Chapter 3
Basics of Entomology

CHAPTER 3

Basics of Entomology

Edited and revised by Dr. Alan Eaton, University of New Hampshire Cooperative Extension

Insects and mites are among the oldest, most numerous, and most successful creatures on earth. It is estimated that over 100,000 different species live in North America. In the typical backyard, there are probably 1,000 insects at any given time. While insects which cause problems for humans are heard about most often, it is important to note that the vast majority are either beneficial or harmless. Insects pollinate fruits and vegetables, provide food for birds and fish, and produce useful products such as honey, wax, shellac, and silk. In addition, some insects are beneficial because they feed on other insects that are considered pests by humans.

Although the number of pest species compared to the total number of insect species is very small (less than 3% of all insects are classified as pests), the troubles for humans wrought by this group reach astonishing proportions. Insects annually destroy millions of dollars worth of crops, fruits, shade trees and ornamental plants, stored products, household items, and other materials valued by man. They transmit diseases of humans and domestic animals. They attack humans and pets, causing irritation, blood loss, and in some instances, death.

This chapter is designed to present basic principles that apply to the identification of insects and mites on horticultural crops, especially those commonly encountered in New England.

Basics of Classification

Identification of the thousands of species of insects would be impossible if they were not organized around a standard classification system. By grouping organisms based on the degrees of similarity among them, we can arrive at a system of classification. At the highest level of this classification system, organisms are divided into five kingdoms. Insects are placed in the Animal Kingdom. The Animal Kingdom has major divisions known as **phyla**. Several of the phyla which contain agricultural pests are:

- Arthropoda (insects, spiders, crayfish, millipedes)
- Nematoda (roundworms, trichina)
- Platyhelminthes (flatworms, flukes, tapeworms)
- Mollusca (snails, slugs, clams)

Insects belong to the phylum Arthropoda. Arthropods are a very important group of animals, as they represent more than three-fourths of the animal species known to exist. Characteristics that place an animal in the phylum Arthropoda include body segmentation and **skeletons outside** (exoskeleton) of their bodies.

The phylum Arthropoda is divided into **classes**. Table 1 describes a few of the more important classes and presents some characteristics that are used to distinguish between the various Arthropod classes. Insects belong to the class Insecta. For an Arthropod to be further classified in the class Insecta, it must have **3 body segments and 3 pairs of legs**.

Classes are further divided into orders. The more important orders of the class Insecta are described in Table 2.

Table 1. Classes of the Phylum Arthropoda

Class	Examples	Body Regions	Pairs of Legs	Agricultural Importance
Crustacea	Crayfish Sowbugs	2	5	Sowbugs can be minor pests.
Arachnida	Spiders, Mites, Ticks	2	4	Some mites are major plant pests.
Symphyla	Symphylan	2	12	Symphylans can be serious pests.
Insecta	Bugs, Beetles, Butterflies	3	3	Large number are pests.

Table 2. Some Orders of the Class Insecta

Order	Common Name	Meta-morphosis	Mouth-parts	Wings
Collembola	Springtails	none	chewing	none
Orthoptera	Crickets Grasshoppers	gradual	chewing	2 pair
Isoptera	Termites	gradual	chewing	2 pair
Thysanoptera	Thrips	gradual	rasping-sucking	2 pair
Hemiptera	True Bugs	gradual	piercing-sucking	2 pair
Homoptera	Aphids, Scales	gradual	piercing-sucking	2 pair
Coleoptera	Beetles, Weevils	complete	chewing	2 pair
Lepidoptera	Butterflies, Moths	complete	chewing or siphoning	2 pair
Hymenoptera	Bees, Wasps, Ants	complete	chewing	2 pair
Diptera	Flies	complete	various	1 pair
Siphonaptera	Fleas	complete	sucking	none
Dermaptera	Earwigs	gradual	chewing	2 pair
Thysanura	Silverfish	gradual	chewing	none

Insect orders are further broken down into a classification known as family. The family is a more finite grouping of very closely related insects. Family names end with "idae." Aphidae (aphids), Muscidae (houseflies), and Blattidae (cockroaches) are examples of families of insects.

Families are further divided into genera and species. These are the most finite levels of our classification system. The housefly, *Musca domestica*, serves here as an example of classification:

Kingdom:	**Animalia**
Phylum:	Arthropoda
Class:	Insecta
Order:	Diptera
Family:	Muscidae
Genus:	Musca
Species:	domestica
Common name:	housefly

The most commonly found insects also acquire common names and sometimes one species will have several common names. For example, *Heliothis zea*, when found on corn, is called the corn earworm, but when it is found on tomatoes it is called the tomato fruitworm. Common names are often used to refer to large groups of insects, such as families or orders. The term beetle refers to the entire order Coleoptera, which includes thousands of different species. The term moth refers to thousands of species in the order Lepidoptera.

Insect Form and Structure - Morphology

All adult members of the class Insecta possess the following characteristics: **three body regions; three pairs of legs; one pair of antennae; and zero to two pairs of wings**. Legs and other appendages are often greatly modified to suit the insect's environment; the form of its appendages is often used to classify an insect.

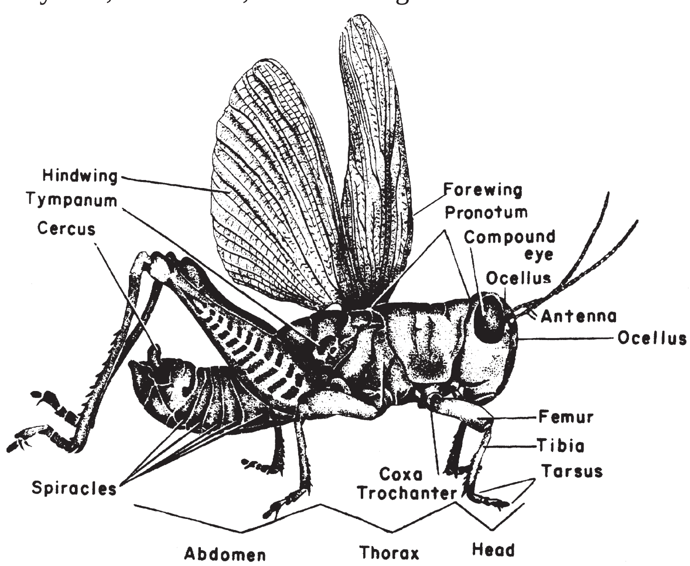
Head, Thorax and Abdomen

The adult insect's body is made up of three regions: **head, thorax, and abdomen**, but the division is not always obvious between thorax and abdomen. An insect's body is not supported by a bony skeleton, but by a tough body wall, or **exoskeleton**. The tough covering of skin is referred to as the **cuticle**.

The cuticle contains a layer of wax which determines its permeability to water and prevents desiccation or drying. The cuticle of each segment is formed into several hardened plates called **sclerites**, which are separated by infolds or sutures to give them flexibility. The cuticle of the immature stage is not usually as hardened as that of the adult.

The thorax is made up of three segments: **prothorax, mesothorax, and metathorax**. Each of these segments bears a pair of legs. The wings are attached to the mesothorax and metathorax, never to the prothorax.

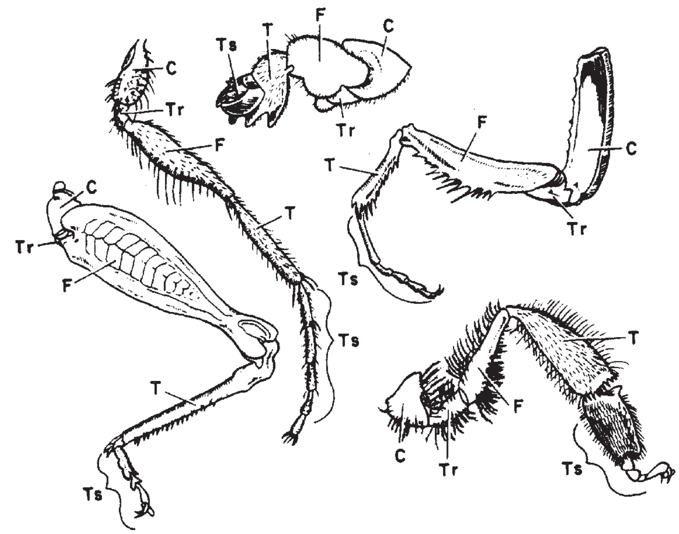
The abdomen may have 11 or 12 segments, but in most cases they are difficult to distinguish. Some insects have a pair of appendages at the tip of the abdomen. They may be short, as in grasshoppers, termites, and cockroaches; extremely long, as in mayflies; or curved, as in earwigs.



Legs

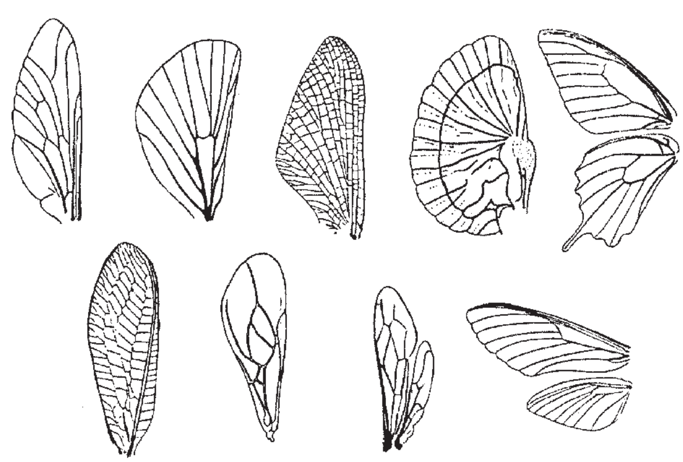
The most important characteristic of an insect is the presence of three pairs of jointed legs. These are almost always present on adult insects and are generally present in the other stages as well. In addition to walking and jumping, insects often use their legs for digging, grasping, feeling, swimming, carrying loads, building nests, and cleaning parts of the body. The legs of insects vary greatly in size and form and are used in classification.

Leg adaptations of some insects (left to right): jumping (grasshopper), running (beetle), digging (mole cricket), grasping (praying mantis), swimming (diving beetle).



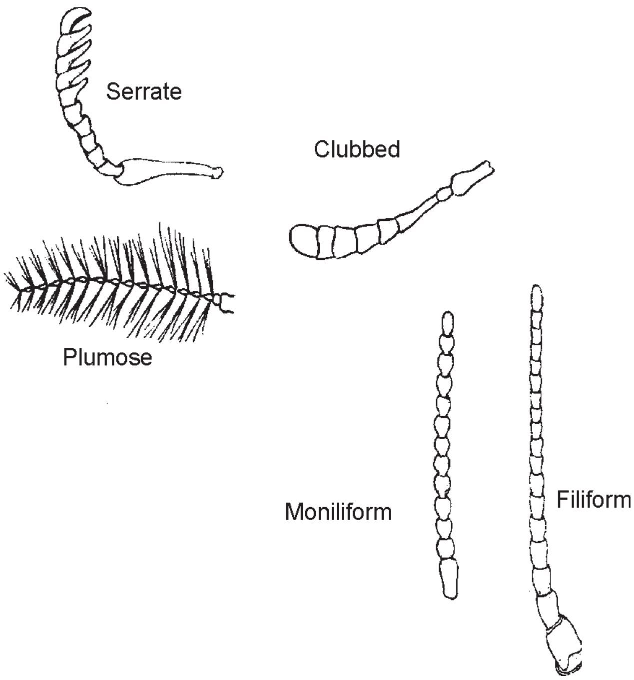
Wings

Venation (the arrangement of veins in wings) is different for each species of insect; thus, it serves as a means of identification. Systems have been devised to designate the venation for descriptive purposes. Wing surfaces are covered with fine hairs or scales, or they may be bare. Note that the names of many insect orders end in "-ptera," which comes from the Greek word meaning "with wings." Thus, each of these names denotes some feature of the wings. Hemiptera means half-winged; Hymenoptera means membrane-winged; Diptera means two-winged; Isoptera means equal wings.



Antennae

The main features of the insect's head are the eyes, antennae, and mouthparts. The antennae are a prominent and distinctive feature of insects. Adult insects have one pair of antennae located on the head usually between or in front of the eyes. Antennae are segmented, vary greatly in form and complexity, and are often referred to as horns or "feelers." They are primarily organs of smell, but serve other functions in some insects.

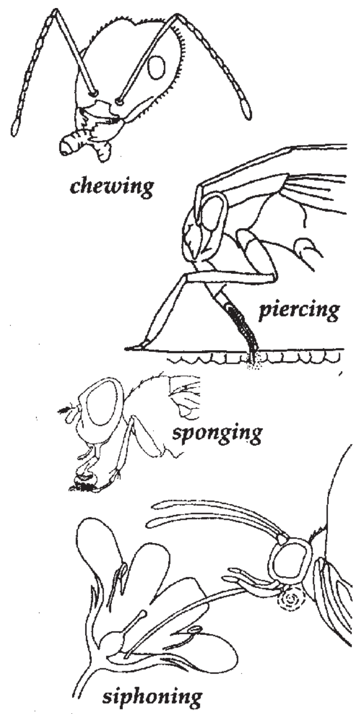


Mouthparts

The most remarkable and complicated structural feature of an insect is the mouth. Great variations exist in form and function of insect mouthparts. And although insect mouthparts differ considerably in appearance, the same basic parts are found in all types. Most insects are divided into two broad categories by the type of mouthparts they possess — those with mouthparts adapted for **chewing** and those with mouthparts adapted for **sucking**.

There are intermediate types of mouthparts: rasping-sucking, as found in thrips; and chewing-lapping, as found in honey bees, wasps, and bumble bees. Sucking types are greatly varied. Piercing-sucking mouthparts are typical of the Hemiptera (bugs), Homoptera (aphids, scales, mealybugs), blood-sucking lice, fleas, mosquitoes, and the so-called biting flies. In the siphoning types, as seen in butterflies and moths, the mandibles are absent and the labial and maxillary palpi are greatly reduced. Houseflies have sponging mouthparts.

Some types of insect mouthparts: A. Chewing-lapping (honey bee); B. Piercing-sucking (plant bug); C. Sponging (housefly); D. Siphoning, coiled (butterfly)



The mouthparts of immature insects tend to be more varied than those of the adults, although nymphs have mouthparts similar to those of the adults. Larval forms generally have the chewing type regardless of the kind possessed by the adults. In some adult insects, the mouthparts are vestigial (no longer used for feeding).

Insect Development — Metamorphosis

In higher animals, the most important development takes place before birth (in the embryonic stage); in insects, it occurs after birth or egg hatch. The immature period of an insect is primarily one of growth, feeding, and storing up food for the pupal and adult stages which follow. Many insects feed very little or not at all during their adult lives.

One of the distinctive features of insects is the phenomenon called metamorphosis. The term is a combination of two Greek words: *meta*, meaning change, and *morphe*, meaning form. It is commonly defined as a marked or abrupt change in form or structure, and refers to all stages of development. Insects undergo one of four types of metamorphosis.

Some insects do not go through a metamorphosis, but rather gradually increase in size while maintaining the same characteristics. Others experience a gradual metamorphosis, going through a nymph stage.

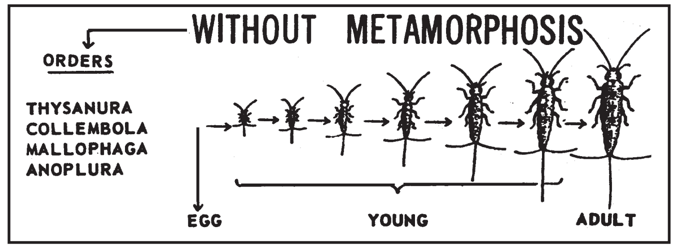
In the case of gradual metamorphosis, the stages are: **egg, nymph, and adult**. In some insects, fertilization of the egg by sperm is not necessary for reproduction. This type of reproduction is known as **parthenogenesis**. Aphids are notable examples of insects that can reproduce by parthenogenesis.

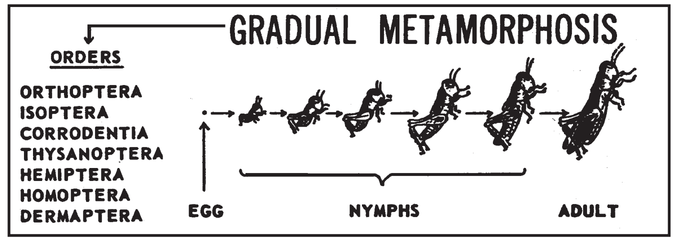
Insects that undergo complete metamorphosis go through the following stages: **egg, larva, pupa, and adult**.

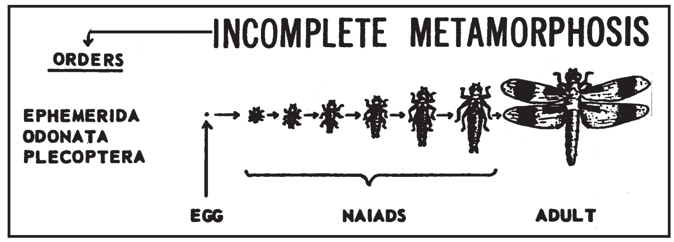
The immature insect sheds its outer skeleton (molts) at various stages of growth, since it outgrows the hard covering or cuticle more than once. Most insects do not grow gradually as many other animals do. They grow by stages. When their skeleton gets too tight, it splits open and the insect crawls out, protected by a new and larger skeleton that has formed underneath the old one. The stage of life between each molt is called an **instar**. Following each molt, the insect increases its feeding. The number of instars, or frequency of molts, varies considerably between species and to some extent with food supply, temperature, and moisture.

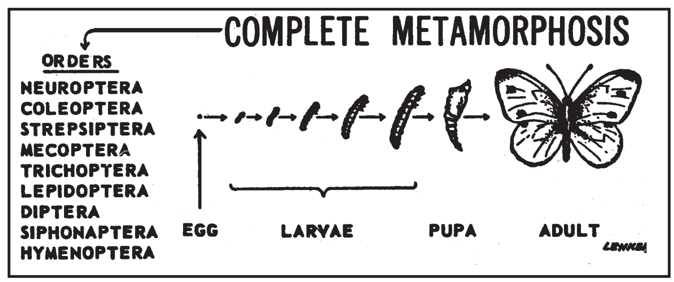
The pupal stage is one of profound change. It is a period of transformation from larva to adult. Many tissues and structures, such as prolegs, are completely broken down and true legs, antennae, wings, and other structures of the adult are formed.

The adult insect does not grow in the usual sense. The adult period is primarily one of reproduction and is sometimes of short duration. Their food is often entirely different from that of the larval stage.









Identifying Insects

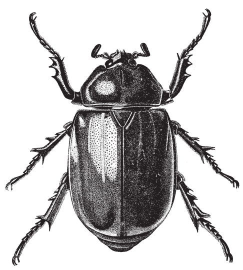
Most home gardeners can classify an insect by the common name of its order, identifying it as a beetle, wasp, or butterfly. The ability to classify an insect to the order level gives the gardener access to much valuable information. This information would include the type of mouthparts the insect has (this tells us how it feeds and gives clues towards methods of control), its life cycle (and proper timing for best control), and type of habitation.

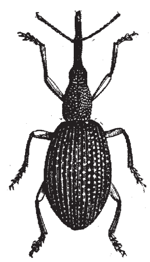
Specific Insect Orders. For your reference, the insect orders have been divided into three sections: those containing insects important to the gardener; those containing insects of lesser importance to the gardener; and common “non-insect” pests in New England. The orders containing insects of importance to home gardeners will be considered in detail.

Insect Orders Important to the Gardener:

Coleoptera - Beetles, Weevils

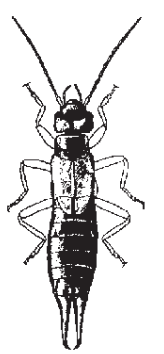
- Adults have hardened, horny, outer skeleton
- Adults have two pairs of wings, the outer pair hardened and the inner pair membranous
- Chewing mouthparts
- Adults usually have noticeable antennae
- Larvae with head capsule, three pairs of legs on the thorax, no legs on the abdomen. Weevil larvae lack legs.
- Complete metamorphosis





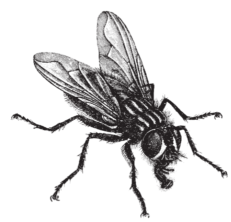
Dermaptera - Earwigs

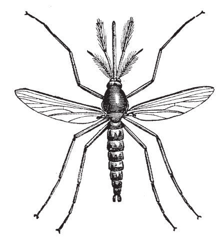
- Adults are moderate-sized insects
- Chewing mouthparts
- Gradual metamorphosis
- Elongate, flattened insects with strong, movable forceps on the abdomen
- Short, hardened outer wings; folded, membranous, “ear-shaped” inner wings
- Adults and nymphs similar in appearance



Diptera - Flies, Mosquitoes, Gnats, Midges

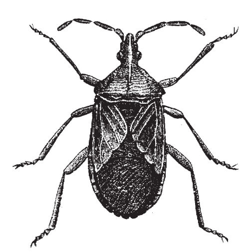
- Adults have only one pair of wings, are rather soft-bodied, and are often hairy
- Adults have sponging (housefly) or piercing (mosquito) mouthparts
- Larvae may have mouth hooks or chewing mouthparts
- Most larvae are legless
- Larvae of advanced forms, housefly and relatives, have no head capsule, possess mouth hooks, and are called maggots; lower forms, such as mosquito larvae and relatives, have a head capsule
- Complete metamorphosis

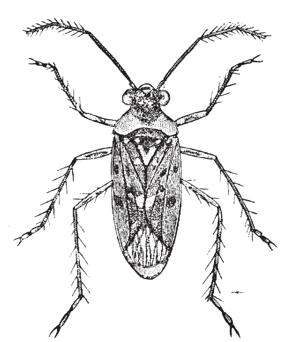




Hemiptera - Stink Bug, Plant Bug, Squash Bug, Boxelder Bug

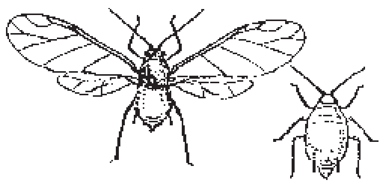
- Have gradual metamorphosis; stages are egg, nymph, adult
- Have two pairs of wings; second pair is membranous, the first pair are “half-wings” -- membranous with thickening on basal half
- Adults and nymphs usually resemble one another
- Have piercing-sucking mouthparts
- Adults and nymphs are both damaging stages





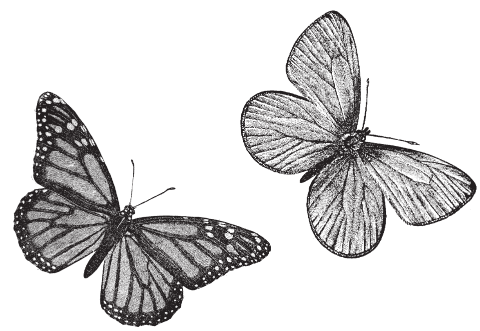
Homoptera - Scale Insects, Mealybugs, Whiteflies, Aphids, Cicadas, Leafhoppers.

- Generally small, soft bodied-insects; cicadas may be large and hard-bodied
- Winged and unwinged forms
- All stages have sucking mouthparts
- Have gradual metamorphosis
- Many are carriers of plant pathogens



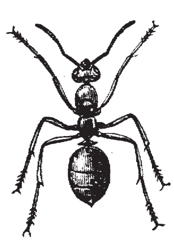
Lepidoptera - Butterflies, Moths

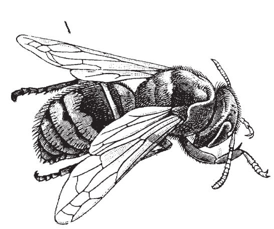
- Adults are soft-bodied, with four well-developed membranous wings covered with small scales
- Larvae have chewing mouthparts
- Adult mouthparts are a coiled, sucking tube; feed on nectar
- Larvae are caterpillars; worm-like, variable in color, voracious feeders
- Larvae generally have legs on the abdomen as well as the thorax
- Complete metamorphosis



Hymenoptera - Bees, Ants, Wasps, Sawflies, Horntails

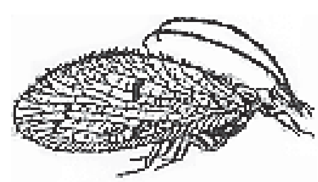
- Adults have two pairs of membranous wings
- Larvae have no legs (wasps, bees, ants) or three pairs of legs on thorax and more than four pair of legs on abdomen (some sawflies)
- Generally have chewing mouthparts
- Rather soft-bodied or slightly hard-bodied adults
- Complete metamorphosis





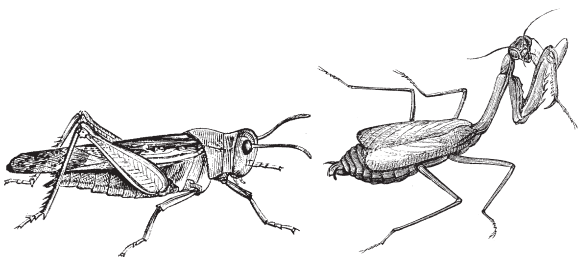
Neuroptera - Lacewings, Antlions, Snakeflies, Mantispids, Dobsonfly, Dustywing, Alderfly

- Insect predators, many are aquatic
- Two pairs of membranous wings
- Chewing mouthparts
- Complete metamorphosis



Orthoptera - Grasshopper, Cricket, Praying Mantid

- Adults are moderate to large, often rather hard-bodied
- Gradual metamorphosis
- Adults usually have two pairs of wings. Fore-wings are elongated, narrow, and hardened; hindwings are membranous with extensive folded area
- Chewing mouthparts; both adults and nymphs are damaging
- Hind legs of many forms are enlarged for jumping
- Immature stages are called nymphs and resemble adults, but are wingless



Thysanoptera - Thrips

- Adults are small, soft-bodied insects
- Mouthparts are rasping-sucking
- Varied metamorphosis (a mixture of complete and gradual)
- Found on flowers or leaves of plants
- Wings in two pairs, slender, feather-like, with fringed hairs

Insect Orders of Lesser Importance to the Gardener:

Order	**Examples**
Anoplura	sucking lice
Collembola	springtails
Diplura	no common examples
Ephemeroptera	Mayflies
Embioptera	webspinners
Isoptera	termites
Mallophaga	chewing lice
Mecoptera	scorpionflies
Odonata	dragonflies and damselflies
Plecoptera	stoneflies
Protura	no common examples
Psocoptera	booklice, barklice
Siphonaptera	fleas
Strepsiptera	no common examples
Thysanura	silverfish and bristletails
Trichoptera	caddisflies
Zoraptera	no common examples

Common "Non-Insect" Pests Found in New England:

Arachnida - Spiders, Spider Mites, Ticks

a. Spider mites: tiny, soft-bodied animals with two body regions, thick waists, four pairs of legs, no antennae.
   Common species:
   - Two-spotted mites and near relatives - two spots on the back, may be clear, green, orange, or reddish; usually hard to see without a magnifying glass.
   - European red mite - carmine red with white spines.
   - Clover mites - brown or gray, flat, very long front legs.

b. Spiders: resemble mites except that most are larger, and the two body regions are more clearly distinct from one another (thin waist). Most spiders are beneficial predators.

c. Ticks: resemble large mites and are important agriculturally and medically in that they are parasites of animals and humans.

Diplopoda - Millipedes

These are elongated invertebrates with two visible body regions: the head and body. They generally have a round cross section, and all but the first four or five body segments possess two pairs of legs. Millipedes are generally inoffensive creatures that feed on fungus and decaying plant material, but at times, they can be fairly destructive to vegetables or plants in greenhouses.

Chilopoda - Centipedes

Centipedes strongly resemble millipedes, except that they have longer antennae, a flat cross-section, and only one pair of legs on each body segment. They are beneficial predators of other arthropods.

Crustacea - Sowbugs, Pillbugs

These are oval with a hard, convex, outer shell made up of a number of plates. Sowbugs are highly dependent on moisture. Generally, they feed on decaying plant material, but they will sometimes attack young plants.

Types of Insect Injury

Injury by Chewing Insects

Insects take their food in a variety of ways. One method is by chewing off the external parts of a plant. Such insects are called chewing insects. It is easy to see examples of this injury. Perhaps the best way to gain an idea of the prevalence of this type of insect damage is to try to find leaves of plants which have no sign of injury from chewing insects. Cabbageworms, armyworms, grasshoppers, Colorado potato beetles, and fall webworms are common examples of insects that cause injury by chewing.

Injury by Piercing-Sucking Insects

A second important way insects feed on growing plants is by piercing the epidermis (skin) and sucking sap from plant cells. In this case, only internal liquid portions of the plant are swallowed, even though the insect feeds externally on the plant. These insects have a slender, sharp, pointed portion of the mouthparts which are thrust into the plant and through which sap is sucked. This results in a very different, but nonetheless severe injury. The hole made in this way is so small that it cannot be seen with the unaided eye, but the withdrawal of the sap results in minute spotting of white, brown, or red on leaves, fruits, or twigs; curling leaves; deformed fruit; or general wilting, browning, and dying of the entire plant. Aphids, scale insects, squash bugs, leafhoppers, and plant bugs are well-known examples of piercing-sucking insects.

Injury by Internal Feeders

Many insects feed within plant tissues during part or all of their destructive stages. They gain entrance to plants either in the egg stage, when their mothers deposit eggs into the plant tissue, or after they hatch from the eggs, by eating their way into the plant. In either case, the hole of entry is almost always minute and often invisible. A large hole in a fruit, seed, nut, twig, or trunk generally indicates where the insect has come out, not where it entered.

The chief groups of internal feeders are indicated by their common group names: borers in wood or pith; worms or weevils in fruits, nuts, or seeds; leaf miners; and gall insects. Each group, except the third, contains some of the foremost insect pests of the world. Nearly all of the internal feeding insects live inside the plant during only part of their lives, and emerge usually as adults. Control measures are most effective when aimed at emerging adults or the immature stages prior to entrance into the plant.

Leaf miners are small enough to find comfortable quarters and an abundance of food between the upper and lower epidermis of a leaf.

Injury by Subterranean Insects

Almost as secure from human attack as the internal feeders are those insects that attack plants below the surface of the soil. These include chewers, sap suckers, root borers, and gall insects. The attacks differ from the above-ground forms only in their position with reference to the soil surface. Some subterranean insects spend their entire life cycle below ground. For example, the woolly apple aphid, as both nymph and adult, sucks sap from roots of apple trees causing the development of tumors and subsequent decay of the tree's roots. In other subterranean insects, there is at least one life stage that has not taken up subterranean habit. Examples include wireworms, root maggots, pillbugs, strawberry root weevils, and grape and corn rootworms. The larvae are root feeders, while the adults live above ground.

Injury by Laying Eggs

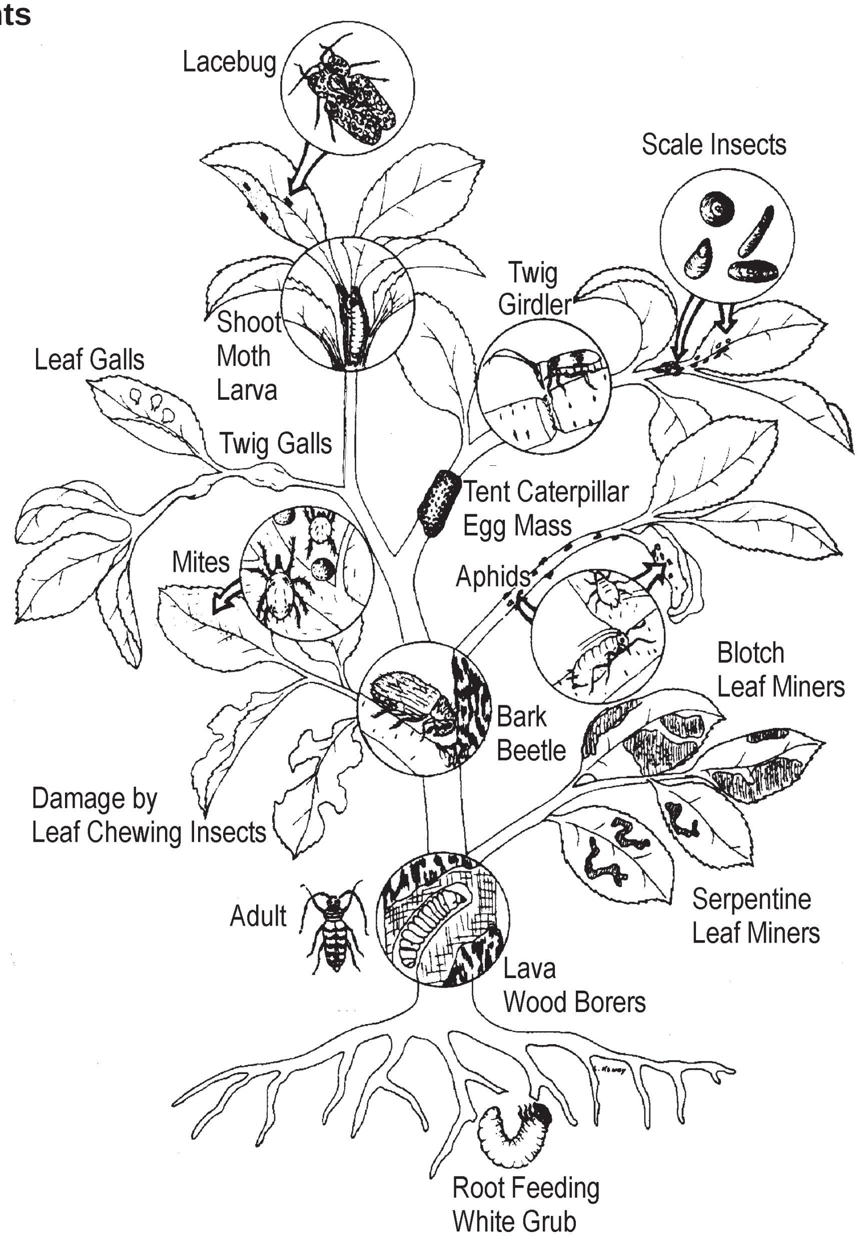
Probably 95% of insect injury to plants is caused by feeding in the various ways just described. In addition, insects may damage plants by laying eggs in critical plant tissues. The periodical cicada deposits eggs in one-year-old growth of fruit and forest trees, splitting the wood so severely that the entire twig often dies. As soon as the young hatch, they desert the twigs and injure the plant no further.

Gall insects sting plants and cause them to produce a structure of deformed tissue. The insect then finds shelter and abundant food inside this plant growth. It is not known exactly what makes the plants form these elaborate structures when attacked by the insects. However, it is clear that the growth of the gall is initiated by the oviposition of the adult (laying eggs inside plant tissue), and its continued development results from secretions of the developing larva. The same species of insect on different plants causes galls that are similar, while several species of insects attacking the same plant cause galls that are greatly different in appearance. Although the gall is entirely plant tissue, the insect controls and directs the form and shape it takes as it grows.

Use of Plants for Nest Materials

Besides laying eggs in plants, insects sometimes remove parts of plants for the construction of nests or for provisioning nests. Leaf-cutter bees nip out rather neat, circular pieces of rose and other foliage, which are carried away and fashioned together to form thimble-shaped cells.

Examples of insect injury to plants.



Ways in Which Insects Injure Plants

- **Chewing -** devouring or notching leaves; eating wood, bark, roots, stems, fruit, seeds; mining in leaves.

  Symptoms: ragged leaves, holes in wood and bark or fruit and seed, serpentine mines or blotches, wilted or dead plants, or presence of "worms."

- **Sucking -** removing sap and cell contents and injecting toxins into plant.

  Symptom: usually off-color, mis-shapen foliage and fruit.

- **Vectors of diseases -** carrying pathogens from plant to plant, e.g., elm bark beetle - Dutch elm disease, various aphids - virus diseases.

  Symptoms: wilt; dwarf,off-color foliage.

- **Excretions -** honeydew deposits lead to the growth of sooty mold, and the leaves cannot perform their manufacturing functions. A weak-ened plant results.

  Symptoms: sooty black leaves, twigs, branches, and fruit.

- **Gall formation -** galls may form on leaves, twigs, buds, and roots. They disfigure plants, and twig galls often cause serious injury.

- **Oviposition scars -** scars formed on stems, twigs, bark, or fruit.

  Symptoms: scarring, splitting, breaking of stems and twigs, misshapen and sometimes infested fruit.

- **Injection of toxic substances -**

  Symptoms: scorch, hopper burn.

Insects as Disseminators of Plant Diseases

In 1892, it was discovered that a plant disease (fire blight of fruit trees) was spread by an insect (the honeybee). At present, there is evidence that more than 200 plant diseases are disseminated by insects. The majority of them, about 150, belong to the group known as viruses, 25 or more are due to parasitic fungi, 15 or more are bacterial diseases, and a few are caused by protozoa or mycoplasms.

Insects may spread plant diseases in the following ways:

- by feeding, laying eggs, or boring into plants, they create an entrance point for a disease that is not actually transported by them;
- they carry and disseminate the causative agents of the disease on or in their bodies from one plant to a susceptible surface of another plant;
- they carry pathogens on the outside or inside of their bodies and inject plants hypodermically as they feed;
- the insect may serve as an essential host for some part of the pathogen's life cycle, and the disease could not complete its life cycle without the insect host.

Examples of insect-vectored (insect-carried) plant diseases, their causative agents, and vectors include:

Disease	Vector
Dutch Elm Disease (fungus)	Small Beetle
Fireblight (bacterial)	Pollinating Insects
Tomato spotted wilt (virus)	Thrips
Cucumber Mosaic (virus)	Aphids
X-Disease of Peach (mycoplasm)	Leafhoppers

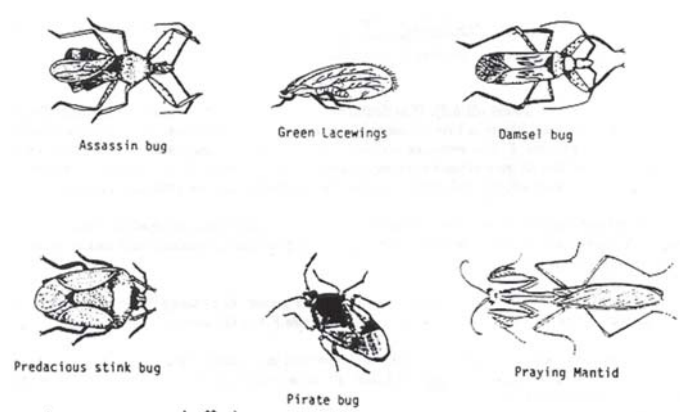
Benefits and Value of Insects

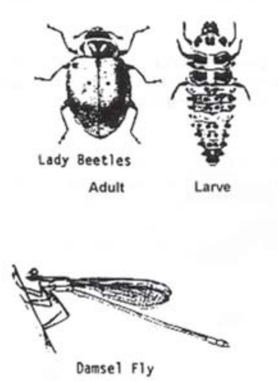
Insects must be studied carefully to distinguish the beneficial from the harmful. People have often gone to great trouble and expense to destroy insects, only to learn later that the insect destroyed was not only harmless, but was actually saving their crops by eating destructive insects.

Insects are Beneficial to the Gardener in Several Ways:

- Insects aid in the production of fruits, seeds, vegetables, and flowers by pollinating the blossoms. Most common fruits are pollinated by insects. Melons, squash, and many other vegetables require insects to carry their pollen before fruit set. Many ornamental plants, both in the greenhouse and outdoors, are pollinated by insects (chrysanthemums, iris, orchids, and yucca).
- Insects destroy various weeds in the same ways that they injure crop plants.
- Insects improve the physical condition of the soil and promote its fertility by burrowing throughout the surface layer. Also, the dead bodies and droppings of insects serve as fertilizer.
- Insects perform a valuable service as scavengers by devouring the bodies of dead animals and plants and by burying carcasses and dung.

Beneficial Insects





Common species that cause no damage in the garden and help control other injurious insects.

Many of the benefits from insects enumerated above, although genuine, are insignificant compared with the good that insects do fighting among themselves. There is no doubt that the greatest single factor in keeping plant-feeding insects from overwhelming the rest of the world is that they are fed upon by other insects. Insects that eat other insects are considered in two groups known as predators and parasites.

Predators are insects (or other animals) that catch and devour other creatures (called the prey), usually killing and consuming them in a single meal. The prey is generally smaller and weaker than the predator.

Parasites are forms of living organisms that live on or in the bodies of living organisms (called the hosts) from which they get their food, during at least one stage of their existence. The hosts are usually larger and stronger than the parasites, and are not killed promptly. Some continue to live in close association with the parasite, rather than be killed.

Soil Preparation

For most fruits and vegetable crops, maintain a slightly acidic soil (around pH 6.5). If in doubt, have a soil analysis done through your local Extension office. The appropriate pH allows vegetable plants to have access to all the necessary soil nutrients and provides a suitable environment for earthworms and microorganisms. Follow recommended fertilizer practices. Supplement chemical fertilizers with organic material or compost to help assure that all trace elements and major nutrients are available. Feed the soil, not just the plants; providing an appropriate environment for all soil life will result in healthy plants which can resist pests and diseases.

When using manure and compost, be sure they are worked into the soil. Otherwise, millipedes, white grubs, and other pests may be encouraged. If these insects become a problem, you may be using too much; consider other means of adding organic matter, such as cover-cropping or mulching.

When diseased plant material is added to compost to be used on the garden, delay using the compost until all material has decayed beyond recognition. Compost piles must be hot (160 degrees F.) to kill disease organisms, insect eggs, and weed seeds.

Till the soil in the fall to expose those stages of pests which live near the surface of the soil to natural enemies and weather, and to destroy insects in crop residues. If you do not till in the fall, do so early enough in the spring to give remaining vegetation time to degrade before planting time.

Plant Selection

Plant crops that are suited to the soil and climate of your area. If you do plant vegetables or fruits that are not normally grown in your area, do your best to provide necessary conditions. For example, watermelons prefer a light, warm, well-drained soil; don’t try to plant in heavy clay without first adding copious amounts of compost or other soil-lightening material, and allow the soil to warm up before seeding or setting plants out.

Use disease-free, insect-free, certified seed if available. Select disease/insect-resistant or tolerant species and varieties. Resistance in plants is likely to be interpreted as meaning immune to damage. In reality, it distinguishes plant varieties that exhibit less insect or disease damage when compared with other varieties under similar circumstances. Some varieties may not taste as good to the pest. Some may possess certain physical or chemical properties which repel or discourage insect feeding or egg laying. Some may be able to support insect populations with no appreciable damage or alteration in quality or yield.

Select plants that are sturdy and have well-developed root systems. Diseases and insects in young seedlings may start in greenhouses or plant beds and cause heavy losses in the garden. Buy plants from a reputable grower who can assure you that they are disease/insect-free, or grow your own from seed.

Avoid accepting plants from friends if there is any chance of also getting free insects or diseases!

Cultural Practices

The most effective and most important of all practices is to observe what is going on in the garden. Many serious disease or insect problems can be halted or slowed early by the gardener who knows what to look for and regularly visits the garden for the purpose of trouble-shooting.

Rotation. Do not grow the same kind of produce in the same place each year. Use related crops in one site only once every three or four years. Some related crops are as follows: (a) chives, garlic, leeks, onions, shallots; (b) beets, Swiss chard, spinach; (c) cabbage, cauliflower, kale, Brussels sprouts, broccoli, kohlrabi, turnips, rutabagas, Chinese cabbage; (d) peas, broad beans, snap beans; (e) carrots, parsley, celery, celeriac, parsnips; (f) potatoes, eggplant, tomatoes, peppers; (g) pumpkins, squash, watermelons, cucumbers, muskmelons; (h) endive, salsify, lettuce.

Interplantings. Avoid placing all plants of one kind together; alternate groups of different plants within rows or patches. If an insect lays eggs or otherwise attacks a specific species, the presence of other species in the area can interrupt progress of the attack by diluting the odor of the preferred plants. This can also slow the spread of diseases and pests, giving the gardener more time to deal with them.

Thinning. Thin young plants to a proper stand. Overcrowding causes weak growth and subsequent insect and disease problems.

Watering. Water in the morning, so plants have time to dry before the cool evening when fungus infection is most likely. Drip irrigation prevents foliage from getting wet at all when watering. For plants susceptible to fungus infections, such as tomatoes, leave extra space between plants to allow good air flow and orient rows so that prevailing winds will help foliage dry quickly after a rain or watering. While this may reduce the number of plants per square foot, yields may still be higher due to reduced disease problems. To prevent spreading diseases, stay out of the garden when the plants are wet with rain or dew.

Time Planting. Time plantings in such a way that the majority of the crop will avoid the peak of insect infestations. For example, carrot rust fly problems can be avoided by delaying planting until June 1 and harvesting by late August. Keep a record of the dates insect problems occur. Also, by planting warm-weather crops after the soil has warmed, problems with seed and root rots will be avoided, and growth will be more vigorous.

Sanitation. Do not use tobacco products such as cigarettes or cigars when working in the garden. Tomato, pepper, and eggplant are susceptible to a mosaic virus disease which is common in tobacco and may be spread by your hands. Remove infected leaves from diseased plants as soon as you observe them. Dispose of severely diseased plants before they contaminate others. Clean up crop refuse as soon as harvesting is finished. Old sacks, baskets, decaying vegetables, and other rubbish which may harbor insects and diseases should be kept out of the garden.

Staking plants. Staking or planting them in wire cages prevents the fruit from touching the soil. This also helps prevent fruit rots. Caging helps reduce sun scald often seen in staked tomatoes, since caged plants do not require as much pruning, leaving a heavier foliage cover. Boards or a light, open mulch such as straw, placed beneath melons, will prevent rotting.

Avoid injury to plants. Cuts, bruises, cracks, and insect damage are often sites for infection by disease-causing organisms. In cases where fruit is difficult to remove, such as with cucumbers and watermelons, cut them instead of pulling them off the plant. If you cultivate your garden, avoid cutting into the plant roots.

Mulching. Use a mulch to reduce soil splash, which brings soil-borne pathogens into contact with lower leaves.

Weed control. Control weeds and grass. They often harbor pests and compete for nutrients and water. They provide an alternate source of food and can be responsible for pest build-up. They provide cover for cutworms and slugs.

Mechanical Controls

Handpicking. Inspect plants for egg clusters, bean beetles, caterpillars, and other insects as often as possible. Handpick as many as possible. If you don’t like squashing the pests, knock the insects and egg clusters into a coffee can or quart jar with a small amount of water, and then pour boiling water over them. Kerosene is often recommended, but poses a disposal problem once you have finished; besides, water is cheaper.

Traps. Use appropriate insect traps to reduce certain insect populations. A simple, effective Japanese beetle trap can be made from two milk jugs or a single milk jug and a plastic bag. The bait used to attract the beetles is available at most farm and garden supply centers. Place traps away from desirable plants. Most scent-based insect traps are used for monitoring populations, not for control of pests.

Light traps, particularly blacklight or blue light traps (special bulbs that emit a higher proportion of ultraviolet light that is highly attractive to nocturnal insects), are good insect-monitoring tools, but provide little or no protection for the garden. While they usually capture a tremendous number of insects, a close examination of light-trap collections shows that they attract both beneficial and harmful insects that would ordinarily not be found in that area. Those insects attracted but not captured remain in the area, and the destructive ones may cause damage later. Also, some wingless species as well as those species only active during the day (diurnal, as opposed to nocturnal) are not caught in these traps. Consequently, the use of a light trap in protecting the home garden is generally of no benefit and, in some instances, detrimental.

Upturned flower pots, boards, newspaper, etc. will trap earwigs, sowbugs, and slugs; collect them every morning, and feed them to pet frogs, toads, turtles, and fish, or destroy them with boiling water. Indoors, white flies can be caught with yellow sticky traps, made with boards painted yellow and lightly coated with oil or grease. There are also commercial sticky traps available through some catalogs.

Barriers. Aluminum foil and other reflective mulch has been shown to repel aphids. However, the environmental impact and energy consumption involved in making aluminum foil deserves consideration. Spread crushed eggshells or hydrated lime around plants to discourage slugs. While heavy mulch is good for weed control, it gives slugs a place to hide.

Exclusion. Various materials can be used to physically block or repel insects and keep them from damaging plants. Place wood ash, cardboard tubes, or orange juice cans around seedlings to keep cutworms away from plant stems. Use paper bags over ears of corn to keep birds and insects out; do not cover until pollination is complete. Net-covered cages over young seedlings will help prevent insect, bird, and rabbit damage. Cheesecloth screens for cold frames and hot beds will prevent insect egg-laying; sticky barriers on the trunks of trees and woody shrubs will prevent damage by crawling insects. Floating row covers of spun bonded polyethylene are a little more expensive, but their effectiveness in excluding insects is proven by the number of commercial growers that use them, particularly on cole crops and strawberries. Remember that such materials can exclude pollinating insects.

Biological Controls

Predators, Parasites, and Pathogens. The garden and its surrounding environment are alive with many beneficial organisms that are present naturally; however, they may not be numerous enough to control a pest before damage is done. Actually, parasites and predators (usually other types of insects) are most effective when pest populations have stabilized or are relatively low. Their influence on increasing pest populations is usually minimal since any increase in parasite and predator numbers depends on an even greater increase in pest numbers. Disease pathogens, however, seem to be most effective when pest populations are large.

Take advantage of the biological control already taking place in your garden by encouraging natural predators, such as preying mantids, ladybugs, lacewings, ground beetles, and others. Purchased natural predators are often effective for only a short period, however, since they tend not to remain in the place where they are put. Research the likes and dislikes of these helpers as to foods, habitat, etc. Provide these conditions where possible; some beneficial insect suppliers now offer a formulation for feeding/attracting the beneficials to keep them in the garden longer.

Learn to recognize the eggs and larvae of the beneficial insects, and avoid harming them. You can often find preying mantid egg cases in weedy lots; just bring the twig with the cluster into the garden and set it in a place where it will not be disturbed. Spiders, toads, and dragonflies are also beneficial, and should not be a source of fright to the gardener; in most cases, they are harmless to people.

Learn to recognize parasites and their egg cases; for example, the tomato hornworm is often seen with a number of white cocoons, a little larger than a grain of rice, on its back. These were produced by parasitic wasps. The hornworm will die and more wasps will emerge. You may wish to leave such parasitized caterpillars alone, rather than killing them.

Pesticides

Nonsynthetic Pesticides

Botanicals. Natural pesticidal products are available as an alternative to synthetic chemical formulations. Some of the botanical pesticides are toxic to fish and other cold-blooded creatures and should be treated with care. Safety clothing should be worn when spraying these, because some may be more toxic than synthetics. Botanical insecticides break down readily in soil and are not stored in plant or animal tissue. Often their effects are not as long-lasting as those of synthetic pesticides.

Insecticide	Use Against
Pyrethrum	Aphids, leafhoppers, spider mites, cabbageworms.
Rotenone	Spittlebugs, aphids, potato beetles, chinch bugs, spider mites, carpenter ants.
Ryania	Codling moths, Japanese beetles, squash bugs, potato aphids, onion thrips, corn earworms.
Sabadilla	Grasshoppers, codling moths, moths, armyworms, aphids, cabbage loopers, blister beetles.

Some of these products may be very difficult to find, expensive, and may not be registered for use in New England.

In addition to botanical insecticides, some biological products can help in the battle against insects. *Bacillus thuringiensis* is an effective product commonly used against caterpillars; B.T., as it is known, is a bacterium that gives the larvae a disease, and is most effective on young larvae. Presently, there is research underway to develop strains that work against other types of insect larvae. Several formulations are available to the gardener under different trade names to provide effective control of several caterpillars without harming humans and domestic animals. More than 400 insect species are known to be affected by this important insect pathogen. *Bacillus thuringiensis* is quite slow in its action. For example, caterpillars that consume some of the spores will stop eating within 2 hours, but may continue to live and move around until they die, which may be as long as 72 hours. When this occurs, the untrained gardener may assume the material was ineffective because of the continued pest activity and impatiently apply a chemical pesticide. *B.t. kurstaki* is effective on caterpillars. *B.t. israelensis* is used for larvae of mosquitoes, black flies and fungus gnats. *B.t. san diego* is used for Colorado potato beetle larvae. *B.t. bui bui* may soon be available for Japanese beetle control.

Nosema locustae is a disease organism which shows some promise for controlling grasshoppers. There are claims that this parasite may be effective for up to five years after initial application. In some areas, this parasite is available commercially under different trade names. It is still too early to make extensive claims about its effectiveness in home gardens.

Enlist the aid of birds. In rural areas, chickens, guineas, and other domestic fowl can be released in unused areas of the garden to eat grubs and insects. Wild birds will also help, but they aren't as controllable. Provide appropriate conditions (i.e., shelter, nesting material, water) to encourage insect-eating birds.

Soaps. Commercial insecticidal soap (a special formulation of fatty acids) has been proven effective against aphids, leafhoppers, mealybugs, mites, pear psylla, thrips, and whiteflies. Homemade soap sprays also work to some extent: use three tablespoons of soap flakes (not detergent) per gallon of water and spray on plants until dripping. Repellent sprays, such as garlic sprays and bug sprays (made from a puree of bugs), have been found useful by some gardeners, but their effectiveness is questionable. Some researchers believe that bug sprays may work if a disease is present in the insect, which is spread through the spray to other insects. Be careful! Homemade soap sprays can injure some plants.

Synthetic Pesticides

Synthetic pesticides, by their simplest definition, are those pesticides made by humans in chemical laboratories or factories. Examples of these include malathion, diazinon, and sevin. The real surge of development of synthetic pesticides began in World War II with the discovery of DDT. For more information, refer to the Pesticides chapter.

Summary

Insects constitute one class of the phylum Arthropoda, and yet they are one of the largest groups in the animal kingdom. The insect world is made up of individuals that vary greatly in size, color, and shape. Although most insects are harmless or even beneficial to humans, the few that cause damage have tremendous impact. Harmful species can usually be recognized with some basic knowledge of their host, habits, life cycle, and the type of damage they inflict. Feeding damage varies due to the type of mouthparts an insect possesses. Harmful insects can be controlled in many ways without resorting to the use of pesticides. Good cultural practices and proper selection of plant varieties, coupled with mechanical and biological controls, will control insect populations. Use insecticides judiciously, wisely, and safely. Read and follow label directions carefully when applying any pesticide.