Lesson 1: Introduction to Entomology

What is an insect? An insect is any kind of bug. Well, no, that is not a very descriptive or clear definition. An insect can be defined simply as a small, six-legged animal. Of the million kinds of animals that scientists have described and named, more than 800,000 are insects. Around 7,000 to 10,000 new kinds of insects are discovered every year. Insects live almost everywhere on earth – from steamy tropical jungles to cold polar regions, from snow-capped mountains to deserts below sea level.

Entomology

The study of insects is called *entomology*. The study of insects includes their development, anatomy, physiology, life history, behavior, environment, and classification. Why should we spend time studying insects? Why is entomology important to us? Although some people may think that the study of insects is a small, isolated field, entomology is important to all of us because of the wide range of influence insects have in our lives. Their effect is both direct and indirect, both positive and negative. Entomology gives people a better understanding of the environment, biology, and the world in which they live. An understanding of entomology is also needed to reduce the extensive economic losses in crop damage and health problems caused by insects.

Uses of Insects

Agriculture: In agriculture, insects are considered harmful and beneficial. Agriculture includes any field involved in growing crops for food and fiber, horticulture (fruits, flowers, and ornamental plants), forestry (managing forests, wood production, and wood products), and animal science (raising and caring for animals whether as pets or for food production). Insects are one of the chief competitors for food and fiber. Each year insects cause millions of dollars in damage to field crops, vegetables, fruits, and fibers in all stages of growth, production, storage, processing, and distribution.

Insects are not just pests to our society. Many are beneficial to humans. Insects are an important part of the food chain. Birds and fish eat insects directly to survive. Many mammals and reptiles feed on insects as well. The indirect contribution can be seen in the work of bees. Not only do bees make honey, but they also play an important role in pollinating plants. Some insects are helpful to humans by preying on and destroying other insects that are considered harmful. Another example of useful insects is the silkworm, which makes a valuable fiber for clothing and other items.

Environmental sciences: Besides their role in the agricultural fields, insects are very active in breaking down many of the substances in the environment. Many kinds of chemicals, minerals, and organic matter are broken down, recycled, and reused in the environment. Insects play an instrumental part in this degradation process, which is very important to the earth.

Medicine: Insects can transmit diseases by many methods. Insects are a very important part of the research to find out about diseases. This includes animal and plant diseases as well as human diseases.

Because insects reproduce so efficiently and can be handled so easily in large populations, they have been used extensively in genetic research. This contribution to science has provided researchers with a great wealth of knowledge about heredity, biological growth and development, and the causes and treatments of diseases.

Construction: Another large area of insect management is in building construction and maintenance. A knowledge of entomology is important when choosing the type of wood to be used in buildings and other structures. Termites cause much damage to wooden structures and building framing. Soil insects are an important consideration when constructing building foundations, roads, structural supports, and landscaping.

Product development: Insects are used in the research and development of many products used in society. Some of the most common products are cosmetics, shampoos, cleaning materials, food preservatives, manufacturing supplies, and medicines.

Entomology

Careers in Entomology

Scientists devote much study to insects that affect plants or animals which are important to man. Scientists who specialize in studying insects are called *entomologists*. Entomologists are involved in a wide variety of professions, both directly and indirectly. Some careers require an extensive knowledge of entomology while other careers only require a general knowledge of insects. Many of these career areas overlap one another. One specialty may be used in many different ways in many different fields.

Entomologists can be grouped by their area of insect study. Most professional entomologists are engaged in some branch of *economic* or *applied* entomology. This is a very broad category that describes the basic focus of these individuals. They not only want to control the numbers of insects, but to increase those insect populations that are beneficial and to decrease those that are harmful to people's welfare. Economic and applied entomologists use the study of insects in a practical way. Other entomologists study insects solely to learn more about their life cycles and behaviors.

Agricultural entomologists: Agricultural entomologists study insects that affect the production of foods and fibers. These individuals work in areas of agriculture such as agronomy, animal science, horticulture, floriculture, forestry, and wood processing. Some of the careers as an agricultural entomologist follow.

◊ Crop scout – Scouts monitor crop fields and take samples of the types and quantities of insects present. This is important in determining the amount of potential damage which may be done by the insects. From this information, a producer is better able to select an appropriate insect management plan. Usually, attending a training program is the minimum requirement for a scout. However, experience and education in entomology will enhance an opportunity for a better job in scouting.

◊ Agricultural product dealer – Any background at all in entomology will help one as a product dealer. Dealers must keep up with a wide variety of agricultural products and how they work. Since insect control is a major concern for producers, dealers are frequently asked for their suggestions and recommendations in selecting the products to be used.

◊ Pest controller – Individuals have a large selection of jobs as pest controllers. Pest controllers evaluate insect populations and damage, recommend insect management programs, implement these programs, apply insecticides, and dispose of any chemicals. Home care, industrial insect management, and termite control are leading employers in this area. Depending on the particular job responsibilities, individuals may need little or much formal education. Certain types of insecticides require special certification.

◊ Insecticide applicator – Insecticide applicators are responsible for the correct application and disposal of insecticides. This includes applications on the ground or by air, privately or commercially, and on domestic or public grounds. Usually, the applicator needs to attend a special training course to be certified.

◊ Researcher – There are many options in research involving insects. Most university and industrial research positions require a doctoral degree. To be a research assistant, a laboratory technician, or field technician, individuals may need a master's degree, a bachelor's degree, or less depending on the place of employment and the responsibilities of the position. Consultants may have any level of education, although a graduate degree is frequently required.

◊ Forester – Forest entomologists specialize in studying insects that affect different woods and how to properly treat these woods. A bachelor's degree is usually necessary.

◊ Greenhouse manager – Working in a greenhouse or any similar environment involves insect control. Some fruits and vegetables as well as flowers are grown and shipped to all parts of the country. A bachelor's degree or higher is standard at this management level. Technicians and assistants may be hired with less qualifications.

Entomology instructors: Individuals may teach entomology at elementary, secondary, and postsecondary levels. An individual can be an educator in many areas of specialization. Different training levels are required depending on the educational setting and student level. A doctoral degree is frequently needed to teach in a university. High school and vocational teachers need a bachelor's degree. Some states require that high school teachers be certified in pesticide application as well.

Medical and veterinary entomologists: These entomologists are concerned with insects that influence the health of humans and animals. It is largely through the efforts of these scientists that insecticides have been developed to protect crops and to reduce the incidence of insect-borne diseases. Jobs in this area generally require a graduate degree in the area of medical specialization. The degree may or may not be in entomology, but extensive college training in entomology is necessary. It is possible to become a research assistant, laboratory technician, or teaching assistant with a bachelor's degree or perhaps even a 2-year degree. There are a variety of choices and flexibility in this area.

Industrial entomologists: Individuals work in the research and manufacture of many types of products for industrial and domestic use. There are some jobs available for individuals with a high school diploma and some technical training. Many other jobs will require additional training. A knowledge of insects is useful in the testing and development of products. Examples of products are cosmetics, shampoos, cleaning materials, food products, industrial supplies, medicines, and insecticides. Many products contain insecticides as a preservative or as part of the chemical formulation.

Ecological entomologists: These entomologists are concerned with making regulations and enforcing the standards for protecting the environment, public health, and safety. Proper waste disposal and treatment are also included. Usually a bachelor's degree or higher is necessary.

Career Areas Enhanced by Entomology

There are many careers that do not require a professional degree in entomology, but they are enhanced by a general or working knowledge about insects. The job will determine how much knowledge about insects is required. Some occupations may require special licensing, such as in pesticide application. Occupations that benefit from a working knowledge of entomology include landscaping and turf management, animal and human medical care, food science, and biological science.

Landscaping and turf management: This area involves the care and maintenance of landscaped areas. People in this area take care of lawns and ornamental plants at domestic homes, public grounds, parks, golf courses, etc. Generally, a bachelor's degree or higher is required to be a supervisor. Less education is needed to be a technician or assistant. The job requirements will vary greatly depending on the size of the operation and the responsibilities one has. The area of pest control greatly overlaps here. Workers may need to have a pesticide certification if they apply certain insecticides.

Animal and human medical care: Areas of animal and human health care enhanced by a working knowledge of insects include medical assistants, research assistants, field technicians, horse groomers, livestock workers, and pet shop workers.

Food science: This is a large area involving any aspect of handling food. This includes processing, preservation, storage, packaging, transportation, and distribution of food for people or animals. People involved in food science also work in the development of new foods and serving methods. They work in restaurants or cafeterias and as dieticians. Some individuals work with agencies concerned with the regulation and enforcement of food quality and health and safety standards.

Biological science: This area includes all aspects of agricultural, ecological, and environmental sciences. For example, a conservationist needs to understand how changes in the environment affect insect populations.

Entomology

Summary

Entomology is the study of insects. Entomologists study the development, anatomy, physiology, life history, behavior, environment, and classification of insects. The impact of insects on society is enormous. There are many fields that employ entomologists and many others that are enhanced by a working knowledge of insects.

Credits

Apply Pesticides Correctly. Washington, DC: U.S. Department of Agriculture, U.S. Government Printing Office, 1975.

Bland, R.G. *How to Know the Insects*. Dubuque, IA: Wm. C. Brown Company Publishers, 1978.

Borror, D.J., and R.E. White. *A Field Guide to the Insects*. Boston, MA: Houghton Mifflin Company, 1970.

Boyd, E.M. *Toxicity of Pure Foods*. Cleveland, OH: CRC Press, 1973.

Evans, Howard E. *Insect Biology: A Textbook of Entomology.* Reading, MA: Addison-Wesley Publishing Company, Inc., 1984.

Greenhouse Operation and Management. University of Missouri-Columbia: Instructional Materials Laboratory, 2002.

Guidelines for Insecticide Use. Lexington: University of Kentucky, Department of Entomology, 1989.

Guidelines for the Control of Insect and Mite Pests of Foods, Fibers, Feeds, Ornamentals, Livestock, and Households. Washington, DC: U.S. Department of Agriculture, U.S. Government Printing Office, 1982.

Insect Control Recommendations. Columbia: University of Missouri Extension, 1990.

Pest Management Strategies in Crop Protection. Washington, DC: Congress of the United States, Office of Technology Assessment.

The Random House Encyclopedia. New York: Random House, Inc., 1977.

Lesson 2: Insect Collection

Making an insect collection is an ideal way to learn about insects. It opens the doors to the world in which these small creatures live. The collector is able to discover things about insects that he or she may not get from books. It allows insects which are very different to be studied and compared at the same time. Collecting insects is a very interesting hobby as well. Constructing an insect collection is not difficult, but it does require some care and time. There are certain steps and procedures that need to be followed when preparing insects for display. Some standard guidelines are given here.

Collecting Insects

Preparing a killing jar: A killing jar needs to be prepared before the insects are collected. Insects should be killed in a killing jar as soon as possible after they are collected. Therefore, the killing jar should be taken along when collecting insects. Killing jars or bottles can either be made or purchased. Wide-mouth jars (6 to 16 oz. size) with airtight lids are the most common. An alternative is to carry a large test tube or slender bottle with a cork or stopper in it. The insects are killed later.

Ethyl acetate, which acts as a fumigant, can be used to make a killing jar. It can be obtained from biological or chemical supply companies. It is much safer than other types of killing agents. The ethyl acetate type of killing jar can be made easily by following the procedure listed below. See Figure 2.1.

1. Make a thick mixture of plaster of paris and water.

2. Pour the mixture into a clean jar to a height of about 1 inch (20–30 millimeters). Allow it to air dry at room temperature (this requires several days) or under low heat (light bulb or lowest oven temperature).

3. When completely dry, add enough ethyl acetate to saturate the plaster of paris. With the lid on, let it stand for a few minutes. Then, pour back any excess liquid and replace the lid. There should not be any standing liquid. Be careful not to breathe the ethyl acetate fumes.

4. Place enough cotton to cover the plaster of paris. The insect should not come into direct contact with the plaster of paris.

5. Tape can be placed on the bottom and lower sides of the jar to reduce the chance of breakage.

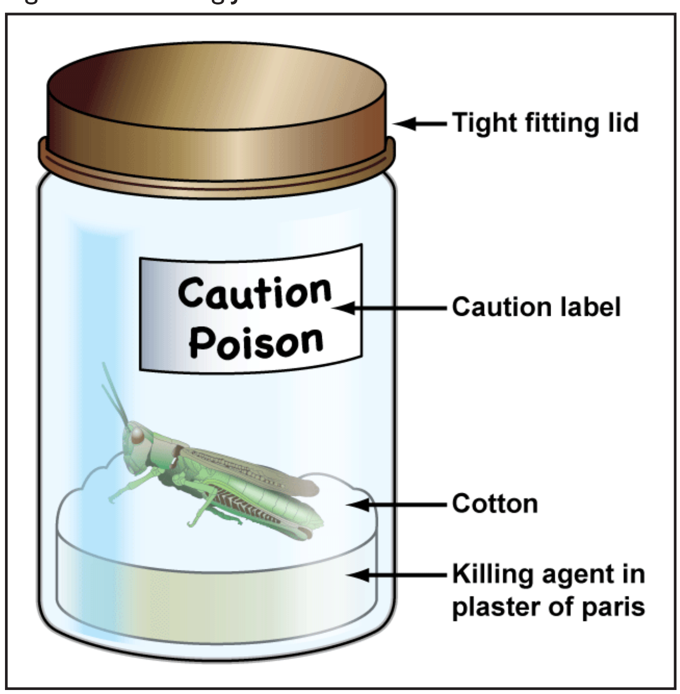
6. Label the jar "poison."

7. Ethyl acetate must be reapplied to the plaster of paris after several hours of collecting insects depending on how often and for how long the lid was removed. The lid should always be left on unless the collector is actually placing an insect in or removing one from the jar.

Locating insects: Insects can be found almost anywhere in the world. The more places you look, the more kinds of insects you are likely to find. Insects are commonly found in flower and vegetable gardens, grasses in lawns and fields, weeds, bushes, aquatic plants, fruit and shade trees, and animals.

Many insects can be found hiding in plants. Look between the petals in flowers and inside the stem. Leaf damage may indicate the presence of insects. If the stem has holes,

Figure 2.1 – Killing Jar



swellings, or a dead portion, it should be split to locate larvae living there. Soil insects, which feed on roots, are often found near or inside roots. Decaying fruits, nuts, vegetables, bark, logs, and wood piles are homes of many insects. Check tree holes that are filled with water for mosquito larvae and other insects.

Flying insects enjoy sunny, calm days. Certain flies, winged ants, and termites swarm in the spring and fall, especially when it is warm and sunny after rain. Use a net to catch flying insects, or check the radiator or front grill of a car for usable specimens. Certain insects may be found beneath or on top of the water. Mud along water shorelines is also the hiding place for many insects. Like plants on land, water plants are also homes for several kinds of insects.

A lot of insects may be hiding in garden topsoil, mulch, compost piles, and forest litter. To find certain soil insects, dig down about 6 inches under grasses and in garden soil. Since insects are almost everywhere, there are many other places to find them. Outside areas like under stones, logs, plant debris, and picnic trash bins are homes of insects. Household pests may be found in garages, basements, and food storage areas. Parasitic insects live in bird feathers and animal skin and fur. Some insects are not present during the day, but may be found at night.

Catching insects: The simplest way to catch insects is by hand. Place them in a killing jar or container. Gloves are recommended for catching insects. Many beginners may be hesitant to reach out and grab an insect because they are afraid that it might bite or sting. Although this is a common fear, it is not very likely to occur with most insects. Insects which bite do so by moving their jaws sideways and pinching, or by piercing with their beak. Actually, there are very few pinching insects capable of causing pain or breaking skin. Most biting insects cannot bite if they are grasped firmly by the sides of their body. Insects which sting do this by using a structure located at the back end of their body. Only female bees, wasps, and some ants can sting.

A net, envelopes, small boxes, forceps, a hand lens, flash lights, and killing jars are useful when gathering insects. A net is used by swinging it at insects as they go by or swinging it through vegetation or along the surface of water. To prevent the insect from escaping, quickly turn the net handle so that the bag folds over the rim. Insects should be removed from the net as gently and carefully as possible to prevent damage. To remove insects from the net, you can 1) remove them directly by gently grasping them with fingers or a tool, 2) insert a box or bottle into the net and ease the insect into this container, or 3) work the insect into a fold in the net and place this fold into a killing jar to stun the insect directly. If the insect is one that stings, it can be worked into a fold in the net and stunned by pinching the thorax before removal.

Killing insects: Place insects immediately into the killing jar after they are captured. If the killing jar is in use, the insects can be placed into another container with a lid. It is important to kill the insects as soon as possible so that they do not damage their body parts.

Preserving Insects

Specimens are kept in killing jars until it is time to preserve them. Most insects are normally preserved by "pinning." Pinning is a way to mount and preserve insects indefinitely. Insects should be pinned immediately after they are killed. Otherwise, they become very brittle after drying and can easily break if mounted later. Soft-bodied insects, larvae, and nymphs need to be preserved in liquid. The bodies of these insects will shrivel when dried. The most common liquid used for killing and preserving these insects is an alcohol solution.

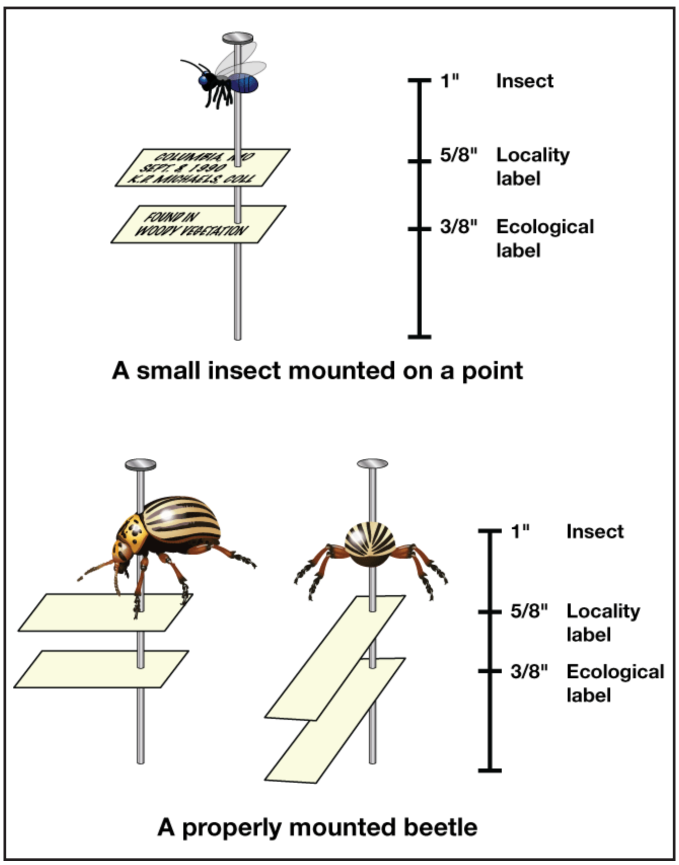
Another method for preserving insects is to keep them in envelopes. This works best for insects that have relatively slender and fragile bodies, such as dragonflies, damselflies, and crane flies. Using envelopes saves a lot of space and protects these types of insects better than mounting on pins. Envelopes can be made of paper or plastic. Label information is either written on the outside of the envelope or written on a piece of paper and placed inside the envelope.

Labeling

Locality and ecological labels: Labeling is a very important part of an insect collection. The information should be accurate and written clearly. Without data a specimen is useless. The first label, which is the locality label, *must* include the date when the insect was found and the place where it was caught. It may include the collector's name. A second label, called the ecological label, may be used. The ecological label would contain information or observations about the insect's environment or habitat.

These labels are made of fairly stiff white paper. They are about 1/4 by 3/4 inches or smaller in size. The labels are mounted on the pin at the proper heights and parallel with the insect (or point). The insects and labels could be mounted using a pinning block at the following marks: insects at the 1 inch mark, locality labels at the 5/8-inch mark, and ecological labels at the 3/8-inch mark. See Figure 2.2. They can be mounted so that they are read from either the right or left. Just make sure that all labels are read from the same direction. This helps keep the collection neat and orderly. For specimens mounted on microscope slides, the information is written on a slide label.

Figure 2.2 – Insect and Label Placement



Identification labels: An insect collection should contain some identification labels. Specimens in a collection should be arranged into groups according to insect orders. One label is used to identify each group. If the insects are labeled to the scientific level of species, an identification label is used for each individual specimen. A piece of paper about an inch square is used for the identification label. This is placed alongside a group of insects or at the base of the pin for individual insects. These types of labels contain the order of the group of insects or the scientific name of the insect, the name of the person identifying it, and the month and year when the identification was made.

Pinning

A special system has been developed for pinning insects. The procedures should be followed as closely as possible. Pinning is done with special *insect pins*, pins which are made especially for this purpose. They are sold in several sizes. The most common are Number 1 (very thin), Number 2 (thin), and Number 3 (thick, for larger insects). The simplest way to handle an insect for pinning is to hold the insect between the thumb and forefinger of one hand and insert the pin with the other hand.

Different insect types are pinned in different places. See Figure 2.3. Most insects are pinned through the thorax vertically. Beetles and hoppers are pinned through the front part of the right wing. Make sure the pin does not damage a leg as it comes through on the underside of the body. True bugs are pinned through the scutellum, if they are large enough. The scutellum is the triangular area between the bases of the wings. Otherwise, they are pinned like beetles through the right wing. Grasshoppers and crickets are pinned through the thorax between the bases of the front wings and just to the right of the midline.

Dragonflies and damselflies can be pinned in two ways. The best way is to pin them sideways. The left side should face up with the wings together above the body. The pin goes through the thorax below the wing bases. If the wings are not together when the insect is removed from the killing jar, place the specimen in an envelope with the wings together above the body for a day or two. The specimen is ready to pin when it has dried enough for the wings to stay in position. The other way is to pin the insect through the thorax with the wings placed horizontally.

When mounted, all of the insects and labels on pins should be the same height. The easiest way to do this is to use a pinning block. See Figure 2.4. A pinning block is usually made of wood. The block can be shaped as a solid rectangle or like stair steps. Holes are drilled to 1, 5/8, and 3/8 inches in depth. The following procedure should be followed when using a pinning block.

1. After placing a specimen on a pin, insert the pin in the 1-inch hole.
2. Then, add the first label and insert the pin in the 5/8-inch hole.
3. Finally, add the second label, if there is one, and insert the pin in the 3/8-inch hole.

Figure 2.3 – Pinning Locations

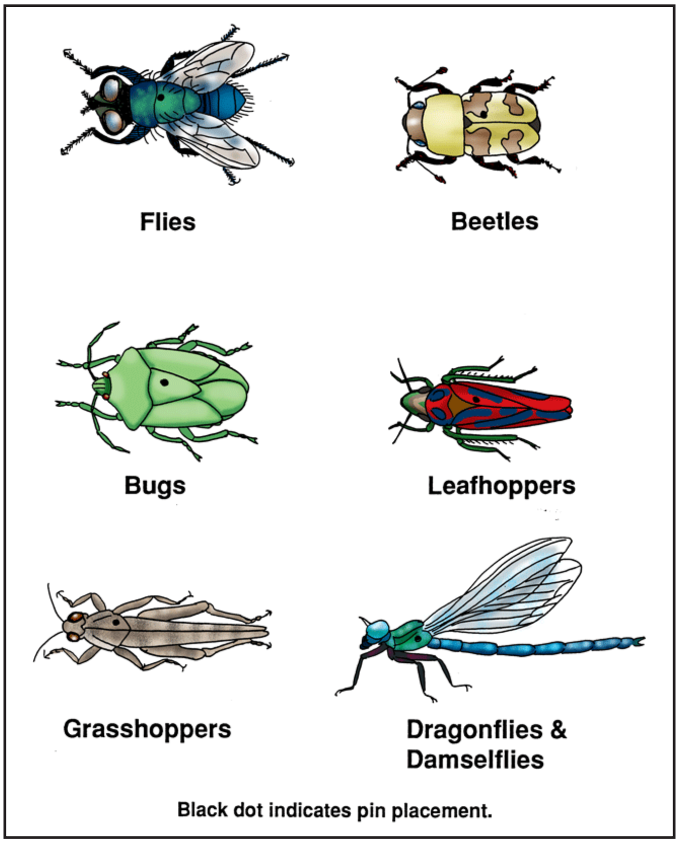
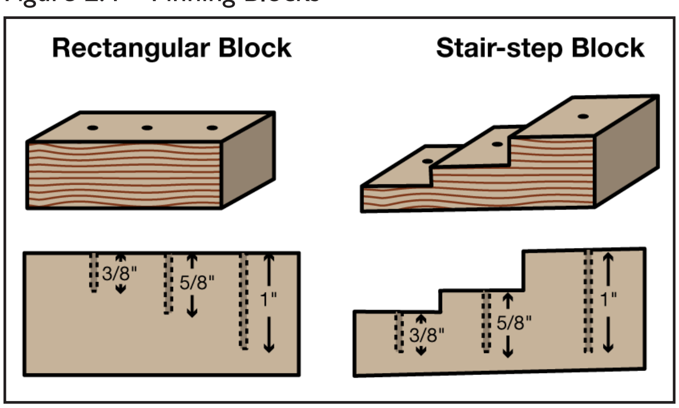


Figure 2.4 – Pinning Blocks



A mounted insect with two labels should look like Figure 2.2. Pinned specimens can be temporarily stored on a sheet of cork, balsa wood, or other soft material until placement into the collection.

The abdomen of some insects, such as dragonflies, may sag when pinned. One of the following techniques can be used to prevent this. The insects should be allowed to dry completely before they are placed in the collection.

1. Stick the pinned insect onto a vertical surface with the abdomen hanging down.
2. Place a small piece of cardboard on the pin just under the insect so that the abdomen is supported.
3. Insert two pins so that they cross under the abdomen. They will support the sagging abdomen.

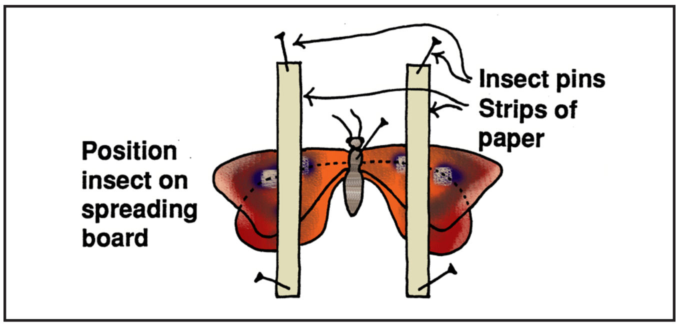
Some insects may be too small to put a pin through. These are usually mounted on a small triangular piece of cardboard called a *point*. Points are about 3/8 inch (8 millimeters) long and 3/16 inch (3–4 millimeters) wide at the base. The insect is glued to the tip of the triangle and the pin is put through the wide base. The entire setup is then mounted on the block as described before. Be careful to glue the insect so that the body parts you want to examine are not hidden. The suggested way is to glue the insect on the right side with the head facing away from the pin. A household cement or glue should be used.

Spreading Butterflies and Moths

For most insects, the exact position of the legs and wings is not generally important as long as all of the body parts can be seen. Insects such as butterflies and moths need to have their wings spread before being put into the collection. Insects can be spread on a spreading board or on a flat surface. To "spread" an insect on a spreading board follow the steps below. If a spreading board is not available, spread the specimen upside-down on a flat surface.

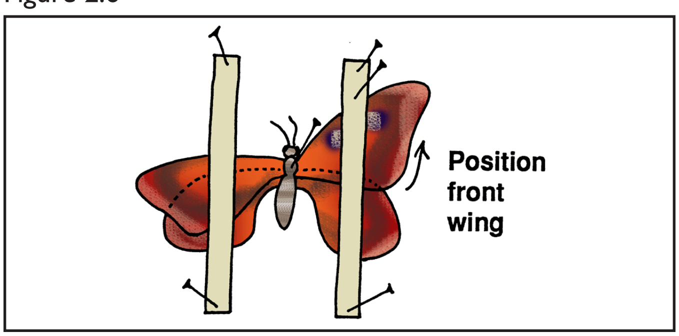
Step 1: Hold the specimen by grasping it by the thorax, the middle section of an insect. Holding it right side up, insert a pin through the middle of the thorax. Move it to the 1-inch position on the pin. The pinned specimen is then lowered onto the spreading board. The pin should go into, and maybe even through, the bottom of the groove. Push the pin through the board until the underside of the wings is even with the top piece of the spreading board. Pin narrow strips of paper over the wings on each side as indicated in Figure 2.5.

Figure 2.5



Step 2: Remove the pin on one side at the lower end of the strip of paper. Raise the front wing until the rear edge is at a right angle to the body. See Figure 2.6. Forceps, a pin, or some other tool may be helpful in doing this. Be careful not to tear or puncture the wing. When the wing is in place, insert a pin through the strip of paper just in front of the tip of the wing. Pin the lower edge of the paper strip back into place.

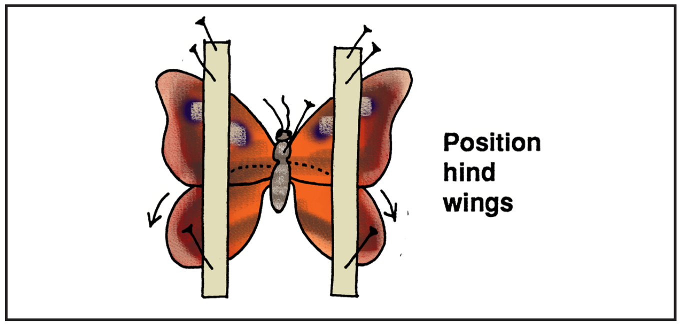
Figure 2.6



Step 3: Repeat this procedure with the other front wing.

Step 4: Use forceps, a pin, or some other tool to raise the hind wing on one side until the space between the two wings is reduced, as shown in Figure 2.7. The front and hind wings of theses insects will overlap at the base with the front edge of the hind wing under the rear edge of the front wing. Move the pin in the lower part of the paper strip until it is just below the tip of the hind wing.

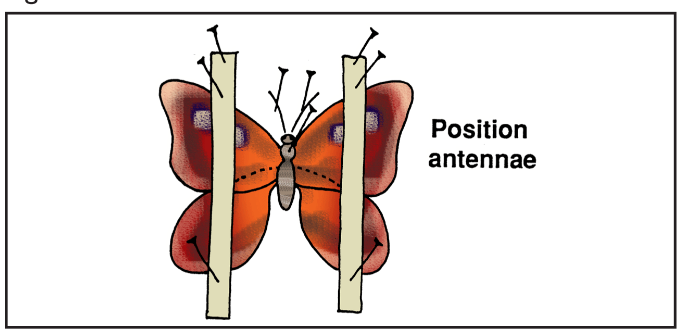
Figure 2.7



Step 5: Repeat this procedure with the hind wing on the other side.

Step 6: Now, position the antennae so that they appear balanced. Put pins alongside of the antennae to hold them in place. See Figure 2.8.

Figure 2.8



Step 7: Fasten the legs close to the body at right angles to the body. This is done by placing a strip of paper across the entire body.

After spreading the wings, the insect is left in position until it dries. How long it takes the insect to dry completely depends on the size of the insect, the temperature, and humidity. A large butterfly may take several days at room temperature or an hour with heat. Ovens or electric lamps are used as sources of heat. A specimen is dry when the abdomen is stiff when gently touched with a pin. If the abdomen is still flexible, the insect is not dry enough.

Collection Arrangement and Care

Once the insects are collected, preserved, pinned, and labeled, they need to be kept in an orderly and safe way. There is no exact way to organize an insect collection. The way the insects are arranged will depend on the size of the collection, the types of insects collected, and the preference of the individual. Whatever way it is done, the collection should be neat and orderly, and the insects easily seen. Specimens are kept in some sort of display for study and storage. There are several different kinds of mounting displays. These mounting containers can be bought at a local supply store or handmade.

Mounting box: The most common type of display for pinned insects is a mounting box. The box is made of wood or heavy cardboard. Boxes can be any size but usually measure about 9 x 12 x 3 inches and have a tight fitting lid. The bottom is lined with a material that is sturdy enough to securely support the pins but soft enough to easily insert the pins. These materials are usually sheet cork, balsa wood, Styrofoam, or corrugated cardboard.

Riker mounting: The Riker mount is a box with one piece of glass on the top. The box is filled with cotton and the insects are mounted on the cotton just under the glass. A small depression is made in the cotton before putting in a thick-bodied insect. Insects in a Riker mount can be seen easily and the mounts handled without damaging the samples. However, only one side of the specimen can be seen. Also, some insects, such as moths, tend to fade after a lot of exposure to the light.

Glass mount: The glass mount is another kind of display. This type has two pieces of glass, one on the top side and one on the bottom side of the box. The size and the materials used for glass mounts are similar to Riker mounts. Glass mounts contain no cotton. This makes it possible to see both sides of an insect specimen. Each glass mount contains only a few insects. They are relatively inexpensive and provide a safe, attractive method for storing and displaying insects.

Plastic mount: Plastic mounts are made of two sheets of thick plastic. The insect is mounted between the plastic. Then, the edges are sealed with acetone or tape. An alternative type of plastic mount is made by embedding an insect in a block of plastic. This is a very involved process, but the end product is very attractive, durable, and permanent.

Slide mount: Insects or parts of insects can be studied in detail by mounting them on slides. Small insects, insects that shrivel up when dried, and soft bodied insects are commonly mounted on slides. Also, parts of insects such as the wings, mouth parts, genitalia, legs, and antennae are mounted on slides for further study. Some specimens have areas that are dark colored. Usually these areas are treated before mounting. The treatment removes some of the dark coloring so that it can be seen well. Samples are mounted on microscope slides using different chemicals. These chemicals have different functions. More information on the purposes of these chemicals can be found in technical books on the subject.

Insect collections need to be protected from beetles and other pests that can attack and damage the specimens. Collections should be examined regularly for signs of damage. Special pest repellents can be bought to treat collections. For a box display, the repellent can be placed in a small pillbox or wrapped in a piece of cloth. It is then placed securely in one corner of the box. For Riker mounts, the repellent can be placed underneath the cotton. Specimens sealed in glass mounts or in plastic need to be treated with repellent before the mount is sealed.

Insect specimens are very brittle when they are dry. They always need to be handled with care. Otherwise, the legs, antennae, wings, and other parts may be broken off. However, if parts do get broken off, use glue or cement to replace them.

Summary

Making an insect collection is an ideal way to learn about insects. It allows insects that are very different to be studied and compared at the same time. Constructing an insect collection involves making a killing jar and locating, preserving, pinning, mounting, labeling, and arranging the insects. The proper techniques should always be followed when making an insect collection. When properly done, a collection can last a very long time. An insect collection is a great adventure into the world of insects.

Credits

Bland, R.G. *How to Know the Insects*. Dubuque, IA: Wm. C. Brown Company Publishers, 1978.

Borror, D.J., and R.E. White. *A Field Guide to the Insects*. Boston, MA: Houghton Mifflin Company, 1970.

Evans, Howard E. *Insect Biology: A Textbook of Entomology.* Reading, MA: Addison-Wesley Publishing Company, Inc., 1984.

The Random House Encyclopedia. New York: Random House, Inc., 1977.

Lesson 3: Insect Identification

Lesson 2 presented information on where to look for insects, how to collect them, and how to prepare specimens for a collection. The next step is to learn the details of insects' bodies, the distinguishing features of each order, and how insects are divided into groups.

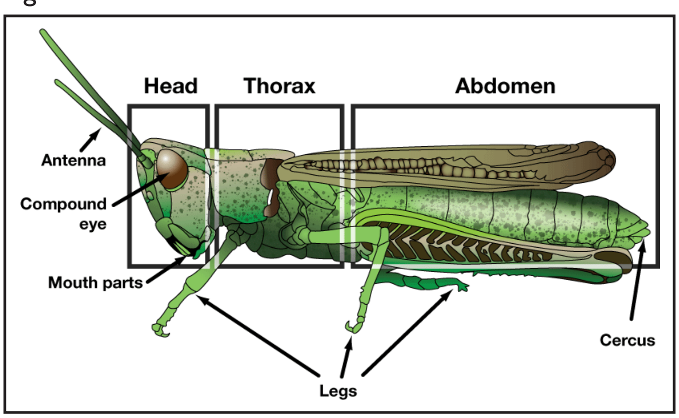
Distinguishing Characteristics of an Insect

What exactly is an insect? In Lesson 1, an insect was defined as a small six-legged animal. In this lesson, an insect will be more clearly defined. What determines which animals are put into this class and which are not? There are certain characteristics which set insects apart from other animals. An insect is a small animal without a backbone that has the following external characteristics as an adult.

◊ A hardened external skeleton
◊ Three distinct body regions: head, thorax, and abdomen
◊ One pair of segmented antennae
◊ Three pairs of segmented legs on the thorax segment
◊ One pair of compound eyes (Some insects have no eyes.)
◊ One or two pairs of wings (Some adults are wingless.)

Before becoming adults, insects are called *immatures*. The shape of immatures depends on the species. The best way to study and identify insects is to look at the three main body sections: the *head, thorax, and abdomen*. See Figure 3.1

Figure 3.1 – Three Main Sections



The Three Main Sections of an Insect

Head: The head is the hardened region at the front of the body, which includes the eyes, antennae, and mouth parts. There are two types of eyes. Simple eyes are small eyes located on top of the head of adults. Compound eyes are the large eyes found on most adult insects. These eyes contain a few to several thousand individual eye units. Often insects can only see light and dark areas and cannot see objects distinctly.

Insects have one pair of antennae. Antennae are two long, jointed feelers that grow from the insect's head. Antennae are flexible and come in a variety of shapes. See Figure 3.2. Antennae function as sensors to detect the odor, sound, taste, and feel of the surrounding environment. The mouth parts are also in the head region. Chewing and piercing-sucking are the two main types of mouth parts. See Figure 3.3. Some insects will have a modification or adaptation of these. Mouth parts determine how the insect feeds. Chewing mouth parts are strong, curbed, and toothed. They are used for chewing, cutting, crushing, or grinding. Chewing mouth parts crush hard seeds and tear food into pieces. Mouth parts may have other functions as well. Chewing jaws can be used like scissors or tongs. They can also dig like little shovels or plow like tiny bulldozers.

Figure 3.2 – Types of Antennae

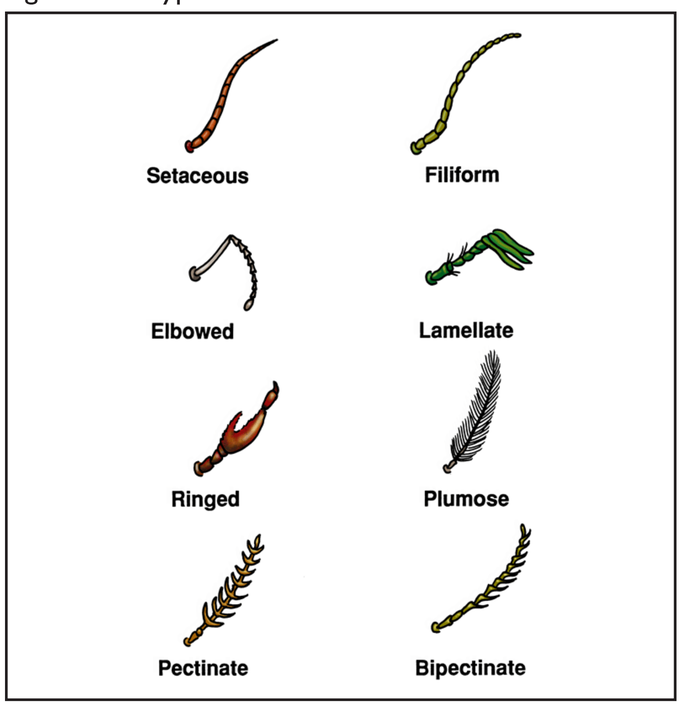
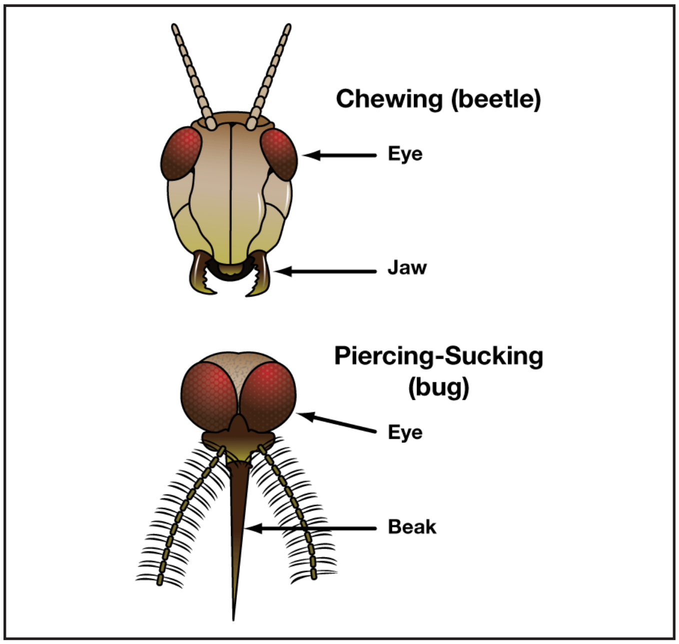


Figure 3.3 – Mouth Parts



Some insects use their strong jaws to squeeze their enemies to death or to cut off their heads.

Piercing-sucking mouth parts are long and needle-like for piercing leaf surfaces or skin. Special sucking structures suck up the fluids. Examples of mouth parts that are a variation of chewing and piercing-sucking are rasping-lapping, reduced chewing, chewing-sucking, and sponging. How these are used depends on the particular insect species.

Thorax: The thorax is the second section of an insect's body. This section contains the nerve centers and muscles that control the insect's movement. Wings and legs are attached to the thorax. Insects have three pairs of legs. Each leg has five parts, although sometimes the parts are hard to see. The legs come in many forms depending on their functions, such as running, jumping, grasping, or swimming. See Figure 3.4.

Adult insects may not have wings. There is a great variety in the shape, size, color, thickness, and vein pattern of insect wings. See Figure 3.5. The shape of the wings and the pattern of the veins are used widely in identification.

Abdomen: The abdomen is the third section of an insect's body. It may be visible or hidden underneath the wings. This section contains the internal organs of the insect. It is the location of the stomach and intestines, where food is digested and absorbed. There is also a place that is used to store food and to carry it back to the nest for other insects. The sexual organs are in the abdomen as well. The abdomen has glands that secrete different types of fluids, such as liquids that mark their trails or drive enemies away. This section may also have a needle-like projection for piercing or stinging.

Life Stages of Insects

The development of insects refers to growth in size and changes in form. There are three stages of development for every insect: the embryo stage, the immature stage, and the adult stage. See Figure 3.6. Insects begin life as an egg.

Insects may lay from a few to many thousand eggs at a time. The insect lives as an embryo within the egg. The egg is well supplied with a nutritious yolk and surrounded by a delicate outer shell. It may take days, weeks, or months for the insect to hatch. After hatching, the little insect continues to feed and grow through several more stages until it reaches the adult stage.

Figure 3.4 – Types of Legs

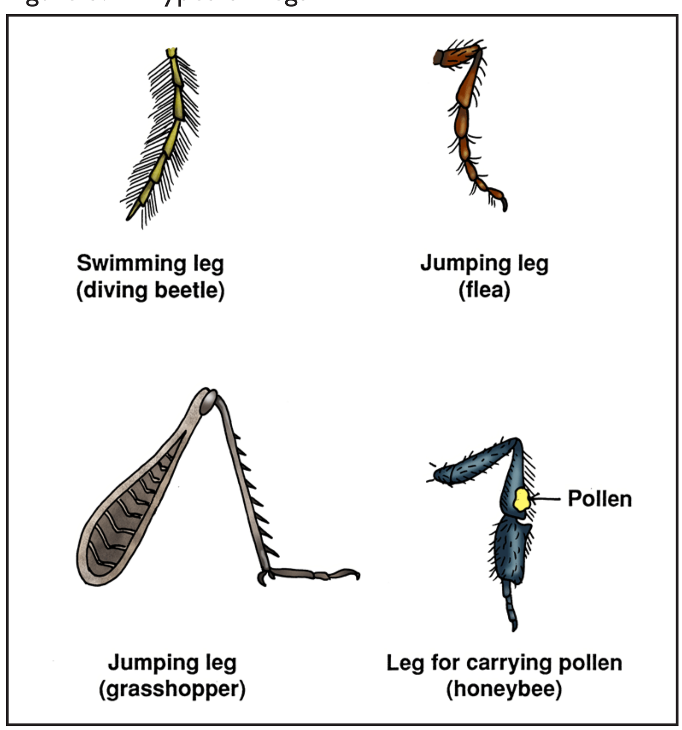
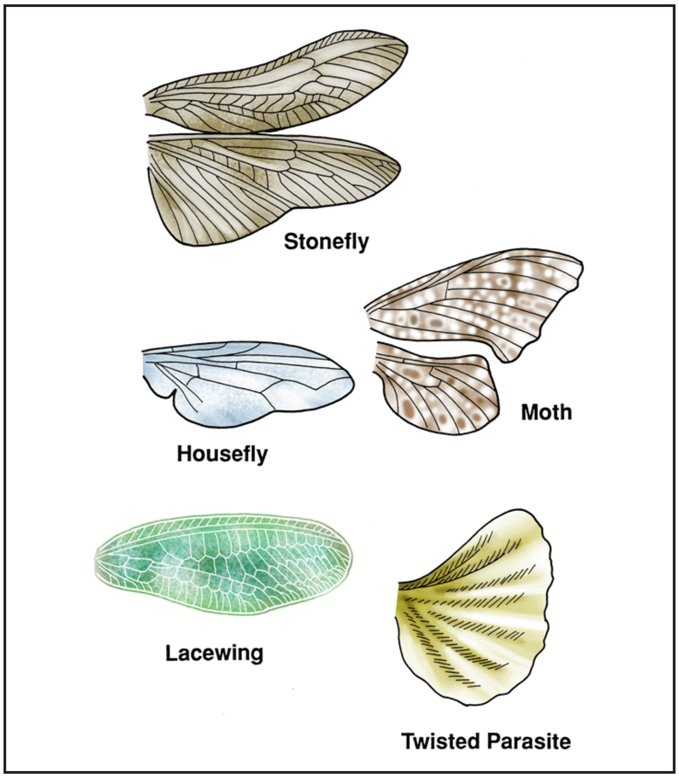
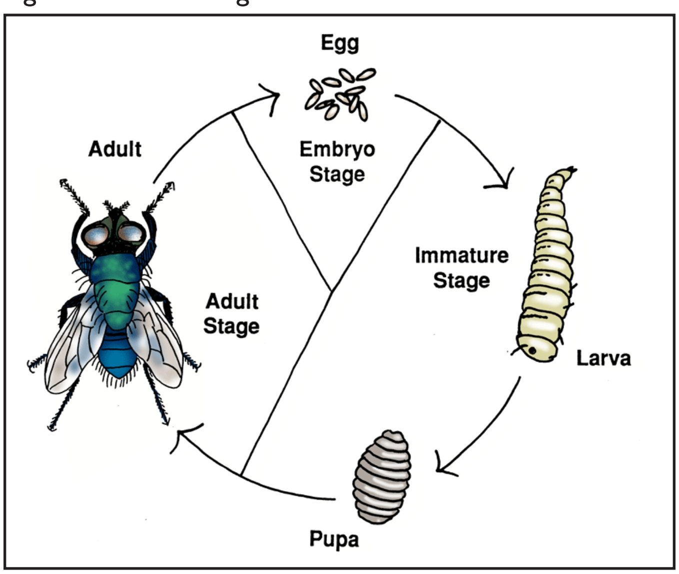


Figure 3.5 – Examples of Wings



After the insect hatches, it is called an *immature*. The life of an immature insect is divided into growth stages called *instars*. During each instar, the insect changes in form and size. As the insect grows, it forms an outer layer to protect its body from the environment. This layer is hard and rigid. When the insect grows too big to continue living in this hard layer, it begins to break out of it. The older layer is

Figure 3.6 – Life Stages

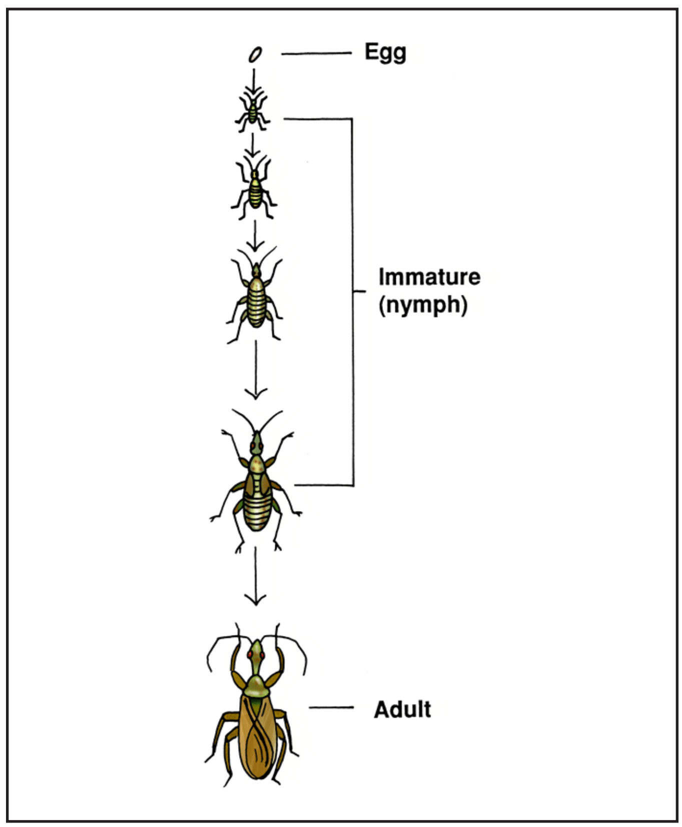


shed and a new outer layer is formed. The process of shedding the old layer is called *molting*. The most dramatic changes in the growth and form of an insect are seen when the insect molts.

Insects go through a series of instar growth, molting, instar growth, molting, etc. This continues until it becomes an adult insect. The entire process of development is called *metamorphosis*. Most insects go through one of two basic types of metamorphosis, incomplete and complete. There are a few primitive species of insects that do not go through metamorphosis at all.

Incomplete metamorphosis is the first type of insect development. See Figure 3.7. The immature insects look like the adults, only smaller. The immatures of incomplete metamorphoses are called *nymphs*. The changes are mainly an increase in size and the development of wings and sexual organs. Nymphs usually eat the same type of food as the adults. Examples of insects having incomplete metamorphoses are the grasshopper, thrip, stink bug, leafhopper, and aphid.

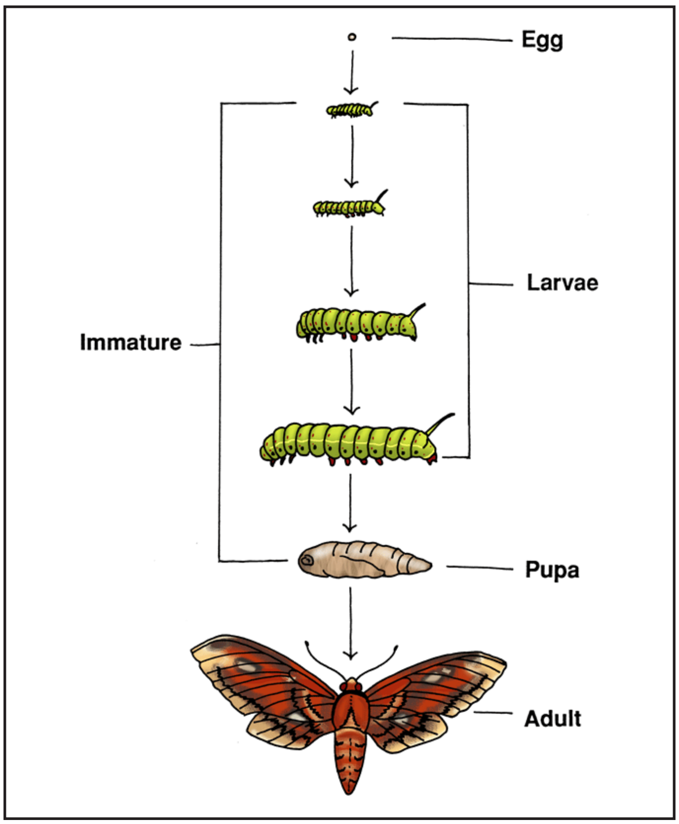
Figure 3.7 – Incomplete Metamorphosis



The second type of insect development is complete metamorphosis. See Figure 3.8. These insects do not look like the adults when in the immature stage. The immatures of complete metamorphoses are called *larvae*. Larvae are small, white forms that do not have eyes or legs. They do have a head and mouth parts. Examples of insects having complete metamorphoses are the lady beetle, weevil, fly, and moth. Insects with complete metamorphoses have also one additional stage of development called the *pupa*. When the larva becomes mature, it sheds its skin (or molts) one more time and emerges as a pupa. The pupa is shaped like an insect with the legs and antennae folded against its body. The larvae of some insects surround themselves with a cocoon just before they molt and emerge as pupas.

Although it does not eat and barely moves, great changes take place in the body of the pupa. Most of the structural changes take place during the pupa stage. The adult's digestive system and reproductive system are fully formed. The adult's wings, legs, antennae, and mouth parts develop completely. When the adult's body is completely formed, the insect breaks out of the outer, pupal skin. If there is one, the cocoon is left at the same time. Other insects may help the young one break out.

Figure 3.8 – Complete Metamorphosis



When the insect first emerges as an adult, the wings are crumpled and the body is soft. Within minutes to hours, the adult's body dries, hardens, and develops color. The wings expand as air blows between them and their structure becomes more rigid. The adult starts its normal life. Depending on the species, adults may live from 1 hour to 20 years. In general, adults live only a few weeks.

Insect Classification

In order to identify each type of animal, the animal kingdom is divided into many groups. Insects belong to one of the basic divisions of the animal kingdom called *Arthropoda*. This division also includes centipedes, crabs, lobsters, scorpions, and spiders. Arthropoda is divided into several *classes*. Insects make up the class *Insecta*. Insecta is a Latin word that can be broken down into its basic meanings: in = "into" and sect = "cut." An insect is identified by its segmented body. This class is further divided into *orders* of insects. The different orders are determined by certain characteristics, such as wing structure, mouth parts, and life cycle. Presently, entomologists agree on 29 orders of insects.

Orders are further divided and sub-divided into other groups. Each of these groups becomes more and more specific until, at last, each insect species can be identified by its own name. See Figure 3.9.

Each insect is identified by a scientific name. This name has two parts: the *genus* name (written capitalized) followed by the *species* name (written lower case). The genus is like a person's last name, or family name. The species is like a person's first name. Insects may also have common names. Insects' common names would be like nicknames. For example, a person may have his name listed as "Doe, Jonathan," but his friends call him Johnny. An insect may have the scientific name "Romalea microptera," but is commonly called a grasshopper. When learning scientific names, it is very helpful to find out what the name means. This often gives a clue to some part of the insect's life and makes it easier to remember.

Figure 3.9 – Insect Classification

Phylum – Arthropoda
Class – Insecta
Subclass – Pterygota
Infraclass – Neoptera
Series – Exopterygota
Superorder – Orthopterodea
Order – Orthoptera
Suborder – Caelifera
Family – Acrididae
Subfamily – Romaleinae
Genus – Romalea
Species – microptera

Scientific name: Romalea microptera
Common name: Eastern lubber grasshopper

It is impossible to memorize all the insects and their classification. Books such as field guides or insect keys should be kept close at hand and referred to often. Insect guides contain information such as a description of the insect, distinguishing features of the order, how different insects are related to one another, and the lifestyle and environment of the insect. Each guide is a little different so the introduction on how to use the book should always be read first. Beginners are advised to select a guide that has many clear pictures or drawings. The various parts of the insects should be clearly identified and labeled.

The 29 orders and a brief description of each are summarized in the following paragraphs. The summaries include the scientific name, the meaning of the name, the common name, the number of species in each order, the type of metamorphosis, the type of mouth parts, and the main characteristics that distinguish each order.

The Insect Orders

1. **Collembola** • "*glue peg*" • springtails • 1,500 species • no metamorphosis • chewing mouth parts, withdrawn into head • wingless; long antennae; reduced compound eyes or none; most species can jump using a forked springing organ on the abdomen
2. **Protura** • "*first tail*" • Proturans • 170 species • no metamorphosis • piercing-sucking or chewing mouth parts, withdrawn into head • wingless; no eyes; only insects with no antennae; front legs carried upright like antennae and used to sense touch
3. **Diplura** • "*double tail*" • campodeids, japygids • 660 species • no metamorphosis • chewing mouth parts, withdrawn into head • wingless; long, slender antennae; no eyes or small eyes shaped like a slit
4. **Thysanura** • *"tassel tail"* • bristletails, silver fish • 350 species • no metamorphosis • chewing mouth parts • wingless; long, slender antennae; compound eyes reduced or absent; usually scaly body; two or three bristlelike tails; run swiftly or jump when disturbed
5. **Ephemeroptera** • *"short-lived, wings"* • mayflies • 1,000 species • incomplete metamorphosis • chewing mouth parts • usually two pairs of membranous wings that are held flat over body when at rest, hind wings much smaller than front wings; very short antennae; large eyes; two or three long tails; adults do not eat and die soon
6. **Odonata** • *"toothed"* • damselflies, dragonflies • 5,000 species • incomplete metamorphosis • chewing mouth parts • two pairs of equal-sized, transparent, and membranous wings that cannot be folded; very small antennae; huge eyes; strong fliers; cannot walk, but legs used to catch prey in air; mate in flight
7. **Dermaptera** • *"skin wings"* • earwigs • 1,200 species • incomplete metamorphosis • chewing mouth parts • wingless or two pairs of wings: front wings short and leathery, hind wings large and membranous, folded under front wings when at rest; forceps on abdomen
8. **Grylloblattodea** • **"***cricket cockroach"* • rock crawlers, icebugs • 12 species • incomplete metamorphosis • chewing mouth parts • wingless; legs adapted for running; small eyes are long and segmented; antennae are long; live in low-temperature places; active at night; rare

9. **Isoptera** • *"equal wings"* • termites • 2,000 species • incomplete metamorphosis • chewing mouth parts • two pairs of similar, membranous wings held flat over the body when at rest; wings shed after mating flight; workers and soldiers are wingless

10. **Dictyoptera** • *"net wings"* • cockroaches and mantids • 5,300 species • incomplete metamorphosis • chewing mouth parts • front wings are thick and hind wings are membranous and folded; have short wings or are wingless, fly poorly

11. **Phasmida** • *"phantom"* • walking stick or leaf • 2,000 species • incomplete metamorphosis • chewing mouth parts • slow-mowing; some are wingless and look like sticks; wings and legs of others look like broad leaves; can change color

12. **Orthoptera** • *"straight wings"* • crickets, locusts, grasshoppers • 20,000 species • incomplete metamorphosis • chewing mouth parts • two pairs of wings: front wings narrow and leathery, hind wings are broad and membranous and folded under front wings when at rest; medium to long antennae; some species wingless, some species make shrill creaking sounds by rubbing special body structures together

13. **Embioptera** • *"lively wings"* • web spinners • 140 species • incomplete metamorphosis • chewing mouth parts • females and some males are wingless, most males have two pairs of membranous wings; front legs have organs for spinning silk

14. **Plecoptera** • *"pleated wings"* • stone flies • 1,300 species • incomplete metamorphosis • chewing mouth parts • two pairs of membranous wings: folded flat over body when at rest, hind wings larger than front wings; long antennae; small eyes

15. **Zoraptera** • *"pure, wingless"* • zorapterans • 16 species • incomplete metamorphosis • chewing mouth parts • have four wings or are wingless: wings have few veins, adults break off wings; compound eyes and small eyes; thread-like, segmented antennae; rare

16. **Psocoptera** • *"gnawing wings"* • bark lice, book lice • 1,700 species • incomplete metamorphosis • piercing-sucking mouth parts • two pairs of membranous wings: roofed over back when at rest, front wings larger than hind wings, some species are wingless

17. **Mallophaga** • *"to eat wool"* • chewing lice • 2,675 species • incomplete metamorphosis • chewing mouth parts • wingless; have reduced eyes or no eyes; parasites of birds and a few mammals, feed on feathers, hair, and skin

18. **Anoplura** • *"unarmed tail"* • sucking lice • 2,900 species • incomplete metamorphosis • piercing-sucking mouth parts • wingless; short antennae; have reduced eyes or no eyes; parasites that suck the blood of mammals

19. **Thysanoptera** • *"fringe wings"* • thrips • 4,500 species • incomplete or complete metamorphosis • chewing mouth parts • two pairs of wings fringed with long hairs and fold flat over body when at rest, some species are wingless; short antennae; females of many species can reproduce without mating; males are unknown in some species

20. a) **Hemiptera** • *"half wings"* • true bugs, chinch bugs • 28,000 species • incomplete metamorphosis • piercing-sucking mouth parts • two pairs of wings: bases of front wings are thick and leathery, hind wings are membranous and fold under front wings when at rest, some species are wingless

    b) **Homoptera** • *"same wings"* • aphids, cicadas • 32,000 species • incomplete or complete metamorphosis • chewing mouth parts • wingless or one or two pairs of membranous wings, roofed over body when at rest; females of some species can reproduce without mating

21. **Neuroptera** • *"nerve wings"* • ant lions, lacewings, alderflies, and dobson flies • 4,500 species • complete metamorphosis • piercing-sucking mouth parts, sucking parts are shaped like a coiled tube when not in use • two pairs of wings: similar,

membranous, covered with many vein's, and roofed over body when at rest; long, slender antennae; larvae and adults are predatory

22. **Coleoptera** • *"sheath wings"* • beetles • 350,000 species • complete metamorphosis • chewing or chewing-lapping mouth parts • two pairs of wings: front wings modified into thick, horny wing covers, hind wings membranous and fold under the front wings when at rest, some species are wingless

23. **Strepsiptera** • *"twisted wings"* • strepsipterans • 300 species • complete metamorphosis • piercing-sucking mouth parts • males have one pair of membranous hind wings, front wings are reduced to clublike parts; females do not have antennae, eyes, wings, or legs; they live in other insects

24. **Mecoptera** • *"long wings"* • scorpion flies • 300 species • complete metamorphosis • reduced chewing mouth parts • two pairs of long, slender, and membranous wings, laid flat or roofed over the body when at rest, some species are wingless; long, slender antennae; large eyes; long legs; tip of abdomen of some males are curved like a scorpion's tail

25. **Siphonaptera** • *"tube, wingless"* • fleas • 1,000 species • complete metamorphosis • reduced chewing mouth parts • wingless; body flattened from side to side; simple or no eyes; long hind legs for jumping; parasites that suck blood of birds and mammals

26. **Diptera** • *"two wings"* • flies, mosquitoes • 70,000 species • complete metamorphosis • chewing mouth parts • front wings transparent, hind wings replaced by short, knobbed structures; large eyes

27. **Trichoptera** • *"hair wings"* • caddis flies • 3,000 species • complete metamorphosis • piercing-sucking or sponging mouth parts • two pairs of hairy, membranous wings, roofed over the body when at rest; long antennae; larvae live in cases of silk and debris near or on water; adults eat little

28. **Lepidoptera** • *"scale wings"* • butterflies, moths • 165,000 species • complete metamorphosis • piercing-sucking mouth parts • two pairs of scaly, usually broad, wings, front wings are usually larger than hind wings; long antennae; large eyes

29. **Hymenoptera** • *"membrane wings"* • ants, bees, wasps • 110,000 species • complete metamorphosis • chewing or chewing-sucking mouth parts • two pairs of wings: small, stiff, and membranous, interlock during flight, front wings are larger than hind wings, worker ants and a few other insects are wingless

Summary

Insects are identified and classified according to common characteristics. Features commonly used are the wings, body shape, mouth parts, and type of metamorphosis. Insects are grouped into 29 orders based on these characteristics. Insect identification guides or keys are very helpful references. They contain a systematic way of finding a great variety of information on many types of insects.

Credits

Bland, R.G. *How to Know the Insects.* Dubuque, IA: Wm. C. Brown Company Publishers, 1978.

Borror, D.J., and R.E. White. *A Field Guide to the Insects.* Boston, MA: Houghton Mifflin Company, 1970.

Evans, Howard E. *Insect Biology: A Textbook of Entomology.* Reading, MA: Addison-Wesley Publishing Company, Inc., 1984.

The Random House Encyclopedia. New York: Random House, Inc., 1977.

Lesson 4: Methods of Control

Insects can be controlled by several different methods. Each of these methods has its own advantages and disadvantages. The methods of control are grouped as biological, cultural, physical and mechanical, and chemical. Usually, an effective insect control program uses a combination of methods, depending on the needs of the individual.

Biological Control

The biological control of pests is the oldest control method available. All creatures in nature have natural enemies that repel, kill, and consume them. If these natural enemies were not here, the world would be overrun with insects. Biological control is the use of naturally occurring bacteria, diseases, fungi, viruses, insects, nematodes, birds, fish, toads and frogs, lizards, snakes, rodents, weeds, and others to control insects.

These methods require that the individual has an extensive knowledge about the insect's life cycle, habitat, and response to environmental conditions. Individual insect types cannot be selectively controlled. Biological control requires a lot of time to become effective and then may be only partially effective. It also requires a knowledge of how the environment will be affected by any particular method. The effects on the environment cannot be very well predicted. Although not all biological control methods are costly, they can be very expensive and labor intensive. At this time, these methods are not practical for commercial agriculture. There are four general areas of biological control.

Natural enemies of the insect: This involves selectively increasing the population of the enemies that destroy a particular insect. Insects, such as the ladybug and the praying mantis, are valued because they prey upon a variety of insects that are considered harmful to producers. This method can also involve releasing a virus or disease that infects and kills a particular insect.

Resistant plant varieties: Plant varieties resistant to insect attacks are developed both in nature and through research programs. These host plants are resistant to insects and diseases.

Crop rotations: Crop rotation is an effective biological control method that is used against certain insects. It involves rotating the type of crop grown in a particular spot so that the same crop is not grown year after year. By changing the host species and the environment, insects are less able to build up their populations. Crop rotation is especially effective where insects are not very mobile. This method works because it disrupts the life cycle of the insect and the alternate crop is not suitable for the insect's growth and development.

Sterilization: Radiation or chemicals can be used to sterilize or to genetically alter insects so that they cannot reproduce. These insects can be released into the environment. The particular insect population is then reduced, because it cannot reproduce. This method seems promising but is not yet practical for normal field conditions.

Cultural Control

Cultural control is the management of insect populations by modifying the environment. A thorough knowledge of the insect's life cycle, habitat, and response to the environment is essential for these practices to be successful. Usually, the goal is the make the environment less attractive or agreeable for insects by using standard agricultural practices. These methods are based on disrupting the physical conditions that favor insect life. It is essential to know which conditions to disturb and when to disturb them.

Cultural control methods are only partially effective and individual insect types cannot be selected out. These methods do not require special machinery or equipment and most are not labor intensive. Common cultural methods include tillage, crop rotation, sanitation, timing of harvesting and planting, and water management.

Tillage: How the soil is prepared affects the temperature, moisture, and physical conditions of the soil. Insects may be killed directly by tillage or indirectly. Insects brought to the surface are unprotected and can easily die due to exposure or from being eaten. Often, immature insects living in the soil are killed before they can complete their life cycle.

Crop rotation: This is considered a means of cultural control as well as biological control.

Sanitation: This means removing weeds or crop residues where insects might live. Weeds may attract insects that spread to crop plants. Also, weeds and crop residues may keep insects alive between crop plantings. Plowing under or shredding weeds and crop residues can reduce many insect problems.

Timing of harvest and planting: Insects may be active in large numbers only for a brief period of the season. If it is possible, time the planting and harvesting of crops so that crops are not growing when insects are most active.

Water management: Many insects depend on water or soil moisture for proper growth and development. Regulating water sources can help control insects.

Physical and Mechanical Control

The goal of physical and mechanical control methods is to destroy insects directly or to modify the environment so that it is unsuitable for insect pests. Physical methods destroy insects by using the physical properties of the environment. Mechanical methods require machinery or manual operations to destroy insects. Often these methods are used together. These methods are different from cultural methods because special equipment or operations are used in addition to regular agricultural practices.

Physical and mechanical methods can give immediate and noticeable results. However, they may be expensive and labor intensive. Also, they are only partially effective. There is limited application in commercial agriculture and large field operations. A good knowledge of the insect's life cycle and habitat is necessary when using these techniques. Determining the type of physical and mechanical control methods that can be used depends on how an insect responds to temperature, humidity, odors, and light. Physical and mechanical control methods include cold storage of fruits and vegetables, applying heat, flooding insects out with a wash, treating agricultural products with protective gases, burning crop stubble and field edges, and insect traps used with an attractant (such as roach motels, or sticky insect strips).

Chemical Control

Chemical control primarily involves the use of insecticides. Chemical insecticides work very quickly and effectively. Insect control can be managed better with chemicals than any of the other methods. Insecticides can be extremely dangerous to people, animals, and the environment, if they are not applied properly. They may destroy beneficial insects as well as harmful ones, but it is possible to control a particular insect without harming other beneficial insects, humans, plants, or animals. Some harmful insects develop a resistance to insecticides after a few generations, thus causing the insecticide to be useless in their control. Only a general knowledge of the insect's life cycle, habitat, and response to the environment is needed. Chemical control is usually not labor intensive. Chemical insecticides are usually classified by how they are made. The main groups are known as organic, inorganic, botanical, and bacterial.

Organic: These are manufactured materials that consist mainly of carbon, hydrogen, and oxygen. They are the most widely used type. Numerous organics are available. Organic insecticides are classified in three groups.

1. Chlorinated Hydrocarbon – These insecticides, which are also called organic chlorines, are considered long-lasting because once they are used, they affect living things for several years. They do not break down easily in the environment. Examples are DDT, chlordane, and lindane. Chlorinated Hydrocarbon is slowly being replaced by other kinds.

2. Organic Phosphate – These insecticides contain phosphorus. They can be used on food crops because they do not leave harmful deposits on or in foods. They must be handled carefully because they are highly poisonous to man. Parathion and malathion are examples.

3. Carbamate – Carbamates contain groups of nitrogen and hydrogen and can be used to kill most insects. They do not leave harmful deposits on food, but some are harmful to warm-blooded animals. Aldicarb, bendiocarb, carbaryl, and carofuran are examples.

Inorganic: These are usually made from minerals. Many inorganics are used to protect cotton, fruit trees, vegetables, and livestock. Since several of these do not break down easily in the environment, they are being replaced by substances that break down more quickly. Lead, arsenate, boric acid, and sulfur powder are examples of inorganic insecticides.

Botanical: These are made from plants. Plant parts are processed and used as either the active killing ingredient or as an attractant. Nicotine, potenome, and dried pyrethrum flowers are examples.

Bacterial: Bacteria are used to infect insects with diseases. Most insecticides work on a general class of insects, whereas a bacterial insecticide specifically kills one kind of insect. They are used on Japanese beetles and caterpillars.

Summary

Insect control is very important in our society. There are several different methods for controlling insects. These control methods are classed as biological, cultural, chemical, and physical and mechanical. Each of these methods has its own advantages and limitations. Usually, an effective insect control program uses a combination of the methods, depending on the needs of the individual.

Credits

Evans, Howard E. *Insect Biology: A Textbook of Entomology*. Reading, MA: Addison-Wesley Publishing Company, Inc., 1984.

Guidelines for the Control of Insect and Mite Pests of Foods, Fibers, Feeds, Ornamentals, Livestock, and Households. Washington, DC: United States Department of Agriculture, U.S. Government Printing Office, 1982.

Insect Control Recommendations. Columbia: University of Missouri Extension, 1990.

The Random House Encyclopedia. New York: Random House, Inc., 1977.

Lesson 5: Chemical Control Methods

This lesson will focus on chemical insect control. The purpose of insect control is to reduce the damage that can result from insect pest activity. Most producers want a level of control that is effective as well as economical. Chemical control is the most widely used type of insect control because it is direct, very effective, target specific, usually economical, practical for commercial production, and easy to buy and apply.

Pesticides

The term pesticide is a general term for any chemical used to kill any pest. These chemicals are designed to kill, control, or prevent pests from causing damage. A pest can be any living thing that competes with humans for food and fiber, or that attacks people directly. Insecticides are pesticides that are specifically made for controlling insects.

When Is an Insects Considered a Pest?

Insects are considered pests when they compete with humans for food and fiber, or attack people directly. Insects are pests when they feed on leaves; tunnel or bore in stems, stalks, and branches; feed on and tunnel in roots; suck the sap from leaves, stems, roots, fruits, and flowers; carry plant and animal diseases or disease agents; feed on and/or feed in seeds and nuts; and feed on and/or feed in humans and animals.

Pesticide Types

Pesticides are classified by the types of pests they are designed to control. The pest for which a pesticide is intended is called the *target pest*. The most common classes of pesticides and their target pests are given in Table 5.1.

Any type of pesticide may effectively control pests other than the desired target group. Most pesticides can kill organisms that are biologically similar to the target pest as well as the target pest. For example, insecticides may kill beneficial insects as well as pest insects.

Mode of Action

Pesticides function in different ways. Attractants attract pests. Repellents keep pests away. Desiccants and defoliants remove or kill leaves and stems. Plant growth regulators stop, speed up, or otherwise change normal plant processes. How a pesticide works is called the *mode of action*. Common modes of action for insecticides are given below.

◊ Contacts – Once an insect comes into contact with a contact poison, it dies.

◊ Systemics – Systemics are applied to the animal or plant on which the insects are feeding. Once the insects feed on the treated host, they die.

◊ Fumigants – Fumigants are gases that kill when they are inhaled or otherwise absorbed by the insect.

◊ Protectants – Once applied to plants, animals, structures, and/or products, protectants prevent entry or damage by insects.

◊ Sterilants – Sterilants make insects unable to reproduce.

◊ Selective insecticides – Selective insecticides kill a particular type of insect without harming other insects.

Table 5.1 – Pesticides and Target Pests

Type of Pesticide	Target Pest
Acaricide	mites, ticks
Avicide	birds
Bactericide	bacteria
Fungicide	fungi
Herbicide	weeds
Insecticide	insects
Miticide	mites
Molluscicide	snails, slugs
Nematicide	nematodes
Piscicide	fish
Rodenticide	rodents (rats, mice)

◊ Nonselective insecticides – Nonselective insecticides kill any insects present.

◊ Growth regulators – Growth regulators prevent immature insects from reaching adulthood.

◊ Biologicals – Living microorganisms, such as viruses, bacteria, and fungi, are applied to a host to cause a disease in the insect feeding on that host.

Methods of Insecticide Application

The key to using insecticides effectively without injuring plants, animals, or agricultural products is to **follow the directions on the label**. Do not use any insecticide product for any purpose for which it was not specified. The methods of insecticide application are described by special terms.

◊ Pre-emergence – Insecticide is applied before crops or weeds emerge.

◊ Preplant – Insecticide is applied before the crop is planted.

◊ Band – Insecticide is applied to a strip over or along each crop row.

◊ Broadcast – Insecticide is applied uniformly to an entire, specific area.

◊ Dip – Dip refers to the complete or partial immersion of a plant, animal, or object in an insecticide.

◊ Directed – In directed application, the insecticide is aimed at a portion of a plant, animal, or structure.

◊ Drench – Drench can mean saturating the soil with an insecticide or the oral treatment of an animal with a liquid insecticide.

◊ Foliar – Foliar refers to applying insecticide to the leaves of plants.

◊ In-furrow – Applying insecticide to or in the furrow in which a plant is planted is the in-furrow application technique.

◊ Over-the-top – Insecticide is applied over the top of a growing crop.

◊ Pour-on – Insecticide is poured along the midline of the back of livestock.

◊ Sidedress – Insecticide is applied along the side of a crop row.

◊ Soil incorporation – Insecticide is applied and incorporated into the soil using tillage implements.

◊ Spot treatment – Spot treatment means to apply insecticide to a small area.

Insecticide Formulations

An insecticide formulation refers to the specific way the product is made. Insecticide formulations have two parts: 1) the active ingredient, which is the chemical that does the work, and 2) the inert, or inactive ingredients, which are the materials that make the active ingredient easier to apply.

There are several common formulations. They are usually made and applied as a liquid, gas, or solid. Each of these has a specific letter abbreviation, frequently used on labels and in recommendations.

Liquid formulations: An emulsifiable concentrate (EC or E) can be mixed with water to form an emulsion in a spray tank. An emulsion is a mixture in which one liquid is suspended as tiny drops in another liquid (such as oil in water). A flowable (F or L) can be mixed with water to form a suspension in a spray tank. A suspension is made by mixing finely divided solid particles in a liquid. A solution (S) is a mixture of one or more substances that are completely dissolved. These ready-to-use formulations are often used on livestock and in barns.

Ultra-low-volume solutions (ULV) are formulations that may contain only the active ingredient itself. They require special application equipment. Aerosols (A) are low concentrate solutions, which are usually applied as a fine spray or mist indoors. Some come in pressurized cans. Liquified gases are fumigant formulations that turn into a gas when applied. Some have to be packaged in pressurized containers.

Dry formulations: Dusts (D) are made by adding the active ingredient to a fine inactive powder. Dusts must be used dry. Granules (G) are made by adding the active ingredient to coarse particles, or granules, of some inactive material.

Granule particles are much larger than dust particles. Soluble powders (SP) are made from an active ingredient that dissolves when added to water. Wettable powders (WP or W) are made by combining the active ingredient with a fine powder and a wetting agent. A wetting agent is a chemical that causes a liquid to cover a surface more thoroughly. Wettable powders look like dusts, but they are made to be mixed with water. Wettable powders need continuous agitation to maintain in suspension. Baits (B) are made by adding the active ingredient to a substance that attracts insects or is eaten by insects.

The following should be considered when selecting the insecticide formulations for a given job:

◊ Life cycle and habitat of the insect
◊ Type and density of plants
◊ Type of coverage needed
◊ Type and condition of the target plant or animal
◊ Type of insecticide
◊ Formulation
◊ Weather conditions
◊ Equipment used
◊ Cost of the insecticide product
◊ Best and safest method of control

Applying Insecticides

Weather conditions play an important part in using insecticides. Although some air movement is helpful, it is not wise to spray in winds. Winds can cause an insecticide dust or spray to be unevenly distributed on the plants and to drift away from target areas. Be cautious about spraying if rain is predicted. The effectiveness of an insecticide treatment may be reduced if rain falls soon after spraying. Cold weather may have the same effect. Check the label for any precautions concerning the weather.

The equipment used to apply an insecticide is very important to the success of the insect control job.

The type of application equipment selected depends on the insecticide formulation. Insecticides may be sprayed, dusted, used in a dipping tank, injected, or mixed with insect food. Liquids are generally applied using some kind of sprayer. Sprayers are chosen according to the size of the area being sprayed and the insecticide formulation. There are several sprayer types.

Hand sprayers: Hand sprayers are best for small jobs around the home or farm. They can be used in restricted areas where a power sprayer is not suitable. They are economical, simple, and easy to use, clean, and store. However, hand sprayers may give an uneven application rate because of hand operation. They do not usually have the agitation and screening needed for wettable powder formulations. They must be shaken often to provide agitation.

Low-pressure field sprayers: These sprayers are usually used for treating field and forage crops, pastures, and fence rows. They are also used to apply fertilizer-pesticide mixtures. These sprayers are equipped with medium to large tanks. This sprayer is more versatile and flexible than the hand sprayer. It can be operated at a low cost. A high volume of insecticide is usually needed to make the most effective use of these sprayers. Low pressure will limit penetration. Agitation is also limited.

High-pressure sprayers: High-pressure sprayers are also called hydraulic sprayers. They are designed to handle high volumes (100 or more gallons per acre) at high pressure (above 100 psi). They are usually used on fruits, vegetables, landscape plants, and livestock. These sprayers are well built for extended use. Mechanical agitation keeps the insecticide mixed. They are expensive to operate because large amounts of water, power, and fuel are needed. With high pressure, the spray drifts easily.

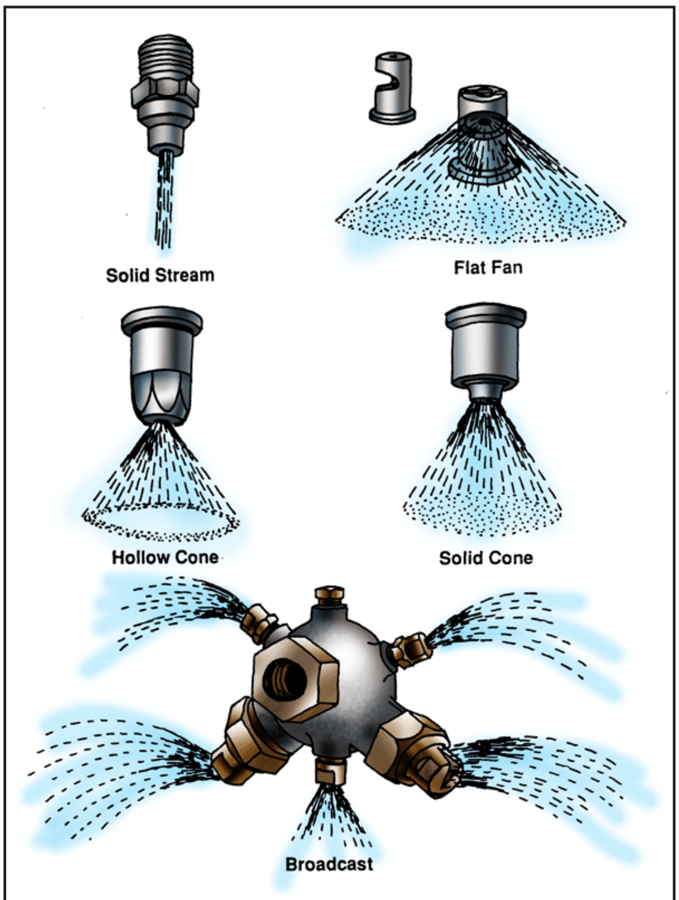
Air-blast sprayers: The output from the nozzle is broken up into fine drops by a high-speed airstream. The insecticide moves with the airstream to the target. These sprayers provide good coverage and penetration. Only low pump pressure is required. They usually have mechanical agitation. The sprayer may be difficult to control in small areas. If not properly operated, they may cause an over application of insecticide.

Ultra-low-volume (ULV) sprayers: These sprayers deliver special ultra-low-volume insecticide formulations. High-speed airstreams are used to break up and direct the spray. No water is needed for these sprayers and less insecticide is used. Since no water is used during application, there is a danger of an over application. Care must be taken when applying high-concentration insecticides. Few insecticides can be sprayed this way.

There are five basic nozzle types. See Figure 5.1. Each of these has a special spray pattern. The type of nozzle selected depends on the type of job.

Solid stream: A solid stream is used in handguns to spray a distant target. It is also fixed in a nozzle body to apply a narrow band or inject it into the soil. There is little drift with these types.

Figure 5.1 – Nozzle Types



Flat fan: There are different kinds of flat fan nozzles. The regular flat fan nozzle makes a narrow oval pattern with lighter edges. It is used on booms for broadcast spraying. The nozzles are mounted on the boom so that the spray overlaps 30–50 percent for even distribution.

Solid cone: The solid cone nozzle forms a circular pattern. The spray is well-distributed throughout the pattern. It is used for spraying insecticides at high pressure and flow rates.

Hollow cone: This nozzle forms a circular pattern with tapered edges. Little or no spray is in the center. It is used for spraying foliage. There are two types of hollow cone nozzles: the core and disk nozzle and the whirl chamber nozzle.

Broadcast: This nozzle forms a wide "flat fan" pattern. It is used on sprayers with or without a boom. When attached to the end of a boom, it expands the width of the area sprayed. This provides good coverage for a wide pattern.

Nozzles are made of brass, stainless steel, plastic, aluminum, tungsten carbide, and ceramic. Each type has advantages and limitations.

Sprayer Calibration

For all spraying applications, there are some standard procedures that should always be followed. Always read the operator's manual supplied by the manufacturer. Choose the speed, pumping pressure, and nozzles that you want to use. For thorough and accurate coverage, the insecticide must be applied evenly and accurately. To do this, the sprayer must move at a constant speed when in use. The insecticide must be pumping out at a constant pressure. Each nozzle in the system must deliver the correct amount of insecticide. The nozzles must be of the correct type and size. All of the nozzles need to be the same kind. Each nozzle must be clean and mounted at the right height.

Calibrating a sprayer simply means to adjust the equipment so that the desired rate of insecticide can be applied. This is very important to make sure that each insecticide is used as directed on the label. Too much insecticide is dangerous, costly, and wasteful. Too little insecticide will not do an effective job. The best results are safely obtained by calibrating correctly.

There are many ways to calibrate a sprayer. The methods selected will depend on the equipment used and personal preference. Refer to University Extension Guide Sheets for additional information on calibrating sprayers.

Summary

Pesticides are chemicals designed to kill, control, or prevent pests from causing damage. A pest can be any living thing that competes with humans for food and fiber, or that attacks people directly. Selection of a particular insecticide depends on the needs of the producer, the type of insect, the mode of action, and the formulation of the insecticide. There are a variety of sprayers and nozzles available for applying insecticides. Equipment is selected depending on the formulation and application instructions of an individual chemical.

Calibrating a sprayer is very important for safe and effective use of insecticides. It is very important to make sure that each insecticide is used as directed on the label. There are several ways to calibrate a sprayer, depending on the chemical formulation, the equipment used, and the preference of the applicator.

Credits

Apply Pesticides Correctly. Washington, DC: United States Department of Agriculture, U.S. Government Printing Office, 1975.

Boyd, E.M. *Toxicity of Pure Foods*. Cleveland: CRC Press, 1973.

Greenhouse Operation and Management. University of Missouri-Columbia: Instructional Materials Laboratory, 2002.

Guidelines for Insecticide Use. Lexington: University of Kentucky, Department of Entomology, 1989.

Guidelines for the Control of Insect and Mite Pests of Foods, Fibers, Feeds, Ornamentals, Livestock, and Households. Washington, DC: United States Department of Agriculture, U.S. Government Printing Office, 1982.

Insect Control Recommendations. Columbia: University of Missouri Extension, 1990.

Lesson 6: Safe Use of Insecticides

Chemical control is a common part of insect management. It is important to know how to work safely with these materials. When using any type of pesticide, it is very important to **always** read and follow label directions exactly. Although the following information applies to any kind of pesticide, this lesson will be referring specifically to insecticides.

The Insecticide Label

The insecticide label contains important information. **Always read and follow the label directions exactly**. It is unlawful to use an insecticide in any manner or for any other purpose than those specified on its label. By reading the label, the individual will be able to determine the type of insecticide being used, the target insects, application techniques, the effects of the product on different plants and insects, the toxicity level, signal words, safety guidelines, disposal methods, and first aid procedures.

Insecticide Toxicity

Insecticide toxicity levels were established by the Federal Insecticide, Fungicide, and Rodenticide Act, also known as FIFRA. FIFRA regulates all stages of pesticide use, manufacture, registration, and transportation. The Missouri Pesticide Act meets these federal guidelines.

LD_{50}: Insecticide toxicity is measured by a standard test called the LD_{50} Test. The "LD" stands for "lethal dose" of a chemical. The lethal dose is determined as the amount of the chemical necessary to kill half (50%) of a test population, such as mice. The LD_{50} is expressed in milligrams per kilogram of body weight. The lower the LD_{50} number, the greater the chemical toxicity and the less it takes to kill. For example, an insecticide with an LD_{50} rating of 5 would be much more poisonous than an insecticide with an LD_{50} rating of 300. Table 6.1 shows the oral and dermal LD_{50} values of some common chemicals. For comparison purposes, the LD_{50} values of caffeine, aspirin, and table salt are given. This comparison does **not** imply that pesticides less toxic than these materials should be used unwisely.

Signal words: Signal words indicate how toxic the chemical is. They are located on the front panel of insecticide labels just below the statement "Keep Out of Reach of Children." There are three categories of signal words. Class I insecticides are labeled "Danger" or "Danger – Poison" with an accompanying drawing of a skull and crossbones. The letters are printed in red. Insecticides in this category are extremely toxic when taken into the body through the mouth, through the skin, and/or through breathing. In addition, these insecticides will cause severe eye and skin burning. Insecticides in Class I have an oral LD_{50} rating of 0–50. Some of the Class I insecticides are so highly poisonous that even a taste could kill an adult human.

Class II insecticides are labeled with the signal word "Warning." Insecticides in this category are moderately poisonous to humans and have an oral LD_{50} rating of 50–500. As little as a teaspoon taken by mouth of some of these pesticides could be deadly.

Class III insecticides have the signal word "Caution." These insecticides are slightly toxic to humans and have an oral LD_{50} rating of 500–5,000. As little as one ounce of certain of these chemicals taken internally could be fatal.

The insecticide label also contains warning statements such as "fatal if swallowed" or "may irritate eyes, nose, throat, or skin." These warning statements are meant to get your attention, not to indicate the only method of entry for the insecticide. Many insecticides could be harmful to the body if any contact at all is made. It is crucial to wear proper protective clothing whenever applying insecticides.

Pesticide Certification

Applicators may or may not need to be certified in order to handle a particular pesticide. Certification depends on the way the pesticide is used. Pesticides are classified as 100 percent general use, 100 percent restricted use, or a mixture of the two. This information will be clearly stated on the label of the container. A general use pesticide is defined as one not likely to harm people, wildlife, and/or the environment when used according to label instructions. Certification is not required in order to

Table 6.1 – LD_{50} Values of Chemicals

Chemicals	Oral LD_{50} (mg/kg)	Dermal LD_{50} (mg/kg)
Organochlorine Insecticides		
aldrin	39	98
chlordane	335	840
heptachlor	100	195
lindane	88	1,000
methoxychlor	5,000	>6,000
strobane	200	>5,000
Organophosphorus Insecticides		
abate	8,600	>4,000
carbophenothion	30	54
diazinon	108	900
dioxathion	43	235
malathion	1,375	>4,444
parathion	13	21
stirofos	>4,000	2,500
Carbamate Insecticides		
aldicarb	0.8	3
carbaryl	850	>4,000
carbofuran	8.7	>1,000
mesurol	130	450
zineb	>5,000	>2,500
Other Insecticides		
binapacryl	63	810
ethylene dibromid	146	300
napthalene	2,200	>2,500
permethrin	4,000	3,000
rotenone	60	>940
Other Chemicals		
Caffeine	174	—
Aspirin	750	—
Table salt	3,320	—

apply general use pesticides. Some examples of these pesticides are Malathion, Sevin, and Pyronone.

A restricted use pesticide can cause serious injury to people, wildlife, or the environment. These pesticides must be applied by someone who is well-trained, competent, and certified, or under the direct supervision of a certified pesticide applicator. Certification is required for handling restricted use pesticides. Some examples of these pesticides are Lannate, Nicotine, and Thiodan.

Pesticide certification is given to people who take a special training course set up by the State of Missouri Department of Agriculture. After completing the instructional process, applicants must then pass a test in the safe handling and use of pesticides. Finally, a license is issued to each person who successfully completes the pesticide training session.

There are two types of licenses for certified pesticide applicators: private applicator and commercial applicator. Private applicators administer restricted use pesticides onto their own land, onto land they rent, or onto the property of another person with whom they trade services. A certified private pesticide applicator's license is valid for 5 years and then must be renewed.

Commercial applicators are hired to apply restricted use pesticides on the property of others. Commercial applicators are trained and tested like private applicators, but receive additional instruction to specialize in various areas. A certified commercial pesticide applicator's license is valid for 3 years and then must be renewed.

Safety Guidelines for Using Insecticides

Since insecticides may be absorbed through the skin, eyes, and ears, inhaled and/or swallowed, insecticides must be handled very carefully. First and foremost, always read and follow insecticide label directions **exactly**. Label directions will not only indicate the application procedures, but the pre-harvest interval and safe re-entry time as well. The pre-harvest interval is the time required between applying the insecticide and the date when the crop can be safely harvested for human consumption. Safe re-entry refers to the time needed between the time an insecticide is applied to an area and the time you need to wait before the area can safely be entered again. Before applying an insecticide, all people, pets, and foodstuffs need to be removed from the area. Never smoke, eat, or drink when applying insecticides.

Protective clothing should always be worn and protective equipment always used to prevent exposure to external irritant insecticides. The following are standard safety clothing and procedures:

◊ Wear clean long trousers and a long-sleeved shirt, or coveralls made of closely woven cloth.

◊ Wear unlined rubber gloves and rubber boots made of neoprene.

◊ Wear shirt sleeves outside of the gloves and wear pant legs outside of the boots to prevent insecticides from entering.

◊ Wear close-fitting eye goggles or a face shield.

◊ Wear a wide-brimmed waterproof hat, one that is easy to clean or is disposable.

◊ Wear a respiratory device that prevents internal poisoning whenever applying an insecticide.

◊ Clean clothing and equipment as directed by the insecticide label or by the poison control center recommendations.

Respiratory devices: Insecticides give off fumes and some quickly become gases. This poses a great threat of injury or death by inhalation to insecticide applicators. Respiratory devices cover the mouth and nose and filter the air of harmful substances. Although they are recommended whenever using insecticides, they are especially important when working in confined or closed areas. Be sure that every respirator carries a seal of approval for insecticide use from the National Institute for Occupational Safety and Health (NIOSH) as well as from the Mine Safety and Health Administration (MSHA). Carefully read the accompanying instructions for the use and care of each respirator. There are several different types available depending on the spraying conditions.

◊ Cartridge respirator – used for occasional exposure to most insecticides.

◊ Gas mask or canister respirator – used when the applicator is exposed to an insecticide for a relatively long period of time or is exposed to high concentrations of insecticides for a short period of time, and working in a confined or closed area.

◊ Self-contained breathing apparatus – used if the oxygen supply is low or the insecticide vapor concentration is high.

Precautions should always be taken to avoid insecticide drift. Insecticide drift occurs when the insecticide tends to drift away from the target area. This can be avoided by always following the label directions, using the proper equipment for the job, and not spraying when it is windy.

After applying insecticides, remove clothing and take a shower with plenty of soapy water; shampoo and rinse the hair well. Wash insecticide exposed clothing separately from other clothing. If disposable clothing is worn, dispose of it properly.

If insecticides are applied on a regular basis, a health watch program should be established with a physician. Inform the doctor about the type of insecticides being used. Then the doctor can review the chemical formulations, poisoning symptoms, and treatments. In addition, the physician can stock a supply of the necessary drugs needed for treatment. Being prepared in case insecticide poisoning occurs is important because there are no drugs to prevent it.

Applicators who work regularly with carbamate or organophosphate insecticides should set up a cholinesterase testing program with their physicians. Cholinesterase is a biological enzyme that is part of the body's nervous system. Carbamate and organophosphate insecticides can cause serious health hazards by interfering with the availability of cholinesterase in the body. Therefore, the doctor should perform a cholinesterase test in January to establish a "base line level" for each applicator. Then periodic retests must be taken to check cholinesterase levels.

If the applicator's cholinesterase level falls too low, then the doctor will limit or stop the patient's contact with these two types of insecticides.

Disposal of Insecticides and Containers

Always try to mix the correct amount of insecticide solution for each application to avoid the need to dispose of any extra chemical. Any extra insecticide solution must be disposed of safely to avoid harming people, animals, or the environment. The U.S. Department of Agriculture and the U.S. Environmental Protection Agency have set up specific guidelines for insecticide disposal. The State of Missouri Department of Natural Resources can help with questions and problems concerning the safe disposal of insecticides and insecticide containers. The address and phone numbers are as follows:

Missouri Department of Natural Resources
Division of Environmental Quality
PO Box 176
Jefferson City, MO 65102
Business phone: (573) 526-3315
Emergency response phone: (573) 634-2436

Carefully read and follow the instructions for precautions and/or disposal methods on the insecticide container label. **Never** flush insecticides down the drain or into sewers. If there are additional areas having the same insect problem, apply the extra insecticide on those areas as well. If this is not possible, then take the excess insecticide and/or insecticide containers to a landfill that has a permit for toxic waste disposal. This should also be done for outdated or unwanted insecticides. Keep in mind that many solid waste landfills do not have this special permit and, therefore, are not legally able to handle insecticides. Federal regulations require that organic insecticides be disposed of by burial or by burning.

Do not leave insecticides or insecticide containers at the place where the chemicals were applied. Never reuse insecticide containers. Keep all insecticide containers out of the reach of children. Any insecticides leftover should be kept in tightly closed containers in a storage facility.

Symptoms of Insecticide Poisoning

Since different insecticides affect people differently, there are no standard symptoms of insecticide poisoning. Symptoms will vary depending on the type of insecticide, amount and length of exposure, the time interval between exposures, and the general health of the victim.

Insecticide poisoning may be divided into external irritants, internal poisons, or a combination of both. External irritant insecticides may cause swelling, stinging, redness, blisters, and/or rash when splashed on the skin or external body tissues, such as eyes, ears, and mouth. Insecticides causing internal poisoning are dangerous when swallowed, inhaled, or absorbed through the skin.

These may cause such symptoms as headache, nausea, vomiting, and diarrhea. Some insecticides can cause both external irritation and internal poisoning at the same time.

Insecticide poisoning symptoms may be similar to symptoms of other illnesses, such as the flu. However, flu medicine should not be used to relieve these symptoms as they may make insecticide poisoning much worse. Therefore, it is important to talk with a doctor who can diagnose the difference and prescribe proper treatment.

First Aid Procedures for Insecticide Poisoning

When you think an insecticide poisoning has occurred, **always act immediately**. The amount of time between the insecticide poisoning and getting to the doctor may make the difference between life and death for the poisoning victim. It is extremely important to stay calm and take quick action. Follow these steps:

1. Protect yourself from contamination. Wear protective clothing and/or equipment. You won't be able to assist anyone else if you are not protected yourself.

2. Without endangering yourself, remove the victim from the contaminated area.

3. Remove contaminated clothing from the victim.

4. Flood the affected area with a generous amount of water.

5. Contact the Poison Control Center or a doctor and administer first aid procedures as indicated. Keep the insecticide label handy for reference.

First Aid Kit

First aid supplies should always be near any place where insecticides are handled. The container used for the first aid supplies should keep the supplies clean and be easily accessible

A first aid kit should contain items such as the following:

◊ Adhesive tape
◊ Assorted adhesive and gauze bandages
◊ Blanket – enclosed in plastic to keep clean and dry
◊ Merthiolate
◊ Syrup of ipecac
◊ Teaspoon
◊ Two quarters – taped to the inside cover of the first aid kit for phone calls

Poison Control Center

The local Poison Control Center number should be located by the phone for easy access. In Missouri, the Poison Control Center is staffed 24 hours a day by medical professionals. These professionals will ask questions about the victim and about the insecticide. It is important to have the insecticide label or container close by when contacting the center.

The statewide center may refer calls to a local hospital specifically equipped to treat poisoning emergencies. Information about Missouri's statewide center and its toll-free number are given below.

Missouri Regional Poison Control Center
Cardinal Glennon Memorial Hospital
1465 South Grand Avenue
St. Louis, MO 63104
Telephone: 1-800-222-1222

Summary

To avoid toxic chemical injury to humans, animals, and/or the environment, it is crucial to read and follow all label directions for the insecticide being applied. Depending on the insecticides to be applied, the applicator may be required to have a certified pesticide applicator's license.

Appropriate clothing and protective equipment should always be worn when applying insecticides. Insecticides should always be handled with care and disposed of properly.

Credits

Guidelines for Insecticide Use. Lexington: University of Kentucky, Department of Entomology, 1989.

Guidelines for the Control of Insect and Mite Pests of Foods, Fibers, Feeds, Ornamentals, Livestock, and Households. Washington, DC: United States Department of Agriculture, U.S. Government Printing Office, 1982.

Insect Control Recommendations. Columbia: University of Missouri Extension, 1990.

Pest Management Strategies in Crop Protection. Washington, DC: Congress of the United States, Office of Technology Assessment.

Lesson 7: Integrated Pest Management

Agriculturalists are always looking for ways to produce food and fiber with a quality and in the quantity the world wants. Buildings, roads, and other structures need to be safe and to last. Health professionals are always looking for ways to keep humans and animals in good health. And this must usually be done at a profit. The job of the entomologist is to manage the huge and diverse insect population so that these goals can be achieved.

IPM

Insect control programs must be developed for each individual situation. There are certain steps which greatly help when developing an insect control program. These steps form an efficient system which is called an *IPM program*. The letters "IPM" are used to refer to two different programs. The general program is called Integrated Pest Management. This refers to any pest control program. If the pest in question is specifically insects, then the letters can stand for Insect Pest Management.

Why IPM is Important

The basic goal in insect pest management is to prevent insect populations from reaching a level that can cause substantial damage to a crop. This is referred to as the *economic injury level (EIL)*. The economic injury level is the amount of damage insects do to a crop that equals the cost it requires to use measures that suppress the insects. Insect suppression measures have different functions. Some are designed to prevent the insect population from increasing. Others work to reduce the population already present. Still others work to prevent a particular insect population from becoming a problem in the first place.

Economic Threshold

It is not always necessary to start insect control measures when insects are seen on a crop. The *economic threshold* is used to determine when insect control measures should be considered. The economic threshold indicates the level of damage done by an insect that is used to warn the agriculturalist of potential problems. To determine when the economic threshold is reached, careful sampling must be done. This may involve counting the actual number of individual insects per unit. Other methods used involve some form of removal, trapping, visual estimates, or assessing the amount of plant damage. When the economic threshold is reached, it is necessary to use methods to keep the insect populations from reaching the economic injury level.

Steps in an IPM Plan

Once it has been determined that insect control measures need to be considered, an IPM plan can be developed. There are specific steps in developing an IPM plan.

Identify the problem: Never try to control a problem until you are sure what it is. Identifying the cause of a plant problem or symptom correctly can be very difficult. There may be many reasons why a plant is not growing properly. For example, plant leaves may turn yellow because of insect attacks, plant diseases, nutrient deficiencies, or herbicide injury. Insects may be the indirect cause of poor plant health. A plant that is already nutrient deficient tends to attract insects. The insects are not the direct cause of the problem, the nutrient deficiency is. Even if the insects are eliminated, the plant would not recover until the nutrient deficiency is corrected.

Identifying the problem incorrectly may cause the wrong method of control to be selected. This not only wastes money but probably will not fix the problem as well. In fact, the real problem will usually get worse. Determining the reason(s) for plant problems in a field environment is often very challenging. It takes an experienced and well-trained individual to find the correct answers.

If an insect problem has been identified, and you know how the insect grows, how it spreads, and what damage it does, you can begin to plan how to control it. Using an insecticide is one of many ways to control pests. The use of a combination of methods is basic to all pest control. Be sure to think about what other methods might work before you decide to apply an insecticide. You can minimize insect problems by:

◊ Encouraging the growth of insects' natural enemies
◊ Planting crop varieties that resist insects

- ◊ Destroying crop residues
- ◊ Practicing good fertilizer and manure management
- ◊ Good management of the selected tillage system

Assess the damage: In addition to finding the root cause of the problem, it is very important to determine exactly how extensive the damage may be. Plants have a remarkable ability to recover from insect attack. Some injuries are only on the surface. Even though it may look bad, the crop is not damaged to the point of economic losses. For example, a 5 percent or 10 percent leaf loss appears very damaging, but most plants can grow out of it. On the other hand, small insects and soil insects may not be noticed and yet can be responsible for significant plant damage.

The stage of development of the plant and insect is another point to consider. When assessing plant damage, there is no substitute for a knowledgeable person. It can be very expensive and unnecessary to start measures to suppress or contain insects that may not be causing real damage.

Prepare cost/benefit analysis: A cost/benefit analysis can be difficult to do. A cost/benefit analysis means comparing the cost of an insect control plan with the benefits that the control plan will give. The value of the increased crop yield should be equal to, or higher than, the cost of the actions taken to control insects. The benefits include the short-term value of increased crop yield as well as the long-term value of keeping the insect population under control for the rest of the growing season and following years. Often, it is possible to control an insect population by suppressing the first generation. Later in the season, the number of insects may be greater and more difficult to control. You also need to consider what effects control measures may have on beneficial insects. Lowering the beneficial insect population can increase the harmful insect population and increase control costs overall.

Insect control is necessary only when the insect is causing more damage than is reasonable to accept. Even though an insect is present, it may not do much harm. It could cost more to control the insect than would have been lost by insect damage.

Select a management strategy: There are many insect management strategies to choose from. You need to consider the various factors that influence the selection of a plan. These include:

- ◊ Present crop
- ◊ Cropping system
- ◊ Tillage system
- ◊ Life cycle and habitat of the harmful insects
- ◊ Life cycle and habitat of the beneficial insects
- ◊ Kind of damage that the insect causes
- ◊ Type and condition of the plants or animals under attack
- ◊ Time of year
- ◊ Environmental conditions
- ◊ Geographic location
- ◊ Cost of insect control
- ◊ Goals of the producer

The most common strategies are planting pest-resistant crop varieties and applying insecticides. These measures are used because they are effective, easily available, economical, and in general, can be used easily by anybody. Other strategies include crop rotation, biological control, and modifying the planting time. However, these measures may not be as efficient or effective. They also require a greater knowledge of entomology and pest management.

Implement the management strategy: When selecting a management strategy, a major factor is the ability to actually put it into action and see it through to completion. There are many strategies and alternatives from which to choose. One who is devoted to biological control may be unable to implement it effectively or efficiently. On the other hand, some people are all too ready to employ chemical control exclusively because the materials are readily available. An experienced individual will consider a variety of measures for any particular situation or problem.

Planning is essential for an insect management plan to be successful. Many cultural and biological controls need to be implemented before or during soil preparation and crop planting. For example, a crop rotation, soil insecticide, or choice of insect resistant seeds needs to be made in advance.

It is not always necessary to plan for the worst. Insect populations can be watched and sampled throughout the growing season. Remember that a few insects do not mean a crisis is at hand. When insect damage is noticed, begin monitoring the damage. Now consider the plant growth, the remaining growing season, the climate, and the insect's life cycle. The insect population may not be causing substantial economic damage, or the crop may not be seriously injured. With this information, an appropriate strategy can be made to determine if control measures are needed at all, and if so, how much should be spent on them.

Follow-up of the plan: Following up on a regular basis is an important part of any insect management program. The effectiveness of the measures selected can be judged only by carefully watching the insect populations and crop growth. This can be done through regular sampling. We cannot assume that an insect problem has been thoroughly controlled just because the control measures have been put into action. Control measures may need to be alternated, modified, increased, or decreased as the growing season progresses. Keeping careful records will give a great deal of information on how well the selected plan is working and how efficient and effective the measures are.

Crop Calendars

Most IPM programs begin by focusing on the crop. From there, other factors are added to give a better perspective on the situation. Making a crop calendar is a good way to evaluate any possible problems and different insect control plans. See Figure 7.1. A crop calendar is an outline of the crop's growing season. It provides a systematic and efficient way of looking at the components in a cropping system. Management decisions are easier to make. The basic steps in developing a crop calendar are given below.

1. Set up a table with the 12 months across the top. The left column will indicate crop information such as the following: crop growth stages, insects (be specific), tillage operations, fertilizer applications, herbicide applications, and harvesting.

2. If different insect stages affect the crop at different times, indicate what stage the insect is in and when it causes damage.

3. Indicate the period when insects are most likely to be present and when populations are most likely to cause economic damage.

Now, look at the crop calendar to see when each particular insect will most likely cause the most damage. Look at the growth stage of the crop at this time and think about the following questions.

◊ Is the insect attack happening at a critical time in the growth of the crop?
◊ Will the crop be able to grow out of any damage?
◊ Can the insect damage be prevented?
◊ What insect control measures can be used?
◊ What are the advantages and limitations of each of these methods?
◊ How much insect control is needed at this time, considering both the growth stage of the crop and the insect's life cycle?
◊ How will each of the methods affect the rest of the crop calendar?
◊ How much will it cost?
◊ When should the selected measures be started?
◊ What other factors should be considered in selecting a management plan?

With this information, it is easier to evaluate a potential problem and make a decision. There is no "right" or "wrong" choice in selecting control methods. Each situation is different. Only with practice will an individual become a knowledgeable and experienced insect manager.

Summary

There are many factors to consider when developing insect control plans. The individual plan selected will be different for each particular situation.

Crop calendars provide a systematic and efficient way of looking at the components in a cropping system and evaluating different possible control plans.

Entomology

Figure 7.1 – Sample Crop Calendar for Corn

Crop Information	**Jan.**	**Feb.**	**Mar.**	**April**	**May**	**June**	**July**	**Aug.**	**Sept.**	**Oct.**	**Nov.**	**Dec.**
Crop Growth Stages				Seedling	Knee-high	Whorl	Tassel	Silk, Dent, Dough	Maturity			
Insects Cutworms				***XXXXXXXX***								
Corn Flea Beetle				**XXXXXXX********								
Corn Leaf Aphid						*******XXXXXX**						
Corn Rootworms					**XXXXX***XXXXX*******	larvae		adults				
European Corn Borer		eggs 1st generation larvae 2nd generation larvae			*XXXX** **XXXXXXX**		**XXXX**					
Tillage Operations Fertilizer Applications Herbicide Applications Harvesting												

* – Period when insects are most likely to be present.
X – Period when populations are most likely to cause economic damage.

Credits

Apply Pesticides Correctly. Washington, DC: United States Department of Agriculture, U.S. Government Printing Office, 1975.

Bland, R.G. *How to Know the Insects*. Dubuque, IA: Wm. C. Brown Company Publishers, 1978.

Insect Control Recommendations. Columbia: University of Missouri Extension, 1990.

The Random House Encyclopedia. New York: Random House, Inc., 1977.

Glossary

These terms are commonly used in entomology and insect control. Some of these words have several meanings. Those given here are the meanings that relate to insect control.

Absorption – The process by which a chemical is taken into plants, animals, or minerals. Compare with adsorption.

Activator – A chemical added to a pesticide to increase its activity.

Adherence – Sticking to a surface.

Adjuvant – Inactive ingredient added to a pesticide formulation to make it work better.

Adsorption – The process by which chemicals are held on the surface of a mineral or soil particle. Compare with absorption.

Aerobic – Living in air. The opposite of anaerobic.

Aerosol – An extremely fine mist or fog consisting of solid or liquid particles suspended in air. Also, certain formulations used to produce a fine mist.

Agitation – The process of stirring or mixing in a sprayer.

Anaerobic – Living in the absence of air. The opposite of aerobic.

Animal Sign – Evidence of the presence of an animal in an area.

Antagonism – The loss of activity of a chemical when exposed to another chemical.

Antibiotic – A substance which is used to control pest microorganisms.

Antidote – A practical treatment for poisoning. This includes first aid.

Aqueous – A term used to indicate the presence of water in a solution.

Aseptic – Free of disease-causing organisms.

Booting – The growth stage of cereal crops when the upper leaf sheath swells due to the growth of a developing spike or panicle.

Botanical Pesticide – A pesticide made from plants. Also called plant-derived pesticides.

Broadleaf Weeds – Plants with broad, rounded, or flattened leaves.

Brush Control – Control of woody plants.

Carbamate – A synthetic organic pesticide containing carbon, hydrogen, nitrogen, and sulfur.

Carcinogenic – Capable of causing cancer.

Carrier – The inert liquid or solid material added to an active ingredient to prepare a pesticide formulation.

Causal Organism – The organism that produces a specific disease.

Chemosterilant – A chemical that can prevent reproduction.

Chlorinated Hydrocarbon – A synthetic organic pesticide that contains chlorine, carbon, and hydrogen. Same as organochlorine.

Chlorosis – The yellowing of a plant's green tissue.

Cholinesterase – A chemical catalyst or enzyme found in animals that helps regulate the activity of nerve impulses.

Compatible – When two or more chemicals can be mixed without affecting each other's properties, they are said to be compatible.

Concentration – The amount of active ingredient in a given volume or weight of formulation.

Contaminate – To make impure or to pollute.

Corrosion – The process of wearing away by chemical means.

Deflocculating Agent – A material added to a suspension to prevent settling.

Degradation – The process by which a chemical is reduced to a less complex form.

Dermal – Pertaining to the skin; through the skin.

Dermal Toxicity – Ability of a chemical to cause injury when absorbed through the skin.

Diluent – Any liquid or solid material used to dilute or carry an active ingredient.

Dilute – To make thinner by adding water, another liquid, or a solid.

Dispersing Agent – A material that reduces the attraction between particles.

Dormant – State in which growth of seeds or other plant organs stops temporarily.

Dose, Dosage – Quantity of a pesticide applied.

Emulsifier – A chemical that aids in suspending one liquid in another.

Emulsion – A mixture in which one liquid is suspended as tiny drops in another liquid, such as oil in water.

Fungistat – A chemical that keeps fungi from growing.

GPA – Gallons per acre.

GPM – Gallons per minute.

Hard Water – Water containing soluble salts of calcium, magnesium, and sometimes iron.

Heading – The growth stage of cereal crops when the seed head is emerging from the upper leaf sheath.

Herbaceous Plant – A plant that does not develop woody tissue.

Host – The living plant or animal a pest depends on for survival.

Immune – Not susceptible to a disease or poison.

Impermeable – Cannot be penetrated. Semipermeable means that some substances can pass through and others cannot.

Jointing – The growth stage of cereal crops when stem internodes begin elongating rapidly.

Larva – The early form of an insect with complete metamorphosis from the time that it leaves the egg until it becomes a pupa.

LC_{50} – The concentration of an active ingredient in air which is expected to cause death in 50 percent of a group of test animals treated with the active ingredient. A means of expressing the toxicity of a compound present in air as dust, mist, gas, or vapor. It is generally expressed as micrograms per liter in the case of a dust or mist and as parts per million (ppm) in the case of a gas or vapor.

LD_{50} – The dose of an active ingredient taken by mouth or absorbed by the skin which is expected to cause death in 50 percent of a group of test animals treated with the active ingredient. If a chemical has an LD_{50} of 10 milligrams per kilogram (mg/kg) it is more toxic than one having an LD_{50} of 100 mg/kg.

Leaching – Movement of a substance downward or out of the soil as a result of water movement.

Mammals – Warm-blooded animals that nourish their young with milk. Their skin is more or less covered with hair.

Metamorphosis – A change in shape, form, and size in insects. A system of insect development.

Miscible Liquids – Two or more liquids that can be mixed and will remain mixed under normal conditions.

MPH – Miles per hour.

Mutagenic – Capable of producing genetic change.

Necrosis – Localized death of living tissue such as the death of a certain area of a leaf.

Necrotic – Showing varying degrees of dead areas or spots.

Nitrophenols – Synthetic organic pesticides containing carbon, hydrogen, nitrogen, and oxygen.

Noxious Weed – A plant defined as being especially undesirable or troublesome.

Nymph – The early form on an insect with incomplete metamorphosis from the time that it leaves the egg until it becomes an adult. They look like the adult but do not have fully developed wings.

Oral – Pertaining to the mouth; through or by the mouth.

Oral Toxicity – Ability of a pesticide to cause injury when taken by mouth.

Organic Compounds – Chemicals that contain carbon.

Organochlorine – Same as chlorinated hydrocarbon.

Organophosphate – A synthetic organic pesticide containing carbon, hydrogen, and phosphorus; two examples are parathion and malathion.

Ovicide – A chemical that destroys eggs.

Parasite – A plant or animal that lives on or in another plant or animal from which it gets food.

Pathogen – Any disease-producing organism.

Penetration – The act of entering or ability to enter.

Pest – Living things that compete with people for food and fiber, or attack people directly.

Phytotoxic – Harmful to plants.

Pollutant – An agent or chemical that makes something impure or dirty.

PPB – Parts per billion. A way to express the concentration of chemicals in foods, plants, and animals. One part per billion equals 1 pound in 5,000 tons.

PPM – Parts per million. A way to express the concentration of chemicals in foods, plants, and animals. One part per million equals 1 pound in 500 tons.

Predator – An animal that destroys or eats other animals.

Propellant – Liquid in self-pressurized pesticide products that forces the active ingredient from the container.

PSI – Pounds per square inch.

Pupa – The last stage of an immature before becoming an adult in the development of insects having complete metamorphosis.

RPM – Revolutions per minute.

Safener – A chemical added to a pesticide to keep it from injuring plants.

Seed Protectant – A chemical applied to seeds before planting to protect seeds and new seedlings from diseases and insects.

Soil Sterilant – A chemical that prevents the growth of all plants and animals in the soil. Soil sterilization may be temporary or permanent, depending on the chemical.

Soluble – Will dissolve in a liquid.

Solution – Mixture of one or more substances in which all ingredients are completely dissolved.

Solvent – A liquid which will dissolve a substance to form a solution.

Spreader – A chemical which increases the area that a given volume of liquid will cover on a solid or on another liquid.

Sticker – A material added to a pesticide to increase its adherence.

Surfactant – A chemical which increases the emulsifying, dispersing, spreading, and wetting properties of a pesticide product.

Susceptible – Capable of being diseased or poisoned; not immune.

Susceptible Species – A plant or animal that is poisoned by moderate amounts of a pesticide.

Suspension – Finely divided solid particles mixed in a liquid.

Synergism – The joint action of two or more pesticides that is greater than the sum of their activity when used alone.

Target Pest – The pest at which a particular pesticide or other control method is directed.

Tillering – The growth stage of cereal crops when additional shoots are developing from the flower buds.

Tolerance – 1) The ability of a living thing to withstand adverse conditions, such as pest attacks, weather extremes, or pesticides. 2) The amount of pesticide that may safely remain in or on raw farm products at time of sale.

Toxicant – A poisonous chemical.

Trade Name – Same as a brand name.

Vapor Pressure – The property which causes a chemical to evaporate. The lower the vapor pressure, the more easily it will evaporate.

Vector – A carrier, such as an insect, that transmits a pathogen.

Viscosity – A property of liquids that determines whether they flow readily. Viscosity usually increases when temperature decreases.

Volatile – Evaporates at ordinary temperatures when exposed to air.

Wetting Agent – A chemical that causes a liquid to contact surfaces more thoroughly.