

CMG GardenNotes #312

Insect Anatomy and Growth

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Identification and classification of insects is based on their structure and physiology. A basic understanding of insect physiology will enable the gardener to identify most insects to order and some to family.

External Structure

The exterior body wall, called an *exoskeleton*, provides the structural support for the insect. It is composed of five distinct layers made of waxy lipoproteins and *chitin* (a cellulose like polymerized glucosamine). The acid resistant exoskeleton protects the insect from excessive dryness, humidity, and disease organisms.

This external skeleton is somewhat cylindrical and typically made up of 21 hardened, ring-like *segments*. These segments are arranged in three groups or body regions, the *head*, *thorax* and *abdomen*. The body may be covered by *setae* (hairs) and may have external protuberances, such as horns, spines, or spurs. [Figure 1]

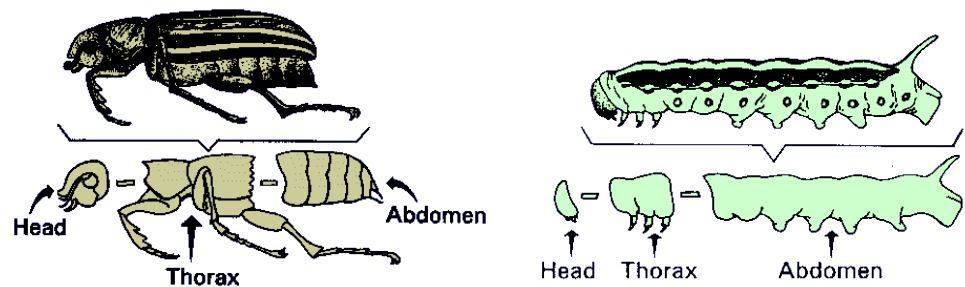


Figure 1. Body regions of beetle (left) and caterpillar (right).
[Line drawing: Colorado State University Extension]

Head

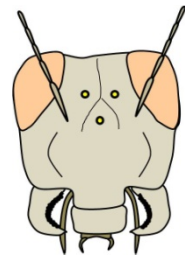
The head serves as a sensory center and for the intake of food. Main features of an insect's head include the eyes, antennae, and mouthparts.

Eyes

Insects have two types of eyes. To detect movement, most adult insects have a pair of lateral **compound eyes** comprised of multiple *ommatidium* (cornea). The number of ommatidia in the eye determines how well insects see. For example, dragonflies have approximately 50,000 per eye, house flies about 4,000 and ants about 50. These large compound eyes often occupy the greater portion of the insect head. Insects with large compound eyes are often predators, while insects with small compound eyes are often the prey. [Figure 2]

The *ocelli* or simple eyes are used for light responsiveness. Two or three are typically located between the larger compound eyes on most insect adults. Some immatures may have one to eight lateral ocelli. [Figure 2]

Figure 2. Grasshopper head; note large eyes, three ocelli between eyes, and large mandibles (chewing mouthparts). [Line drawing: David Whiting]



Antennae

All adult insects and many immature stages have a pair of segmented antennae, used for sensory function. Many modifications in form occur and these variations are often used in identification.

Mouthparts

The most remarkably complicated structural feature of insects is the mouth. Mouthparts are modified for various types of feeding, chewing, or sucking.

The *mandibles* or *chewing mouthparts* move horizontally on insects. Insects with chewing mouthparts consume the plant or insect they are feeding upon. [Figure 3]

Figure 3. Chewing mouthparts of a beetle. [Photograph by David Whiting]



Sucking-type mouthparts vary greatly for different feeding habits. **Piercing-sucking** mouthparts are typical of the *Hemiptera* (true bugs), *Homoptera* (aphids, scales) and blood sucking lice, fleas, mosquitoes, and the so-called biting flies. These are designed to punch and suck on the plant's sap, victim's blood, or in the case of predatory insects to suck out the insides of the victims. [Figures 4 & 5]

Figure 4. **Piercing-sucking mouthparts of a cicada** — Insects with piercing-sucking mouthparts feed on plant sap, blood, or in the case of predators, their victim's insides. They do not consume the plant or insect tissues. [Photograph by David Whiting]

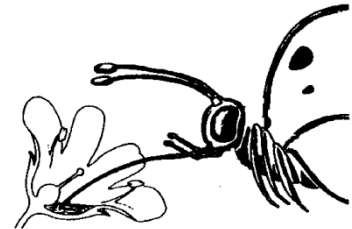


Figure 5. **Lapping mouthparts** — Flies are an example of an insects with lapping mouthparts. . [Line drawing: Colorado State University Extension]



The **siphoning** type found in butterflies and moths is a long coiled tube designed to suck up nectar. It looks like a cinnamon roll coiled up under the head. [Figure 6]

Figure 6. **Siphoning mouthparts** — Butterflies and moths have a coiled siphoning tube. To reach the nectar in flowers, the uncoiled tube may be longer than the butterfly's body. [Line drawing: Colorado State University Extension]



Intermediate types of mouthparts include the **rasping-sucking** type found in thrips, and the **chewing-lapping** types found in honey bees, wasps, and bumble bees.

Thorax

The **thorax** is made up of three segments (*prothorax*, *mesothorax* and *metathorax*).

Legs – A pair of legs is attached on each thorax segment. The insect's leg consists of five independent movable parts. Legs may be specially adapted for leaping, walking, digging, grasping, swimming, etc.

Wings – Insects may have one or two pairs of wings or no wings. The wings are attached to the latter two thorax segments. The wing **venation** (arrangement of the veins) is different for each species of insect and is often a means of identification. Wing surfaces are covered with fine hairs, scales or may be bare. On beetles, the thickened front wing, call **elytra**, serves for protection when not in flight.

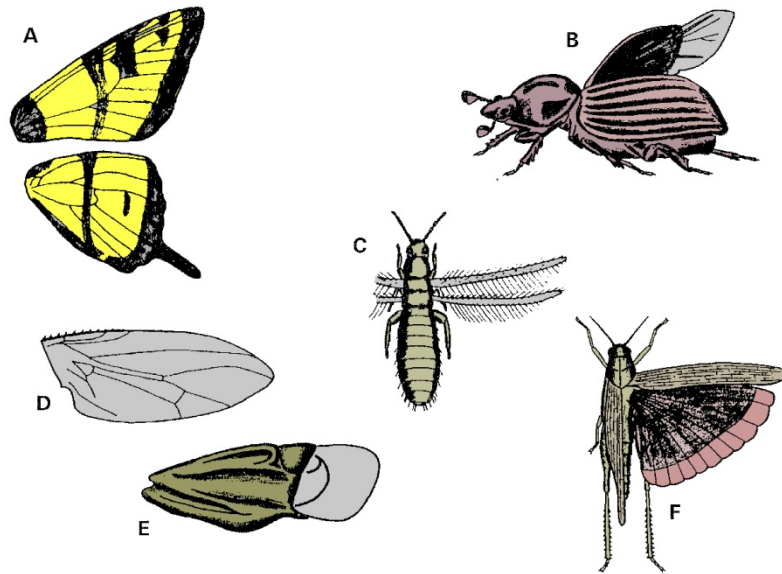


Figure 7. Types of insect wings: (A) scaly wing of moths and butterflies, (B) armor-like (elytron) and membranous wings of beetles, (C) feather wings of thrips, (D) membranous wing of a fly, (E) half-leathery/half-membranous wings (memelytron) of true bugs, and (F) wings of grasshoppers. Line drawing: Colorado State University Extension]

Abdomen

The **abdomen** may have eleven or twelve segments, but in most cases they are difficult to distinguish.

Prolegs (fleshy leg-like projections) occur on some larva such as caterpillars and sawfly larva. Prolegs, with tiny crochet-type hooks on the bottoms help the insect cling to plants. [Figure 8]

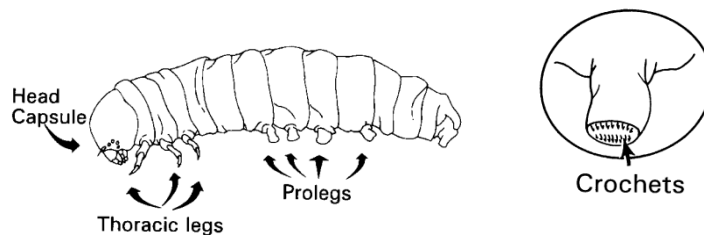
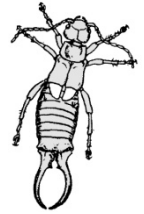


Figure 8. **Prolegs** (leg-like appendages on the abdomen of caterpillars and sawfly larvae) have small crochet-like hooks that help the insect cling to plants. [Line drawing: Colorado State University Extension]

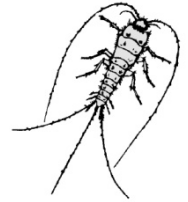
Some insects have a pair of appendages called **cerci** at the tip of the abdomen. The pinchers on earwigs are the best-known example of cerci. Cerci may be short, as in grasshoppers, termites and cockroaches, extremely long as in mayflies, or curved as in the earwigs. [Figure 9]

Figure 9. Earwig with cerci (pinchers) on end of abdomen.



Some groups have additional long segmented *filaments*, which appear like antennae. [Figure 10]

Figure 10. Silverfish with three filaments on end of abdomen.



The females of some insects have a prominent structure for depositing eggs, called an ovipositor. In bees, wasps, and ants, the ovipositor is modified into a stinger. [Figure 11]

Figure 11. Horntail with large ovipositor on end of abdomen



The *spiracles*, external openings used for respiration, are also present on the abdomen. Digestion, respiration, excretion, and reproduction are the main functions of the abdomen.

Internal Structure and Physiology

The muscular, digestive, circulatory, respiratory, nervous, and reproductive systems of insects are highly efficient. The insect's skeletal system has already been discussed, as part of the external structure.

While insect **muscles** are very small, they are very strong and often capable of extremely rapid contractions. Grasshoppers are said to have over 900 distinct muscles and some caterpillars over 4,000. In comparison to humans, insect muscle tissues are very strong.

The **circulatory system** of insects is an open type. The blood is pumped by the heart from the abdomen toward the head, bathing the organs in the body cavity. Blood functions to transport nutritive materials to the tissues and to carry away certain wastes. With a few exceptions, the blood of insects contains no red corpuscles, and plays no part in respiration.

The **respiratory system** consists of a series of slender branching tubes or *tracheae*, which divide and subdivide throughout the body. Movement of oxygen and carbon dioxide is primarily by diffusion. Breathing-like movements help to ventilate the tracheae.

Insects have a two-part **nervous system**. The sympathetic nervous system controls functions of the heart, digestion, respiration, and possibly other systems. The peripheral nervous system controls sensory stimulations from the external environment.

Most insect **reproduction** is sexual, (the union of an egg cell from the female with the sperm cell from the male). Some species are capable of producing young

without fertilization (*parthenogenesis*). A few species carry the eggs internally, giving birth to live young (*ovoviviparous*). Glands of the insect reproductive systems are similar to that found in higher animals.

Growth and Metamorphosis

The series of events from egg to adulthood constitutes the insect's *life cycle*. The life cycle varies for each insect species. For example, mosquitoes under optimum environmental conditions may develop from egg to adult in 10 days, whereas the periodical cicadas require 13 to 17 years to complete their life cycle.

An understanding of the insect's life cycle is a critical element in insect management practices.

Because the *exoskeleton* cannot expand sufficiently to accommodate an increase in size, it is cast off during the process called *molting*. The number of moltings varies considerably in the insect world. The form of an insect between successive molts is called an *instar*.

The *pupa* is a non-feeding stage during which the larval structures are transformed into adult structures. *Cocoon* refers to pupa cases made of silk from the modified salivary glands of the larva. *Chrysalis* is a term that denotes the pupa of a butterfly.

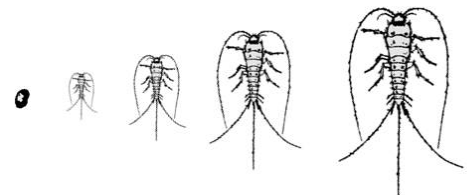
Metamorphosis

One of the most distinctive features of the insect world is *metamorphosis*, the marked or abrupt change in form, structure, and habit. Four basic types of metamorphosis are observed in the insect world.

No Metamorphosis

Upon hatching from the egg, the young insect with "no metamorphosis" development looks exactly like the adult except for size and minor differences in spines and setae (hairs). Size is the major change between each instar. Some species may molt after sexual maturity. The young and adults live in the same environment, and have the same types of mouthparts and feeding habits. These groups of very primitive, wingless insects include the *Thysanura* (silverfish) and *Collembola* (springtails). [Figure 12]

Figure 12. No Metamorphosis of silverfish: from egg (left), nymphs, and adult (right)

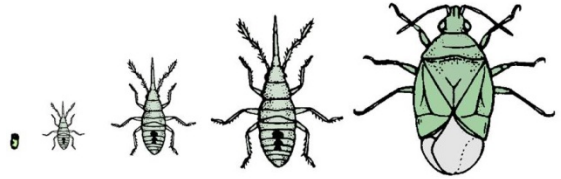


Simple Metamorphosis

In simple metamorphosis, the insect goes through three basic changes, egg, nymph, and adult. The nymphs typically go through three to five instars. Some books further divide simple metamorphosis into gradual and incomplete types.

In **gradual metamorphosis**, the newly hatched insect resembles the adult in general body form, but lacks wings and external genital appendages. With each successive molt, the nymph resembles the adult more than it did in the previous instar. Both nymphs and adults have the same type of mouthparts and food habits. Grasshoppers, squash bugs, and aphids are examples of insects with gradual metamorphosis. [Figure 13]

Figure 13. Simple-Gradual Metamorphosis of stink bug: from left to right: egg, nymphs, and adult.



Incomplete metamorphosis is characteristic of some orders with aquatic nymphs, such as *Ephemeroptera* (mayflies), *Odonata* (dragonflies), and *Plecoptera* (stoneflies). The changes that occur during the immature instar stages are more pronounced than in the case of insects with gradual metamorphosis, but not nearly so dramatic as in complete metamorphosis. The young, called *nymphs* or *naiads*, are aquatic insects found in rivers and streams, while the strikingly different fly-like adult is aerial. [Figure 14]

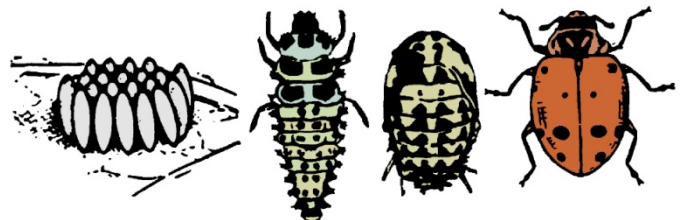
Figure 14. Simple-Incomplete Metamorphosis of Dragonfly from egg (left), naiads, and adult (right)



Complete Metamorphosis

Insects with complete metamorphosis have four developmental stages; **eggs**, **larva**, **pupa**, and **adult**. The insect may have several instars and molts as a larva, but it does not pick-up the characteristics of the adult with each molting. The larval stage is primarily an eating and growing state. All larvae have chewing or modified chewing mouthparts. [Figure 15]

Figure 15. Complete metamorphosis of beetle from left to right: egg, larva (grub), pupa, and adult.



Various names apply to the larvae of insects from different orders. Beetle larvae are known as **grubs**, butterfly and moth larvae are called **caterpillars**, and the larvae of flies are known as **maggots**. Grubs typically have three pair of legs on the thorax segment and no prolegs on the abdomen. Caterpillars have three pair of legs on the thorax segment and up to five pair of prolegs (fleshy leg-like structures

on the abdomen). By comparison, sawfly larvae have more than five pair of prolegs. Maggots are typically legless.

When the larvae have attained maturity, it ceases to feed and following a period of inactivity transforms to the pupa stage. In the pupa stage the insect usually remains inactive and does not feed, but undergoes marked physiological and morphological changes. The insect emerges from the pupa stage as a functional adult.

In the case of many insects, provisions are made by nature to protect the helpless pupa. Some seek protection in the ground, while others hide under the bark of trees. Some spin cocoons of silk (moths) or pupate in the last larval skin (flies).

The primary function of the adult insect is reproduction. In many insect groups, the adults die soon after mating and laying eggs. Some adults do little or no feeding.

Insects with complete metamorphosis may have entirely different types of mouthparts and food habits in the larval and adult stages. For example, caterpillars (larva of butterflies and moths) have chewing mouthparts and feed on a variety of materials, while the adults have siphoning mouthparts and normally feed on nectar of plants. Flea larvae feed on inert organic materials with their chewing mouthparts, while the adults suck the blood of their hosts.

Diapause is defined as a state or period of suspended activity in any stage of the life cycle. This state is initiated or terminated by environmental stimuli, such as photoperiod (length of the daylight), temperature, moisture, nutrition, or a combination of these. Diapause should not be confused with the cycles in metamorphosis.

Because eggs and pupa are non-feeding stages, they are resistant to insecticides. This is important point to remember when dealing with insect management.

Insect Names

All insects are classified into orders, families, genus, and species using scientific Latinized names. Scientific names are unique for that insect throughout the world. Genus names always begin with a capital letter, and species names are written entirely in lower case. Scientific names are printed in italics or underlined. In technical papers, the first entry of an insect name is followed with the name of the author whom first described the species. For example the honey bee, first described by Linnaeus is written *Apis mellifera* Linnaeus.

Common names, generally used by the public, often refer the insect to its groups such as orders, suborders, families or subfamilies, rather than individual species. For example, "beetles" applies to all species in the order *Coleoptera*; "leaf beetle" applies to species in the family *Chrysomelidae*.

Generally, only the insect species commonly known by the public have common names. Most insect species occurring in the world do not have a common name.

Most common names of insects that consist of a single word (i.e., beetles, earwigs, thrips, or termites) refer to an entire order. Most common names applying to

families consist of two or more words, the last being the name of the larger groups. For example, Carrion beetles, lady beetles, bark beetles, and blow flies.

Some common names are used for insects in more than one order, such as "fly" and "bug". The correct use and spelling of these words will help you identify orders. When a "bug" belongs to the *Hemiptera* order (often referred to as the "true bugs") it is written as two words (bed bugs, stink bugs, water bugs). When it does not belong to this order, it is written as one word (sowbugs, pillbugs, ladybugs). The same principle applies to "flies" and the fly order *Diptera*. Insects in the *Diptera* (fly) order are written as two words (house fly, deer fly, flower fly). When the fly-like insect is of another order, it is written as one word (dragonfly, stonefly, Mayfly).

Changing Taxonomy

Like plants, the taxonomy of insects is constantly changing with new research.

New books combine *Hemiptera* and *Homoptera* into *Hemiptera* with the following subgroupings:

Hemiptera

- *Heteroptera*—True bugs
- *Sternohynncha*—Aphids, physllids and scales
- *Auchenorhynncha*—Leafhoppers and plant hoppers

In this book, we continue to teach the old taxonomy since most books gardeners will be using have the old taxonomy.

Additional Information – *CMG GardenNotes* on Identify Insects

- #310 Identifying Insects: Reference and Study Questions
- #311 Taxonomy of Arthropods (Insects and Insect Relatives)
- #312 Insect Anatomy and Growth
- #313 Insect Orders
- #314 Key #1—Key to Insects Associated with Gardening
- #315 Key #2—Key to Insect Orders
- #316 Worksheet: Identifying Insects
- #317 Homework: Identifying Insects

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Line drawings from USDA. Photographs by David Whiting.

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