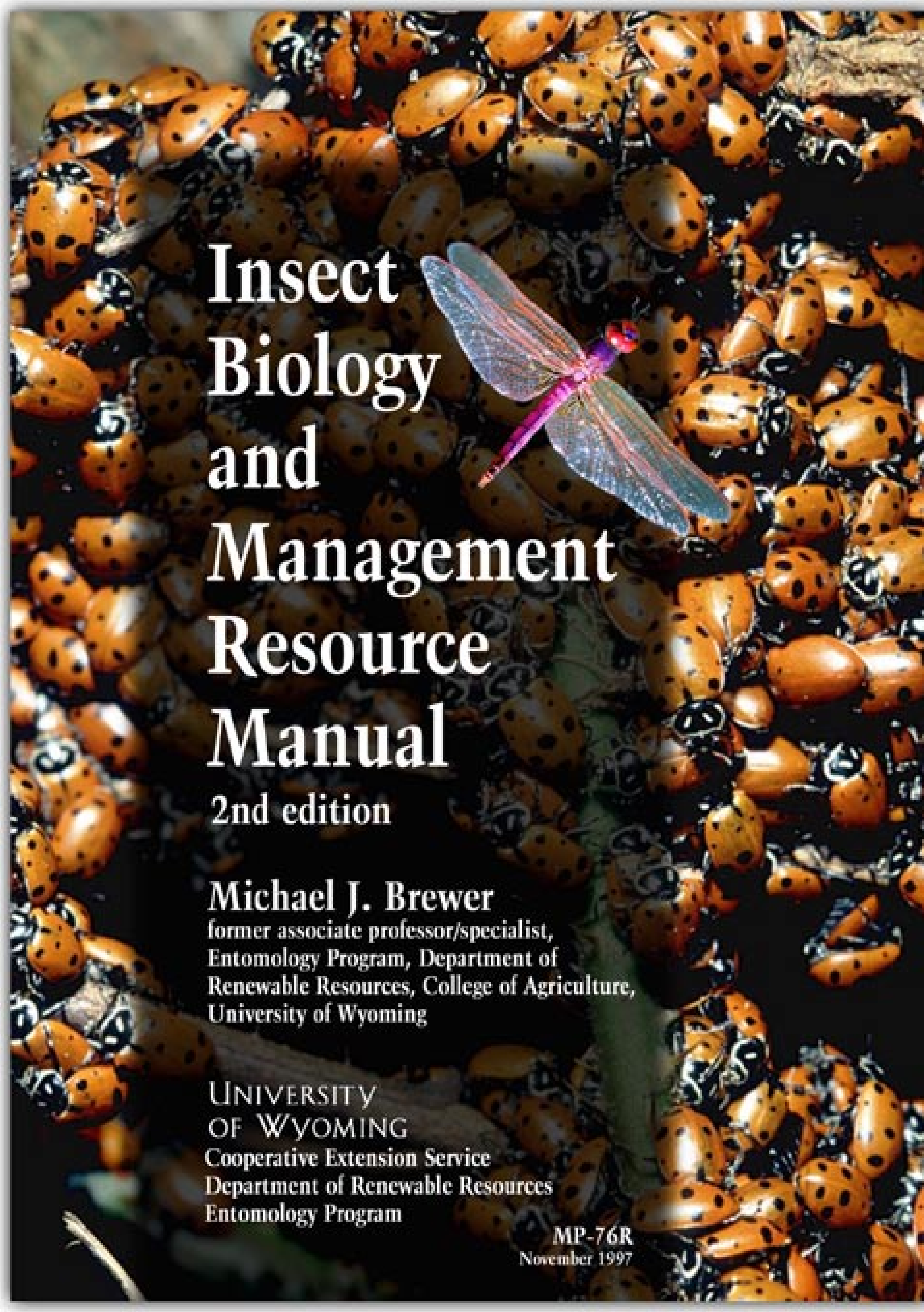

Insect Biology and Management Resource Manual

2nd edition

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UNIVERSITY
OF WYOMING
Cooperative Extension Service
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MP-76R
November 1997

Issued in furtherance of cooperative extension work, acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture. Glen Whipple, director, Cooperative Extension Service, University of Wyoming, Laramie, Wyoming 82071.

Table of Contents

Foreword

The world of insect biology and management is fascinating. There are more species of insects than all other animals and plants combined. As measured by distribution and abundance, insects are generally considered the most successful group of living organisms on Earth. Although it is estimated that less than 0.4 percent of the known insects are in any way detrimental to humans, it is this very small number that can disrupt agriculture and other aspects of human health and activities. Other insect species are of interest because of their beauty and importance to the environment, such as insects that act as decomposers, pollinators, and insects that are food for other animals.

This manual provides information on the general biology of insects, principles of insect management, and resources available for further study of the insect world. Line drawings are provided to assist in identification of insect orders and classes of insect relatives. This basic level of classification, combined with host plant or animal, can often lead to the correct identification of an insect. A general guide to insect collection and preservation is provided, as well as a glossary of entomological terms. Educators and students will be able to use this manual as a good starting point in their study of insects. References are provided for advance study. Insect management practitioners can use this manual to obtain background information, such as basic life cycle information of the insect orders and principles of insect management. Complementary to this manual, texts, and bulletins detaining specific types of insects can be consulted (texts are listed in the reference section; a listing of University of Wyoming bulletins is available through your local Cooperative Extension Service office).

Introduction

As measured by distribution and abundance, insects are generally considered to be the most successful group of living organisms on Earth. Success may be attributed to their mobility, high reproductive rates, short life cycles, their ability to change body form during their lifetime (metamorphosis), and their adaptive nature. Many insects have the capacity to fly during part of their life cycle, making it possible to rapidly disperse to new habitats. Because of their small size, even insects that do not fly may effectively move to new habitats by being wind blown, attached to animals, or transported by human commerce. They often produce from hundreds to thousands of offspring per female. Some species have the ability to reproduce without sex (called asexual or parthenogenic reproduction); in some species males are not known to exist. The life span of insects varies from days to years. Often the hatching of young is timed according to the availability of food. The ability to change body form during the life span of many groups of insects has allowed for specialization of young and adults. Often, the young are highly adapted to exploiting limited food sources, and the adults are adapted to disperse to new resources that can be exploited by the next generation. A resting stage (pupa) occurs in many insects; this is a period of low physical activity, which allows the insect to undergo extreme physiological and morphological changes that result in emergence of the adult stage. The pupal stage may also allow the insect to pass through adverse conditions in protected areas such as leaf litter and soil.

As a group, feeding habits of insects are highly variable. Their adaptive nature may best be realized by noting that insects are found in all of Earth's ecosystems except the oceans (although some species are found in the fur of ocean-faring mammals). Insects include those that feed on living and decaying plant and animal matter. Leaf, stem, and root tissue may be eaten by the many kinds of plant feeders. Plant-feeding insects may be considered beneficial if they specialize in eating weedy species or if "feeding" actually benefits the plant (e. g., pollen "feeding" by insects which results in pollination, is a major reason why flowering plants are so successful). Processed plant materials, such as stored products and wooden structures, are a food source for many species. Other species are beneficial because they feed on dead plant material (decomposers) that is important in nutrient recycling. The feeding habits of animal feeders may specialize on the internal organs of living animals (endoparasite) or the skin, hair, and feathers (ectoparasite). Humans are also attacked by selected species. Animal feeders include beneficial insects that are predators or parasites of insects and other arthropods. Other beneficial animal-feeding insects feed on dead animal tissue (decomposers) and animal waste (dung feeders).

There are more species of insects than all other animals and plants combined; approximately 750,000 species have been described, over 87,000 of which are in North America. Current estimates put the total number of insect species at 2 million, although some authorities believe that up to 30 million species may exist. Among these, there are about 600 species in North America that are of primary economic importance to plant and animal production systems, stored products and structures, and human health. These species include selected beneficial organisms such as honey bees and predators and parasites of damaging insects. The rest of the species are generally harmless and may be considered beneficial because they are an important component of natural and agricultural ecosystems, functioning as decomposers of plant and animal matter, generalist pollinators, predators, and parasites. It is estimated that less than 0.4 percent of the known insects are in any way detrimental to humans, but it is this very small number that can disrupt agriculture and other human activities and has led to efforts to document insect-plant and insect-animal interaction and to search for insect management strategies. Sustainable pest management strategies (host plant resistance, biological control, cultural control, and mechanical/physical control) are of particular relevance today because of the interest in avoiding the risk of environmental contamination by the unnecessary use of insecticides. Use of multiple and compatible insect management strategies, with particular emphasis on sustainable strategies, is desirable.

Insect Life Cycles

All insects begin their development as eggs produced by the adult female. A few species, such as aphids, give birth to live young, but the young are actually hatched from eggs carried inside the mother. After the eggs hatch, insects grow in a series of distinct stages. Periodically, the immature insect sheds its exoskeleton (molt) and expands the soft new exoskeleton by inhaling air. In a few hours the new exoskeleton hardens and there is no further change in body size until the following molt. Through this process the insect is able to expand in size despite being encapsulated in an external skeleton. In some cases, such as many soft-bodied larvae, the exoskeleton is soft, allowing limited expansion between molts, but the insect still must molt to complete development. In many insect species, there are also specialized molting events in which the insect not only sheds its old exoskeleton, but forms a new exoskeleton with new features. All growth ceases following the final molt to the adult stage of the insect. An adult insect will not increase in size as it ages.

The specialized molting process in which the insect undergoes a major change in form is called metamorphosis. The kinds of change vary among different insect groups.

Two general types of development predominate: incomplete metamorphosis (hemimetabolous insects), and complete metamorphosis (holometabolous insects). Several of the more primitive orders of insects undergo no distinct metamorphosis (ametabolous insects) directly developing from young to adult changing in size but not form. Examples are the Collembola and Thysanura, which develop directly into adults without major changes in structure. Arachnids undergo development similar to that of ametabolous insects. Arachnids may add body segments or additional appendages, and some will molt after they have reached adulthood.

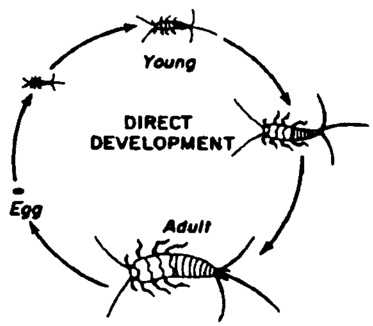

Fig. 1. Gradual growth without metamorphosis displayed in silverfish growth.

Insects undergoing incomplete metamorphosis have three basic life stages: egg, nymph, and adult. The nymphs typically pass through three to five instars, molting between each to attain the larger size of the next instar. Nymphs and adults often live in the same habitat. The principal changes occurring during metamorphosis are changes in body proportions, sexual maturity, and the development of wings. Examples of insects that undergo incomplete metamorphosis include grasshoppers and crickets (Orthoptera), earwigs (Dermaptera), cockroaches (Blatteria), "true" bugs (Hemiptera), and aphids and their relatives (Homoptera).

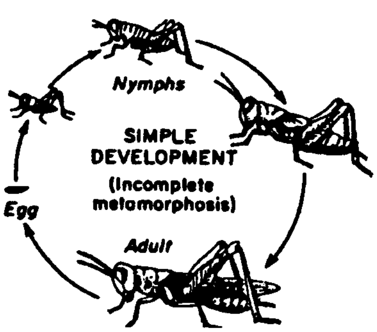

Fig. 2. Incomplete metamorphosis displayed in grasshopper growth.

Insects that undergo complete metamorphosis pass through four basic life stages: egg, larva, pupa, and adult. Caterpillars, maggots, and grubs are common examples of larvae. During the larval stage there may be three to seven instars, all of which are usually active and often ferocious feeders. The pupal state (e.g., cocoon, puparia, and chrysalis) is a non-feeding stage that follows the specialized molt from the larval stage. During the pupal stage, many physiological and morphological changes occur. Internally, the insect is going through the process of changing into the adult form. During the final molt, the adult emerges from the exoskeleton of the pupal case. Adults are usually winged and may differ from the larvae in a number of ways including type of legs, mouthparts, and feeding habits. Adult insects undergoing complete metamorphosis are very different in form from the larvae. They may be found in habitats similar to the larvae, such as some beetles, or in very different habitats than the larvae, such as bees and butterflies. Insects with complete metamorphosis include butterflies and moths (Lepidoptera), beetles (Coleoptera), "true" flies (Diptera), and lacewings (Neuroptera). The larval stage tends to specialize in feeding. The adult stage specializes in dispersal and reproduction, but may feed and cause economic damage as well.

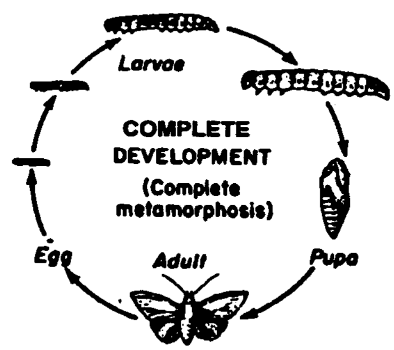

Fig. 3. Complete metamorphosis displayed in moth growth.

Insect-Plant and Insect-Animal Interactions

The impact of insects feeding varies from being extremely detrimental to valuable. Plant response can vary from loss of plant tissue or fluids, decay (such as yellowing of leaves), plant structure deformation (such as galling), or no adverse plant response. Insect feeding may also result in increasing the plant's susceptibility to disease organisms, or in transmitting a disease into the plant. In many cases, insect feeding results in little adverse plant response either because of low plant susceptibility to insect feeding or a low number of insects causing damage. In some cases insect feeding is actually beneficial to the plant. In the process of gathering nectar and pollen, honey bees and other wild pollinators fertilize flowering plants. Insects that feed on dead and dying plant tissue are an important part of the carbon cycle, replenishing the soil profile with nutrients.

When insects feed on live animals, the response can vary from loss of animal tissue, blood, skin, hair, or feathers. Allergic and toxic responses can result in further health problems. Insect feeding may increase the animal's susceptibility to disease organisms or transmit an animal disease. As with plants, insect feeding may result in little adverse animal response either because of low animal susceptibility or a low number of insects causing damage. Insects that specialize in feeding on dead animal matter and dung are important recyclers in the environment.

Insect Management

Insect pest management is defined as the use of management strategies to reduce (or maintain) insect populations at levels that do not cause economic injury. The goal of insect pest management is to use control strategies that result in the suppression of the target organism(s) without disruption to non-target organism(s) or other components of the environment. Control strategies are commonly categorized into biological control (biocontrol), chemical control, cultural control, regulatory control, and mechanical/physical control. Use of these strategies may require development of insect sampling protocols.

Biological Control

Biological control is the action of natural enemies (e.g., some phytophagous species that are weed feeders, parasitoids, and predators) that result in the death or suppression of pests. Some authorities recognize pathogens and naturally occurring plant and animal products that control insects as biocontrol agents (e.g., pheromones, plant and animal odors [baits], and pathogens). A parasitoid is a specialized organism that is usually about the size of its host as an adult; the immature stage kills its host internally or externally and requires only one host for development into the free-living stage (adult). A predator is an organism that is usually larger than its prey, kills its prey by feeding externally, requires more than one prey to complete its development, and is a free-living organism throughout its life. A pathogen is a microorganism, including viruses that cause disease of the infected organism.

Biological control can be naturally occurring or manipulated by either classical or augmentative approaches. Naturally occurring biocontrol is not actively manipulated. It is the background mortality due to naturally occurring organisms in the plant or animal system. Classical biocontrol and augmentative biocontrol refer to active use and management of natural enemies by humans. In classical biocontrol, the natural enemy is released in the range of the pest over a relatively short period of time (possibly only one release or as many as several releases per year for several years). Afterward, recovery efforts may be made to determine the rate of success of the natural enemy, but regular long-term releases are not made. Initial manipulative efforts may be large, but this is a very low-input sustainable pest management system if the biocontrol agent is successful in reproducing and sustaining a population sufficient to reduce the pest population to noneconomic levels. Even partial control of the pest is beneficial because such control often helps other control efforts. Augmentative biocontrol differs from classical biocontrol in that regular long-term releases are scheduled, requiring much more manipulation. Therefore, such efforts are usually restricted to systems in which the biocontrol agent does not permanently establish in the release area, but the crop or animal value and pest status is sufficient to warrant the cost in continually releasing the biocontrol agent.

Is biological control feasible? Obviously, naturally occurring biocontrol is always advantageous because it requires no artificial inputs. Assistance can be provided to naturally occurring biocontrol by using insecticides that are less harmful to biocontrol agents, and by scheduling insecticide use only when necessary to control pest that are expected to cause economic damage. The feasibility of implementing classical biocontrol or augmentative biocontrol is dependent upon the answer to several questions:

1. How much injury is tolerated? In general, the lesser the amount of tolerated damage the more severe the limitation to implementing biocontrol. This is because biocontrol agents typically do not completely eliminate a pest population; therefore, some pressure of the pest and damage must be tolerable (that is, a small amount of damage does not warrant implementing a control strategy).

2. What is the value of the commodity? In general, commodities with low value are good candidates for attempting classical biocontrol. In these commodities there is less likelihood of frequent use of insecticides that can disrupt biocontrol agents, and there is more likelihood that some damage can be tolerated. Interestingly, there have been cases of great success in high-value commodities such as citrus and dairy, often using augmentative methods of biocontrol in addition to the classical methods.

3. What is the length of the growing season? There have been greater rates of success of biocontrol in perennial systems than in short-term annual systems. In general, a perennial system provides longer biocontrol agent/pest population contact; therefore, the biocontrol agent is more likely to persist. Greenhouse systems where there is continuous production of annuals may also permit long term contact of the biocontrol agent and pest management.

4. Is the pest native or exotic? Insects introduced into a new geographic range may become pests because they are released from predation by biocontrol agents in their home range. Therefore, controlling exotic pest populations with introductions of biocontrol agents from the original home range of the pest population is more likely to be successful than controlling a native pest population with a biocontrol agent that has previously not been associated with the pest population. In general, naturally occurring biocontrol agents are more likely to control native pest populations than an introduced natural enemy that has not been in previous contact with the pest.

Overall advantages in using biocontrol:

1. Often specific to the target pest.
2. Off-target effects are minimal.
3. Often very cost efficient (particularly in the case of naturally occurring and classical biocontrol).
4. There is a cumulative long-term control effect, with naturally occurring and classical biocontrol, because the natural enemy persists.

Overall disadvantages in using biocontrol:

1. Impacts on the pest species is often slow (often a gradual reduction in pest population over multiple generations).
2. Not compatible with most insecticides (most broad-spectrum insecticides will kill the pest species and its natural enemies).
3. Conditions (such as climate) may prevent the use of classical biocontrol or hamper the ability of naturally occurring biocontrol to reduce pest populations below a level of economic concern. In such cases augmentative biocontrol is a biocontrol option, but this can be excessively expensive.
4. Cannot be regarded as a second line of defense to be used if other methods fail because the control strategy is slow-acting.

Chemical control

Chemical control is the use of chemical compounds to kill and/or reduce numbers of insects. There are diverse opinions about what constitutes an insecticide. Broadly defined, an insecticide is a chemical (synthetic or naturally occurring) with toxic (causes death or illness), inhibitory (such as repellents), or protective action against insects. This definition identifies insecticides as synthetic broad- and narrow-spectrum compounds and naturally occurring plant and animal compounds with insecticidal activity. Narrowly defined, an insecticide is a synthetic chemical with toxic, inhibitory, or preventive action. This definition includes synthetic broad- and narrow-spectrum compounds and mimics of naturally occurring plant and animal compounds with insecticidal activity. Insecticides are regulated by federal and state agencies. These agencies determine the classification of an insect "chemical" control agent.

As detection of compounds with narrow spectrums of biological activity increases, the distinction between chemical control and biological control may become less clear. Remember, one definition of biological control identifies naturally occurring plant and animal products for insect control as biocontrol agents. But by one definition of chemical control, the same chemical product synthetically produced would be classified as an insecticide. It may be best to consider the spectrum of activity of the control agent. A "good" chemical or biological control agent should restrict killing activity (whether it is due to toxic action, predation, or parasitism) to the target organism(s) with no adverse activity on non-target organisms, including natural enemies and humans. Unfortunately, more than 50 percent of insecticide use involves broad-spectrum products that have limited compatibility with biological controls. Some new products and others in development have narrower spectrums of activity.

Overall advantages in using chemical control:

1. Impact on the pest species is often quick.
2. There are often limited cumulative long-term control effects (limited persistence in the environment).
3. Often compatible with other chemical compounds (e.g., herbicides).
4. Can be used as a second line of defense, because of its quick action, if other methods fail.

Overall disadvantages in using chemical control:

1. Because there is often limited cumulative long-term control effects, products must often be reapplied.
2. Persistence may be a problem with some products (detrimental persistent effects such as groundwater contamination and toxic effects due to bioaccumulation.)
3. Often a lack of target specificity (e.g., off-target effects are often great).
4. Applicator safety must be carefully considered because of off-target effects, including mammalian effects.

Some characteristics are listed as advantages and disadvantages. The nature of the specific chemical in consideration will determine if, for example, long residual activity is an advantage because of extended insect control or a disadvantage because of environmental contamination.

Cultural control

Cultural control is the reduction of insect populations or their effects through agricultural practices. Cultural control involves changing normal farming practices rather than adding special procedures. The best cultural controls become stable farming practices (often serving multiple purposes), and it is often forgotten that insect control was one reason for establishing the practice.

Examples of cultural control include:

1. Plant resistance to insect attack (host plant resistance).
2. Crop rotation (rotating out of a susceptible crop into a crop that is tolerant of an established insect pest population).
3. Crop residue destruction and sanitation to reduce an insect pest population.
4. Timing of planting to avoid insect damage.

Regulatory control

Regulatory control is the regulation of an area to eradicate, prevent, or manage insects and their injury to plants, animals, and humans. Agencies involved in regulatory control are the USDA Animal and Plant Health Inspection Service, the US Post Office, state Departments of Agriculture, and Weed and Pest Control Districts.

Examples of regulatory control include:

1. Quarantine: regulations forbidding the sale or shipment of plants, plant parts, or animals, usually to prevent the spread of diseases, insects, nematodes, or weeds.
2. Host-free periods: periods of time in which the host plant is not planted, allowing for possible disruption of the insect life cycle.
3. Eradication: complete destruction of a pest from a region.

Mechanical and physical controls

Mechanical and physical controls use machines, implements, or climatic conditions for the control of insects (often part of cultural control).

Examples of mechanical or physical controls include:

1. Plow down cultivation to disrupt insect activity.
2. Use of screens and traps to limit the activity of insects or to directly kill them.
3. Hot/cold storage or treatment to directly kill an infestation or make the environment unattractive for insect colonization.

The greatest challenge in insect management is the selection of the most appropriate combination of control strategies and employing these strategies only when necessary and appropriate.

Insect sampling and economic thresholds

In sampling for pests, we are interested in estimating a trait of the pest population or commodity that is a good indicator of the damage potential of the pest (such as estimating pest population density or percent of damage plants in a cropping system). In all cases, some basic information should be considered before establishing an informal or formal sampling plan. Knowledge of the life history and identification features of the pest is critical. It is not an uncommon mistake to be looking for the pest during the wrong stage of development. Early in the season immature insects may look very different than adult insects. Proper identification can be crucial in determining whether or what type of a control strategy should be implemented. For example, the severity of damage and control strategies differs for two-spotted spider mite and Bank's grass mite infesting corn.

Another crucial aspect of pre-sampling knowledge is an understanding of pest/plant interaction. Plant response to pest damage may not only vary by the species of the pest, but also by the species or cultivar of the plant, the growth stage of the plant, and the health/vigor of the plant at the time of pest infestation. Certainly plant species vary greatly in susceptibility to a pest. Pests that do damage to a specific plant species commonly have a name associated with its host plant, although this is not a strict rule. Plant cultivars also can vary greatly in susceptibility to pests, and such variability has been used in breeding plants resistant to insects. Plant and animal susceptibility will also vary, at times greatly, according to the growth stage of the plant/animal at the time of infestation. For example, pests may be very harmful when a plant is in the seedling stage but not after the plant becomes established; theses are known as "seedling" pests. A final aspect of plant/pest interaction to consider is the health/vigor of the plant when it is exposed to a pest infestation. Often, but not always, plants that are nutrient or water stressed are more susceptible to pest injury than if they are vigorously growing.

Sampling programs and protocols have the aim to assess a sampling trait in a population. In sampling pest populations, the sampling trait is usually the pest itself or damage of the commodity. In pest ecology, we are usually concerned with density or the frequency of occurrences of sampling traits (usually the pest but this also can be plant or animal damage). Sometimes we are only concerned with detection (some governmental inspection services aim to detect the entry of pests into a new region). Examples of estimates of pest densities include number of grasshoppers per square foot, number of insects caught per day in a trap, and number of larvae per sweep (using a sweep net). Examples of frequency estimates of occurrence include the proportion of plants (or animals) that are infested or damaged.

Ultimately, the economic value of a sampling protocol and implementation of a control strategy relates to the prevention of a commodity loss because a control strategy was implemented at the appropriate time based on good estimates of pest damage potential. Of course, the savings associated with preventing a commodity loss should be greater than the cost of using the sampling protocol and control strategy. An economic threshold is defined as the level (usually pest density) at which the cost of sampling and implementing control strategies is equal to the cost of the expected commodity loss if a control strategy is not implemented. If the economic threshold is exceeded, it becomes economically viable to implement a control strategy. Economic thresholds are typically and most appropriately used for implementing short-term control strategies, such as chemical control and to a lesser degree regulatory control. Based on the factors mentioned above that affect pest-plant interactions, as well as variability in commodity price, economic thresholds should not be considered stagnant levels. Usually, economic thresholds will be pertinent to a particular pest stage or plant growth stage. Thus, it is very important to consider that economic thresholds should be used as suggested guides that aid you in determining whether to implement a control strategy. Keep in mind that most economic thresholds are constructed from information on commodity and control economics and an understanding of pest-plant interactions. Other factors, such as the presence of beneficial organisms (wildlife, honey bees, natural enemies of pests), potential contamination of soil and water sheds, and potential human exposure to pesticides, should be considered prior to implementing a pesticide control strategy.

Other control strategies may be available that typically involve long-term sustainable approaches to pest control (such as biological control and cultural control). If successful, these strategies usually do not require active season-to-season manipulation by a grower (such as pest control by established exotic natural enemies of an introduced pest) or these strategies may become part of the normal production practices of a grower (such as growing cultivars that are resistant to a pest). Because of the nature of these control strategies, they are not implemented according to the standard use of economic thresholds. These sustainable approaches to pest control are admirable because they usually are very much in keeping with the goal of good pest management, such as the use of control strategies to reduce pest populations to levels that do not cause economic injury to the commodity without exposing humans to harmful control agents, disrupting non-target organism(s), and causing other forms of harm to the environment.

Insect classification

Before dealing specifically with insects and related organisms significant to human endeavors, it is important to establish a general classification of animals to determine where insects belong. There are seven basic levels of classification. The classification applied to the common house fly, *Musca domestica* is shown below.

Kingdom – Animal
- Phylum – Arthropoda
  - Class – Insecta
    - Order – Diptera
      - Family – Muscidae
        - Genus – *Musca*
          - Species – *domestica*

An insect is part of the animal kingdom, classified within the Phylum Arthropoda (from the Greek, meaning "jointed leg"). Among the common features of arthropods, the most readily visible are a segmented body, paired jointed appendages, and an external skeleton made of chitin. Immature arthropods grow through the molting process. There are five groups of arthropods of particular economic importance: Crustecea, Diplopoda, Chilopoda, Arachnida, and Insecta.

Insect relatives

Characteristics of common arthropod groups related to insects are:

Crustecea (Crayfish, shrimp, sowbugs, pillbugs, etc.)

Distinguishing characteristics:
Five to seven pairs of legs
Two body regions (cephalothorax and abdomen)
Two pair of antennae

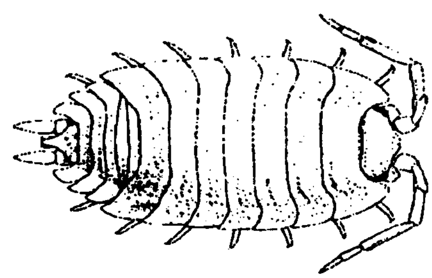

Fig. 4. Class crustacean: a sowbug. (length ~1/3 in.).

Diplopoda (Millipedes)

Distinguishing characteristics:

Elongated, usually rounded bodies

Numerous body segments (typically around 50)

Appear to have two pairs of small legs at each segment

Fig. 5. Class Diplopoda: A millipede, **Narceus** *sp. (length ~ 2 in.).*

Chilopoda (Centipedes)

Distinguishing characteristics:

Elongated, flattened bodies

14 to 20 body segments

Appear to have one pair of legs at each segment

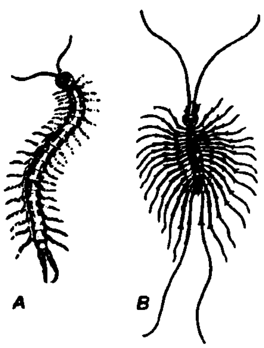

Fig. 6 Class Chilopoda: a large garden centipede, **Scolopendra obsura** *(Newport) (length 6 in.)(A) and a house centipede,* **Scutigera coleoptrata** *(L.) (length ~1.5 in.) (B).*

Arachnida (spiders, harvestmen, scorpions, ticks, and mites)

Distinguishing characteristics:

Four pairs of legs

Two body regions (cephalothoraxes and abdomen)

No antennae

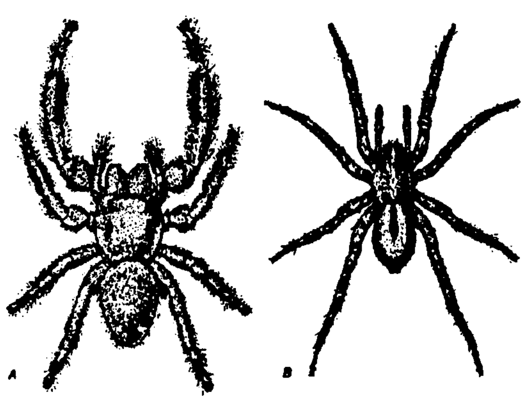

Fig. 7 Class Arachnida: a jumping spider, **Phidippus audax** *(Hentz) (length 0.5 in.) (A) or ground spider,* **Lycosa** *p. (length 1.5 in.) (B).*

The Insects

Insect bodies are separated into three regions (head, thorax, and abdomen), three pairs of legs on the thorax, two pairs of wings present on the thorax (wings may be absent or highly modified), one pair of antennae, and the other features common to the Arthropoda.

The class Insecta (also called Hexapoda) is divided into orders, which are classification divisions that can assist in identifying an insect. Classification is an important step in determining the economic status of an insect. Common information to an order includes the type of metamorphosis and structure of the mouth parts and wings. Order information will help identify the diversity of the group, such as where they may be found, types of food they eat, and variations in general body structure. With order information and information on host plant or host animal affiliations (i.e., what an insect is feeding on), it is often possible to determine if the insect is one of the primary pests or beneficial insects in the United States. By consulting texts with information on order and host plant or host animal affiliation, specific identification can be made and management options can be considered.

There are differences in opinion on the number of orders that should be recognized and the names that should be applied to these groups. The classification system used here is that which is used by Borrer et al. (1989). A list of economically important orders is given on the following pages. The common name(s) of the orders are placed beside the order name. The following information is provided for each order: order name, common name(s) approximate number of described species, type of metamorphosis, type of mouthparts, type of wings, body form, and habitat and economic importance.

Collembola (Springtails)

About 1,500 species known

Metamorphosis: none (direct development)

Mouthparts: chewing

Wings: none

Body form: about 1/32 to ¼ inch long, elongated to robust, most with furcula (a forked structure arising on the ventral surface of the abdomen which is used to propel the insect through the air.)

Habitat and economic importance: terrestrial; found in leaf litter, and under bark, fungi, and soil; feeds on decaying plant material, fungi, and bacteria. Selected species occasionally damage young, tender plants near the soil surface.

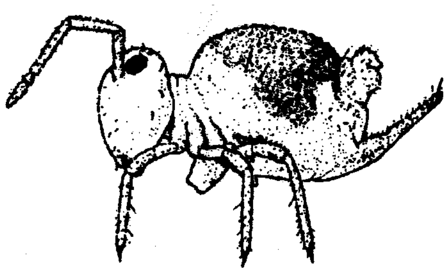

Fig 8. Order Collembola: a springtail, **Bourletiela hortensis** *(Fitch) (length ~ 1/32 in.).*

Thysanura (Silverfish)

About 400 species known
Metamorphosis: none (direct development)
Mouthparts: chewing
Wings: none
Body form: about 3/8 inch long or shorter, elongated and slightly flattened, two or three long tail-like appendages (cerci) at the end of the abdomen, the body is usually covered with scales.
Habitat and economic importance: terrestrial; found in leaf mold, humus, and buildings. They are decomposers; no major agricultural importance, an indicator of inadequate sanitary practice in urban situations.

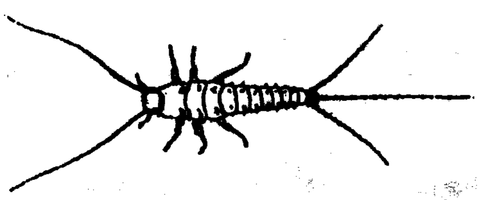

*Fig. 9 Order***Thysanura***: a silverfish (length ~ 0.5 in. or less)*

Ephemeroptera (Mayflies)

About 1,500 species known
Metamorphosis: incomplete
Mouthparts: chewing in nymphs, vestigial in adults
Wings: one to two pairs, membranous with numerous veins, wings held together above the body when at rest.
Body form: about ¼ to ¾ inch in length, two or three long tail-like appendages at the end of the abdomen, front wings are usually triangular and larger than the hind wings for adults; nymphs are variable in form, usually with leaf-like or plumose gills along the side of the body.
Habitat and economic importance: adults are terrestrial, short-lived, and do not feed; common around lakes and streams. Nymphs are aquatic, and feed on algae and detritus. No agricultural importance; important food source for fish.

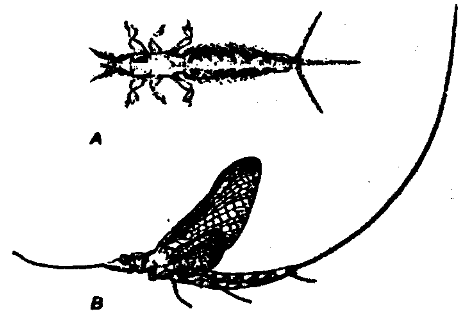

Fig. 10. Order Ephemeroptera: a nymph, **Stenonema canadense** *(Walker) (length ~ 1/16 in. or less) (A) and an adult (length ~ ¾ in.) (B).*

Odonata (Dragonflies and damselflies)

About 5,000 species known
Metamorphosis: incomplete
Mouthparts: chewing
Wings: two pair, elongate, membranous with numerous veins, dragonfly wings are held flat and protrude out from the body, damselfly wings are held together above the body when at rest.
Body form: variable in adult, about ¾ to five inches, compound eyes are large and multi-faceted, abdomen is elongated. Nymphs are variable in form; gills are leaf-like at the end of the abdomen in damselflies or recessed in the body in dragonflies.
Habitat and economic importance: adults are terrestrial; common around ponds, lakes, and slow moving streams; feed on insects such as mosquitoes while in flight. Nymphs are aquatic; feed on other aquatic insects and small fish. No agricultural importance; important food source for fish.

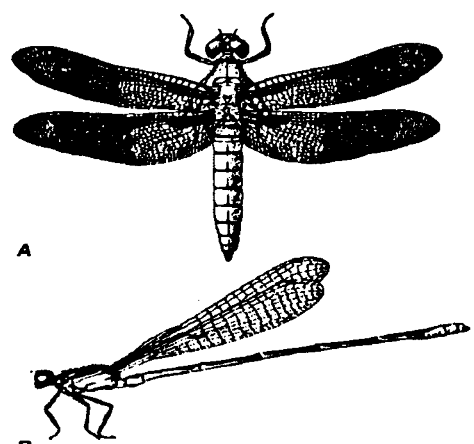

Fig. 11. Order Odonata: a pond dragonfly, **Plathemis Lydia** *(Drudy) (wing span ~ 2.5 in.) (A), and a damsel fly,* **Enallagma exsulans** *(Hagen) (length ~ 2 in.) (B).*

Orthoptera (Grasshoppers and crickets)

About 24,000 species known
Metamorphosis: incomplete
Mouthparts: chewing
Wings: two pair or none, front wings are elongated and thickened with many veins, hind wings are membranous and folded underneath the front wings when not in flight. Wings may be reduced in length.
Body form: variable, from less than one (1) inch up to four (4) inches in length, hind legs are modified into jumping organs, body is long and slender with paired tail-like appendages (cerci) extending from the end of the abdomen, antennae are conspicuous.
Habitat and economic importance: terrestrial; most are plant feeders, some cause economic damage to range and crop lands. Some feed primarily on non-economically important plants or weedy species.

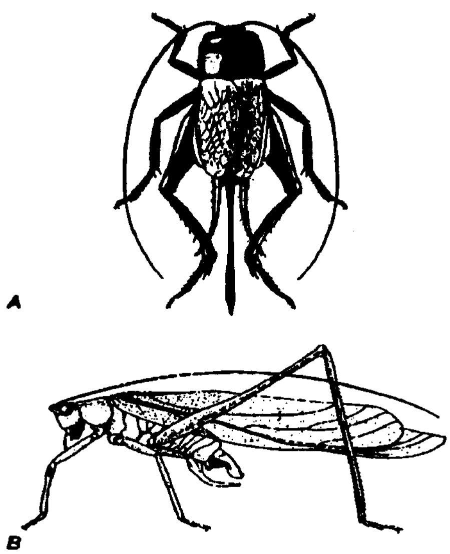

Fig. 12. Order Orthoptera: a cricket (length ~ 1 in.) (A), a katydid (length ~ 1.5 in.) (B).

Mantodea (Mantids)

About 1,500 species known
Metamorphosis: incomplete
Mouthparts: chewing
Wings: two pair, front wings are elongated and thickened with many veins; hind wings are membranous and folded underneath the front wings when not in flight.
Body form: variable, from less than one (1) inch up to four (4) inches in length, front legs are greatly modified into grasping organs, the first part of the thorax is elongated giving the body the appearance of having a long neck, body is long and slender with cerci extending from the end of the abdomen, antennae are apparent.
Habitat and economic importance: terrestrial; all species are predaceous, feeding on other insects. Sold as biological control agents, typically they are unable to reduce pest species population below an economic level because of slow generation turnover.

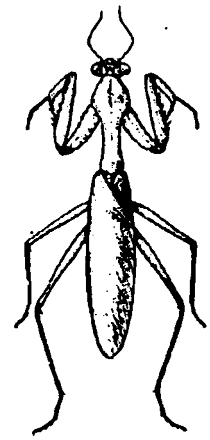

Fig. 13. Order Mantodea: Carolina mantid, **Stagmomantis Carolina** *(L), (length ~ 2 in.).*

Blattaria (Cockroaches)

About 1,500 species known
Metamorphosis: incomplete
Mouthparts: chewing
Wings: two pair, front wings are thickened with many veins, hind wings are membranous and folded underneath the front wings when not in flight. Wings may be absent or reduced in length.
Body form: variable, about ¼ to one inch in length, body is somewhat oval and flattened with cerci extending from the end of the abdomen, antennae are long.
Habitat and economic importance: terrestrial; cockroaches are primarily tropical but some are adapted to more temperate regions. They are scavengers and can feed on various household items including stored products.

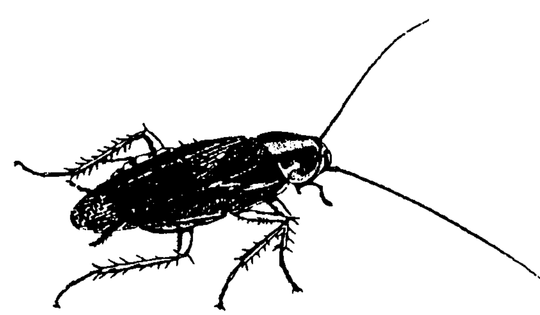

Fig. 14. Order Blattara: german cockroadh, **Blattella germanica** *(L) (length ~ ½ in.).*

Isoptera (Termites)

About 1,900 species known
Metamorphosis: incomplete
Mouthparts: chewing
Wings: two pair, front and hind wings are equal in size or nearly so (in ants the front wing is longer than the hind wing). Only the reproductive caste has wings; they are shed at the end of the mating flight. Wings are held flat over the abdomen.
Body form: variable, about 1/8 to 1 inch in length, soft-bodied and usually light-colored (the reproductive caste is darker than the other castes). Size and form differs among castes. In all castes, the abdomen is broadly joined to the thorax (in ants the union is constricted). Antennae are straight, slender, and typically beaded (ant antennae have a pronounced bend). The reproductive caste is winged and the worker and soldier castes are not winged. The soldier caste usually has enlarged mandibles.
Habitat and economic importance: terrestrial; they are social insects dividing the labor of the colony into different castes. Some colonize in moist soil; others colonize in dry habitats above ground. All are able to digest cellulose. Some are serious pests of wooden structures. They are also important decomposers of woody plant material in natural systems.

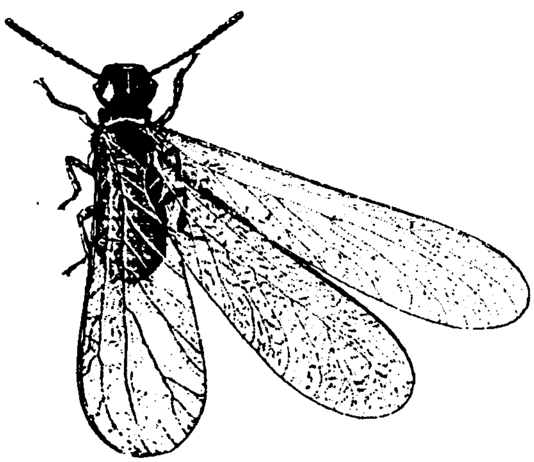

Fig. 15. Order Isoptera: eastern subterranean termite, **Reticulitermes flavipes** *(Kollar) (length ~ 1/3 in.).*

Dermaptera (Earwigs)

About 1,000 species known
Metamorphosis: incomplete
Mouthparts: chewing
Wings: one or two pair, front wings are short, leathery and without veins. Hind wings (if present) are folded underneath the front wings. Wings are held flat over the abdomen.
Body form: about ¼ to ½ inch in length, soft-bodied, elongated and somewhat flattened. Antennae are often long and beaded. One pair of cerci is at the end of the abdomen. The cerci are conspicuous, and modified into pinching structures.
Habitat and economic importance: terrestrial; nocturnal. They feed on dead vegetable matter, occasionally feeding on tender parts of living plants (such as the silk of corn). Some are predaceous on other insects. They are important decomposers of plant material in natural systems.

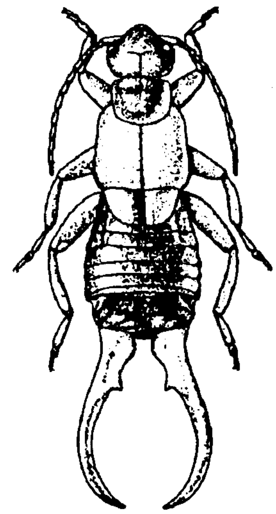

Fig. 16. Order Dermaptera: a male European earwig, **Forficula auricularia** *(L) (length ~ 2/3 in.).*

Plecoptera (Stoneflies)

About 1,500 species known
Metamorphosis: incomplete
Mouthparts: chewing
Wings: two pair, membranous and multi-veined, wings are folded flat over abdomen when at rest.
Body form: adults are about 1/8 to 1½ inches in length, somewhat flattened, soft-bodied, antennae are long and slender, and cerci are present. Nymphs are elongated, somewhat flattened, and soft-bodied. Antennae and cerci are long. Gills are present on the thorax and bases of the legs.
Habitat and economic importance: adults are terrestrial, poor flyers, and are commonly found along shore lines. Nymphs are aquatic, often found underneath stones in streams; they are plant-feeders, feeding mainly on blue-green algae. They are not agriculturally important; important food source for fish.

Fig. 17. Order Plecoptera: a common stonefly, **Neoperla clymene** *(Newman) (length ~ ½ in.).*

Psocoptera (Psocids)

About 1,000 species known
Metamorphosis: incomplete
Mouthparts: chewing
Wings: two pair or none, membranous, wings are held arched over abdomen when at rest.
Body form: less than 1/8 inch in length, soft-bodied, they generally have the appearance of lice (common names include bark and book lice).
Habitat and economic importance: terrestrial; decomposers of plant and animal matter. They also feed on algae, stored products, pollen, molds, and paper of high fiber content.

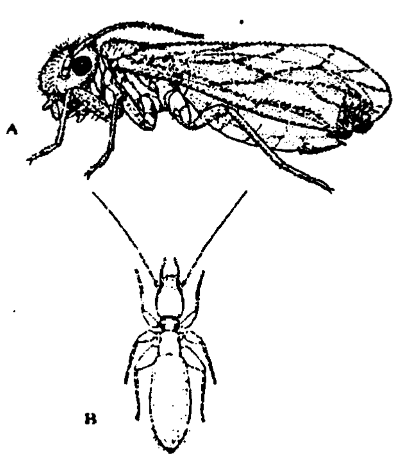

Fig 18. Order Psocoptera: a winged psocid (barklouse) **Ectopsocus pumilis** *(Banks) (length ~ 1/8 in.) (A), and a wingless psocid (booklouse)* **Liposcelis divinitorius** *(Mueller) (length ~ 1/16 in.) (B).*

Phthiriaptera (Lice)

About 3,000 species known
Metamorphosis: incomplete
Mouthparts: chewing (suborder: Mallophaga) or piercing-sucking (suborder: Anoplura).
Wings: none
Body form: less than 1/8 inch in length, soft-bodied, and flattened. The head is broad in chewing lice. The head is narrow in sucking lice.
Habitat and economic importance: terrestrial; most chewing lice are ectoparasites of birds, but some feed on the skin of livestock. They feed on feathers, hair, and skin flakes. Sucking lice only feed on mammals. They are blood feeders and some transmit disease organisms. Lice are important to human (two species of sucking lice attack people) and animal health. Some chewing lice are serious pests to poultry and cattle and some sucking lice are serious pests to cattle.

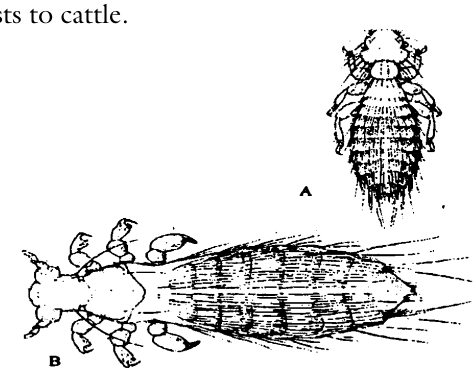

Fig. 19. Order Phthiriaptera: a chewing louse (suborder Mallophaga), **Meromenopon meropiss** *(Clay and Meinertzhagen) (length ~ 1.16 in.) (A), and a sucking louse (suborder Anopluar),* **Polyplax stephensi** *(Christopher and Newstead) (length ~ 1/16 in.) (B).*

Hemiptera ("True" bugs)

About 52,000 species known
Metamorphosis: incomplete
Mouthparts: piercing-sucking, beak arises from the front of the head and usually extends back along the ventral side of the body.
Wings: two pair, the basal portion of the front wing is thickened and leathery and the tip is membranous. The hind wing is membranous and is folded underneath the front wing when at rest. The wings fold flat over the body.
Body form: adults are variable, 1/32 to 2 inches in length. Antennae are apparent. The body is somewhat flattened. A small triangular region (scutellum) is visible at the mid-section of the body from a top view. Nymphs have the same body form as adults except the wings vary in length from barely visible buds to fully developed when matured to the adult stage. There are usually five nymphal instars.
Habitat and economic importance: terrestrial; some are semi-aquatic; all stages generally feed on the same food source. Many are plant feeders, feed-

ing on leaves, stems, seeds, and fruit structures. Some are predaceous, feeding on insects and eggs of insects. A few species feed on the blood of humans and other animals. The semi-aquatic species (they are not true aquatics because they must take in surface air) dive in the water or skim the water surface.

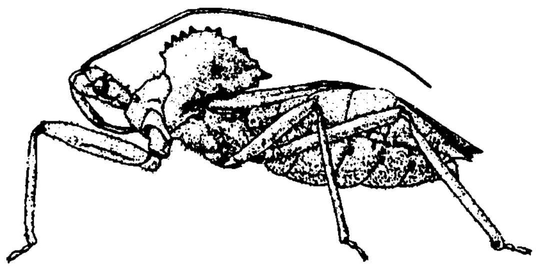

Fig. 20. Order Hemiptera: the wheel bug, **Arilus cristatus** *(L.) (length ~ ¾ in.).*

Homoptera (Cicadas, hoppers, psyllids, whiteflies, aphids, and scale insects)

About 32,000 species known
Metamorphosis: incomplete
Mouthparts: piercing-sucking, beak arises from the back of the head and usually extends back along the ventral side of the body. In some adults the mouthparts are absent or reduced.
Wings: usually two pair, or none, front wing is uniformly membranous or slightly thickened, hind wing is membranous and is folded underneath the front wing when at rest. The wings are arched over the body when at rest. Wingless forms occur in some species. Sometimes winged and wingless forms occur in the same sex; in these species, formation of wings may be linked to host plant condition.
Body form: this is a highly variable group. Cicadas and hoppers: 1/8 to 1 inch in length, short antennae and bristle-like. Cicadas have membranous wings, hoppers have somewhat thickened front wings. Psyllids: less than 1/8 in length. They resemble cicadas in form. They have jumping legs and relatively long antennae. Adults are winged. Whiteflies: about 1/16 inch in length. Adults are winged and resemble small white moths. A white dust covers the wings. The first instar nymphs are active crawlers; latter instars are sessile and resemble scales. Aphids: about 1/16 to ¼ inch in length, generally pear-shaped with tubular protrusion (cornicles) at the end of the abdomen, generally long antennae. In some species, wingless forms occur, sometimes winged and wingless forms occur in the same sex. Eggs are produced, but in some species females can give birth to live young without mating. Scales: variable, 1/16 to 1 inch in length. Females are wingless, legless, and sessile. Males have one pair of wings, a style-like process at the end of the abdomen, and resemble small gnats. The first instar nymphs are active crawlers; later instars are sessile, wax or scale is secreted and covers the body when viewed from above. Many species can reproduce asexually.
Habitat and economic importance: terrestrial; they suck sap from stems, leaves and roots of plants. Species may be specialized to feed on certain plant species and structures. Some are vectors of plant pathogens, some cause plant deformities called galls, and some cause leaf streaks and other forms of discoloration.

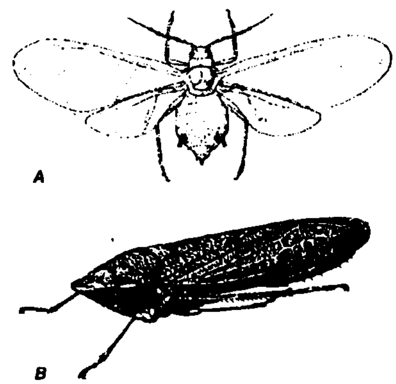

Fig 21. Order Homoptera: a winged aphid, **Rhopalosiphum padi** *(L.) (length ~ 1/16 in.) (A), and a leafhopper,* **Dareculacephala Minerva** *(Ball) (length ~ ¼ in.) (B).*

Thysanoptera (Thrips)

About 4,000 species known
Metamorphosis: incomplete
Mouthparts: piercing-sucking or rasping-sucking
Wings: two pair, slender and fringed with hair. They lay flat on the back at rest and may not be noticed. Wings may be absent in some species.
Body form: adults are 1/32 to 1/8 inch in length and slender in form. Antennae are apparent but short. Asexual reproduction occurs in some species.
Habitat and economic importance: terrestrial; typically plant feeders, found on flower and fruiting heads and new growth. Some are vectors of plant disease and some are predaceous on other insects.

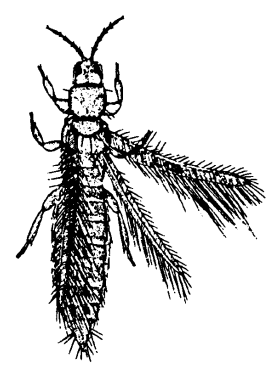

Fig 22. Order Thysanoptera: a flower thrips, **Frankliniella tritici** *(Fitsch) (length ~ 1/16 in.).*

Neuroptera (Lacewings, Snakeflies, Adlerflies, and others)

About 5,000 species known

Metamorphosis: complete

Mouthparts: chewing

Wings: two pair, membranous and multi-veined. They lay arched over the back at rest.

Body form: adults are variable, about 3/8 to 3 inches in length and slender in form, soft-bodied. Antennae are long and slender. Larvae are also soft-bodied, slender to stout in form and may be very active. Larvae of aquatic species have processes extending laterally from the abdomen.

Habitat and economic importance: terrestrial and aquatic species. All species are predaceous as larvae. Adults may or may not feed. Generally feed on other insects. Lacewings mostly feed on aphids.

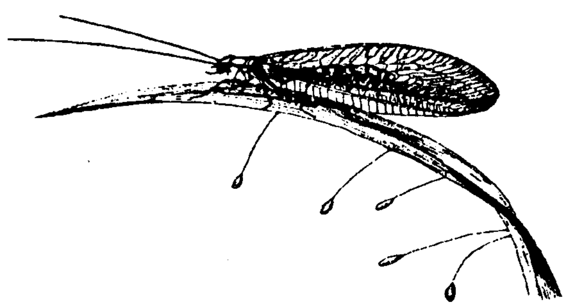

Fig. 23 Order Neuroptera: a goldeneye lacewing, **Chrysopa oculata** *(Say) (length ~ ¾ in.) with eggs attached to leaf.*

Coleoptera (Beetles)

About 265,000 species known

Metamorphosis: complete

Mouthparts: chewing, adult weevils have reduced mouthparts retracted at the end of a snout.

Wings: two pair, the front wings are thickened, leathery or hard, forming a protective shield as seen from above. The hind wings are membranous, usually longer that the front wings, but folded underneath the front wings when at rest. In some species, the wings are reduced.

Body form: adults are variable, about 1/32 to 3 inches in length, hard-bodied. Antennae are variable in length (from short, not extending past the head, to longer than the length of the body) and form (from knoblike to slender). Larvae are also variable in size and form (slender to stout), generally soft-bodied. Slender-bodied larvae with well-developed true legs tend to be active and likely search for their food (many scavengers, and predators). Stout-bodied larvae with weakly developed legs, or with legs absent, tend to be sessile or slow moving and likely feed on stationary food sources (many plant feeders).

Habitat and economic importance: most terrestrial and some aquatic species. Adults tend to be strong fliers and are the dispersal and reproductive stage of the insect. Feeding by adults may be common or limited, some feed on the same food source as the larvae. Larvae are highly variable. Some are plant feeders, foliage feeders, wood and stem borers, fruit feeders, root feeders and leaf miners. Some species are scavengers feeding on stored products and grains, fungi, animal waste, and dead plant and animal material. Some species are predators feeding on other insects. A few species are animal parasites. Some plant feeders are considered beneficial because they feed only on weedy plant species. Because of this diversity of feeding, this order consists of many beneficial and destructive insects.

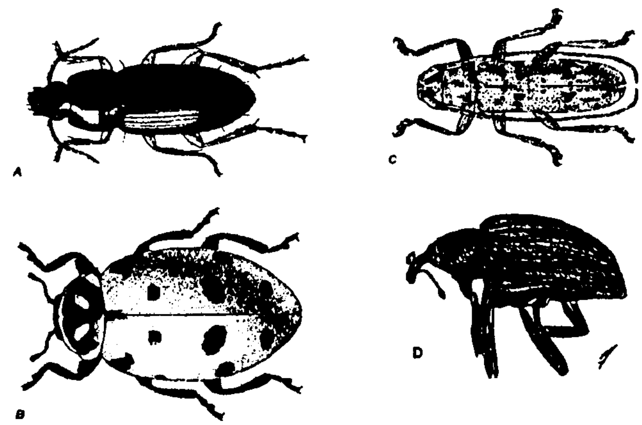

Fig. 24. Order Coleoptera: a ground beetle, **Harpalus pennsylvanicus** *(De Geer) (length ~ 1 in.) (A), a ladybird beetle,* **Hippodamia convergens** *(Guerin-Meneville) (length ~ 1/3 in.) (B), a long-horned beetle,* **Monochamus titillator** *(Fabricius) (length ~ 1 in.) (C), and a root weevil, subfamily* **Otiorhynchinae** *(length ~ 1/3 in.) (D).*

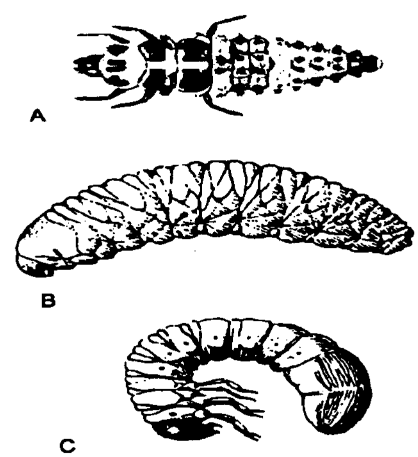

Fig. 25. Order Coleoptera: larval forms, a ladybird larva (length ~ ½ in. or less) (A), a weevil larva (length ~ 1/3 in. or less) (B), and a white grub (length ~ ½ in. or less) (C).

Siphonaptera (Fleas)

About 1,100 species known
Metamorphosis: complete
Mouthparts: sucking
Wings: none
Body form: adults are less than 1/8 inch in length, body is laterally flattened with stout hairs arising from the body, all tending to point toward the end of the body. Most species have long well-developed legs enlarged for jumping. Larvae have a simple tubular body with hairs tending to point toward the end of the body. The body is whitish and has a pair of blunt appendages at the end of the body. There are no legs.
Habitat and economic importance: terrestrial; adults of both sexes feed on the blood of their hosts. A wide range of hosts are attacked, but a given species usually has a limited host range. Larvae are active but usually not seen because they are found in the nesting material of their host. They feed on animal waste, dried blood, and possibly decaying plant material that is used to construct the nest. Some species are vectors of animal diseases.

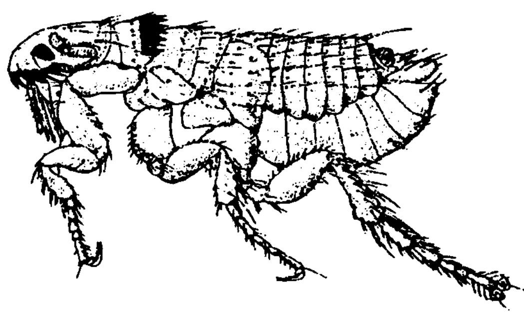

Fig. 26. Order Siponaptera: the cat flea, **Ctenocephalides felis** *(Bouche) (length ~ 1/16 in.).*

Diptera ("True" flies)

About 85,000 species known
Metamorphosis: complete
Mouthparts: sucking, various modifications occur resulting in piercing-sucking, sponging-sucking, and lapping-sucking functions. In some species, the mouthparts are highly reduced and non-functional. Mouthparts of some larvae are chewing.
Wings: one pair, second pair is modified into small knobby structures called halteres. The fore wings are membranous, often with multiple veins.
Body form: adults are variable, less than 1/8 to ¾ inch in length, soft-bodied. Antennae are short and stout to long and slender. The union of the abdomen and thorax is broad, not constricted as in most bees and wasps. Larvae are legless and generally maggot-like. Two general groups occur: 1) primitive families have a well-developed head capsule and strong chewing mandibles, 2) families more recently evolved have the head reduced, a head capsule may or may not be apparent, mouthparts have been modified into hooks that can be retracted into the body.
Habitat and economic importance: terrestrial; many larvae can be termed semi-aquatic because they feed in very moist habitats. Adults are found in a wide range of habitats. Some species feed on blood, other species feed on decaying organic matter or nectaries, a few species do not feed. Some are animal and plant disease vectors. Larvae are slow moving and feed on a variety of food sources, including decaying animal and plant material, plant roots, stems (stem borers), and leaves (leaf miners), and organic material in semi-aquatic habitats. Some species are beneficial, feeding on other insects as predators or parasites. Some species are endoparasites of mammals.

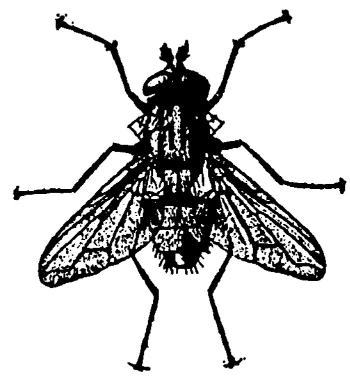

Fig. 27. Order Diptera: the striped horsefly, **Tabanus lineola** *(F.) (length ~ ½ in.).*

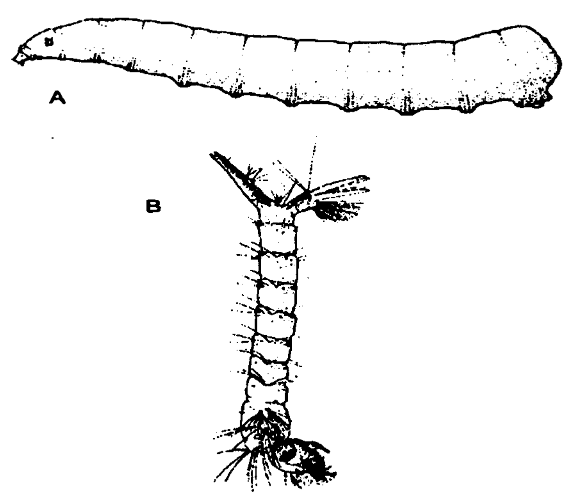

Fig. 28. Order Diptera: larval forms, a maggot-form house fly larva, **Musca domestica** *(L.) (length ~ 1/3 in. or less) (A), and a primitive-form larva with strong chewing mandibles and well developed head capsule, the northern house mosquito,* **Culex pipines** *(L.) (length ~ ¼ in. or less) (B).*

Trichoptera (Caddisflies)

About 4,500 species known

Metamorphosis: complete

Mouthparts: chewing, mandibles are reduced in the adult.

Wings: two pair, membranous wings, multi-veined, and hairy. They are usually arched over the abdomen when at rest.

Body form: adults are 1/16 to 1½ inches in length, soft-bodied, similar to moths in general appearance. Antennae tend to be long and slender. Larvae have caterpillar-like form (eruciform). They have a well-developed head capsule and thoracic legs. A pair of hooked structures occurs at the end of the abdomen.

Habitat and economic importance: terrestrial as adults, larvae are aquatic. Adults are weak flyers, found near the edge of water. Larvae are either free-living species or species that are housed in cases made by the larvae. Some species are found attached to rocks in flowing streams, others are found in ponds or lakes. No agricultural importance; they are an important food source for fish and other aquatic organisms.

Fig. 29. Order Trichoptera: a caddisfly, **Phryganea vestita** *(Walker) (length ~ ½ in.).*

Lepidoptera (Butterflies and moths)

About 105,000 species known

Metamorphosis: complete

Mouthparts: chewing in larvae, siphoning in adults.

Wings: two pair, membranous wings with scales. Butterflies hold their wings arched over the abdomen when at rest. Moths usually hold their wings flat over the abdomen when at rest.

Body form: adults are variable, ¼ to 4 inches in length, soft-bodied. Antennae tend to be long and slender. Larvae are caterpillar-like, with a well-developed head capsule, thoracic legs, and up to five pairs of false fleshy legs (prolegs) along the underside of the abdomen. Usually at the bottom of the prolegs are small hooks (crochets). Some species, mostly leaf miners, do not have legs. Various forms of processes (hairs, spines) may extend from the body wall or may be reduced or absent.

Habitat and economic importance: terrestrial; a few species are aquatic as larvae. Adults feed on the nectaries of plants. Larvae most often feed on plants. Feeding habits vary greatly; leaf miners, stem borers, tree borers, foliage feeders, fruit feeders, and fruit borers. Some species feed on cloth fiber and stored products and grains. Some plant feeders can be considered beneficial because they feed primarily on weedy plant species.

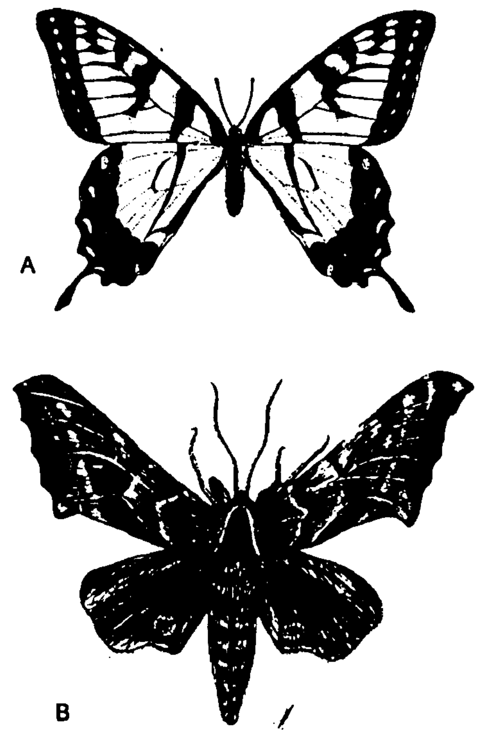

Fig. 30. Order Lepidoptera: a swallowtail butterfly, **Papilio glaucus** *(L.) (wing spread ~ 3.5 in.) (A), and a hawk moth (length ~ 3.5 in.) (B).*

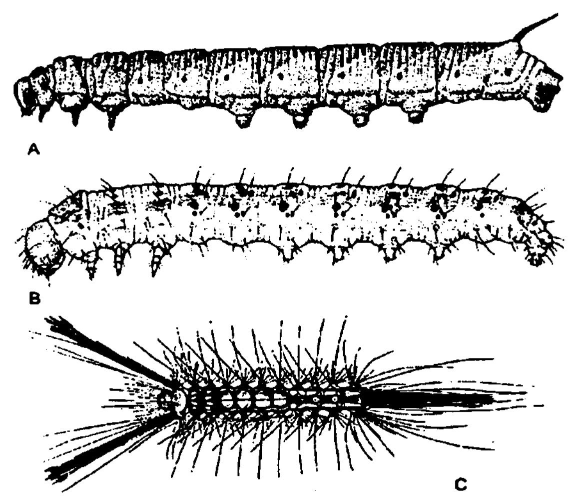

Fig. 31. Order Lepidoptera: larval forms, all caterpillar-like, the tomato hornworm, **Manduca quinquemaculata** *(Haworth) (length ~ 3 in. or less) (A); corn earworm,* **Helicoverpa zea** *(Boddie) (length ~ 2 in. or less) (B); and whitemarked tussock moth,* **Orgyia leucostigma** *(J.E. Smith) (length ~ 1.5 in. or less) (C).*

Hymenoptera: (Sawflies, wasps, ants, and bees)

About 110,000 species known

Metamorphosis: complete

Mouthparts: chewing, in adult bees and other species the mouthparts are modified into a tongue-like structure through which liquid is taken.

Wings: two pair, or absent, membranous. The hind wing is smaller than the front wing. Venation is moderate to highly reduced. In some species, wingless forms occur.

Body form: highly variable group, antennae are generally long, ovipositor of the female is usually well developed or modified into a stinger. Adult sawflies are about 3/8 to 1½ inches in length, union of the thorax and abdomen is broad. Larvae are caterpillar-like with a well-developed head capsule. They have six to eight, usually eight, pair of prolegs without crochets. Parasitic wasp adults are variable, less than ¼ to more than 1 inch in length. Membranous wings have few veins. Union of the thorax and abdomen is constricted. Larvae are grub-like, often concealed in the body cavity of the host insect or other arthropod. Ant adults are less than ¼ to ½ inch in length, they have elbowed antennae, union of the thorax and abdomen is constricted. These features distinguish adult ants from adult termites. Wings are present during the mating flight and are shed afterward. A separate non-reproductive caste, the workers, does not have wings (ants are social insects with queen, male, and worker castes). Larvae are grub-like, whitish in color. They are secluded in the ant colony. Adult bees and stinging wasps are ½ to 1 inch in length. Union of the thorax and abdomen is constricted. The ovipositor is modified into a stinging organ. Some species are social and have separate castes. The queen is larger than the other castes (such as honey bees) and is responsible for reproduction in the colony. Larvae are grub-like, concealed within the nest or colony.

Habitat and economic importance: terrestrial; great variety of habitats. Larvae of sawflies are external feeders on foliage, and some species are wood borers. A few species of chalcid larvae feed inside seeds and stems, possibly causing gall formation. All ant species are social with three castes. Ants forage from a central colony, with one queen per colony. Most species nest in the ground, but some nest in cavities in plants. Parasitic wasps are parasites of insects and some other arthropods. Larvae feed internally or externally on the host. Stinging wasps use their stinger to paralyze their prey, which is used as a food source for larvae that are tended, to varying degrees, in a nest. Bees use their stinger as protection. They forage on flowers to obtain nectar and pollen. The pollen is provided to larvae in the nest or colony. The food sources of the various species include animal flesh, plants, fungi, sap, nectar, and honeydew. Overall, most species of Hymenoptera are beneficial functioning as parasites and pollinators.

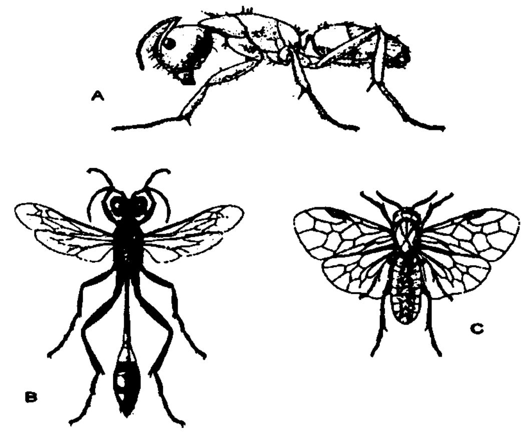

Fig. 32. Order Hymenoptera: a common ant, **Campontus castaneus** *(Latrielle) (length ~ ¼ in.) (A); a parasitic wasp (length ~ ¾ in.) (B); and the European pine sawfly,* **Neodiprion sertifer** *(Geoffroy) (length ~ ¼ in.) (C).*

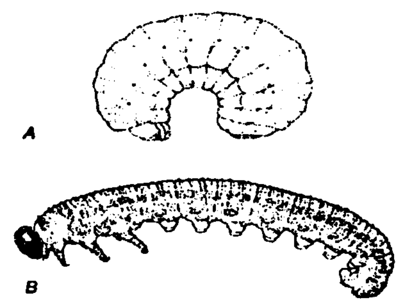

Fig. 33. Order Hymenoptera: larval forms, a megachilid bee (length ~ 1.2 in. or less) (A) and the European pine sawfly, **Neodiprion sertifer** *(Geoffroy) (length ~ ¾ in. or less) (B).*

Insect Collection and Preservation

A properly prepared insect collection is a repository of information that can be consulted and admired well into the future. Properly prepared insect specimens can last for centuries. The value of a preserved insect lies in its beauty and label information, which provides an indication of the biological importance of the specimen. The equipment used to assemble an insect collection need not be elaborate or expensive. A collecting net and killing bottle is needed to collect insects. To preserve insects, insect pins and storage boxes are needed with soft bottoms to secure hard-bodied insects. Insect labels are needed to document where the insect was collected, when it was collected, and who collected it.

When collecting insects, determine if you want your collection to represent the wide diversity of insects or a selected group (such as butterflies in my backyard, insects found in an alfalfa field, or the Orthoptera of Goshen County). You should also determine whether you wish to collect adult insects, immature insects, or both. The tools needed for collecting and preserving insects will determined by your collection preferences. In addition to a collection net and kill jar, forceps or a fine brush for picking up small insects, a knife for opening plants or digging into soil, traps to catch insects, small envelopes, boxes or vials for temporarily storing insects, bags for storing plant material, a hand lens, and a notebook for taking notes and label data are also useful.

Three types of collecting nets are available. Aerial nets are designed to collect butterflies and other flying insects. Sweep nets are designed to sweep through vegetation. Aquatic nets are designed to screen insects out of water. Traps can be used to collect insects that are difficult to catch with nets because they are not highly mobile, fly at night, or are found near the ground. Light traps are advantageous because many flying insects are attracted to light. A 15-watt ultra-violet fluorescent light source is often the best attractant for insects. Flying insects are attracted to the light, hit baffles surrounding the light source, and fall into a collection jar filled with alcohol or a collection bag with plant material placed in the bag (for the insects to rest on until the bag is inspected). Light traps are available through biological supply houses (some are listed in the supply house section of this bulletin). Pitfall traps collect ground-dwelling insects. A simple pitfall trap may be made by placing bait in a wide-mouthed jar and placing the jar overnight in a location where ground-dwelling insects are suspected to occur. Different baits collect different insects; apple cider absorbed onto tissue or a piece of meat placed at the bottom of the jar or suspended in the jar are two commonly used baits. The trap can be placed along lush vegetation or dug into the ground with the mouth of the jar level with the ground. Vaseline should be spread along the inside rim to make sure that the insects do not escape.

The killing and preservation of insects should be done carefully to ensure preservation of a good specimen. Insects should not be haphazardly killed if they are not to be used in a collection and they are not harmful (the vast majority of insects either do not harm human endeavors or are beneficial). Killing soft-bodied insects in alcohol or other liquid media should be done with care. Ethanol mixed with water (70 to 80 percent alcohol) is usually a satisfactory killing and preserving agent. Isopropyl alcohol (rubbing alcohol) is an acceptable and commonly available substitute. Larvae of most insects should be first killed in boiling water to "fix" their proteins, which prevents them from turning black. The "fixed" larvae then can be placed in alcohol for long-term storage and display. Hard-bodied insects can be killed in a kill jar. This is a preferable killing method for many hard-bodied insects because placement in alcohol may distort the shape of the soft intersegmental regions of the body. A kill jar can be made of a wide-mouth glass jar containing a liquid killing agent. Plaster of Paris may be poured into a jar (about 2.5 centimeters) and dried. Ethyl acetate (finger nail polish remover) is then poured onto the plaster. The absorbed ethyl acetate will be sufficient to kill most insects (be sure that excess liquid has been poured out of the jar). The time needed to kill an insect will depend upon its size and type and may vary from minutes to hours.

Prior to preservation or pinning, specimens can be temporarily stored. Larval specimens should be prepared for long-term storage in alcohol (usually 70 to 80 percent) as soon as possible. Larvae can temporarily be placed in alcohol before "fixing" the larvae in boiling water. Do not temporarily store larvae in cool water before they are "fixed". Hard-bodied insects and almost all adult insects can be temporarily stored in the refrigerator or in dry storage prior to pinning. Insects placed in the refrigerator should be in well-sealed containers with moistened tissue paper. This is a good method of temporary storage because the specimens should not become brittle. Insects placed in dry storage, such as in a plastic or cardboard box sitting at room temperature without moisture, must be rehydrated prior to pinning. To rehydrate, the dried insects should be placed in a well-sealed container with moistened tissue paper for one to three days depending upon their size and type.

Soft-bodied insects are commonly preserved in alcohol and stored in glass vials with rubber corks or screw caps. Different-sized vials are available from biological supply houses. As previously mentioned, larvae of most insects should first be killed in slow boiling water for a few minutes to "fix" their proteins, which prevents them from turning black. The "fixed" larvae then can be placed in 70 to 80 percent alcohol. Parasitic Hymenoptera are best killed and preserved in 95 percent alcohol. Hard-bodied insects are commonly preserved as pinned specimens. Insects should be pinned directly on the pin

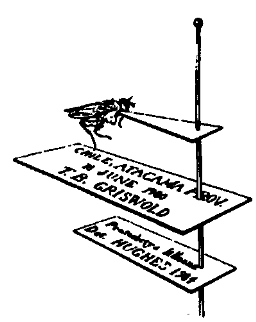

Fig. 34. A properly pinned insect on a card point with locality and determiner labels.

or placed on card mounts that are then pinned. Direct pinning can be used if the insect is large enough so that the pinning will not break the insect apart. Standard insect pins are 38 millimeters long, rust-proof, and have a rounded-head end for easy handling. Entomologists commonly use pins of size 2 (0.46 mm in diameter). No. 3 and 4 size pins are useful for very large insects. Biological supply stores carry insect pins that meet these specifications.

Insect should be pinned vertically through the body. Most insects are pinned to the right of the midline so that all characteristics of one side of the body will definitely be retained. The pinned insect should be level (the long-axis of the body at a 90 degree angle from the length of the pin). The insect should be placed two-thirds or three-fourths the way up from the base of the pin to allow placing the locality and determiner labels underneath the insect (Figure 34). Pinning blocks, which allow adjusting specimens and labels to uniform heights on the pin, are available from biological supply houses or can be home-made. Where the pin is placed along the length of the body depends on the type of insect. Orthoptera should be pinned through the back of the thorax. Large Hemiptera and large hard-bodied Homoptera should be pinned through the triangular scutellum. Large Hymenoptera and Diptera should be pinned through the thorax between the base of the forewings. Large Coleoptera should be pinned through the rightwing cover near the base. Large Lepidoptera and Odonata should be pinned through the thorax at its thickest point; the wings should be spread apart uniformly (figure 35).

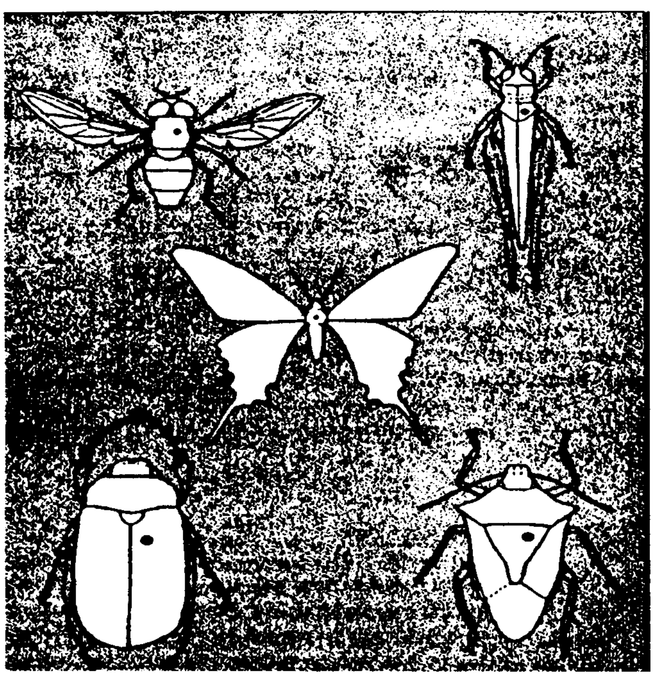

Fig. 35. Proper placement of a pin on different types of insect.

Small insects that would break apart if directly pinned should be mounted on card points that can be pinned. Card points are small triangular pieces of stiff paper (stiff paper of 50 percent rag or more), no more than 12 millimeters long and 3 millimeters wide. Cutting out the card points with scissors is satisfactory. For those who collect many small insects that need to be pointed, a special punch to make card points is available from biological supply houses. The card point is pinned through the broad end, and the insect is then glued to the point. Clear finger nailpolish or white glue is acceptable adhesives to use. For most insects, the card point is attached to the right side of the insect, (with the left and middle section clear of the card.) For better adhesion with some insects, the tip of the card point may be bent down, where the insect will be placed, at a slight angle (Figure 34). Insects to be preserved with wings spread uniformly away from the body are dried in this position on spreading boards. A spreading board is a smooth surface on which the wings are spread and positioned horizontally. The body of the insect is placed in a longitudinal groove in the board with the pin secured into a layer of soft material. Spreading boards can be purchased from biological supply houses or home-made. Wings of Lepidoptera, Odonata, and Orthoptera with distinctive hindwings should be spread. The pin is inserted in the central groove of the spreading board and pushed down until the base of the wings is flush with the top edge of the spreading board. The forewing is spread outward by gently pulling it with an insect pin placed behind a large vein at the front edge of the wing. The hind edge of the forewing should be at a 90 degree angle from the length of the body. The hindwing should be spread so that the front edge of the hindwing overlaps the hind edge of the front wing (the front edge of the hind wing should naturally spread underneath the hind edge of the front wing). The positioning of the wings should be secured with strips of paper placed across the wings and pinned to the spreading board (Figure 36). Drying time will depend upon the size of the insect and humidity; drying time may vary from one to two weeks.

Once the insect is pinned or placed in vials with storage fluid, label(s) should be added to the specimen (Figure 34). Although a preserved insect itself is of value for its beauty, a specimen is of the most value when labeling information is included indicating where and when the specimen was collected, who collected it, and on what host it was found. Two labels are commonly used for pinned insects (locality and determiner labels). One label with all the necessary information is commonly used for insects stored in liquid. The locality label contains the location of collection, date of collection, the name of the collector, and if available the host plant or host animal with which the insect was associated. The first line should include the state or county where collected

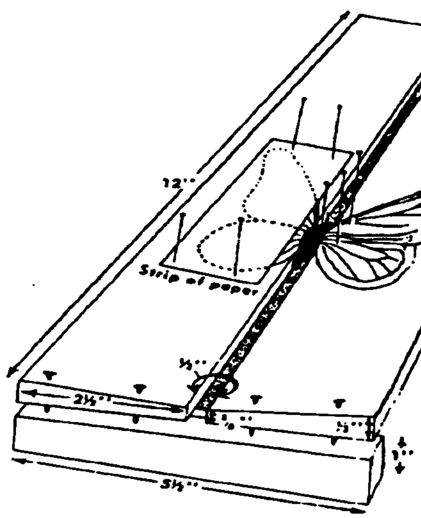

Fig. 36. A butterfly with wings spread on a spreading board.

followed by more specific township and site information (an additional line can be used if necessary). The state should be capitalized and printed on the upper left hand corner of the label followed by the other information (for example: WYO:Evantson, 5I. West along I-80). The date of collection should be recorded on the next line in day-month-year order (23 June 1993). Host plant or host animal affiliation should next be noted if available. The collector's name should be printed on the next line after or before the letters COL, which signify that this is the collector's name (COL: M. Henry). Any other unusual collection circumstances can also be placed on the label (such as burned forest area). The scientific identity of the specimen should be placed on a separate label, called a determiner label (for specimens to be placed in liquid storage, this information should be printed on the locality label). The first line should indicate the order and family of the specimen (Lepidoptera:Noctuidae). The second and/or third lines should indicate the common and/or scientific names. The last line should indicate the person making the species determination printed after DET: (DET: A. Peters). A name should not be placed on the last line if a species determination has not been made. Label data for pinned insects should be printed in India ink on paper of at least 50 percent cotton fiber content, using a rapidograph or ultra fine-pointed crow-quill dip pen (pencil can be used, but ballpoint pen should never be used because this ink fades rapidly). Label data for specimens placed in alcohol or other fluid should be printed in soft lead pencil or India ink (the ink should be well dried prior to being placed in alcohol).

Specimens should be stored in containers with tight joints and closely fitting lids to prevent entry of unwanted insects. To prevent fading, pinned insect specimens should not be stored in brightly lit places. The type of box or case depends upon your personal needs and the expected use of the collection. If pinned insects are to be put on display, a glass- or clear plastic-covered case is preferable. Cases are available from biological supply houses or can be homemade. Small boxes with wood covers are also available and can be easily stacked for storage. Naphthalene (moth balls), a commonly available fumigant, should be kept inside storage containers to prevent damage from insects. This fumigant should be enclosed in a small box and secured in the specimen case. Specimens should be grouped together by order and by family in that order. An acceptable phylogenetic sequence can be found in the insect section of this guide.

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American Entomologist
Annals of the Entomological Society of America
Biological Control
Canadian Entomologist
Environmental Entomology
Journal of Economic Entomology
Medical Entomology

Public Agency Publications

Various publications dealing with insects issued from agricultural experiment stations, cooperative extension services, state departments of agriculture, the United States Department of Agriculture, and the Environmental Protection Agency are available. In Wyoming the principal agencies that generate such material are the University of Wyoming Agricultural Experiment Station and the University of Wyoming Cooperative Extension Service.

Supply houses for entomological equipment

Bio Quip Products, Inc., 17803 La Salle Avenue, Gardena, CA 90248 (Phone: 310-324-0620, Fax: 310-324-7931).

Carolina Biological Supply, 2700 York Road, Burlington, NC 27215 (Phone: 800-334-5551, Fax: 800-222-7112, internet: www.carosci.com.

Glossary of terms used in Entomology

Beneficial insect: an insect with habits that benefit human activities, such as pollinators, parasites, and predators of other insects, and insects that feed on weedy species of plants.

Ectoparasite: see external parasitoid.

Endoparasite: see internal parasitoid.

External parasitoid: a parasitoid with young (the parasitic stage) that live attached to the outside of the body wall of the host.

Insect collection: a collection of preserved specimens that is used for reference purposes.

Insect label: information attached to a preserved specimen that identifies the insect, collection site and date, collector, identifier, and host of the insect if known.

Insect vector: an insect that transmits a disease-inducing organism or agent.

Instar: a growth stage of an immature insect. Insects pass through multiple instars.

Internal parasitoid: a parasitoid with young (the parasitic stage) that live inside the body of the host.

Metamorphosis: a major change in body form of an insect resulting from a molt.

Molt: insect growth process in which the old exoskeleton is shed in order to form a new larger exoskeleton.

Natural enemies: parasitoids, predators, and some phytophagous species that are weed feeders that result in the death or suppression of pests. Some authorities recognize pathogens and naturally occurring plant and animal products for insect control as biocontrol agents (e.g., pheromones, plant and animal odors [baits], pathogens).

Parasite: an organism that lives on or in some living plant or animal (called a host) and obtains all or part of its nutrients from it.

Parasitoid: a specialized organism that is usually about the size of its host as an adult; the immature stage kills its host internally or externally and requires only one host for development into the free-living adult stage.

Pathogen: a microorganism, including viruses, which cause disease.

Pest: any creature or plant interfering with human endeavors.

Predator: an organism that is usually larger than its prey and kills its prey by feeding externally, requires more than one prey to complete its development, and is a free-living organism throughout its life.

Pollinator: an organism that transfers pollen from the male to female flower of flowering plants.

Morphological terms

Abdomen: third and posterior body region of an insect.

Antenna (pl. antennae): a pair of segmented sensory appendages on the head.

Beak (=proboscis, = snout)**:** any protruding snout on the head of an insect; usually housing the mouthparts but may include other parts of head (ex: weevils, order Coleoptera).

Campodeiform: slender-body form of larva with well-developed legs, designed for good mobility, refers to overall body form of some larvae.

Caudal: pertaining to the posterior or tail end of the body.

Cephalothorax: fused head and thorax of Crustecea and Arachnida.

Cercus (pl. cerci): appendage on last or second to last segment of abdomen, usually paired; one to may segments.

Chelicera (pl. chelicerae): anterior and medial pair of appendages of Arachnida, used for chewing food.

Chitin: a secretion of the epidermis involved in sclerotization.

Compound eye: main eyes of most insects; the outer surface is composed of numerous facets called ommatidia.

Corium: thickened parchment-like basal part of the wing of "true" bugs (Hemiptera).

Costa: vein along the anterior margin of a wing.

Coxa: basal, first segment, of an insect leg (segments of appendages are always counted starting from the base).

Elytron (pl. elytra): thickened and hardened front wing of beetles and few other insects; may have ridges or grooves but no true veins.

Eruciform: caterpillar-like in form, refers to overall body form of some larvae.

Exoskeleton: refers to the hardened body wall of insects to which muscles are attached (insects do not possess an internal skeleton).

Femur (pl. femora): third segment of an insect leg; usually long and the thickest segment of the leg.

Filiform: thread-like in structure, usually refers to a type of antenna.

Furcula: a forked structure arising on the ventral surface of the abdomen used to propel the insect through the air (present in Collembola).

Halter (pl. halteres): small knobbed organ on the side of metathorax of flies (Diptera); paired; probably represents the reduction of the hindwing.

Hemelytron (pl. hemelytra): from wings of true bugs (Hemiptera), the basal part is thickened and the distal part is membranous.

Lamellate: pertaining to flat plates (lamellae) or plate-like segments.

Mandibles: jaws, usually the primary biting or chewing mouthparts; often modified for sucking; found beneath the labrum.

Meso: a prefix meaning 'in the middle'; an Arabic numeral 2 is sometimes written as a subscript to indicate the same thing, e.g., $coxa_2$ = mesothoracic coxa.

Mesothorax: the second or middle segment of the thorax; when two pairs of wings are present, the front pair is always on the mesothorax.

Meta: prefix meaning 'at the back.'

Metathorax: the third or last segment of the thorax; when two pairs of wings are present, the hind pair is always on the metathorax.

Moniliform: beaded in structure, usually refers to a type of antenna.

Notum (=tergum) (pl. nota): the dorsal part of a body segment. Notum usually refers to a thoracic segment, tergum to an abdominal segment.

Ocellus (pl. ocelli): eye with single lens; often found between compound eyes; never more than three ocelli are present in adults; in larvae can be found in clusters.

Ommatidium (pl. ommatidia): visual unit of a compound eye.

Ovipositor: egg-laying organ; sometimes modified to form a stinger; usually composed of three paired structures called valves.

Palpus (pl. palpi): a paired, segmented appendage on the maxillae and labium (mouthpart segments).

Pedipalpi: second pair of appendages of Arachnids, homologous to mandibles of insects; not used for walking, used like antennae and for capturing and holding food.

Pleuron: lateral part of an insect segment.

Pro: prefix meaning 'ahead of.'

Proboscis: see beak.

Proleg: false flesh leg arising off the ventral surface of the Lepidoptera and sawfly (Hymenoptera, in part) larvae. ***Prothorax***: first segment of the thorax; wings are not born on the prothorax.

Sclerite: plate of the body wall of an insect, bordered by suture or membranes.

Sclerotin: the substance that forms the hard part of the exoskeleton, sclerotization is the process of hardening of the body wall.

Scutellium: posterior sclerite of the thoracic notum, usually triangular.

Seta (pl. setae): hair.

Simple eye: see ocellus.

Snout: see beak.

Spine: a process arising off the body wall, may be external or internal.

Spiracle: outside opening of tracheal system found along the lateral aspect of the body; insects breath through these holes.

Sternum: ventral part of a body segment.

Suture: groove or seam in body wall between two sclerites or plates.

Tarsal claw: claw at the tip of the tarsus, usually one pair, not considered a separate segment of the tarsus or leg.

Tarsus (pl. tarsi): last or distal part of an insect leg; may be divided into one to five segments.

Tegmen (pl. tegmina): thickened parchment-like front wings of grasshoppers, cockroaches, and mantids.

Tergum (pl. terga) (=motum): dorsal part of a body segment, usually refers to the abdominal segment; notum is used for the dorsal part of thoracic segments.

Tibia (pl. tibiae): fourth segment of an insect leg; usually as long as or longer than the femur but not as thick as the femur.

Trachea (pl. tracheae): tubes throughout the body of an insect for respiration, containing air except for the finest branches, which are filled with fluid; connected to the spiracles.

Trochanter: second segment of an insect leg.

Tympanum: membrane that serves as an eardrum or covers the auditory organs.

Insect management terms

Biological control: control of pests by means of predators, parasites, and disease producing organisms.

Chemical control: use of chemical compounds used for killing and/or reducing number of insects.

Chlorosis: yellowing of plant's normally green tissue because of a partial failure of the chlorophyll to develop or a degradation of chlorophyll.

Crop rotation: rotating out of a susceptible crop into a crop that is tolerant of an established insect pest population.

Cultural control: reduction of insect populations or their effects through agricultural practices.

Economic threshold: an index, based on a measure of insect presence, used to time implementation of a management strategy. If an economic threshold is met or exceeded, a management strategy is warranted because the cost of the management strategy is less than the cost of the damage caused by the insect.

Eradication: complete destruction of a pest from a region.

Host-free period: periods of time in which the host plant is not planted, thereby disrupting the life cycle of a pest population.

Host plant resistance: the ability of a plant to resist insect injury by either being a poor host to an insect or being able to host an insect population without showing injury.

Insect pest management: use of management strategies to reduce (or maintain) an insect population to (at) levels that do not cause economic injury. A combination of management strategies that are compatible is conducive to a stable insect management system.

Integrated pest management: see insect pest management, may also include the management of weeds, plant, and animal pathogens.

Mechanical control: use of machines, implements, or climatic conditions for the control of insects (often part of cultural control).

Necrosis: death of plant tissue.

Pest: any creature or plant interfering with human endeavors. Pest status is a function of the number of insects present, value of the commodity, type of damage caused by the pest, and susceptibility of the host to pest damage.

Physical control: use of machines, implements, or climatic conditions for the control of insects (often part of cultural control).

Regulatory control: regulation of an area to eradicate, prevent, or manage insects and their injury to plants, animals, and humans.

Quarantine: regulations forbidding the sale or shipment of plants, plant parts, or animals, usually to prevent the spread of diseases, insects, nematodes, or weeds.

Row covers: physical barriers placed over plants that allow penetration of light and prevent entry of insects.

Sustainable agriculture: an agricultural production system that increases the inherent productive capacity of natural and biological resources to keep in step with demand; allows farmers to earn adequate profit, provides consumers with wholesome, safe food, and minimizes adverse impact on the environment.

Sustainable pest management: use of pest management strategies that are compatible with the goals of sustainable agriculture.

Insecticide use terms

Acaracide: a compound used to control mites and ticks.

Active ingredient: actual toxic materials present in a formulation.

Acute oral LD_{50}: in toxicity studies, it is the dosage required to kill 50 percent of test animals when given a single dosage. The dose is expressed by the weight of the chemical per unit of body weight.

Acute toxicity: toxic response of poisoning expressed soon after exposure to a chemical.

Adjuvants: combined with spray material to act as wetting or spreading agents, stickers, penetrants, emulsifiers, etc., aiding in the action of the toxic materials.

Adulticide: chemical that kills adult insects.

Antidote: practical immediate treatment including first aid in case of poisoning.

Band application: application of spray, dust, or granules to a continuous restricted area such as to or along a crop row rather than over the entire field area (broadcast).

Botanical insecticide: naturally occurring compounds derived from plant parts and toxic to insects.

Broadcast application: application of spray, dust, or granules over an entire area of interest.

Carbamates: group of chemicals that include carbaryl and carbofuran.

Carrier: plant or animal internally carrying an infectious disease agent (e.g., virus) but not showing marked symptoms. A carrier plant can be a source of infection to others. An insect contaminated externally with an infectious agent (e.g., bacterium, virus, fungi, and nematode) is sometimes called a carrier. Also the liquid or solid material added to a chemical or formulated to facilitate its field use.

Chemical control: use of chemical compounds used for the kill and/or reduction in numbers of insects.

Chlorinated hydrocarbons: group of chemicals that includes D.D.T., Endrin, Aldrin, and Dieldrin.

Cholinesterase: body enzyme necessary for proper nerve function that is destroyed or damaged by organophosphates and carbamates taken into the body.

Chronic toxicity: condition in which a chemical accumulates in the body causing a gradual poisoning, bringing on illness or sometimes death.

Compatibility: refers to chemical materials that can be mixed together without adversely changing their effects on pests, plants, and animals; also refers to management strategies that are compatible.

Concentrate: agricultural chemical before dilution.

Contact insecticide: compound that causes the death of an insect when it touches its external parts. It doe not need to be ingested to be effective.

Dermal toxicity: measures the amount of a poisonous compound that can be absorbed through the skin of animals to produce toxic symptoms.

Detergent: cleaning agent or solvent such as water or soap that acts as a wetting agent.

Diluent: liquid or solid used to carry the active ingredient (e.g., carrier).

Dormant spray: spray applied when plants are in a dormant condition.

Drift: movement of material outside of the intended target area.

Emulsifiable concentrate (EC): formulation produced by dissolving the toxicant and an emulsifying agent in an organic solvent. The resulting mixture can then be either sprayed on with water or oil as a diluent.

Emulsifying agent: surface active material that facilitates the suspension of one liquid in another, usually water and oil.

Formulation: manner in which the active ingredient and the carrier are mixed.

Granules: pesticide formulations in which the active ingredient is impregnated on small particles of clay.

High volume spray: spray application of more than 60 gallons/acre.

Horticultural oils: oils that have insecticidal properties and are generally safe to use on plant tissue if applied properly, these oils are particularly effective on certain sessile insects.

Illegal residue: residue that is in excess of a pre-established government-enforced safe level.

Incompatible: agricultural chemicals that cannot be mixed or used together because of undesirable reactions.

Insecticidal soaps: soaps that have insecticidal properties, and are particularly effective on certain sessile insects.

Insecticide: broadly defined, a chemical (synthetic or naturally occurring) with toxic (cause death or illness), inhibitory (such as repellents), or protective action against insects. This definition identifies insecticides as synthetic broad- and narrow-spectrum compounds and naturally occurring plant and animal compounds with insecticidal activity. Narrowly defined, a synthetic chemical with toxic, inhibitory, or preventive action. This definition includes synthetic broad- and narrow-spectrum compounds and man-made mimics of naturally occurring plant and animal compounds with insecticidal activity.

Label: legal identification attached to containers of any commercially sold chemical giving a summary of its properties and uses.

Larvicide: chemical that kills the larvae.

Legal residue: residue that is within a safe level according to the regulations of the appropriate regulatory agency.

Low-volume spray: spray application of diluted compounds, of five (5) to twenty (20) gallons/acre.

Microbial insecticide: insecticide in which a microorganism, or product from a microorganism serves as the active ingredient.

Microencapsulated insecticide: insecticide that is in a slow release formulation in which the insecticide gradually migrates out of a carrier membrane.

Miscible: two or more liquids, when mixed together, form a uniform mix.

Organophosphates: group of chemicals including parathion, phosdrin, and malathion.

Oral toxicity: degree of toxicity of a compound when it is ingested.

Ovicide: chemical that kills eggs.

Parts per million (ppm): number of parts by weight or volume of a given compound in one million parts of the final mixture.

Pesticide: any substance or mixture of substances used to control plant and animal life.

Pesticide tolerance: established quantity of a pesticide that can legally remain in harvested, edible products.

Phytotoxicity: compound that causes death or injury to plants.

Poison control center: center with expertise in the effects of toxins on humans and the medical treatment of such toxic effects.

Pyrethroids: group of chemicals including fenvalerate, permethrin, and cypermethrin.

Reentry interval: waiting interval required before a field can be entered without protective clothing or equipment after using a pesticide.

Registration: legal permission to market agricultural chemicals.

Repellent: compound that is unpalatable, unpleasant, or annoying to a certain organism, resulting in the organisms moving from the repellent source.

Residual insecticide: compound that kills insects that come in contact with it over relatively long periods of time. ***Residue***: amount of chemical that is on or in the crop at the time analysis is made.

Resistant (resistance): sum of the inherent qualities of a host plant or host animal that retard the activities of the causal agent. A plant or animal may be slightly, moderately, or highly resistant. Plants or animals may be resistant to insect attack. Insects may be resistant to control agents.

Restricted use product: product with use restricted to those who possess a license for its use. Licensing is a function of state department of agriculture.

Selective pesticide: compound capable of killing or inhibiting specific pests while not harming other organisms.

Solution: two or more liquids or a liquid and solid, when mixed together, for a true solution with no separation of the original compounds occurring.

Spreader: see wetting agent.

Stomach insecticide: compound that causes the death of an insect once it is ingested.

Surfactant: materials used in pesticide formulations to impart emulsifiability, spreading, wetting, dispensability, or other surface-modifying properties.

Systemic: compound, when taken up by the plant, is made effective throughout its whole system. Usually refers to insecticides.

Toxicity: degree to which something is poisonous.

Translocation: property of a chemical that is taken up by plants and moved throughout the system.

Ultra low volume spray: spray applications of diluted compound, less than five (5) gallons/acre; concentrated compounds are sprayed in ounces/acre for ultra low volume applications.

Volatile: refers to substances that evaporate or vaporize (change from liquid to gas) at ordinary temperatures upon air exposure.

Wetable powder: solid formulation that, upon the addition of water, forms a suspension used for spraying.

Wetting agent: material when added to a spray solution that causes the spray to spread over and wet the plant surfaces more readily.

Acknowledgement

Figures 23B, 24D, 25A, 30B, and 32B were provided by Alice Minney. All others were provided with permission by the U. S. Department of Agriculture, Agricultural Research Service, from G. C. Steyskal, et al. (1986: Insects and mites: techniques for collection and preservation, U. S. Department of Agriculture, Miscellaneous Publication No. 1443)

Parts of the text were modified from teaching material provided by J. Wheatley (Department of Crop Science, California Polytechnic University, San Luis Obispo, California).