winged and somewhat resemble moths. They usually are found near water, and since they do not feed, live for only a few weeks.

Order: **LEPIDOPTERA** (Butterflies, moths, skippers)
Pronunciation: lep-id-op'-terr-uh

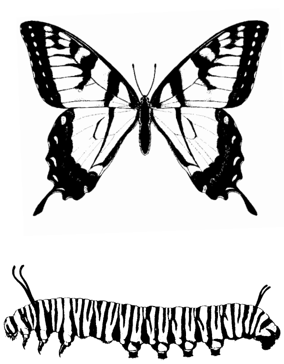
Derivation: Greek for "scale wing," a reference to the flattened scales that cover and mark the wings
Metamorphosis—Complete



Moth adult and larva

Adult features:
- Two pairs of wings
- Wings with some scales
- Mouthparts primarily designed to suck (siphon) fluids or are non-functional (vestigial)

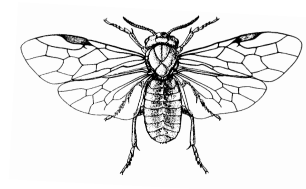
Immature (larva) features:
- Larvae have prolegs as well as true legs
- Differentiated from sawflies (Hymenoptera) by having two to five pairs of prolegs
- Prolegs have hook-like crochets on the ends



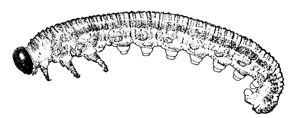
Butterfly adult and larva

Habits—Essentially all members of this order develop by feeding on plants during their immature "caterpillar" stage. With the possible exception of the Homoptera, this is the most important order of insects that includes crop pests, e.g., cutworms, cabbageworms, armyworms, tobacco budworm, tomato hornworm, the corn earworm. However, most species do not cause any serious plant injury, and adult stages are moths or butterflies, which feed on nectar, oozing plant sap, or do not feed at all. Many moths pupate within a silken *cocoon*, while butterflies make a *chrysalid*, usually tied to a plant. Most pest Lepidoptera are moths.

Order: **HYMENOPTERA** (Sawflies, wasps, ants, bees, etc.)
Pronunciation: hy-men-op'-terr-uh
Derivation: Greek, includes "hymeno," the god of marriage, a reference to the union of the front and hind wings by hamuli
Metamorphosis—Complete

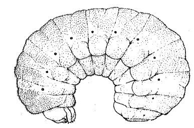


Sawfly adult and larva



Adult features:

- Two pairs of wings, but often hooked together by a set of hooks (hamuli) so that they function largely as one
- Mouthparts of most species are chewing type. Some suck fluids. Mouthparts of bees combine both features; ability to suck nectar/fluids and a chewing mouthpart
- Most species have a distinct constriction between the thorax and abdomen (wasp waist) (Exception: Sawfly/horntail group do not have a wasp waist)
- Antennae are jointed, sometimes elbowed

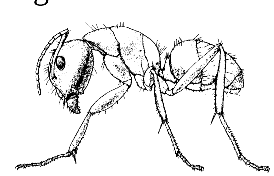


Bee larva

Immature (larva) features:

- Larvae of most species are rarely observed. They either occur within colonies, nests, or nest cells (ants, bees, yellowjackets), or develop internally in other insects (parasitic wasps)
- Distinct head capsule
- No legs (Exception: Sawfly larvae have prolegs as well as "true" legs on thorax.)
- Differentiated from Lepidoptera by having 6+ pairs of prolegs

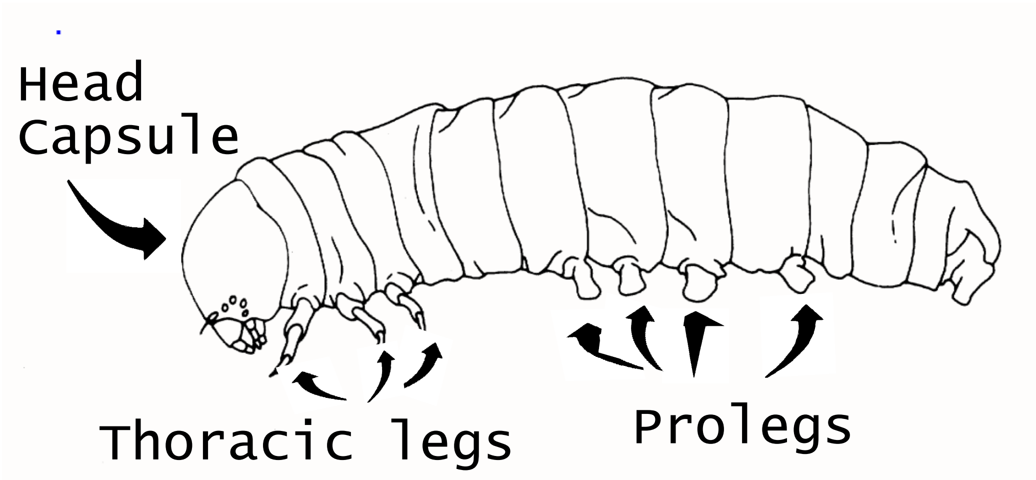
Habits—Along with the beetles (Coleoptera) and flies (Diptera), members of this order have the most diverse habits. For example, many are social insects which produce a colony, e.g., the ants, yellowjackets, and honeybees. Many of these also can sting. Members of this order include the most important insects that pollinate plants, the bees. Also, many are important in biological control of pest insects; the ichneumon and braconid wasps. The sawflies are one of the only groups in this order that chew and damage plants; the larvae are often confused with caterpillars.

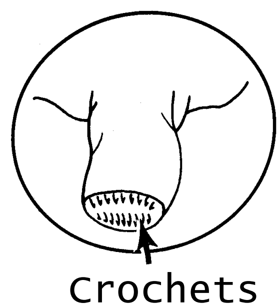


Ant

Features of Immature Insects from Orders with Complete Metamorphosis

Order	*Legs present*	*Prolegs present*	*Head capsule present*	*Other features*
Coleoptera	Yes. Legs absent or very reduced in size on larvae that develop within plants (weevils, borers).	No	Yes	
Lepidoptera	Yes. Legs of clearwing borers are very reduced in size.	Yes. 2–5 pairs. Crochets present.	Yes	
Trichoptera	Yes	No	Yes	Aquatic insects. Some construct cases of pebbles, sand, small sticks, etc.
Hymenoptera (Most species, except sawflies)	No	No	Yes	Most larvae in this order possess a head capsule but lack legs. These live internally in plants, in animal/ insect hosts, or are reared in nest cells.
Hymenoptera (Sawfly group)	Yes	Yes. Six or more pairs. No crochets.	Yes	Sawflies are plant-feeding insects that resemble caterpillars but differ in the number and structure of the prolegs.
Diptera (Suborder Brachycera)	No	No	No. Head is reduced to pair of recessed mouth hooks.	Larvae in the suborder Nematocera do possess a head capsule.
Diptera (Suborder Nematocera)	Yes	No	Yes	Most larvae live in moist or aquatic areas.
Neuroptera	Yes	No	Yes	Prominent, forward projecting mouthparts are present. Predators.





Features used to identify some immature insects.

History of Entomology

Men have been interacting with and studying insects since time began. The Chinese have been cultivating silkworms for thousands of years. Chinese records show silkworm culture prior to 4700 B.C. Beekeeping was also carried out by the Chinese as early as 600 B.C. and they used galls to create dyes, drugs and tanning agents at about the same time. The culture of dye-making insects was also a practice in ancient India.

There is evidence of insect pests of ancient man. Lice and other blood-sucking insects were fairly common in many ancient cultures. There are numerous references to grasshopper (locust) plagues in many countries. Of the 10 plagues of Egypt that are recorded in the Biblical book of Exodus, insects were the direct cause of 3 and were involved in others. Lice, flies, and locusts were the three named in Exodus 7–11. These pests still plague man today.

Homer's epics (850 B.C.) use examples of insect life to illustrate points and tell stories. Homer mentions fly larvae, horse flies, wasps, bees, and honey. Aesop told fables of the ant and the fly in 600 B.C. Democritus of Adbera (470–370 B.C.) divided blooded animals - vertebrates (backbone) and bloodless animals—invertebrates (no backbone). Plato (429–347 B.C.) initiated the idea of scientific entomology. It is from Plato that we get the idea of classifying living things into genus and species. Herodotus, a Greek historian, gave concise scientific descriptions of bees and ants and mentioned the use of mosquito nets by Egyptian fishermen. Pythagoras in 450 B.C. rid a Sicilian town of marsh-fever by draining a nearby swamp.

Aristotle may be called the founder of general entomology and entomology as a science. He gave the first systematization of insects. Aristotle wrote *The History of Animals* (a general description and biology of the animal kingdom), *On the Parts of the Animals* (comparative anatomy and physiology), and *Generation of Animals*. Aristotle named about 500 animals. According to Aristotle, 'Entoma' are bloodless animals which have more than 4 feet, and some have wings. Their body is rigid within and without. Theophrastus was a student of Aristotle. He was responsible for identifying a number of kinds of damage and diseases caused by insects. Dioscorides, another Greek, used insects to treat human diseases. His remedies were used for many years. In his book *Materia Medica* he mentions the following remedies: cockroaches when ground with oil and cooked are good for ear ache; cicadas when fried are used for bladder complaints; caterpillars on vegetables when coated with oil are used against the bites of poisonous animals; and beetles containing cantharidin are used for various ailments from cancer to dropsy.

Pliny was a Roman philosopher and prolific writer who wrote an encyclopedia. His *Historia Naturalis* is one of the few works from Roman times that deal with entomology. Pliny's eleventh book deals chiefly with insects. He classified them much as Aristotle, though it is doubtful that he was familiar with Aristotle's work.

There is a fairly large skip in history after the fall of Rome. The centers of knowledge shifted and many of the 'advances in scientific knowledge' were lost. Albertus Magnus appeared in 1255. He wrote an encyclopedia called *De Animalibus* that contained 26 books and characterized every animal known at that time. He only mentioned 33 insects, lumping them into the category small bloodless animals. Bees are discussed in detail.

Entomology was closely connected to medicine and natural history for the next 200 years. Italians like Malpighi, Redi and Valisinieri, medical practitioners, were also interested in insects. Ulisse Aldrovandi (1522–1605) wrote over 700 manuscripts that were published as *De Animalibus Insectis Libiri VII* in 1602. The English doctor Thomas Mouffet wrote a book similar to Aldrovandi's called *Insectorum Sive Minorum Animalism Theatrum.* The invention of the microscope revolutionized the study of entomology by enabling a closer examination of insects than ever before. The microscope led to the foundation of academies and scientific societies in all of the major cities of the world. Many of these early scientists began studying the anatomy and morphology of insects. Jan Swammerdam, a Dutchman, wrote *Historia Insectorum Generalis*, a comprehensive study of insects. Leeuwenhoek, another Dutchman, was also an avid entomologist.

The main achievement in 18th century entomology was the work of Carl von Linnaeus (1707–1778). He published two important works: *Systema Naturae* and *Fundamenta Botanica*. His classification system was the starting point for zoological nomenclature (the naming of animals). Linnaeus developed the system of binomial nomenclature (2 names, *Genus* and *species*) into the most useable way for naming things. Using a single character, the wings, Linnaeus divided insects into four Orders initially: Coleoptera, Angioptera, Hemiptera, and Aptera (*ptera* means wing). He later used seven orders: Coleoptera, Lepidoptera, Hemiptera, Neuroptera, Hymenoptera, Diptera, and Aptera.

J. C. Fabricius, a Danish pupil of Linnaeus, published *Philosophia Entomologica* in 1758. This is actually the world's first textbook of entomology. The text contained sections on history of entomology, morphology, mouthparts, metamorphosis, sex, systematics, nomenclature, distinguishing characteristics, ecology and biology, and applied entomology.

During the Middle Ages insects, as vectors of disease, were responsible for some of the worst epidemics that have struck man. Bubonic Plague (the Black Death) claimed the life of at least 25 million people, more than one-fourth of the population of Europe. This bacterial disease of rodents is transmitted by the Oriental rat flea. When rats die of the disease, the fleas move from the dead animals to other warm blooded hosts, including man. When the fleas bite, they transfer the disease to the new host. This disease is still a threat to man today. Typhus (transmitted by the human louse), malaria (transmitted by the anopheles mosquito), sleeping sickness (transmitted by the tsetse fly), and numerous other diseases were part of the reason for studying and understanding more about insects.

Early Americans were also interested in insects. When colonists came to the New World, they not only brought their crops, but they also inadvertently brought the pests as well. The codling moth was an early introduction and has developed into a serious pest of apple. In 1588, Thomas Harriot, published "A Brief and True Report of the New Found Land of Virginia," in which he described the habits of many insects, mentioning the silkworm and the honey bee in particular. One of the most famous examples is the introduction of the Hessian fly. During the French and Indian War, Hessian troops of the British army brought wheat straw for bedding into the colonies. The Hessian fly, a pest of wheat, escaped from the straw to cause extensive damage to the wheat crop on Long Island as early as 1779. George Washington experimented with the Hessian fly in 1760. In 1763, a Frenchman suggested the use of tobacco water against plant lice, (nicotine sulfate is commonly used for aphids today.) Many of the 'remedies' of the day bordered on the ridiculous. Materials such as salt, lime, alcohol, lampblack, cayenne pepper, ashes and even dung were used. The honey bee was another European introduction to North America. Honey bees were introduced as early as 1640 and were used extensively to provide honey and wax. The American Indians called honey bees "the white man's fly."

William D. Peck, a Massachusetts naturalist, wrote *The Description and History of the Cankerworm* in 1795. He became professor of natural history at Harvard University in 1805 where he continued to study insects. Peck became known as America's first native entomologist. Other early entomologists included B. D. Walsh, state entomologist of Illinois, J. A. Lintner, New York state, and A. S. Packard of the U.S. Entomological Commission.

The father of entomology in the United States was Thomas Say (1787–1834). Say was "the Linnaeus" of the New World. He was a specialist in birds and mollusks, and also developed an interest in insects. His descriptions were good for their time, and were comparative in nature. His accomplishments were even more remarkable considering that he was completely self-taught in the field of entomology. Since Say, most American entomologists have specialized in one way or another.

T. W. Harris, a student of Peck, became a distinguished economic entomologist. He wrote *Report on Insects Injurious to Vegetation*, published in 1841. In 1854, Townend Glover was named entomologist with the U.S. Bureau of Agriculture and Asa Fitch was named New York State Entomologist. C. V. Riley succeeded Glover in 1878.

Riley was a very important figure in American entomology. He founded the U.S. Entomological Commission, which studied and improved control activities for the Rocky Mountain grasshopper. He was also responsible for saving the French grape industry by using grape rootstocks from America that were resistant to grape phylloxera. The French government gave him a gold medal for his assistance to their industry. Riley was also instrumental in the biological control activities in California that saved the citrus industry from the cottony cushion scale through the importation of natural enemies from Australia.

L. O. Howard succeeded Riley as Chief of the Bureau of Entomology in 1894. Howard made lasting contributions to medical entomology, biological control, insect taxonomy, and to entomological research in general.

Another famous entomologist at this time was J. H. Comstock. He graduated from Cornell University in 1874 and remained there to work for the next 40 years. Comstock was the first university teacher of entomology, and he started the first entomology course to be offered at a university. He also wrote one of the first entomology textbooks and established the first university department of entomology in the world. The University of Idaho hired T. H. Parks as the first extension entomologist in 1913, one year before the Smith-Lever Act (1914) created the Federal-State Extension Service.

Information for this section came from *History of Entomology*, R.F. Smith, T.E. Mittler, and C.N. Smith, editors, 1973 and *Fundamentals of Applied Entomology*, Robert E. Pfadt, editor, 1971.

Starting Your 4-H Entomology Project

The Record Book

The most important part of your 4-H project will be to develop a good record of your activities. Take some time to record your entomology accomplishments as they happen. You shouldn't rely on your memory alone to remember the details of your project's progress.

The recording method you choose will depend on the type of projects with which you get involved. You may use a 4-H Project Record Book or a notebook to record some of your more complicated experiments or field observations. A scrapbook can hold news clippings, photographs, illustrations or other mementos of special events and activities.

Accurate, timely record keeping is a useful life skill to develop, especially if you plan a career in science. Scientists are expected to keep accurate records of all their activities, observations, and investigations in the laboratory and the field. You will find many other uses for your record-keeping and writing skills as well. One good example is that keeping accurate and up-to-date records can greatly simplify the process of applying for 4-H awards and other recognition.

Why Make an Insect Collection?
• An insect collection helps develop personal identification skills. • An insect collection can be used to display insects or insect features so that others may learn about them. • An insect collection can allow you to better observe details of insect structures and how they function. • An insect collection can provide a record of when and where various insects occur.

Insect Collections

4-H insect collections are probably the mainstay for entomology. Children (and adults) almost naturally enjoy collecting things and since there are more insects than anything else in the world, they make good subjects for study. All 4-H Entomology participants should begin and add to a base collection throughout their projects. This helps to provide a base for studying insects and their habits. This project like most other 4-H projects provides the basis for self-confidence, for community, for arrangement and opens new worlds for young people and adults to learn to work together.

Insect collections are family affairs. Most adults who have or have had 5th or 9th graders relate to this idea very well. Many have had this conversation on a Friday or Saturday in late September. “Mom, I have an insect collection due in my science class.” “When?” “Monday!” It usually takes Mom, Dad and Gramps, as well, to get the collection done. We have found that if it’s a little more leisurely done, all the family still gets excited about ‘that weird bug’ we caught. That’s one of the things that make it fun.

We also encourage specialty collections which would include Lepidoptera (butterfly and moth) collections or other orders, i.e., Coleoptera (beetles). A Riker mount depicting an insect’s life cycle is also an example of an acceptable other type ‘collection.’ The stereotype concept of a knobby kneed little old man with thick glasses and a pith helmet running across an open field with a butterfly net in hot pursuit of a prize Heliconidae is what many think of when the word ‘entomology’ is mentioned. Yes, we do chase bugs, but there are much smarter ways to catch the prizes than running them down with a net. Traps, black lights, baits and just plain old scouting footwork are methods smart collectors use to catch their prizes. There are more insects than all other animals combined. Many are not yet named. It is entirely possible that a young 4-H collector could collect never-before-reported species and even unnamed species of insects without moving out of the neighborhood.

There are a few basic items needed as a person begins on his journey into the wonderful world of insects. Constructing collecting and display items can also be used to support project work. These may be eligible for display, certainly if they demonstrate a talent that the 4-Her has developed.

Equipment needs

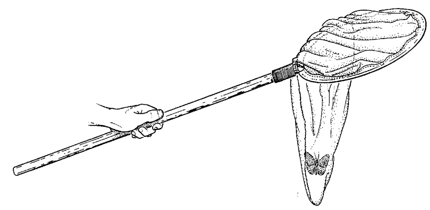
collecting kit	forceps/tweezers	alcohol vials	pins
insect net	pry tool	spreading board	holding box
kill jar	zip lock bags	relaxing jar	display box

Collecting Kit

An old, soft-sided leather or canvas purse or a diaper bag with long shoulder straps makes an excellent collecting kit. The kit must be large enough to hold the kill jars (usually 2) and a couple of alcohol vials. Other useful items include paper, a pencil, lots of plastic bags, forceps, and a pry tool. The bag must leave both hands free, but have the equipment readily accessible to the collector. Every collector needs a bag, but bags can come in many variations - from backpacks to saddlebags.

The Insect Net

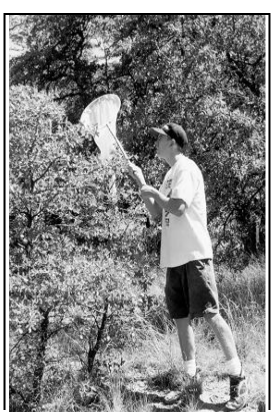
Aerial net



A good insect net can be one of the most important tools for your 4-H entomology project. In fact, several types of nets commonly are used and you may even find you will want to use more than one kind as your collection develops.

Insect nets can be purchased from biological supply companies or they may easily be constructed. The basic components are a handle, collecting bag, and a wire hoop to support the bag and also to connect it with the handle. A sample design for the construction of an insect net is outlined below. Minor changes in the type of material used for the collection bag and in the weight and strength of the handle determine the best end use for the net.

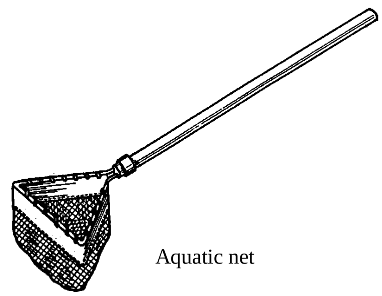
The **aerial net**, sometimes called a "butterfly net," has a bag constructed of a light-weight mesh fabric that allows air to move readily through it and is fine enough to retain the insects. Marquisette or scrim are commonly used materials for this. These nets are easily handled and can be used to capture fast flying insects. They also allow you to see the insects that you have captured, which is very useful when removing butterflies or stinging insects. However, aerial nets also are fairly delicate, and the mesh readily tears. Therefore, they are not good for sweeping vegetation. For this purpose **sweep nets** work best. Sweep nets have a solid cloth sample bag made from muslin, feed-sack cloth, or some other fabric that resists ripping. Usually, the handle is stronger and heavier than that used in an aerial net, and the connection with the wire rim is more highly reinforced. These features allow the sweep net to sample grasses, crops, and shrubs, which can result in captures of large numbers of insects in a short time.



Aerial nets are used to catch flying insects and insects resting on plants.

Using a kitchen strainer to scoop out pond bottoms.

A different design is needed when sampling insects in water. Special **aquatic nets** are constructed more heavily than sweep nets, with a strong mesh that allows water to drain. However, for many purposes, a kitchen strainer may serve as a simple alternative. In rivers and streams, insects can easily be captured by holding the net just downstream as you overturn rocks and gravel. The many insects dislodged are readily captured by this method. A sturdy net also can be used to scoop out pond bottoms, where dragonfly nymphs and many other insects commonly occur.

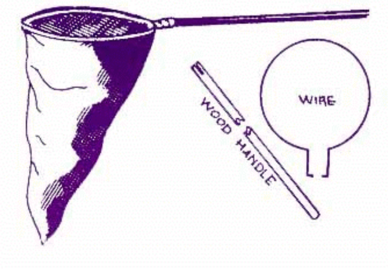


Aquatic net

How to Make an Insect Net

Materials Needed

- Small wooden handle, 30 to 36 inches long. You can use a broom or mop handle.
- 5-foot length of heavy steel wire. Use 1/8-inch steel or no. 14 galvanized wire.
- Two pieces of muslin or netting, 20 inches x 30 inches.
- Strip of fine wire or cord to wrap wire hoop ends to handle.



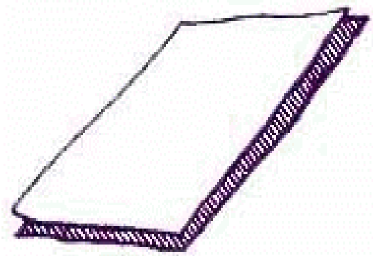


Figure A

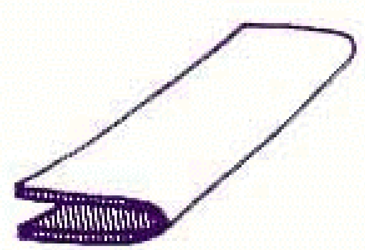
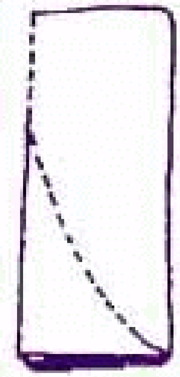


Figure B

Figure C



Procedure

On one end of the handle, cut two grooves lengthwise and as deep as the thickness of the wire. Make one groove 2 ½ inches long and the other 3 ½ inches long. Drill a small hole through the handle at the end of each groove. Bend the steel wire into shape.

To make the net bag, lay a 20 x 30-inch piece of net material on another piece the same size (Figure A). Fold them so they will be 10 x 30 inches (Figure B). Cut the material from the bottom folded corner diagonally up and across to a point 10 inches below the top unfolded corner (Figure C). After you cut, the net bag will be in two roughly triangular pieces. Seam the two halves of net together to about ½ of an inch from the cut edge. Leave 10 inches free on one side at the top where you will insert the net hoop. Turn the cut edges inside and stitch the seam down flat. Make a flat felled seam.

To make a loop for the wire hoop, fold the top edge down 5 inches and stitch hem. If you want to reinforce the hem of aerial nets made of netting, you can make only one fold and cover the fold with a strip of muslin 5 x 40 inches. Then fold again and stitch. The muslin will protect the netting around the wire hoop.

The Killing Jar

A killing jar is a very useful tool when making an insect collection. It allows one to rapidly kill any insects collected in the field so that they remain in good physical condition for use in your display.

Killing jars can be purchased from insect equipment supply houses, or they may be constructed (see below). Ethyl acetate, found in nail polish remover, is probably the best killing agent to use in 4-H collections.

When going on field trips, it sometimes is a good idea to bring along several killing jars. Specimens can be damaged if the killing jar gets overcrowded. Newly collected insects may scratch and tear the more delicate insects. Alternately, the wing scales of moths and butterflies may cover other insects. To avoid these problems, serious collectors usually keep separate killing jars for the more easily damaged, scale-covered insects.

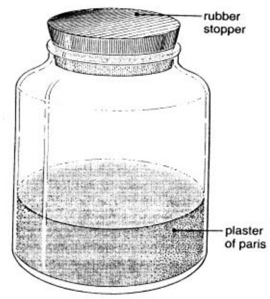
Pinching the thorax of large butterflies or moths will prevent damage that often occurs. A quick squeeze for a couple of seconds paralyzes the wings so that the insect does not flutter. After placing them in the kill jar, remove them as soon as possible so they do not absorb the ethyl acetate killing agent, which discolors the wings, but be sure the insects are dead before removing them. Paper towels or tissue should also be placed in the jar to separate insects.

If insects are collected around a home, an alternative is to freeze them. Once removed from the freezer they should be allowed to thaw before pinning, as the frozen legs and antennae are brittle and easily break. They may also need to be placed in a relaxing chamber as the modern freezers usually remove moisture.

How to Make a Killing Jar

Materials Needed

- An empty, wide-mouthed jar. (Peanut butter or mayonnaise jars do well, but do not use plastic.)
- Plaster of Paris
- Water
- A bottle of ethyl acetate (found in fingernail polish remover)
- A roll of adhesive tape.
- Sawdust or shavings.



Killing jar with plaster of paris bottom.

How to Make a Killing Jar (continued)
Procedure

1. Add about ½" sawdust or shavings to bottom of jar.

2. Mix 8 heaping teaspoons of plaster of Paris with 5 teaspoons of water in a mixing cup. Stir the mixture until it is smooth then pour or spoon out the mixture into the bottom of the jar, over the sawdust. Gently tap the jar against the ground to make the plaster of Paris settle and make a smooth surface.

3. Allow the Plaster of Paris to harden and dry for several days, with the cap off of the jar.

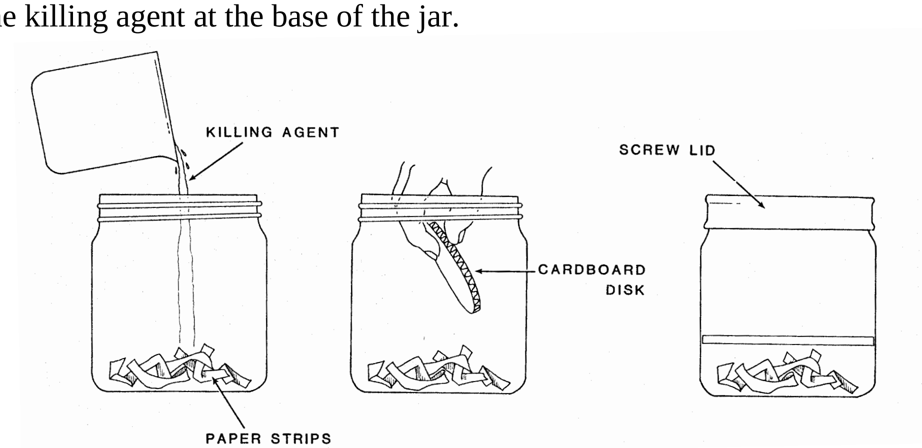
4. Take the jar outdoors when adding the killing agent. Pour ethyl acetate (nail polish remover) onto the surface of the plaster. This will be absorbed into the bottom of the jar. Do not put so much in that the surface remains wet. Caution: Avoid inhaling much of the ethyl acetate. Note: You can put in a piece of tissue or some other cardboard to cover the plaster surface so that insects do not directly contact it.)

5. Place the cap tightly on the jar. By keeping the cap on except when using it, enough of the killing agent will remain to keep it effective for several days. To recharge the jar, just add some more ethyl acetate to the plaster.

6. Wrap the jar on the outside with adhesive tape to protect the killing jar from accidental breakage and reduce condensation in the jar, a particular problem when the jar is exposed to direct sunlight.

7. Mark the jar prominently with the word **Poison**.

Variations: A simpler and more rapidly constructed killing jar replaces the plaster of Paris with some other absorbent material, such as cotton, shredded paper or sawdust. The killing agent can be poured directly on the absorbent matter and then covered with a cardboard circle. This cover must be tight enough so the insects do not slide underneath and directly contact the killing agent at the base of the jar.



Beetles may also be killed by placing them in ethyl alcohol (see p. 62). Captured insects should be removed from the alcohol and processed for pinning within 24 hours of collection.

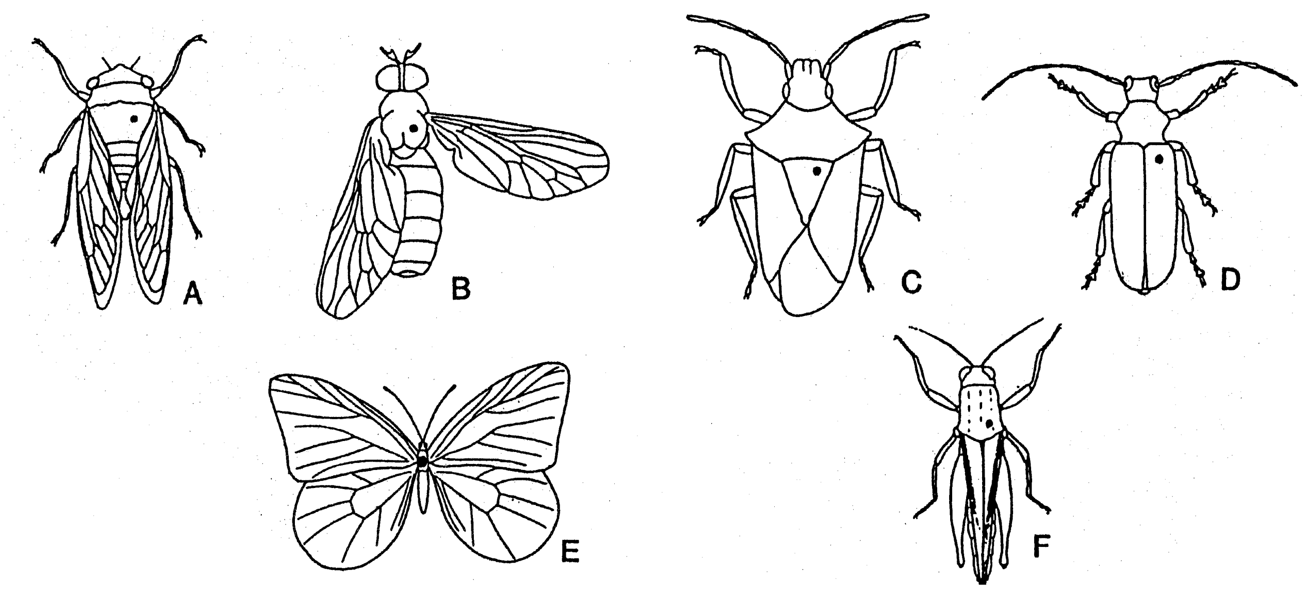
Pinning Insects

For most purposes, collections are best prepared and displayed by pinning the insects.

Special razor-sharp, rust-resistant pins are needed for this purpose. Insect pins come in a range of thicknesses, from the nearly hair thin #00 to thick #7 pins used for very large, thickly plated beetles. For most 4-H collections, the most useful pins will be number 2 or 3 size. Insect pins can be purchased from biological supply houses, university bookstores, and some hobby shops. They are available in most states through the Entomology Department at your land-grant university and often at the County Extension Offices.

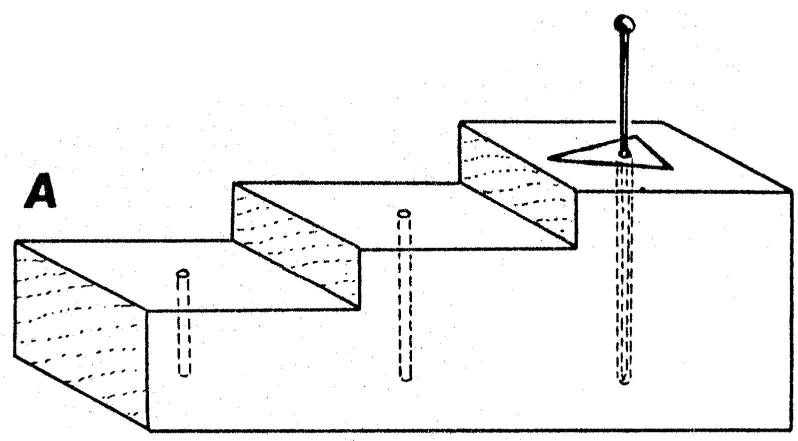
Common straight pins, like those used in sewing, cannot be used for insect collections, as most are too thick and will rust. They are also too short. When these pins are used, the collection looks unsightly and many of the important features of the insect may be damaged.

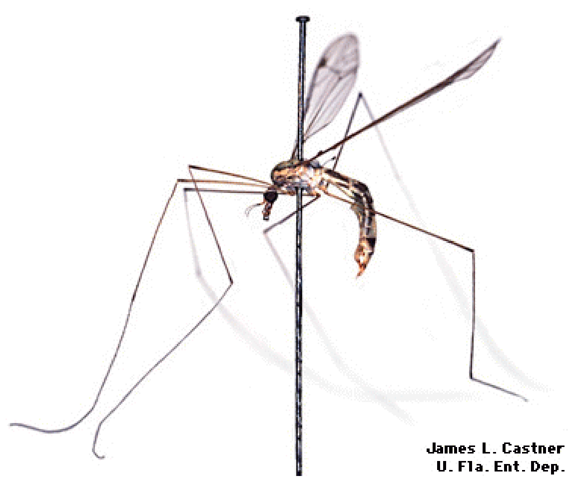
Properly pinning an insect is very important, both to allow its features to be seen and for maintaining an orderly collection. The proper placement of the pin for various types of insects is indicated below.



Proper location of pinning for : (A) cicada, (B) horsefly, (C) true bug, (D) beetle, (E) butterfly, and (F) grasshopper.

Insects should be pinned at a standard height. This is best done with the aid of a **pinning block**. Pinning blocks contain a series of two or three holes drilled at different heights. The insect is pinned and the pin then pressed into the deepest hole until the insect is flush with the surface of the pinning block. Because of the variation in thickness of insects, the pins should be adjusted so that there is ¼" of the pin showing above the dorsal surface of the insect. This will allow the insects to be a uniform height in a collection. The shallower holes are used to set the height of labels attached to the pin. The second hole is set at the proper level for the collection information label, indicating when and where the insect was collected. The lowest hole is used for labels that identify the insect.





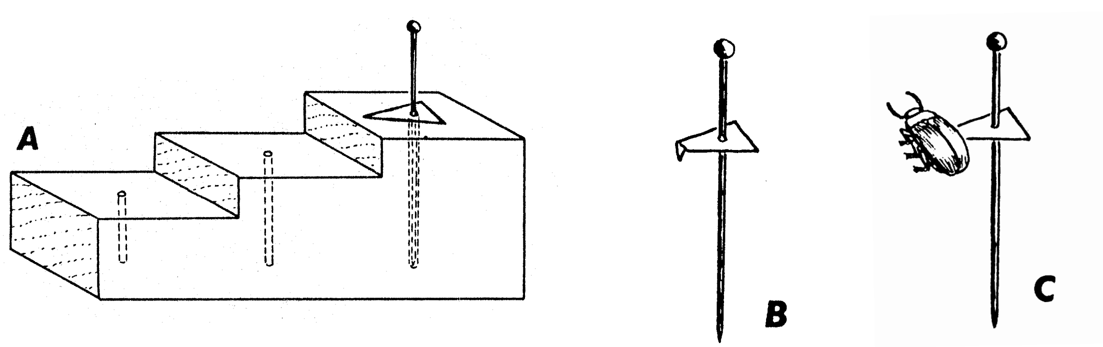
Preserving Small and Fragile Insects

Insects that are too small to be pinned, including small flies, beetles, and wasps, should be mounted on triangular paper **points**. These points can be cut out of index cards and should be no more than ⅜-inch long and ⅛-inch wide.

Push a pin through the base of the card point and push the point to the proper level for mounting an insect, using the deepest hole in the pinning block. Bend the tip of the point slightly using a pair of tweezers or forceps. Put a tiny drop of finger nail polish or white glue on the bent down part of the point then gently press it to the *right* side of the insect. Adjust the insect so it remains squarely in position and allow the glue to dry. This procedure is called **pointing**. Although it is a bit more work, you should generally point any insect that you feel might be badly damaged by pinning .

Some insects should not be pinned. Insects with soft bodies—aphids and immature stages of most insects—should never be pinned or pointed. They will shrink and deform when they dry. Instead, these should be maintained and displayed in vials of alcohol. (This is also a good idea for storing highly fragile insects like small craneflies and mosquitoes.) Immatures of some insects exhibiting simple metamorphosis may be pinned to show the progression from small immature through adult.

When displaying very large or delicate insects, such as craneflies or walkingsticks, you may need a little extra support. One option is to carefully glue them to a card that is then pinned to the display box. An alternate method is to glue the insect to several cut points attached to a pin, allowing the insect to be supported in different locations. Some large insects may also be supported by inserting insect pins or small toothpicks in the abdomen.



Pointing a small insect using a card point.

Storing Insects in Alcohol

Professional insect collections usually use 70 to 80 percent concentrations of ethyl (grain) alcohol for storing such insects. However, ethyl alcohol is not always available to beginning collectors. A fairly good substitute is a 35 percent solution of rubbing alcohol (isopropyl). Since rubbing alcohol is usually sold as a 70 percent concentration, it should be diluted by mixing it in equal proportions with water.

The vials used for storing insects should have a tight fitting stopper to prevent the alcohol from evaporating. Rubber stoppers (or twist-off vial caps that have a plastic nipple insert) are best for this purpose. Regardless of what is used, the storage vials should be checked one or two times per year and the alcohol replaced as it evaporates.

It is best to "fix" caterpillars and larvae before placing them in alcohol vials. This is done because the enzymes in the killed insect often cause it (and the solution) to darken. Discoloration can be prevented by placing the insect larva first in near boiling water for one to five minutes, depending on the size of the insect. This treatment inactivates the enzymes. (Caution: Do not put insect larvae in a microwave oven—they may explode!)

Labels should also be placed in the vials. Most inks will dissolve when placed in alcohol, therefore collection information on labels should be written in pencil or India ink. Producing labels using computer printers also is increasingly popular, although some inks will not remain on the paper in an alcohol solvent.

Preservation of Insect Specimens

When carefully collected and preserved, insects can last indefinitely. Several different types of preservation are used, each appropriate for different insects. In general, soft-bodied insects should be killed and preserved in alcohol and, if tiny, they are best mounted on slides. Insects that can maintain their body shape and features after drying usually are displayed on a pin. Other arthropods (spiders, ticks, millipedes, etc.) are best preserved in alcohol.

Insects

Insects	*Killing and Preservation*
Coleoptera (beetles)	Adults should be killed with ethyl alcohol then pinned. Larvae should be killed and preserved in alcohol.
Lepidoptera (butterflies, moths)	Adults should be killed with ethyl acetate then pinned with wings spread. Larvae should be killed and preserved in alcohol.
Trichoptera (caddisflies)	Adults can be killed with ethyl acetate then pinned or kept in alcohol. Larvae should be killed and preserved in alcohol.
Hymenoptera (bees, wasps, ants, etc.)	Adults of most species should be killed with ethyl acetate then pinned. Ants and small wasps can be killed in alcohol and later pinned or placed on points.
Diptera (flies, mosquitoes, etc.)	Adults should be killed with ethyl acetate then pinned. Small specimens should be placed on points or preserved in alcohol. Larvae should be killed and preserved in alcohol.
Siphonaptera (fleas)	Adults are best killed and preserved in alcohol. They may also be displayed on a point or slide mount. Larvae should be killed and preserved in alcohol.
Thysanoptera (thrips)	Kill and preserve all stages in alcohol. If possible, mount on slides.
Ephemeroptera (mayflies)	Kill and preserve all stages in alcohol. Some large mayfly adults may be pinned.
Plecoptera (stoneflies)	Kill and preserve all stages in alcohol. Some large adults may be pinned.
Odonata (dragonflies, damselflies	Adults should be killed with ethyl acetate then pinned. Nymphs should be killed and preserved in alcohol, but also may be displayed by pinning.
Orthoptera (grasshoppers, crickets)	Adults should be killed with ethyl acetate then pinned. Nymphs should be killed and preserved in alcohol, but also may be displayed by pinning.
Mantodea (mantids)	Adults should be killed with ethyl acetate then pinned. Nymphs should be killed and preserved in alcohol, but also may be displayed by pinning.
Dermaptera (earwigs)	Adults should be killed with ethyl acetate then pinned. Nymphs should be killed and preserved in alcohol, but also may be displayed by pinning.

Insects (continued)

Insects	*Killing and Preservation*
Phasmatodea (walkingsticks)	Adults should be killed with ethyl acetate then pinned. The use of a card or multiple points is useful to support these fragile insects. Nymphs should be killed and preserved in alcohol, but also may be displayed by pinning.
Isoptera (termites)	Kill and preserve all stages in alcohol. Winged forms may be pinned.
Hemiptera (true bugs)	Adults should be killed with ethyl acetate then pinned. Nymphs should be killed and preserved in alcohol but may also be displayed by pinning.
(aphids, scales, etc.)	Soft-bodied species, such as aphids, and all immature stages should be killed and preserved in alcohol. Leafhoppers and cicadas should be pinned, although use of points is best for smaller species. Scale insects should be displayed attached to the twig or leaf on which they were developing.
Phthiraptera (lice)	Kill and preserve all stages in alcohol. If possible, mount on slides.
Collembola (springtails)	Kill and preserve all stages in alcohol. If possible, mount on slides.
Thysanura (silverfish, etc.)	Kill and preserve all stages in alcohol. If possible, mount on slides.

Arthropods That Are Not Insects*

Arthropods	*Killing and Preservation*
Diplopoda (millipedes0	Kill and preserve all stages in alcohol.
Chilopoda (centipedes)	Kill and preserve all stages in alcohol.
Crustacea (pillbugs, crayfish, etc.)	Kill and preserve all stages in alcohol.
Arachnids (spiders, scorpions, etc.)	Kill and preserve all stages in alcohol.

* Arthropods that are not insects are often not allowed in 4-H Entomology displays. Make sure to check local rules associated with 4-H Entomology projects. These may be included in a specialty collection featuring one or more classes of arthropods. See the section on Specialty Collection.

Spreading Insects

Some types of insects are best displayed by spreading their wings. This is particularly important with moths and butterflies because wing patterns often are very important in identification. Other insects with brightly patterned wings, such as certain grasshoppers and mantids, sometimes are spread to make more interesting displays or to show unusual features.

Spreading the delicate wings of an insect can be one of the most difficult challenges in making a collection. The scales that cover butterfly wings easily rub off and wings tear readily. However, with practice and the use of a few tools, a good job of spreading insect wings can be done.

Pins, strips of paper, and a **spreading board** are most useful for spreading insects. A pair of blunt forceps and a probe can be great aids. For spreading, the insect must be flexible. If the specimen is too dry and brittle, wings and other appendages will break during the pinning/spreading process. Dry insects should be placed in a "relaxing jar" until they become flexible.

Spreading boards provide a surface on which the wings are spread to dry. In the center is a sunken groove designed to hold the body of the insect so the wings will remain perpendicular to the body. Insect spreading boards can be purchased from biological supply houses, but they can also be easily constructed. Construct spreading boards using soft wood, such as pine, or stiff plastic foam, such as styrofoam. Modern styrofoam insulation is an ideal material for use as a spreading board.

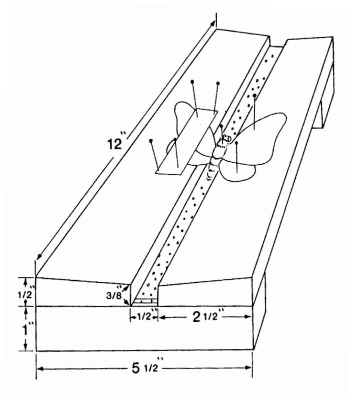
How to Make a Spreading Board

Materials Needed

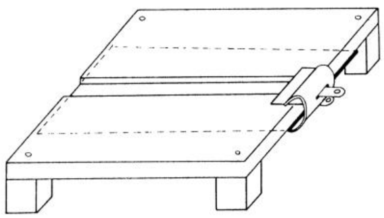
- Two end pieces of wood, 5½" x 1" x ⅝"
- Two top pieces of a soft wood, such as pine or balsa. The pieces should be 12" x 2½" and approximately ½" thick. (Professional spreading boards have these pieces tapered so the inner edge is slightly thinner, approximately ⅜".)
- A strip of balsa wood or cork, about 16" long and at least 1" wide.
- Nails and glue

Procedure

1. Nail the top pieces to the end pieces, leaving a gap of about ½ inch between the pieces to form a center channel. If the top pieces are tapered, the thinner edge should be along the center.
2. Nail or glue the cork or balsa wood on the bottom, to cover the center channel.



A spreading board.

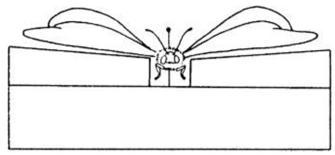


A spreading board of simple design.

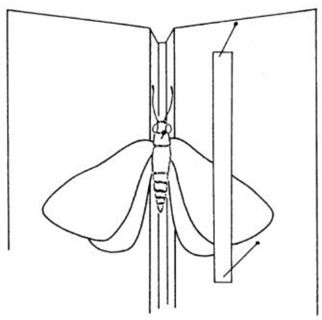
Alternately, the 1" or 1.5" styrofoam insulation can be used as a spreading board. Simply cut the boards into 6" X 18" strips and dado a groove down the middle. The 1" boards will need to have a base added so the insect pins will not be blunted when they penetrate through the bottom.

How to Properly Spread Insects for Display

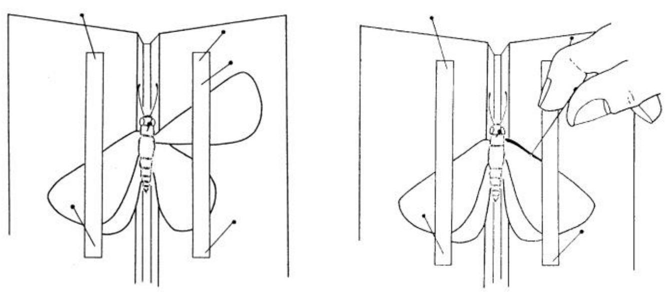
1. After pinning the insect in the normal manner, push the pin into the bottom of the center slot on the spreading board until the outstretched wings of the insect are just level with the surface of the board.



2. Place a paper strip over the wings and fasten the edges of the strip with pins so that the wings remain in place.



3. Carefully place a pin or probe lightly into the large vein at the front of the forewing and move the wing forward. The paper strip may need to be loosened a bit while doing this. When the wing is in its proper position, secure it with the paper strip. Repeat with the other forewing. Ideally the hind edge of the two front wings should form a straight line.



4. Using a probe or an insect pin, tease the hind wing forward by placing the pin behind a large vein close to the body in the wing. Bring the hind wings forward so they rest with the edge slightly underneath the forewing. Tightly secure the paper strips, without putting the pins through the wings. To prevent curling of the wing edges, additional paper strips can be used to cover them.
5. Position antennae and legs as you would like them to appear.
6. Allow the insect to dry. This usually takes at least three to four days, longer with some of the larger moths or butterflies.
7. Insects left too long on spreading boards are subject to damage by scavengers.

Relaxing Dry Specimens

Sometimes insects dry out and become too hard and brittle for mounting. This is a particular problem with butterflies and moths, which are displayed by spreading their wings. Therefore, it is sometimes necessary to first soften the insect. The most common way to do this is by using a **relaxing chamber**. Usually, insects placed in such a container soften sufficiently within 24 to 48 hours, so that they can then be handled and mounted.

A common problem in relaxing insects is mold, which can grow in the moist chamber and destroy the insect. This problem can be reduced by putting a disinfectant into the relaxing jar. Antiseptic mouthwash or moth crystals are good mold inhibitors. However, *insects should never be left for more than a few days before they are removed,* or they will mold.

How to Make a Relaxing Jar

Materials Needed

- Rubberized clear or opaque storage containers are excellent for making relaxing chambers. Wide mouthed jars are also acceptable.
- Sand
- Disinfectant (e.g., mouthwash)
- Cardboard or thin flexible styrofoam

Procedure

1. Pour a layer of sand (about one inch deep into the bottom of the container.
2. Moisten the sand with a disinfectant type of mouthwash (such as Listerine) or water to which a few drops of disinfectant has been added.
3. Place a piece of cardboard over the sand to prevent insects from directly touching the moist sand. Insects should not ever be in direct contact with water.
4. Check the jar every day until the insects have softened enough to be mounted.

An alternative method for some insects is to carefully place the dry specimens (except for moths, butterflies, bees, caddisflies, and some flies) into very hot (but not boiling!) water for about 5 minutes. Beetles placed in alcohol for a few minutes will become flexible enough to handle and pin.

Problems with insects that have become too dry can be avoided by pinning them promptly after they are collected. If this is not possible, you may temporarily store insects for three to four weeks in a freezer. If you do this, keep the insects in a plastic bag or other container to maintain moisture. To avoid problems with condensation, add a piece of absorbent paper towel. These specimens may still need to be relaxed after removal from the freezer.

Labeling Insects

Labels are an important part of the pinning process. Labels placed with the collected insects greatly improve the value of an insect collection. With a proper label, every insect in your collection becomes something important—a piece of scientific information. Insects without labels are **not** pinned correctly and are generally useless for scientific purposes!

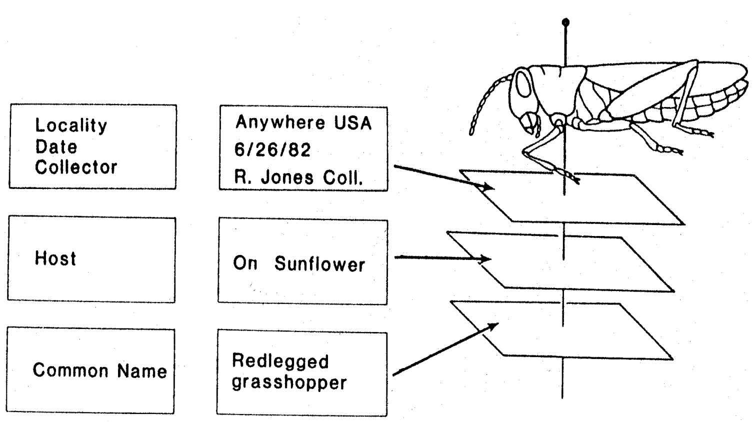
The most important thing to include on a label is information about collecting the insect. This is often referred to as the date and locality label. It should include at least the *where*, *when* and *who* of the insect collection:

- where the insect was collected
- when the insect was collected
- who collected the insect

The scientific record that a proper label provides serves many useful purposes. For example, fairly little is told about many of the insects collected during the course of a 4-H project. A label with information on where an insect was collected can provide very useful information about its range. Where an insect is active tells us information related to its seasonal habits and periods of activity.

It also is useful to include information on *how* the insect was collected. For example, "visiting a light" or "feeding at a flower" can tell others how they might similarly locate the same kind of insect. Make notes on the collection as soon as possible, so your notes are as accurate as they can be. The 'how' label is not generally required in 4-H collections.

At the back of this manual you will find some sample collection labels and labels that can be used to label the insect orders that you have collected.



Information to include on insect labels.

Arranging Insects in a Collection

Once the insect is correctly pinned and labeled, it should be placed in a standard display box. Specimens should be arranged by order, with order names in alphabetical order beginning in the upper left hand corner of the box. Where the glass slides out to the front, proceed down to the lower left side and then back up to the top, filling the box from left to right. Order names should be pinned to the bottom of the box at the head of each order. If an order does not fill a line completely, a new order may be placed immediately following the last specimen of the previous order. Pins should be secured firmly in the box once the arrangement is set. A pair of "L" shaped forceps or pliers are useful for affixing pins. Collections are most often judged for neatness and uniformity, as well as ingenuity in displaying insects.

Storing and Displaying the Collection

A collection of pinned insects must be properly stored in order to protect it from dust, damage and infestations of carpet (dermestid) beetles. For a beginning collector, a small box, such as a cigar box, can easily be turned into an insect collection box. All that is needed is to cut and glue to the bottom of the box some material that is easily penetrated and will hold the insect pin. Such materials as polyethylene foam, corrugated cardboard, cork, balsa wood, or fiber board can serve as the base of such a collection box. However, if you wish to display your insects or maintain the collection for a number of years, a more elaborate, tight-fitting box is desirable.

The standard 4-H display box usually is constructed from a soft, easily worked wood, such as pine. A sliding-glass cover allows the collection to be easily viewed. Construction design is detailed below. Many biological supply houses sell insect collection boxes made of pressed cardboard with a soft bottom for holding pinned insects. All collections should be displayed in the standard display box. These can be purchased through most biological supply houses. At times local lumber companies will construct boxes for 4-H projects. Check with your 4-H agent. Plans for a standard box are included in Appendix A.

Museums use several types of display boxes. The Cornell drawer has the dimensions 16½"(w) x 19" (l) x 3"(d). These are the type used within the museum collections at most of the southern land-grant universities and are the type recommended by Mississippi.

Drawers used at the U.S. Natural History Museum are 18" x 18" X 2⅞" while the California Academy of Science drawer style is 17" x 19" x 3". However, these are all quite expensive to purchase.

Protecting the Collection

Once you have made an insect collection, you probably will want to maintain and display it for a long time. However, dried insects are fragile and can easily be damaged if knocked or jarred. Make sure all insects are securely pinned to the bottom of the display box so they do not come loose. It is particularly important to secure vials or other heavy objects, such as moth balls, that can cause a great deal of damage if they come loose and roll around the box. By placing vials in a box separate from pinned insects, you can prevent damage from this cause. Also, try to leave enough space between the individual insects so you do not accidentally touch and break any when you are putting new insects in or removing them for display. As your collection gets larger and you gain more experience at safely handling the insects, you may wish to place them closer together to conserve space.

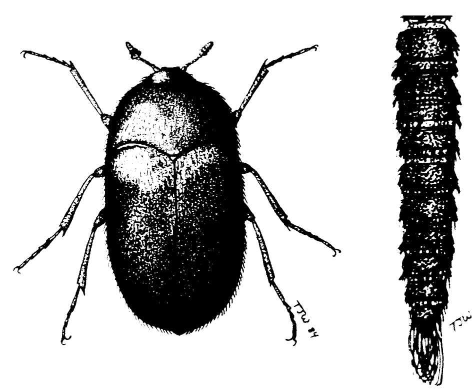
Other insects are one of the biggest threats to an insect collection kept for a long time. Certain types of scavenging insects, known as **carpet beetles** or **dermestids**, commonly get into collections and eat them. Small piles of a sawdust-like material may accumulate under an insect infested by a carpet beetle. Carpet beetle larvae also discard hairy, carrot-shaped skins after they molt.

One of the best ways to prevent injury by carpet beetles is to store the collection in very tight-fitting trays or boxes to exclude the insects. However, most insect display boxes are not entirely immune to infestation by tiny carpet beetle larvae, so it is a good idea to periodically take preventive measures to kill any insects that may be developing in the collection. Placing the display box in a freezer for several days is one way to do this.

Also, carpet beetles can be killed if small pieces of a “pest strip” (containing the insecticide dichlorvos) or moth crystals (containing paradichlorobenzene) are kept in a corner of the collection. These can provide control for several months or even years before they need to be changed. However, “pest strips,” moth balls, and moth crystals all contain insecticides as the active ingredient. Extra caution should be used to avoid unnecessary human exposure to the insecticide, and *collections protected by insecticides should never be placed in freezers or where food is stored*.

NOTE: The active ingredient found in moth balls and moth crystals (paradichlorobenzene or naphthalene) may melt certain plastics, such as styrofoam. If used in a collection, they should not be allowed to directly touch plastic surfaces.

Observing and Rearing Insects


Carpet beetle adult, left, and larva, right.

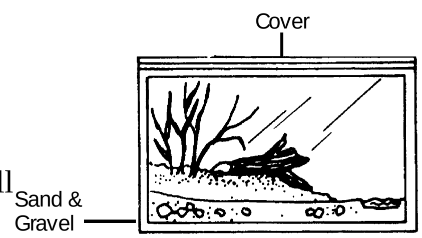
Rearing insects can be a very enjoyable and even entertaining part of your 4-H entomology project. While culturing your “mini-livestock” you get an opportunity to closely watch their various behaviors—how they feed, molt, and lay eggs, or example. Collectors often raise insects to study how they grow and change in form. Caterpillars collected from the garden are more easily identified once they transform into a moth or butterfly. Some insects (crickets, mealworms, wax moths) can even be reared to provide bait for fish or food for lizards and other pets. Also, reared insects are less damaged than those caught in the wild.

When rearing insects you need to keep in mind a few basics.

Type of Container. Insects can be reared in many different types of containers. Size is often not a critical concern, although a small container can lead to overcrowding. When rearing moths or butterflies, the container must be large enough to allow them to expand their wings after they emerge. Space for a stick or some other object that the emerging butterfly or moth can crawl onto is also important.

Large glass jars are perhaps the most frequently used rearing containers for beginning collectors, as they are easy to find and allow one to view the insects. However, they often have only limited space, particularly for insects that live on the ground.

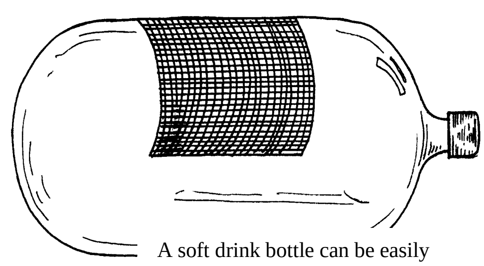
A plastic clothing box or store-bought terrarium also makes an excellent container for insect rearing. Large 2-liter plastic bottles can be modified easily for insect rearing by cutting a panel and covering this opening with screening or fine-mesh fabric.



Terrarium

Rearing cages should have good ventilation to help prevent rapid temperature fluctuations and excess condensation. Punching small holes in the top of the container may be adequate, but it is often better to seal the opening with fabric or wire mesh. Canning jars can be used as excellent rearing chambers by substituting mesh for the cap and holding it in place with the band.

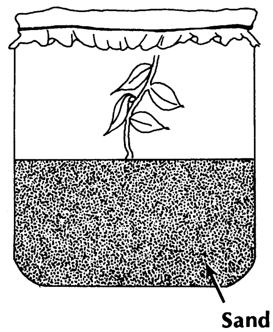
When rearing relatively non-mobile insects, the tops of the containers may not even need to be enclosed if some insect barrier is provided. A band of petroleum jelly or floor wax along the top of the rearing container will prevent most crawling insects from escaping.


A soft drink bottle can be easily modified to make an insect cage.

Once you have set up a terrarium for insects, one important consideration is where to put it. Most places will do adequately as long as they are not overly hot or cold. However, *a terrarium should never be placed in areas that will receive direct sunlight*. Sun-exposed jars or bottles can heat up very rapidly, particularly if not well ventilated. Direct exposure to bright sun on a warm day can kill insects in only a couple of minutes.

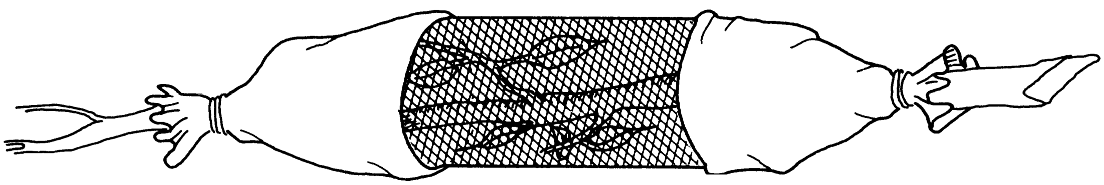
Many times it is best to rear an insect on its host plant. For example, you may wish to identify the type of insect that is developing as a borer in a log. Although you could extract the larvae, they must remain within the log if you wish them to transform to the adult stage. All insects that feed on the sap of plants, e.g., aphids or scales, will not survive long once the plant has been cut and no longer can provide the flow of sap they need. Even insects that chew leaves, e.g., caterpillars and beetle larvae, may do poorly on picked leaves if the leaves dry out too rapidly. Finally, some insects may have attached themselves firmly to the plant and would be injured if removed.

In these cases, rear the insect by covering the plant in place. For example a simple **sleeve cage** consists of making a mesh fabric sleeve that slips over the branch and is tied at both ends to prevent the insects from escaping. When rearing larger insects, such as a wood boring beetle that might chew through fabric, the cage should be made of a sturdier wire mesh.

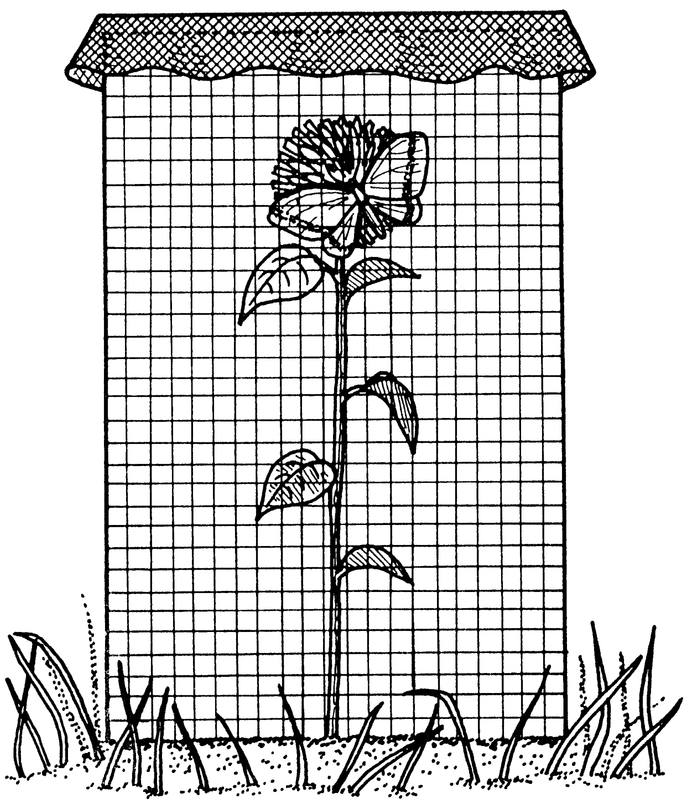


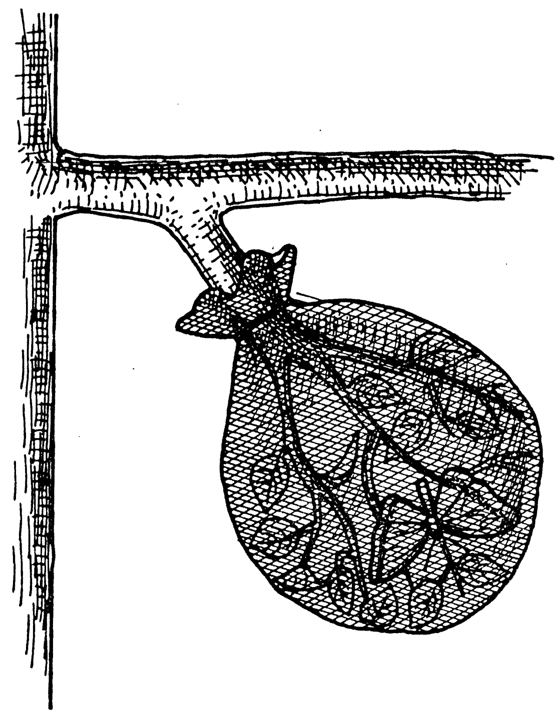
Container with sand at bottom.

Substrate and Shelter. Some sort of shelter is usually needed by insects, particularly those that are active at night and seek dark protected areas during the day. Pieces of bark or rocks are good natural materials for insect cover. Crumpled paper or lightly stacked egg cartons are also commonly used for this purpose. Larger insects and spiders may use a paper drinking cup with a cut opening.



A sleeve cage for observing insects.





More sleeve cages for rearing insects on plants.

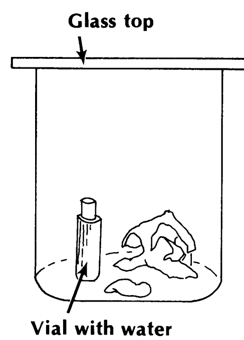
Often some covering material is needed for the base of the terrarium, particularly for insects that need to burrow, pupate, or lay eggs in soil. Although soil can be used, it is often better to use other materials that are less likely to promote molds and will drain better. Sand and peat moss are acceptable mediums for this purpose.

The depth of the substrate depends on the needs of the insects. A layer of sand ½ to 1 inch deep is usually sufficient for most insects.

However, some caterpillars and beetles may burrow several inches to pupate. Some of the larger arthropods that produce tunnels also require a deep substrate of soil or sand. These may include sun spiders, large centipedes, burrowing crickets, and some spiders.

Rocks, bark, leaves or other materials placed on the surface can provide cover for the insects.

For some insects, an environment for specific developmental needs can be provided without covering the entire base of the terrarium. Crickets and many other insects that lay eggs in soil can be induced to lay eggs in small dishes covered with sand or soil. Caterpillars and beetles that normally pupate within soil chambers will often pupate readily in a chunk of moistened Oasis block, available from a local florist.



Container with vial and cotton wick for water source.

Water. Some source of water is very important to the survival of an insect culture. A cotton wick, wet pieces of cut sponge, or moistened cotton balls are commonly used to provide moisture. For some insects, and web producing spiders, misting the container every couple of days can provide the water that is needed. A few insects that are well adapted to dry environments, such as mealworms and other insects that develop on stored foods, can get enough extra moisture if occasionally provided a piece of cut apple or other fruit.

Although water is essential for maintaining a healthy insect colony, too much water can also be a problem. Try to provide water in small amounts to meet the needs of the insects you are caring for. Water pooling on the floor of the container or condensing on the sides for more than a few hours is an indication of too much water.

Food. Each insect requires some sort of food to allow it to develop. Most insects also feed in the adult stage, often loading up on high energy foods such as nectar to sustain them.

When rearing a collected field insect, try to identify the foods that it is known to eat. Note the plant from which it was collected and use that plant as a basis for feeding the critter. Keep such food available at all times, and always clean out the old leaves to prevent molds from developing in the colony.

Some insects can only develop on living plants. Placing stems of cut plants in water wicks can help provide fresh leaves for insects with this requirement. Simple cages can be constructed instead that cover the leaves on which the insects are developing.

In addition some readily available foods can be used for rearing commonly raised insects. These foods might be useful for rearing insects that you have found.

- *Apple slices.* Cut fruit can provide both an important source of moisture and Vitamin C, often deficient in insect diets.
- *Dried dog food.* These mixtures often contain a good blend of nutrients that are readily used by chewing insects such as crickets and cockroaches.
- *Honey.* This high energy source food is used primarily by insects that suck fluids, such as wasps, moths, butterflies, and some flies. It is usually applied as a smear on the side of the rearing container or mixed with water in a cotton wick.
- *Oatmeal.* Oatmeal can enhance the diet of most crickets, grasshoppers, and other chewing insects.

Getting Insects to Overwinter. Some of the more attractive and interesting insects are observed late in summer or early fall. Trying to get them to survive overwinter is a rearing challenge.

Many insects, particularly if they are in adult stages (e.g., praying mantids) will be difficult to sustain for long as the limits of their life span are being approached. The best that can be done is to provide optimal conditions, which may allow them to survive a few more weeks than they would normally outdoors and, if you have mated females, to collect their eggs.

Insect pupae (e.g., butterfly chrysalids), eggs, and dormant larvae (e.g., banded woollybears) collected late in the summer usually are in a state of developmental arrest called *diapause*. Diapause is a very common insect behavior that helps them survive the long cold season, preventing them from emerging prematurely during a period of unseasonably warm winter weather. During diapause, growth of the insect ceases until environmental conditions change in a specific way that signals the time for it to complete its life cycle.

For many insects, the environmental signal for diapause is the length of the day. For others it is a "chilling requirement," typically a length of time during which it is exposed to low temperature. Therefore, many insects cannot be "pushed" to develop without first meeting their diapause requirements.

For most diapausing insects the best way to have them pass time is to keep them outdoors. They should be placed in a protected area, not exposed to the fluctuating temperatures of direct sun, and given some cover, such as a light mulch of leaves. If kept in a container, it should be adequately ventilated to provide some moisture without causing soaking of the overwintering insects. Cool requirements can be easily fulfilled in about 6 weeks from January– March.

Insects can be returned indoors and should again continue to normally develop. Day length requirements can be fulfilled with normal incandescent or grow lights.

Sources of Insects for rearing. There are scores of insects you will be able to readily find during the warmer months that can be reared easily. Most often these are found on garden plants or under rocks and logs. However, you may wish to expand your insect rearing to include insects that are less commonly used, such as aquatic insects found in ponds and streams.
Some of the most easily reared insects are those used as pet food, such as house crickets and mealworms. Such insects are commonly carried by pet stores, which also may sell more exotic arthropods, such as scorpions and tarantulas.

A very wide range of insects is sold by some of the biological supply houses. These normally market to schools and businesses and minimum orders are often required. To find out what is available send for a catalog or check one that a local biology teacher has. Two of the larger biological supply houses that carry live arthropods for starter cultures (and some insect collecting/display equipment) are:

Carolina Biological Supply
2700 York Road
Burlington, NC 27215
http://www.carolina.com/

Ward's Natural Science Establishment
11850 E. Florence Ave.
Santa Fe Springs, CA 90670
https://wardsci.com/

A very good general reference on insect rearing is *Caring for Insect Livestock: An Insect Rearing Manual* (1993), by Gary A. Dunn. This gives tips on rearing about 50 different types of arthropods and is the best single source on insect rearing. Search for used copies online. An arthropod rearing manual is also sold by Carolina Biological Supply, listed above.

Rearing an Insect through Its Life Cycle

Some Questions to Answer before You Start

- What are the diet needs of this insect as it develops?
- Does the insect require any special environments as it transforms to later stages of development? What does it need in order to successfully pupate?
- What is needed to allow the insect to transform to the adult stage, mate and reproduce?
- Does the adult insect have any special food needs?

Some Easily Reared Insects

Mealworms

Mealworms are one of the easiest of all insects to rear and the yellow mealworm (*Tenebrio molitor*) is widely available at pet stores and as fish bait. Placing a few beetles in a container of oatmeal or poultry mash can get you started. Some water source, like a piece of cut apple or potato, should be provided. Replace it when it has dried out. A bit of crumpled or shredded paper on the top provides a good place for the insects to pupate. When the colony gets overcrowded it should be split to prevent cannibalism. Also, don’t allow the colony to get too moist.

House Crickets

The house cricket (*Acheta domestica*) is also widely sold at pet stores and bait shops. A sand bottom is a good substrate and at least some of the sand needs to be kept moist (not saturated!) as a spot for eggs to be laid. (A separate dish of damp sand could be provided to accommodate egg laying.) A drinking water source does need to be provided. Ground, dry pet food and pieces of apple or banana are good foods for rearing house crickets. Pieces of egg carton on crumpled paper can allow for shelter. Field crickets can be reared in a similar manner, but have a longer life cycle.

4-H Beekeeping

The 4-H beekeeping project offers young people the opportunity to study one of nature's most fascinating insects. Almost anyone can keep bees. However, the few people who react strongly to bee stings and pollen should avoid all contact with bees. Honey bees normally only sting to defend themselves or their colony. When colonies are handled properly and precautions are taken, stinging should not be a problem. 4-H members may want to keep bees for the delicious fresh honey they produce or for the benefits of their valuable services as pollinators.

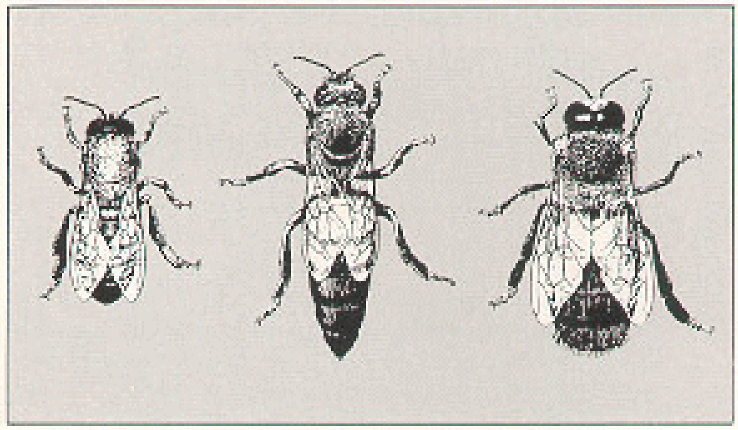
The Colony and Its Organization

Honey bees are social insects. A honey bee colony typically consists of several thousand bees that cooperate in nest building, food collection, and brood rearing. Each member has a definite task to perform, but it takes the combined efforts of the entire colony to survive and reproduce. A colony normally has a single queen, fifty to sixty thousand workers at its peak, and several hundred drones during late spring and summer. Individual queens, workers and drones cannot survive by themselves. The social structure of the colony is maintained by the queen and workers and depends on an effective system of communication. The exchange of chemical secretions among members and communicative dances are undoubtedly responsible for controlling the activities necessary for colony survival. Division of labor within the worker caste primarily depends on the age of the bee but varies with the needs of the colony. Reproduction and colony strength depend on the queen, the quantity of food stores, and the size of the worker force.

There is only one queen per colony, except during swarming preparations or supersedure. Since she is the only sexually developed female, her primary function is reproduction. She produces both fertilized and unfertilized eggs. Queens lay the greatest number of eggs in the spring and early summer. During peak production, they may lay up to 1,500 eggs per day. They gradually cease to lay eggs in the fall and do not begin again until January. The queen is the only colony member that can live for several years. Since the queen's average productive life span is two to three years, most beekeepers find it profitable to requeen their colonies every year or two.

A queen is easily distinguished from other members of the colony. Her body is normally much longer than either the drone's or worker's, especially during the egg laying period when her abdomen is greatly elongated. The qualities of the colony depend on the egg laying and chemical production (pheromones) of the queen. Her genetic makeup, along with that of the drones she has mated with, determines the quality, size and temperament of the colony. About one week after emerging from a queen cell, the queen is ready to leave the hive and mate with several drones in flight. After mating she returns to the hive and will begin laying in about 48 hours.

The queen is constantly attended and fed royal jelly by the colony's worker bees. The number of eggs the queen lays depends on the amount of food she receives and the size of the worker force capable of caring for the brood. Queens develop from fertilized eggs or from young worker larvae not more than three days old. New queens are raised if any of three different impulses occur in the hive: emergency, supersedure, or swarming. When an old queen is accidentally killed, lost, or removed, the bees select older worker larvae to produce emergency queens. The queens are raised in modified worker cells on the comb surface. When an older queen begins to fail (reduced egg laying or decreased production of queen substance), the colony prepares to raise a new queen. Queens produced under the supersedure impulse are usually better than emergency queens, since they receive larger quantities of food (royal jelly) during development. Like emergency queen cells, supersedure queen cells typically are raised on the comb surface. In comparison, queen cells produced in preparation for swarming are found along the bottom of the frames.



Three types of honey bee normally found in a honey bee colony: worker, queen, and drone. (Courtesy of U.S. Department of Agriculture.)

Drones (male bees) are the largest bees in the colony. They are generally present only during late spring and summer. Drones have no stinger, pollen baskets, or wax glands. Their main function is to mate with the queen. They perform no useful work for the hive. While drones normally rely on workers for food, they can feed themselves within the hive after they are four days old. When cold weather begins in the fall and the honey flow stops, drones usually are forced out into the cold and left to starve.

Workers are the smallest and most numerous bees in the colony. They are sexually undeveloped females and under normal hive conditions do not lay eggs. Workers have specialized structures, such as brood food glands, scent glands, wax glands, and pollen baskets, which allow them to perform all the labors of the hive. They clean out the cells, feed the brood, care for the queen, remove debris, handle incoming nectar, build combs, guard the entrance, and air condition and ventilate the hive before going into the field. In the field, they forage for nectar, pollen, water and propolis (plant sap). The life span of the worker during summer is about six weeks. Those reared in the fall may live as long as six months, allowing new generations to develop early in the spring before they die.

Bee Development

All three types of honey bees pass through three developmental stages before emerging as adults: egg, larva, and pupa. Queens complete their development in 16 days, workers 21 days and drones 24 days. Unfertilized eggs become drones, while fertilized eggs become either workers or queens. Nutrition plays an important part in caste development of female bees.

Beekeeping Equipment

Equipment needs will vary with the number of colonies that you plan to manage and the type of honey you plan to produce. You will need the basic components of the hive, protective gear, ancillary gear, and equipment for handling the honey crop.

The hive is the man-made structure in which the honey bee colony lives. A typical hive consists of a hive stand, a bottom board with entrance cleat or reducer, a series of boxes or hive bodies with suspended frames containing foundation or comb, and an inner and outer cover. The hive bodies that contain the brood nest maybe separated from the honey supers (where surplus honey is stored) with a queen excluder.

The hive stand, actually an optional piece of equipment, supports the floor of the hive up off the ground. This support reduces dampness in the hive, extends the life of the bottom board, and helps keep the front entrance free of grass and weeds. Colonies are often supported on concrete blocks, railroad ties, pallets or logs rather than on commercial hive stands. The bottom board serves as the floor of the colony and as a take-off and landing platform for foraging bees. Since the bottom board is open in the front, the colony should be tilted forward slightly to prevent rain water from running into the hive.

The standard ten-frame hive body is available in three common depths or heights. The full-depth hive body, 9-⅝ inches high, is most often used for brood rearing. They are also suitable for honey supers. However, when filled with honey, they weigh over sixty pounds and are heavy to handle. The medium-depth super, 6-⅝ inches high, and the standard shallow-depth super, 5-11/16 inches high, are commonly used for storage of honey.
Prepared by Clarence H. Collison, former Head and Professor, Department of Entomology and Plant Pathology, Mississippi State University

4-H Bee Essay Contest

Each year the American Beekeeping Federation sponsors the 4-H Bee Essay Contest. The state winning essay is due in the Federation offices on March 1 of each year. Only one essay is accepted from each state. The national winner is announced in May and the title for the next essay is given in early June. Examples of winning essays are available on the ABF website - http://abfnet.org. More information is also available by contacting:

American Beekeeping Federation
3525 Piedmont Road, Building 5, Suite 300
Atlanta, GA 30305
Phone: 404-760-2875

Ideas for 4-H Entomology Projects

Your 4-H entomology experience can become much more interesting if you set up some projects. For example try to visit a museum that features insects—several exist in the region, including some that even feature fossil insects. Working with other 4-H members is always a great way to learn more, and as you get further along, you may wish to help some newer members.

Here are some ideas of projects you might want to consider including in your 4-H project:

- ***Plant a butterfly garden***
  Many butterflies feed on nectar from flowers, but some flowers are particularly favored. Also, caterpillar stages sometimes develop on garden flowers, such as the parsleyworm on parsley or dill that later transforms into the beautiful black swallowtail. Keep records of the flowers butterflies most often use and plan a garden to attract these insects. Also observe which native flowers attract butterflies. Plant some of these in your butterfly garden to see if they will be more attractive than introduced plants. Maypop (passion flower) is a very common weed in most areas of the south. It is very attractive to the fritillary butterfly.

- ***Biological control***
  Several insects are important as biological controls of pests. Lady beetles and praying mantids are good examples. Spend some time observing them and watch what they eat, how active they are, and where they occur most commonly. You may want to take your studies indoors, rearing the insects for awhile so you can make better observations. What other common insects are beneficial? Prepare a list of commonly observed insects and determine their potential for being biological control agents. Are there any that are both pests and beneficial?

- ***Beekeeping***
  Honey bees are very important in the pollination of crops. They also produce honey, beeswax and other products. If you live in an area where bees are used to pollinate crops, talk to the growers about the benefits that they get from these helpful insects. If you can find a local beekeeper, try to spend some time with him to learn about the practice of *apiculture*—the keeping of bees. You may even want to set up a hive or two of your own! See the discussion on beekeeping on pages 77–79 in this manual.

- ***Aquatic insects as pollution indicators***
  Insects can be good indicators of the quality of water. For example, most stoneflies and mayflies are very sensitive to changes in pollution levels, temperature and/or how much oxygen is in the water. At several points in a river collect the aquatic insects that live there. Make comparisons of what you find in the different spots.

- ***Insects in the news***
  Insects often end up in the news in one way or another. Go through your newspapers and magazines for a few months and look for articles, cartoons, and other items that feature insects. Make a scrap book and report on what you found.

- ***Fly tying and insects***
  If you like to fly fish, then you know the "flies" really are mimics of actual insects that occur in streams and rivers. Make a display of some fishing flies and find the insects they resemble.

- ***Seasonal occurrence***
  During the course of the year, keep weekly records of what types of insects you see. This will give you an idea of how life in the insect world changes during the seasons. What are the first insects you find in spring? What is common in midsummer? What insects are still around as fall approaches?

- ***Watch an ant colony***
  Observe the activity of an ant colony for a while. What are they bringing in? What are they removing? You may wish to try some simple experiments, such as providing some food or making a small disruption around the entrance. Record what you have noticed. Be careful, especially if fireants are the subject of your study.

Specialty Collections

Making a specialized type of collection can be a valuable way to get involved in an advanced unit project. These types of collections also can tell you something about the insect or how insects are important in a certain environment. Some examples of specialty collections include the following:

- ***Collect large numbers of a single insect***
  Many insects, such as the common "miller moth" (army cutworm) can have highly variable features. Such a collection is called a *series,* and these can be very useful for showing the variability of its features. An intensive collection of one insect throughout the season also can be used to show the periods it occurs. If you are able to travel to several areas, you also may be able to show something about the range of the insect.

- ***Make a display of different insects that mimic each other in their appearance***
  Many insects resemble other insects in shape, color and even sound. This is called *mimicry*. For example, many harmless insects are banded in bright yellow and black, resembling a stinging wasp or bee. Red or orange also are considered "warning colors" that are shared by many insects that are dangerous. They may have defensive chemicals that make them unpleasant to animals that may want to eat them. A special collection of this type might be of insects that all share the same coloration or appearance.

- ***Display insects that show camouflage or other interesting features***
  Many insects try to camouflage their features in order to avoid being found by birds or other predators. Some have colors and patterns that help them blend in with tree bark, soil or leaves. Other insects may even take on the shape of twigs or leaves. A specialty collection of this type may include various insects that use camouflage. If possible, you may also wish to include examples of materials that the insects attempt to mimic.

- ***Collect insects from a single site or habitat.***
  One of the reasons there are so many different kinds of insects is that most have specialized habits. Some may only be associated with a certain environment or even one kind of plant. Examples of special collections of this type might be insects found under logs, insects that occur on a garden plant, or insects found in a water trough or small pond.

- ***Make a collection of beneficial insects***
  Many insects are highly beneficial. Some are predators or parasites of pest insects. Others are pollinators of crop plants. Insects also may be important in recycling nutrients or as food for other animals. A specialty collection might focus on one or more of these types of insects.

- ***Make a collection of crop pests***
  Insects often are known because of the damage they do to crops or other plants. A sample collection of this type might be of insects that damage corn, vegetable gardens, fruit trees, or forests.

- ***Specialize in an insect family***
  Pick a single family of insects, such as silk moths, lady beetles, or grasshoppers. Try to see how many different species you can find.

- ***Collect and rear all stages of insect life cycles***
  Try to find all stages in the life cycle of some insects that are common around your home. If you can't find all the stages, maybe rearing a few will help to supplement this collection. Display as many stages as you can get. And remember—you may need to preserve different stages in different ways. For example, most adult insects can be pinned, but softer immature forms may need to be in alcohol.

Glossary of Terms Used to Discuss Insects

abdomen The posterior of the three main body divisions found in an insect.
abiotic Nonliving.
action threshold The pest density at which a control tactic must be implemented to avoid an economic loss.
active ingredient (AI) The component of a pesticide formulation responsible for the toxic effect.
agroecosystem A relatively artificial ecosystem in an agricultural field, pasture, or orchard.
antenna (pl., *antennae***)** A pair of segmented appendages located on the head above the mouthparts that are used for sensing.
anterior Front, in front of.
aorta The front-most, non-pulsating portion of the dorsal blood vessel of an insect.
aquatic Living in water.
appendage A subordinate part attached to something (legs and antennae are among the appendages of insects).
arthropod Any of the invertebrate animals (such as insects, spiders, millipedes, centipedes, or crustaceans) having an exoskeleton, a segmented body and jointed limbs.
augmentation Biological control practices intended to increase the number or effectiveness of existing natural enemies.
bacterium (pl., *bacteria*) A single-celled microscopic plant-like organism that does not produce chlorophyll.
basal At the base, or point of attachment. Toward the base
beak Colloquial expression for the protruding mouthpart structures of a sucking insect (syn. *proboscis*).
biological control The use of living organisms, such as predators, parasitoids, and pathogens, to control pest insects, weeds, or diseases. Typically involves some human activity.
biorational Having a minimal disruptive influence upon the environment and its inhabitants (e.g., a biorational insecticide).
broad-spectrum (insecticide) Active against a wide range of insects.
brood Individuals that hatch from the eggs laid by one mother.
Bt The bacterium *Bacillus thuringiensis*, which is used as a biological control agent.
caterpillar The larva of a butterfly, moth, or skipper (order: Lepidoptera).
caudal filaments Thread-like filaments found on the posterior end of the abdomen on many insects (e.g., mayflies, stoneflies, bristletails).
cephalothorax A body segment of arachnids that combines the head and thorax, including the legs.
cerci A pair of appendages at the end of the abdomen.
chelicera (pl., *chelicerae*) The anterior, usually fang-like appendages of arachnids. Spider mouthparts.
chemical control Pest management practices that rely upon the application of synthetic or naturally-derived pesticides.

chitin The material of which the cuticle of arthropods is made.

chorion The outer shell of an arthropod egg.

chrysalis/chrysalid The pupa of a butterfly.

class A group of closely related orders.

classical biological control The importation of foreign natural enemies to control previously introduced or native pests.

cocoon Silken case in which the pupal stage of many insects is formed.

cole crops Crops such as cabbage, broccoli, Brussel sprouts, and other crucifers.

commensalism A living together of two or more species, in which none is injured and at least one is benefitted.

community The combined populations of organisms in an area.

complete metamorphosis Type of insect development characterized by four distinct stages: egg, larva, pupa, and adult.

compound eye The type of eye found in many insects that is made up of many individual light-receiving elements (called *ommatidia*) pressed closely together.

conservation Any biological control practice designed to protect and maintain populations of existing natural enemies.

contact poison A pesticide that is absorbed through the body wall, as opposed to one that must be ingested.

coxa The basal segment of the leg.

crochets Tiny hooks on the prolegs of a caterpillar.

cucurbits Vine crops such as cucumbers, melons, squash, and pumpkins.

cultural control Pest management practices that rely upon manipulation of the cropping environment (e.g., cultivation of weeds harboring insect pests).

density (insect populations) The number of insects per unit of measure (e.g., beetles per square meter).

diapause A physiological state of arrested metabolism, growth, and development that occurs at a particular stage in the life cycle of an organism. Diapause is used by many arthropods to survive periods of adverse environmental conditions, such as winter.

distal Toward the end. Farthest from the body or base.

diurnal Active during the day.

dormancy A recurring period in the life cycle of an organism when growth, development, and reproduction are suppressed.

dorsal The back or upper side.

drone A reproductive, male honey bee.

ecology The study of an organism's interrelationship with its environment.

economic threshold *See* action threshold.

elytra (sing., *elytron*) The hardened or horny forewings produced among several insect groups (e.g., Coleoptera, Dermaptera, some Homoptera) to form wing covers that protect the hind wings and abdomen. Elytron is the singular form.

entomopathogenic Insect-attacking organism, (i.e., a disease that attacks insects).

environmental impact quotient (EIQ) A relative value that estimates the environmental impact of a pesticide by taking into account toxicity to natural enemies, wildlife, and humans; degree of exposure; aquatic and terrestrial effects; soil chemistry, etc.

epizootic A disease outbreak within an insect population.

exoskeleton A skeleton or supportive structure on the outside of an insect body.

exotic Introduced from another country or continent (e.g., introduced insect pest).

eyespots Prominent markings resembling eyes on the wings of certain insects.

family A group of closely related genera. The suffix for such grouping is –idae.

femur The third segment of the insect leg, located between the trochanter and tibia.

file A file-like ridge on the underside of the front wing in certain crickets and grasshoppers. Part of the sound producing organ.

foreleg: The first, front pair of legs.

forewings The forward pair of wings. In many insects the forewings are thickened to cover and protect the delicate hind wings.

frass Solid insect excrement typically mixed with chewed plant fragments.

fumigant A substance that produces a gas, vapor, fume, or smoke intended to kill a pest.

fungicide Any substance that kills or inhibits the growth of a fungus.

fungus (pl., *fungi*) Any of numerous plants lacking chlorophyll, ranging in form from a single cell to a body of branched filaments. Includes the yeasts, molds, smuts, and mushrooms.

gall The abnormal growth of plant tissues caused by the stimulus of an animal, microorganism, or wound.

gene A biochemical unit of hereditary, often coding for an entire protein.

generalist A pest or natural enemy that can utilize a wide range of species as host or prey.

generation Period from any given stage in the life cycle to the same life stage in the offspring; typically from egg to egg.

genetic engineering The manipulation of the genetic material of an organism in order to achieve desirable characteristics.

genus (pl., *genera*) A group of very closely related species.

gradual metamorphosis A type of insect development in which there is no prolonged resting stage (pupa). The three stages are: egg, nymph, and adult. Also known as *simple metamorphosis*.

grub A general term to describe the larval stage of many insect larvae, particularly beetles.

GV Granulosis virus.

habitat manipulation Manipulation of agricultural areas and surrounding environment with the aim of conserving or augmenting populations of natural enemies (e.g., the planting of a refuge for natural enemies).

halteres Small, knob-like balancing organs used to replace the hindwings of adult Diptera.

head capsule The structure that contains the head and the appendages attached to it.

head The anterior region of an insect, which bears the mouthparts, eyes, antennae and houses the brain.

herbicide A substance used to kill or control weeds.

herbivorous Feeding on plants (syn., *phytophagous*).

hermaphroditic Having both male and female sex organs in one individual.

hibernation A period of temporary dormancy, usually during the winter, to avoid adverse environmental conditions.

hibernaculum A tiny cocoon spun by first or second instar caterpillars of some species for overwintering shelter.

hilltopping A behavior common among many insects (e.g., harvester ants) where reproductive stages seek out prominent points to aggregate in search of mates.

hind legs The third, posterior pair of true legs, attached to the metathorax.

hind wings The second or rear pair of wings. In flies (Diptera), the hind wings are reduced to a tiny knob-like organ, known as a haltere.

honeydew A sugary, liquid waste product produced by insects that suck plant sap, such as aphids, soft scales and leafhoppers.

host The organism in or on which a parasitoid lives; a plant on which an insect feeds.

host plant resistance The relative amount of heritable qualities possessed by a plant that reduces the degree of damage to the plant by a pest or pests.

hyperparasite A parasite whose host is another parasite.

indigenous Native to an area.

inoculative release The release of relatively small numbers of natural enemies that are expected to colonize, reproduce, and spread naturally throughout an area.

insect growth regulator (IGR) A substance, natural or synthetic, that controls or modifies insect growth processes.

insecticide resistance Genetically inherited ability to withstand doses of pesticide that would kill individuals from strains whose ancestors had not been exposed to the pesticide.

insect resistant (plants) Tolerant of, or resistant to, insect attack (as in plants). Individuals from strains whose ancestors had not been exposed to the pesticide.

instar The stage of an insect between molts. Instar I is the stage that occurs immediately after egg hatch.

integrated pest management (IPM) An approach to the management of pests in which all available control options, including physical, chemical, and biological controls, are evaluated and integrated into a unified program.

integument The outer covering of the insect body that includes the cuticle and the epidermis.

introduction (classical biological control) The importation of a natural enemy from a foreign country or continent, usually to control a pest also of foreign origin.

inundative release The release of relatively large numbers of natural enemies to suppress pest populations, without the expectation that the natural enemies will colonize and spread throughout the area.

larva (pl., *larvae*; adj., *larval*) The immature stage, between egg and pupa of an insect with complete metamorphosis; i.e. caterpillars, maggots, grubs. The term larva is now often used to describe immature stage of all insects, supplanting the term nymph among insects with simple/gradual metamorphosis.

lateral On or pertaining to the side (right or left).

leafy greens Lettuces and other leaf vegetables.

least toxic Having a minimal toxic effect upon non-target organisms.

life cycle The sequence of events that occurs during the lifetime of an individual organism.

macrodecomposers Organisms that help break down large pieces of organic matter into small pieces. Decay and nutrient cycling are sped up by macrodecomposers.
maggot A legless larva without a well-developed head capsule used to describe certain Diptera.
mandibles The anterior pair of mouthpart structures that make up the insect jaw, often hardened and used to crush, chew, or puncture cells.
mass-reared Produced in large numbers, as in natural enemies produced for release programs.
maxillae The pair of mouthpart structures found immediately behind the mandibles.
mechanical control Control of pests by physical means such as the use of screens or row covers.
membranous wings Thin and more or less transparent wings, such as those found on such insects as flies, lacewings and dragonflies.
mesothorax The second, middle segment of the insect thorax, to which the middle pair of legs and the front pair of wings are attached.
metabolism (adj., *metabolic*) Chemical changes that occur in living cells to provide energy for vital activities and to assimilate new material.
metamorphosis A change in body form during development of an insect.
metathorax The third, posterior segment of the insect thorax to which the hind pair of legs and the hind wings are attached.
microbial A microscopic organism; a germ.
microbial insecticide A preparation of microorganisms (e.g., viruses or bacteria) or their products used to suppress insect pest populations.
microsporidia Single-celled life forms, related to Protozoa.
mite Any of several minute invertebrates related to the insects, belonging to the phylum Arthropoda, class Arachnida.
molt The shedding of the exoskeleton by an insect.
morphology Insect form or structure.
multivoltine Having more than one brood or generation per season.
mycelium (pl., *mycelia*) A mass of interwoven filamentous 'threads' that make up the vegetative part of a fungus.
naiad An aquatic gill-breathing nymph—e.g., dragonflies, mayflies
native (insect or plant) Of local origin, not intentionally or accidentally introduced.
natural control The suppression of pest populations by naturally occurring biological and environmental agents.
natural enemies Living organisms found in nature that kill insects, weaken them, or reduce their reproductive potential.
nectar The sugary liquid secreted by many flowers.
nematode An elongated, cylindrical worm parasitic in animals, insects, or plants, or free living in soil or water.
nocturnal Active at night.
NPV Nuclear polyhedrosis virus (an entomopathogenic organism).
nymph An immature stage of an insect with simple metamorphosis; e.g., aphids, bugs and grasshoppers. (Note: The term *larva* is usually the preferred description for immature stages of all insects.)

ocellus (pl., *ocelli*) A simple eye.

ootheca (pl., *oothecae*) An egg capsule produced by certain groups of insects, including cockroaches and mantids.

oral Pertaining to the mouth.

order A group of closely related families.

osmeteria Glands containing defensive compounds that can be extruded from the head to deter predators.

overwinter The act of resting or hibernating by which insects survive the winter.

oviposit The laying or depositing of eggs.

ovipositor The egg-laying apparatus of a female insect.

paedogenesis The production of eggs or young by an immature or larval stage of an animal.

parasite An animal that lives within or on another living animal, drawing sustenance from the tissues of the host and causing injury to it. *See also* parasitoid.

parasitoid An animal that feeds in or on another living animal, consuming all or most of its tissues and eventually killing it.

parthenogenesis Development of an insect, from egg to adult, without fertilization.

pathogen A disease-causing organism.

pedipalps Structures attached to the mouthparts of arthropods that may appear leg-like in form but actually are used for sensing or holding prey. Very large pedipalps occur on male spiders, sun spiders, and scorpions.

pest An organism that damages plants, bites or stings, or otherwise causes annoyance or loss.

pest management *See* integrated pest management.

pesticide A substance that is used to kill, debilitate, or repel a pest.

pest-resistant crops Crops that possess attributes that minimize damage by pests.

phenology The seasonal life history of an insect population.

pheromone A substance, such as a sex attractant, that is given off by one individual and causes a specific reaction in other individuals of the same species.

phylum (pl., *phyla*) One of the largest and most inclusive groupings of plants and animals. For example, all insects, and many other animals such as spiders and centipedes, are grouped together in the Phylum Arthropoda.

physical control Control of pests by physical means such as heat, cold, and sound waves.

plumose Feathery; or bearing many long hairs.

polyembryonic (eggs) A single egg that divides to form two or more (often hundreds) identical embryos.

polyembryony Having several embryos.

population A group of individuals of the same species within a given space and time.

posterior Hind or rear.

predaceous Preying upon other organisms, predatory.

predator An animal that attacks and feeds on other animals, normally killing several individuals during its life cycle. Arthropod predators typically must devour several prey in order to complete development.

proboscis The beak.

pronotum The upper, often shield-like, hardened body-wall plate, located just behind the head of an insect.

posterior Hind or rear.

proleg One of the fleshy abdominal legs found on the abdomen of certain insect larvae such as caterpillars.

prothorax The first, anterior segment of the insect thorax to which the pair of front legs are attached.

protozoan A microscopic, single-celled organism that is largely aquatic and includes many parasitic forms.

pubescent Covered with short fine hairs.

pupa (pl., *pupae*; adj., *pupal*) The transitional stage between larva and adult of insects with complete metamorphosis. In moths and some other insects, the pupal stage usually takes place in cocoons.

puparium (pl., *puparia*) A case formed by a hardening of the skin from the last larval stage, in which the pupa is formed, produced by certain Diptera.

pupate To transform to a pupa.

queen A female insect capable of reproduction found in colonies of social insects such as ants, social wasps, and bees.

raptorial Designed for capturing and holding prey. Used to described the forelegs of several insects that are predators, such as mantids, assassin bugs, and mantispids.

reproductives Members of a social insect colony (e.g., termites, ants) that are capable of reproduction. The female reproductive stages (queens) typically disperse to form new colonies after mating with the male stage (drones, males).

resistance (insecticide or pesticide) *See* insecticide resistance.

resistance (plant) *See* host plant resistance.

resurgence (pest) The development of large populations of pests that had previously been suppressed.

sampling Estimating the density of organisms (pests or natural enemies) or damage by examining a defined portion of the crop.

scape The basal segment of an antenna.

scout, scouting, *See* sampling.

scraper The sharpened angle of front wing of a cricket or grasshopper, a part of the sound-producing mechanism. Scraper and file make up the sound producing organ.

scavenger An animal that feeds on dead plants or animals, decaying materials, or on animal wastes.

scutellum Small plates (sclerites) found on the back of the thorax.

segment A subdivision of the body or of an appendage.

septicemia Blood poisoning caused by pathogenic organisms.

sessile Attached and not capable of moving from place to place.

specialist insect A pest or natural enemy that utilizes a narrow range of species for its host or prey.

species A group of individuals similar in structure and capable of interbreeding in nature and producing fertile offspring. They are different in structure from other such groups and do not interbreed with them. The abbreviation for the singular form of species is *sp.*; plural is *spp.*

spinneret Structure on the posterior of most spiders through which silk is expelled for spinning into webs or other purposes.

spiracles The external openings of the insect breathing (tracheal) system, found along the abdomen.

spore A strongly resistant inclusion that develops in certain bacteria and fungi and will become active under suitable conditions.

stage (life stage) A distinct period in the development of an organism (e.g., for some insects, egg, larval, pupal, and adult stages).

stomach poison An insecticide that is lethal only after it has been ingested by an insect, entering the insect body through the gut.

stridulate To produce a noise by rubbing two surfaces or structures together. Crickets stridulate by rubbing the scraper over the file.

subfamily A group of very closely related genera that comprises a group that is too small or specialized in features to be classified as a family. The suffix for such groupings is –inae.

systematist A biological researcher involved in defining and classifying the interrelationships of species into hierarchical series.

systemic insecticide An insecticide that is absorbed into plant sap and is lethal to insects feeding on or within the treated plant.

talus A slope formed by the accumulation of rock debris.

tarsus (pl., *tarsi*) The part of the leg beyond the tibia, consisting of one or more segments or subdivisions.

taxonomist An individual who describes, names, and classifies organisms.

thorax The middle section of an insect body, where the legs and wings are attached.

tibia The fourth segment of the leg, between the femur and the tarsus.

tolerance (host-plant resistance) The ability of a plant to withstand injury by pests.

transformed Transfer and expression of a gene (e.g., for Bt toxin) into another organism.

trap crop A small area of a crop used to attract pests from a larger area of the same or another crop. The pests, once diverted to the trap crop, may be treated with an insecticide.

tubercles A rounded protuberance, common on many insects, such as caterpillars.

tymbal A skin-like membrane covering a specialized sound-making organ found in certain insects, such as the cicadas.

univoltine Having only one brood or generation per season.

vector An organism capable of carrying and transmitting a disease-causing agent from one host to another.

ventral Lower or underneath; pertaining to the underside.

vestigial Small, poorly developed, nonfunctional.

virus Any of various submicroscopic pathogens that can only replicate inside a living cell.

viviparous Giving birth to live young, not egg laying.

wingspan The measurement between tips of the extended forewings of an insect.

wing cover Thickened hind wings produced by some insects as a means to cover and protect the forewings.

Taken from:
Hoffmann and Frodsham (1993) *Natural Enemies of Vegetable Insect Pests*
Borer, Triplehorn and Johnson (1992) *An Introduction to the Study of Insects*

Selected References on Insects and Other Arthropods

The following list includes some books and references you may find useful in your 4-H Entomology project. Check for them at libraries, bookstores, or museums you visit. If they are not available, most bookstores will order them for you. Just give them the following information: title, author, publisher, and ISBN number.

National Wildlife Federation's, Field Guide to Insects and Spiders of North America, Arthur, V. Evans, 2007, ISBN 13: 978-1-4027-4153-1. This useful field guide includes close-up color photos of the insects discussed. Classification of orders closely follows that of Triplehorn and Johnson's 7th edition of the Introduction to the Study of Insects, 2005, but there are a few minor differences. **This is the standard reference book for Mississippi 4-H Entomology.**

Kaufman, Field Guide to Insects or North America, Eric R. Eaton & Kenn Kaufman, 2007, Hillstar Editions L.C., ISBN 13/EAN: 978-0-618-15310-7. A useful field guide that includes color photos of insects discussed.

Garden Insects of North America, Whitney Cranshaw, 2004, Princeton University Press, ISBN: 0-691-09560-4. This book discusses damaging insects that affect vegetable crops and ornamental plants.

<u>**Golden Guides**</u>—Golden Press, Western Publishing, Inc. Racine, WI. Good, inexpensive guides to specific groups of insects and relatives, and widely available in bookstores. The following are recommended.

- *Spiders and their Kin*. H.W. Levi and L.Z. Levi. 1969. ISBN: 0-307-24021-5. This guide will allow identification of many common spiders to family level and even sometimes to species. It is less accurate but much easier to use than *How to Know the Spiders* because of the many color illustrations. Due to its low cost and ease of use, this is probably the best non-technical guide to spider identification.

- *Insect Pests*. G.S. Fichler. 1966. ISBN: 0-307-24016-9.
  A large number of important plant pests are included and illustrated. It doesn't allow identification of all pest species, but generally one can get close.

- *Butterflies and Moths*. R.T. Mitchell and H.S. Zim. 1977. ISBN: 0-307-24052-5.
  Quite useful for identification of the more showy species of moths and butterflies. It also contains pictures of some economically important caterpillars.

- *Insects*. C. Cottam and H.S. Zim. 1987. ISBN 0-307-24055-X.
  Provides a general overview of North American insects, their arthropod relatives and basic information on collecting.

- *Pond Life*. G.K. Reid and H.S. Zim. 1967. ISBN: 0307-24017-7.
  An excellent introduction to familiar pond animals, including the common aquatic insects.

How to Know the ....series. William C. Brown Co., publishers. This series of books provides identification keys to various groups of organisms. Several of them deal with insects or other arthropods and the following are particularly good:

- *How to Know the Insects*. R.G. Bland and H.E. James. ISBN: 0-697-04752-0. An inexpensive alternative to *Introduction to the Study of Insects* without the comprehensive descriptions of insect biology. Some of the taxonomy is out-of-date and incomplete.

- *How to Know the True Bugs*. J.A. Slater and R.M. Boronowski. 1978. ISBN: 0-697-04894-2. An excellent key to the families in the order Hemiptera. Keys to the generic level with common or some economically important species illustrated.

- *How to Know the Grasshoppers, Crickets, Cockroaches and Their Allies*. J.R. Helfer. 1987. ISBN: 0-486-25395-3. An excellent overview of the taxonomy and distribution of termites, cockroaches, mantids, grasshoppers and crickets found in the United States.

- *How to Know the Beetles*. A. Ross. ISBN: 0-697-04776-8. Illustrates many of the beetles found in the United States and provides keys to common species.

- *How to Know the Spiders*. B.J. Katson. 1982. ISBN 0-697-04898-5. Rather technical, reflecting the difficulties in spider identification, but a useful glossary is provided. Some magnification is needed to observe characters used in these keys. Spider identification is difficult, however this book is unsurpassed as a tool for preliminary spider determination.

Peterson Field Guide Series—Houghton Mifflin Co. Boston, Mass. More expensive than the Golden Guides (see above) and more complete. More species and brief descriptions of the habits are included.

- *A Field Guide to the Insects of America North of Mexico*. D.J. Borror, R.E. White. 1970. ISBN: 0-395-18523-8. Contains illustrations and information about insects of all the major orders. Does not include many keys, but important characteristics of each group are emphasized. Color plates of some of the more common or showy species also are included.

- *A Field Guide to the Beetles of North America*. R.E. White. 1983. ISBN: 0-395-31808-4. A selection of the 27,000 species of beetles in the United States and Canada are illustrated in this more specialized guide. Provides excellent diagnosis sections for separation of beetle families and even genera. Collecting hints for each family are given.

- *Eastern Butterflies*. P.A. Opler and V. Malikul. 1992. ISBN: 0-395-63279-X, hardbound; $16.95, paper. This is an all-new edition of the original classic guide to eastern butterflies, describing 524 species found east of the 100th meridian. Well-illustrated with distribution maps. Many species included in this book are commonly found east of the Rocky Mountains.

Audubon Society Field Guide series. Alfred A. Knopf, publishers. New York, NY. This series is most notable for its combination of extensive use of color photographs combined with moderate price and availability.

- *The Audubon Society Field Guide to North American Insects and Spiders*. 1980. Lorus and Margery Milne. ISBN: 0-394-50763-0.

- *The Audubon Society Field Guide to North American Butterflies.* 1981. Robert M. Pyle. ISBN: 0-394-51914-0.

Introduction to the Aquatic Insects of North America. R.W. Merritt, K.W. Cummins. 1983. Kendall/Hunt, Dubuque, IA. ISBN: 0-8403-3180-0. One of the most comprehensive books dealing with aquatic insects. Excellent keys are provided to adults and immatures are included, as well as information on the biology and ecology of North American species. A special feature is an extensive literature review.

The Bugs in the System: Insects and Their Impact on Human Affairs M. Berenbaum. 1995. Helix Books; Addison-Wesley Publishing Co. ISBN 0-201-40824-4. Packed with interesting information on a wide variety of topics related to insects: how they develop, their importance in agriculture, historical event involving insects—a bit of everything. Written well and very entertaining.

Butterfly Gardening: Creating Summer Magic in Your Garden. Created by the Xerces Society in association with the Smithsonian Institution. 1990. Sierra Club Books, San Francisco, CA. ISBN: 0-87156-615-X. Probably the best single reference on butterfly gardening, the practice of purposefully gardening to attract butterflies. Well illustrated with good lists of attractive nectar plants as well as larval food plants used by most of the more common North American butterflies.

Caring for Insect Livestock: An Insect Rearing Manual. G.A. Dunn. 1993. Published by the Young Entomologists' Society, Inc. 1915 Peggy Place, Lansing, MI 48910-2553. ISBN 1-884256-10-4. Available from the Young Entomologists' Society. A comprehensive, well-prepared book on rearing many of the insects most popularly used in displays and classrooms.

An introductory section gives general instructions related to rearing techniques and is followed with specific instructions on 49 insects and 10 non-insect arthropods.

Life on a Little Known Planet. H.E. Evans. 1993. Lyons and Burford, Pub., New York, NY. ISBN 1-55821-249-3. Probably the best introduction to the world of living insects available. Full of well-written, fascinating stories of common insects and a healthy dose of philosophy.

The Pleasures of Entomology: Portraits of Insects and the People Who Study Them. H.E. Evans. 1985. Smithsonian. ISBN: 0-87474-421-0. Delightful accounts of 12 common insects, plus some entomological history and philosophy.

The Hive and the Honey Bee. J. M. Graham, editor. 1993. Dadant & Sons. Hamilton, IL. ISBN: 0-915698-09-9. Probably the best single publication regarding beekeeping and issues related to bees.

The Practical Entomologist. R. Imes. 1992. Simon & Schuster/Fireside. New York. ISBN: 0-671-74695-2. An introduction to entomology that includes tips on collecting and observing insects as well as information on the common orders of insects. Filled with color photographs and useful figures. An excellent supplement to the *4-H Entomology Manual*.

An Introduction to the Study of Insects. C.A. Triplehorn, and N.F. Johnson. 2005. Thomson Brooks/Cole. ISBN: 0-03-096835-6. This is the standard text for introductory college entomology courses that emphasize insect identification. Excellent keys to adult stages of all North American insect families. Illustrations are among the best for completeness and clarity. A brief description of the biology of each insect family is included. The use of a microscope is necessary for most identifications.

Appendix A: Standard 4-H Display Box

The standard 4-H Display Box is a storage **unit** for pinned insects, a unique display case and if properly built and outfitted a source of protection for collected specimens. The sturdy construction of the box protects the collection when you carry it from place to place. The more airtight the box, the more insect scavenger protected it can be. To protect the insect collection from scavengers, put mothball (or crystals) or an insect kill strip in the box. Attach the strip or the mothball in one corner of the box by using netting or insect pins. A small piece of kill strip gives good protection for several months.

As of July 1999 the dimensions for 4-H Insect Collection display boxes is standardized to 19 x 16 1/2" x 3 inches (outside dimensions). This is the same size as the commercially available "Cornell drawers" that are most often used for institutional collections. This size is easy to handle and can be stored in standard insect cabinets. 4-Hers may choose to make their own collection boxes to match these dimensions, to buy boxes build by local woodworkers, or to purchase boxes from commercial suppliers. In any case, outside dimensions of the finished display box should be 19 inches x 16 ½ inches x 3 inches.

Holding Boxes

Almost any box with a secure top can serve as a temporary holding box for insect specimens. It is important to secure pinned specimens in a tight (airtight if possible) box soon after pinning. Scavengers can attack specimens and destroy a collection in a matter of weeks. Cigar boxes that are deeper than 2-inces make ideal holding boxes. In the bottom of the box, place a piece of flexible styrofoam or other soft medium that will support a pin. Don't forget to put a small piece of kill strip or a mothball in the box to protect against scavengers. To use mothballs, heat the head of an ordinary straight pin with a match while holding the pin with a pair of pliers. Insert the hot pinhead into the mothball and hold it steady for a few seconds.

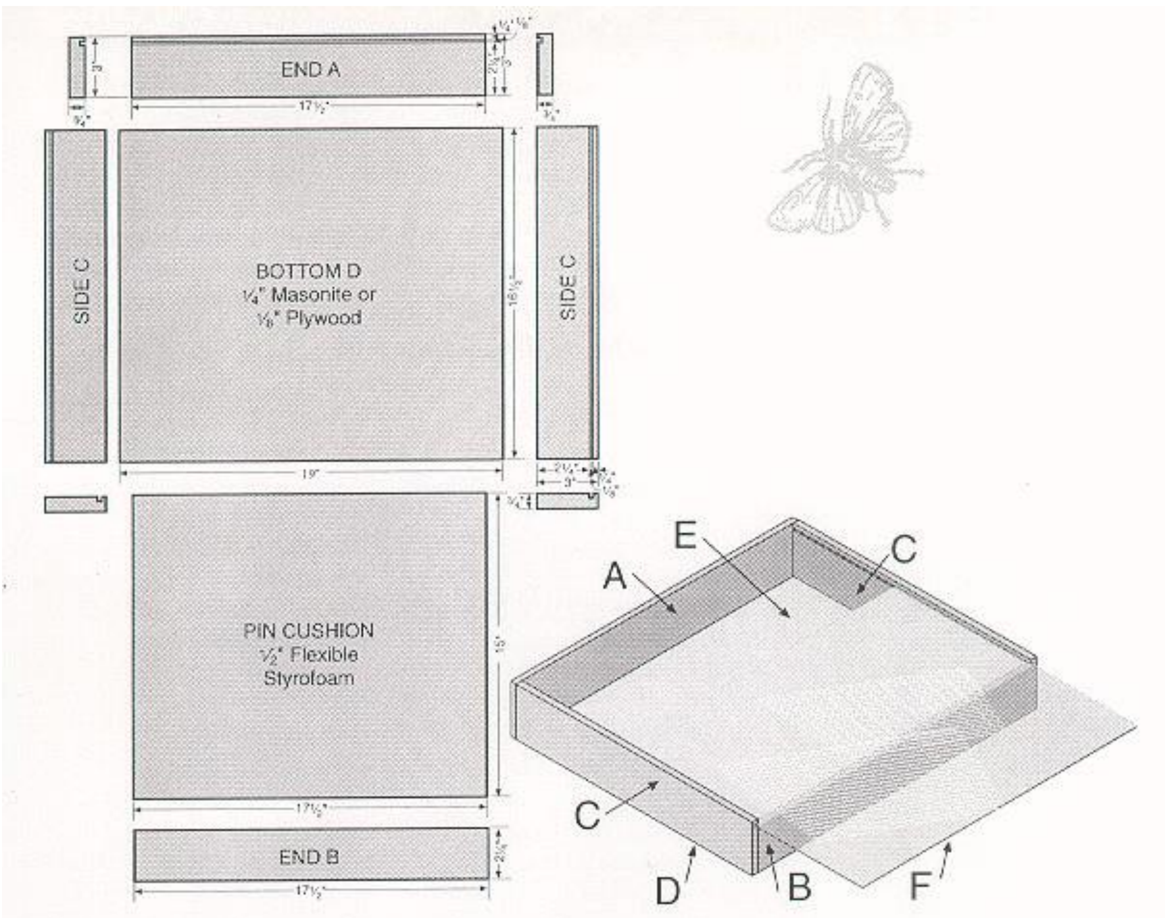
You can adapt other sturdy boxes in much the same way. For short-term storage, use plastic boxes for this purpose. Specimens tend to collect moisture and mold in these types of boxes, so you probably need to add silica packets to plastic containers when they are used for insect storage. You can build a holding box much like the standard display box, but you need to use a tight-fitting lid instead of glass. You can purchase the Standard 4-H Display

For more information on where to purchase the standard boxes or holding boxes, contact the Entomology and Plant Pathology Department, Mississippi State, MS 39762. Ph: (662) 325-2085.

Materials to Build a Standard 4-H Display Box

PART	QUANTITY	MATERIALS	SIZE (inches)
A - End	**1**	**white pine**	**3/4 X 3 X 17-1/2**
B - End	**1**	**white pine**	**3/4 X 2 5/8 X 17-1/2**
C - Sides	**2**	**white pine**	**3/4 X 3 X 16-1/2**
D - Bottom	**1**	**plywood**	**1/8 X 16-1/2 X 19**
E - Pinning surface	**1**	**block foam**	**1/2 X 15 X 17-1/2**
F - Top	**1**	**glass**	**1/8 X 16 X 18-1/8**

<u>Use paneling </u>nails or small wood screws to secure the box. For construction details, see illustrations.



Appendix B: Order Labels for Some of the More Common Orders Seen in 4-H Insect Collections

A complete listing of order names and descriptions is given on pages 30-47. These names here are intended for use in collections.

Blattodea	Blattodea	Blattodea
Coleoptera	Coleoptera	Coleoptera
Collembola	Collembola	Collembola
Dermaptera	Dermaptera	Dermaptera
Diplura	Diplura	Diplura
Diptera	Diptera	Diptera
Embioptera	Embioptera	Embioptera
Ephemeroptera	Ephemeroptera	Ephemeroptera
Grylloblattodea	Grylloblattodea	Grylloblattodea
Hemiptera	Hemiptera	Hemiptera
Hymenoptera	Hymenoptera	Hymenoptera
Isoptera	Isoptera	Isoptera
Lepidoptera	Lepidoptera	Lepidoptera
Mantodea	Mantodea	Mantodea
Mantophasmatodea	Mantophasmatodea	Mantophasmatodea
Mecoptera	Mecoptera	Mecoptera
Microcoryphia	Microcoryphia	Microcoryphia
Neuroptera	Neuroptera	Neuroptera
Odonata	Odonata	Odonata
Orthoptera	Orthoptera	Orthoptera
Phasmatodea	Phasmatodea	Phasmatodea
Phthiraptera	Phthiraptera	Phthiraptera
Plecoptera	Plecoptera	Plecoptera
Protura	Protura	Protura
Psocoptera	Psocoptera	Psocoptera
Siphonaptera	Siphonaptera	Siphonaptera
Strepsiptera	Strepsiptera	Strepsiptera
Thysanoptera	Thysanoptera	Thysanoptera
Thysanura	Thysanura	Thysanura
Trichoptera	Trichoptera	Trichoptera
Zoraptera	Zoraptera	Zoraptera

Appendix C: Entomology Organizations and Museums

Entomology Organizations

Young Entomologists Society, Inc. 6907 W. Grand River Ave. Lansing, MI 48906-9158 (517) 886-0630	An organization for young entomologists that serves as a resource for many publications and supplies that may be useful for the budding entomologist. The society also produces several magazines and newsletters, including *Insect World*, *Y.E.S. Quarterly* and *The Flea Market*.
Entomological Society of America 10001 Derekwood Ln # 100 Lanham, MD 20706-4876 (301) 731-4535	This is the national organization of entomology in North America. In addition to holding several national and regional conferences annually, it also has available reference sources of books, slides and other materials useful for individuals interested in the insect sciences. Among the periodicals produced are *Journal of Economic Entomology*, *Environmental Entomology*, *American Entomologist* and *Insecticide and Acaricide Reports*.
The Xerces Society 4828 SE Hawthorne Blvd. Portland, Oregon 97215 USA (503) 232-6639	An organization dedicated to conservation of invertebrates, primarily butterflies. They produce a magazine, *Wings: Essays on Invertebrate Conservation,* and are involved in organized butterfly counts during early summer, similar to the bird counts conducted by the Audubon Society.
Butterfly Pavilion and Insect Center 6252 West 104th Ave. Westminster, CO 80020-4107 (303) 410-6792	A learning center featuring a variety of living arthropods. Most prominent is the butterfly house where visitors are able to walk through hundreds of butterflies in free flight within a tropical environment. The insect center features many interesting and unusual insects, as well as an observation beehive. Tour groups can be arranged.

Departments of Entomology

Each state within the region supports at least one university department or department section involved in entomology, found within the land-grant institution. Extension programs in entomology are produced within these departments and each department maintains insect collections used to support research in arthropod studies. Although these collections generally are not open to the public, they usually can be visited if prior arrangements are made.

Alabama
Department of Entomology
Funchess Hall, Room 328
Auburn University
Auburn, AL 36849

Arkansas
Department of Entomology
AGRI-321
University of Arkansas
Fayetteville, AR 72701

Florida
Dept. of Entomology & Nematology
PO Box 110620
University of Florida
Gainesville, FL 32611-0620

Georgia
Entomology Department
University of Georgia
413 Biological Sciences Bldg.
Athens, GA 30602-2603

Kentucky
Dept. of Entomology
S-225 Ag Science Center North
University of Kentucky
Lexington, KY 40546-0091

Louisiana
Department of Entomology
402 Life Science Bldg.
Louisiana State University
Baton Rouge, LA 70803-1710

Mississippi
Entomology and Plant Pathology Dept.
Clay Lyle Building
Box 9775
Mississippi State, MS 39762

South Carolina
Department of Entomology
Clemson University
Box 340365
Clemson, SC 29634-0365

Tennessee
Dept. of Ent. & Plant Path.
University of Tennessee
Box 1071
Knoxville, TN 37901

Museums with Entomology Collections

Clemson University
Department of Entomology
Box 340365
Clemson, SC 29634-0365
(864) 656-3111

Clemson houses extensive insect collections.
For more information contact the Entomology Department and ask for Dr. John Morse.

Mississippi State University
Clay Lyle Building
Box 9775
Mississippi State, MS 39762
(662) 325-2085

The MSU Entomology Department houses a museum with extensive insect collections. For more information, contact the department and ask to speak to Dr. Richard Brown.

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Edited by **John Guyton**, PhD, and **Blake Layton**, PhD, Extension Entomologists.

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