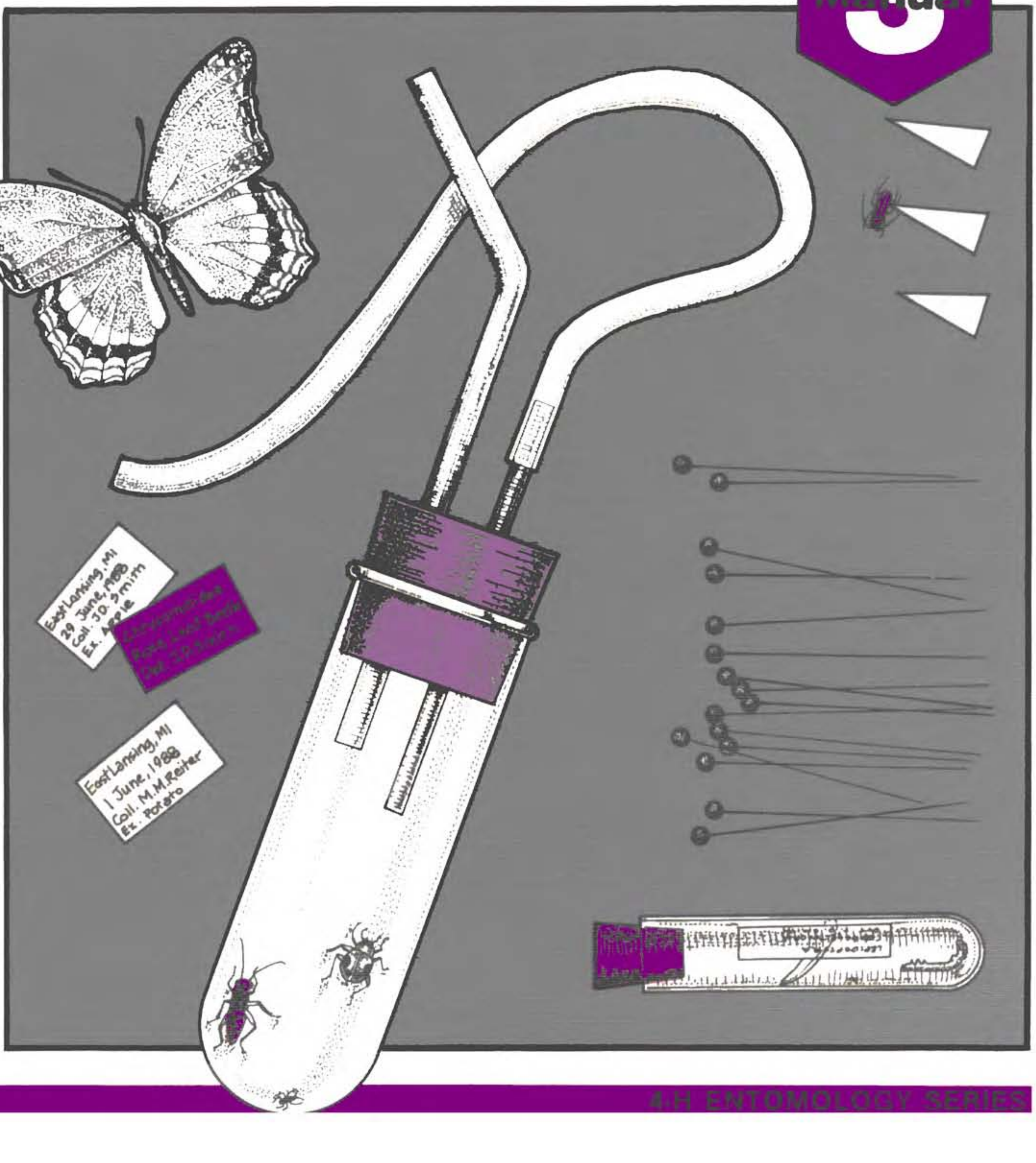
4-H 1406

INSECT LIFE CYCLE STUDIES

Manual 3



4-H ENTOMOLOGY SERIES

AUTHOR

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Welcome to 4-H Entomology

Welcome to the 4-H entomology project. This project will introduce you to many new and exciting experiences. It will be fun and will help you learn how important insects are in the lives of everyone. It may even help you prepare for the study of insects as your life's work.

This manual gives instructions for studying live insects and their life cycles through rearing projects and field studies. There are additional 4-H entomology publications for beginners and people interested in other entomological projects. Information on these publications can be obtained from your leader or county 4-H staff.

Introduction

Entomology (en-toe-mol-o-gee) is from the Greek word **entomo,** meaning insect. Entomology is the science dealing with the study of insects. A scientist who specializes in the study of insects is known as an entomologist. However, you do not need to be an entomologist to learn something about the important and fascinating world of insects.

The main objective of this manual is to introduce you to rearing live insects and studying them in their natural environments. The manual will help you learn the skills necessary for studying live insects. You can use these skills to: (1) observe the behavior of insects, (2) raise insects for profit or fun, or (3) learn about insect life cycles under both artificial and natural conditions.

This manual contains some entomological terms that may be unfamiliar to you. Explanations of these terms can be found in **4-H Entomology Series Manual 1: Basic Entomology** (4-H 1335) or any book on general entomology.

Rearing Insects

Most entomology projects emphasize the study and handling of dead specimens. Most people who set up their own insect collections are careful observers, as well as collectors. They know that the more they learn and understand about insect activity, the easier it will be for them to collect the insect specimens they prize. But many collectors seem to forget that insects are living creatures. Collecting and observing insects are both extremely important parts of entomology. Insects in collections can be studied to learn more about how separate species are alike and different, and how and why insect populations are distributed around the world. They are also helpful in learning the reasons for changes in insect populations. Collections are important!

Entomology is, of course, a biological science. To fully understand insects, people must have firsthand knowledge of insect ways and means of living: how insects feed, grow, behave, disperse and reproduce. This knowledge can only be gained by studying live insects.

WHY REAR INSECTS?

There are several advantages to making insects the focus of a "live animal" study. Most insect species complete their life cycles in relatively brief spans. They take up little space, and their maintenance requirements are fairly simple. Finally, insects make fascinating, low-cost (often free) 4-H projects.

Rearing insects can provide you with valuable learning experiences. Observing insects as they grow and change from one stage to another is certainly interesting, but there is much more to be gained. You can improve your reading skills and your ability to follow directions. You can also learn to measure wood, screening and other building materials as you build cages and other equipment for your live insect studies.

Your live insect studies will help you gather important scientific information. You can learn a great deal about insect life cycles and behavior by closely observing insects. You'll be able to answer questions about the duration of insect life stages (perhaps under varying conditions), and insect mating behavior and response to environmental stimuli. In short, insects can easily be used as laboratory animals in your scientific experiments.

MAKING MONEY WITH "BUGS"

Did you know that you can make money raising and selling insects? Well it's true!

Beekeeping. You may already be familiar with the potential of honey bees as a source of income. In addition to selling honey and beeswax, many beekeepers also rent their hives to farmers who need bees to pollinate their crops. Hive rentals become more important every day because soon there may not be enough wild bee colonies in Michigan to pollinate all the crops that need it. Beekeeping can be quite involved, so you will probably need the guidance of an experienced beekeeper. Your Cooperative Extension Service (CES) office can help you find the 4-H beekeeping leader nearest you. There are many brochures and publications on beekeeping, so it won't be covered in this manual.

Fish bait. Many insects are used as bait by anglers. The popularity of any bait insect depends on the area where you live. You'll need to find out which insects are in demand in your area. Popular fish bait insects include crickets, wax moth larvae (waxworms) and mealworms. Instructions for rearing these insects begin on page 8.

Pet food. Many people keep lizards and tarantulas as pets, and insects are the primary food source for these animals. Many of the insects that can be used for fish bait, especially crickets and mealworms, can also be used to feed exotic pets.

Biological supply companies. Some biological supply companies buy selected insects in large quantities for resale to schools and research institutions. The specimens are then used for teaching or biological research. The insect needs of these companies are constantly changing, so contact them for an up-to-date list of the insect species they need and for shipping instructions. The names and addresses of companies that buy insect specimens are listed in "Appendix A—Companies That Buy Live Arthropods" on page 36.

General Considerations

It is very important to match the natural habitat of the insects you want to rear, including their preferred food and proper light, temperature and humidity conditions. You will need a cage or other container in which to rear most insects. The type of container you use will depend on the species you decide to raise. But no matter what type of rearing chamber you select, it must be constantly tended. For example, most insects won't eat dried leaves, and without a constant fresh food supply the insects will quickly die.

Insects that feed on live plants can be caged over potted plants or fed fresh material from their host plants. With a little ingenuity, a suitable cage can be designed to accommodate your rearing plans. The important thing is to keep the cage tight enough to restrain the insects and still provide enough ventilation that the container doesn't "sweat." Loose, slightly moist soil and leaf litter should also be provided in case the insect pupates in or on the ground.

Terrestrial insects and scavengers do well in containers with a small amount of sand or soil in the bottom. Keep the cage clean and control moisture to prevent molds and diseases.

You can rear insects that infest plants (seeds, galls, leaves or stems) or other materials by placing the infested object in an enclosed container. Don't let such materials get too dry or too moist, or the materials and specimens will mold. If you want to extract sample specimens from such a culture, use an opaque container (one that you can not see through) and insert an open-ended glass vial through a hole (just big enough for the jar) in one end of the container. As adult insects emerge from the infested material, they will be attracted to the light coming through the vial. Once they are in the second container, you can remove them for study or to add them to your personal insect collection. "Appendix B—Classification of Commonly Reared Arthropods" (page 36) will help you classify many of the insects discussed in this manual.

You may also find it interesting to dig large larvae and pupae out of soil or rotten logs and rear them to the adult stage. The larvae probably won't need to be fed as long as you keep some of the rotten wood or soil in the container with the specimens. Place the larvae and soil or wood in a closed jar or other container to retain moisture, and check them periodically. You may be surprised to find freshly emerged specimens of some of the largest and least common beetles and other insects. Remember that the life cycles of some of these large insects may be quite long, so you'll have to be patient. As long as the larvae are plump, moist and healthy-looking, they will probably develop to adulthood. Unhealthy, diseased or dead individuals should be removed from the container and disposed of.

Collecting moth cocoons and butterfly chrysalids is another interesting activity. You may get lucky and find a full-grown caterpillar that is just about to transform into a pupa. These can be collected and observed until the adult butterfly or moth emerges. Since some Lepidoptera overwinter as pupae you may have to wait until the following spring to see them emerge.

SELECTING INSECTS

Some important questions you need to consider when you are deciding on an insect species to rear are listed below.

1. Is the insect an appropriate size for the space you have?
2. Is the insect harmless? Will it cause problems if it escapes?
3. Are there interesting features about the appearance, behavior or life cycle of the species?
4. Is the insect adaptable to culturing? Will it mate in captivity?

Another important step is getting permission from your parents or guardians to raise the insects! Some of the questions mentioned above are answered in the rearing instructions in this manual. The others can only be answered through your experimentation.

OBTAINING LIVE INSECTS

You can start your live insect cultures two ways: purchase insects from biological supply companies or collect your own. (A list of insect and rearing equipment suppliers is included in "Appendix C—Sources of Live Arthropods" on page 36.) The choice between buying or collecting is often influenced by how much money you have, the season you want to start your project, the species you decide on and how much time you have to hunt for insects. Obviously, gathering your own specimens costs virtually nothing, but more importantly, it helps you understand the habitat and natural conditions of the species you are raising.

COLLECTING LIVE INSECTS

The equipment you will need to gather insects is not elaborate. All you really need are your fingers and a collecting carton. However, you may also want to use a garden trowel, forceps, aspirator, insect traps or other tools, depending on the insects you wish to collect. (See **4-H 1336, 4-H Entomology Manual 2: Advanced Entomological Techniques,** for more details.)

Insects collected in the field should be carried in a special collecting carton. Ordinary plastic, glass and metal containers are not satisfactory because they don't "breathe." This can cause your specimens to overheat, mold and die. The best collecting containers are made from quart-sized, cylindrical, unwaxed cardboard cartons (like an ice cream carton). Cut out the bottom of the carton and replace it with window screen or cheesecloth. Cut a ⅝-inch to 1-inch hole in the side of the carton about one-third of the way down from the screened end. The exact location of this hole is not critical. Block the hole with a cork.

When you use the collecting carton, hold it so that the screening is at the top and the removable lid is at the bottom. Put the insects in the carton through the circular hole in the side. Since insects tend to move "uphill," you will find that they congregate at the top of your carton. This means your insects won't try to escape every time you open the entryway.

You'll probably want several collecting containers, since you may need one or more for storage at any given time. Cartons should be available locally from paper manufacturers or from retail stores that handle ice cream, oysters, delicatessen items or other perishable goods. Cylindrical cartons are best, but those with tapered sides can also be used.

To reduce the insect activity in your collecting carton, cover it loosely with a dark cloth. When it's time to transfer the specimens to a rearing cage you may need to further reduce their activity to keep them from escaping or being hurt. You can do this by placing the insects (in their container) in the refrigerator (not the freezer) until their activity slows, then you can easily place them in a rearing cage.

REARING CAGES

Many kinds of containers and cages can be used to hold insects for rearing. Use whatever type is available and that suits your needs. "Appendix D—Sources of Rearing Supplies and Equipment" (page 37) will help you locate any equipment you need to purchase. A good insect rearing cage should be lightweight, sturdy, escape-proof and well-ventilated. It should also allow you to watch the insects easily. Cages constructed of lightweight wood or aluminum and covered with screening make the best all-around rearing cages (see fig. 1 for ideas).

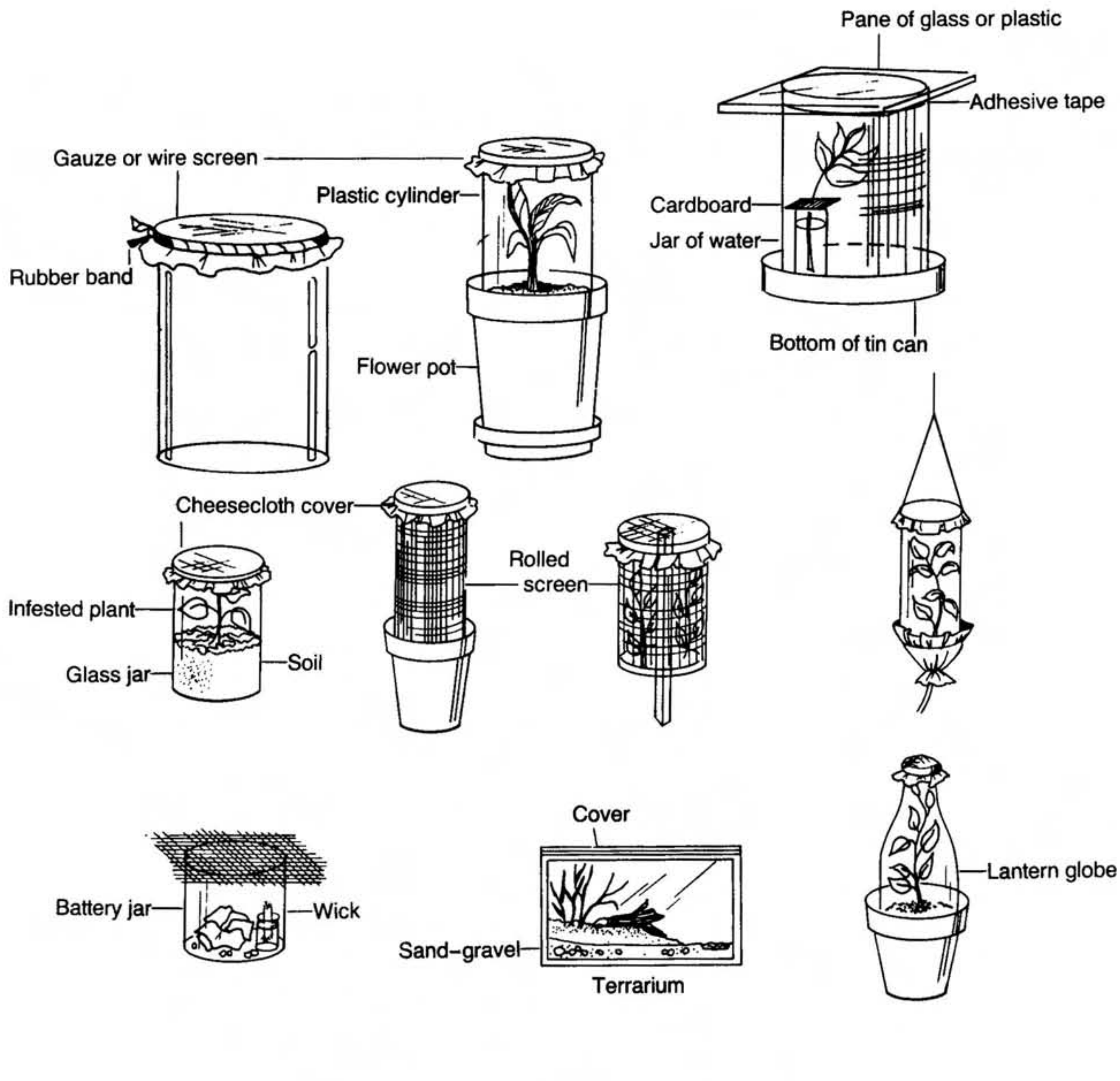

Figure 1. Examples of equipment for rearing insects.

FEEDING YOUR INSECTS

Your insects will require a constant supply of high quality food. Plant eating insects will need a fresh supply of foliage from their host plants. Many other insects can be reared on commonly available food items such as dog food, vegetables, honey, flour and food scraps. Predatory insects need live prey. This means you'll either have to culture a colony of acceptable prey insects or collect live insects from outdoors. You can simplify this task by using insect-collecting traps (pitfall, blacklight, Malaise, windowpane, etc.) to gather the necessary insects. You can also collect leaf litter samples and run them through Berlese funnels to sort out living insects.

WATERING YOUR INSECTS

Most insect cultures need an ample supply of clean drinking water to ensure their successful growth and development. Several ways to provide water to your insects are outlined below. All of the methods are easy to use and require a minimum of maintenance. No matter what method you use, however, you must always keep the "drinking fountain" clean and mold-free.

Fountain 1 (fig. 2). Fill a tall, slender glass or plastic jar with clean water. Place several layers of cheesecloth over the jar opening and secure it with an elastic band. Turn the jar upside down in a shallow dish and place it in your rearing cage.

Fountain 2 (fig. 3). Use a jar similar to the one described above. You will also need a shallow watch glass, petri dish, plastic lid or large jar lid. Fill the jar with clean water. Cut several pieces of paper toweling or absorbent cotton batting to fit inside the lid. Set the lid, with the absorbent material in it, on top of the jar and turn the whole assembly upside down. The insects will drink from the absorbent material, which will also prevent them from drowning.

Fountain 3 (fig. 4). Use a jar or large vial similar to the one used for fountain 2, except this time you must have a lid or cork big enough to fit the container's opening. Bore a hole in the lid or cork and insert a dental wick or similar roll of absorbent cotton or other material into the lid or cork. Fill the jar or vial with clean water and lay it on its side in the rearing cage. The insects will drink from the moist wick.

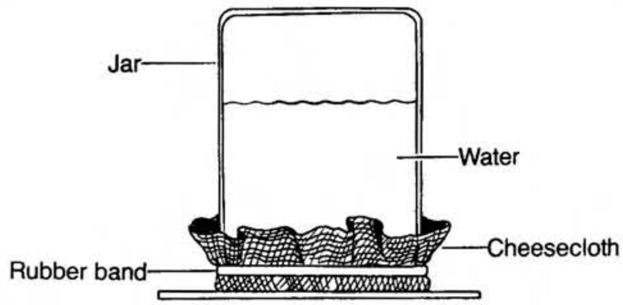

Figure 2. Insect water fountain 1.

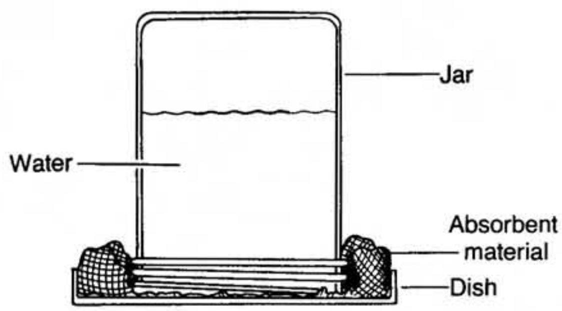

Figure 3. Insect water fountain 2.

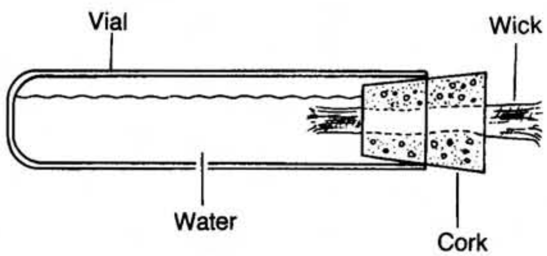

Figure 4. Insect water fountain 3.

Insects You Can Rear

AQUATIC INSECTS

The techniques for rearing aquatic insects are a little different than those for terrestrial insects. You can use any watertight container for rearing aquatic insects, but if you use a glass jar or aquarium you'll be able to see the insect easier. Fishbowls, aquariums and widemouthed (gallon-sized) jars all work well. Spread a 1-inch layer of sand or gravel in the bottom of the container, fill it with dechlorinated water and plant a few aquatic plants in the sand. You can use a variety of plants, from a pond or stream, or from a pet store. The plants provide food and hiding places, and give off the oxygen the insects need. Don't worry too much about algal growth, because the insects can eat algae, too. If the algae gets out of hand, a few snails will perform the necessary housekeeping chores.

Aquatic insects can be collected from any pond, river, stream, roadside ditch or woodland pool. A large variety of them are easily maintained in aquariums and different kinds can be kept in the same container. Collect the insects with an aquatic dip net and transport them in a loosely covered container.

Many aquatic insects are predaceous, which means they feed on other insects or microscopic water animals. If you fill the aquarium with pond water instead of tap water, your insects will get enough to eat. Tadpoles, minnows and guppies serve as food sources for giant water bugs and predaceous diving beetles (and their larvae, known as "water tigers"). Mosquito larvae will eat finely crushed dog biscuits. The tiniest pinch of crushed dog food is enough to feed many mosquito larvae.

HOUSE AND FIELD CRICKETS

Both the black field cricket (*Gryllus* species) and the tan house cricket *(Acheta domestica)* can be reared successfully. Many people rear the house cricket because they can be readily purchased from pet supply houses and "cricket farms."

Habitat requirements. Prepare a suitable cage for your crickets. The cage can be a large glass jar (with a screen or cloth covering) or a screen cage. If you use glass containers it helps to treat the inside, upper portion of the jar with a very thin layer of mineral oil, petroleum jelly or furniture wax to keep the crickets from escaping. Spread 3 or 4 inches of dry, clean sand in the bottom of each cage.

Place a small plastic or glass container of moist sand in the cage so that the top edge is about ½ inch above the dry sand. This container is the egg laying site, and must be kept moist but not wet at all times. Some cricket farmers prefer to have separate egg laying containers. They fill coffee cans with damp sand and then place 20 to 30 adult crickets (half males and half females) in each can. The female cricket is readily distinguished by her long ovipositor (egg laying organ). After moistening the sand for the first time, don't moisten it again for 3 months. The young crickets (nymphs) must have dry sand to remain disease-free.

The small container of moist sand, or the separate egg laying containers, must be kept warm (80 to 90°F) during the incubation period. Eggs will begin to hatch within 3 weeks after they've been laid. The newly hatched nymphs are very tiny and blend in with the sand. You'll need to look very carefully to see them.

Very young nymphs require soft food. You can feed them slices of banana or apple, or powdered dog food laid on pieces of lettuce. Poultry laying mash also works very well.

Place the food in a shallow container with excelsior or hay around it so the crickets have easy access to the food. Placing the food in a dish allows for easier housekeeping. The cage must be kept free of unused food and dead crickets to prevent mold or disease.

Adult crickets will do well on crushed dog nuggets or poultry laying mash. If you wish, you can supplement their diet with bits of banana, apple, lettuce, or other pulpy fruits or vegetables.

Crickets must have a constant supply of drinking water. Indeed, the water supply is more important than a constant supply of food. You can make a drinking fountain by placing an inverted jar in a shallow dish (fig. 3, page 7). Clean the fountain and replace the absorbent material every month, or as needed.

You must provide places for your crickets to hide. Paper or foam egg cartons work very well. You can also use folded corrugated cardboard, excelsior or hay. Young cricket nymphs must be kept separate from the adults until they are one-third to one-half grown, or they are likely to be eaten! After they have reached the required size, they may be safely put in with the adults.

Life cycle. The length of time crickets take to complete their development depends on several factors: temperature, moisture, freedom (amount of space), and the presence or absence of disease-causing organisms, predators or parasites.

If all other conditions are favorable, the developmental time is most directly regulated by temperature. Nymphs held at 90°F may require only 30 to 35 days to complete development, while those held at 80°F may require up to 65 days to mature. Four hundred crickets can be reared every 3 months in a container as small as 24 inches in diameter. A smaller container will result in fewer crickets being produced.

BLABERUS COCKROACHES

The *Blaberus* cockroach is a giant among roaches, measuring up to 3 inches long and 1½ inches wide (depending on the species). These roaches are not native to Michigan; they are found in Florida, the Carribbean, and Central and South America. These insects are easy to rear and observe, and are well-suited to experimentation.

Obtaining the insects. Since these roaches are not native to our area, you will probably have to purchase them from a biological supply house. Because *Blaberus* roaches are potential household pests, a USDA permit is required to have them mailed to you. The supply house will usually handle this for you. Sometimes you can obtain starter cultures from universities or insecticide manufacturers.

Habitat requirements. Any type of cage covered with ordinary window screen will work well for rearing these roaches. Even the smallest nymphs are too large to squeeze through the mesh. Some absorbent material, such as sand, should be placed in the bottom of the cage. The sand should be replaced every 4 to 6 months. Pour the used sand through a sieve to avoid throwing away any small nymphs. Keep in mind that these are tropical insects, and place the cage in a warm location. They seem to do best at about 80°F. Also, the roaches prefer subdued light, so don't keep them in an area with bright lights (don't use a light bulb to warm them unless absolutely necessary).

Any high-protein dry dog food can be a staple in your roaches' diets. Dog food can be fed directly from the package, no pulverizing is necessary. If you see evidence of "wing-nipping" (a tendency toward cannibalism), you can safely assume that your roaches' diet is protein deficient. Supplementing the roaches' diet with protein-rich foods such as powdered milk, meat scraps or fresh liver should eliminate this problem. The protein diet should also be supplemented with fresh fruits or vegetables such as lettuce, carrots, celery tops, apples or potatoes. The apples and potatoes are high in moisture and may eliminate the need for a separate supply of drinking water.

A constant supply of drinking water is important for the roaches' survival. As mentioned before, some fresh fruits and vegetables can actually be a water supply for these roaches. However, you will probably want to use a drinking fountain to ensure that the roaches have plenty of water.

Life cycle. The youngest *Blaberus* nymphs bear little resemblance to the adults. When they first appear, they are about ¼-inch long and quite flat. In some ways they resemble the fossil arthropods known as trilobites. The nymphs grow fairly rapidly through the seven or eight stages, each of which is separated by a molt. Wings appear after the last molt (when the roach becomes an adult). The average time required for development, from the first nymphal stage to adulthood, is a little less than 6 months.

Male and female adult *Blaberus* roaches look very much alike, but you can tell them apart if you look closely. To identify the sex of a *Blaberus* roach, grasp the roach with your thumb pressed against the ventral side of its thorax. Examine the underside of the last abdominal segment. In both sexes there will be a conspicuous pair of appendages (called cerci) projecting from the outer margins of the last segment. The males also have a second pair of appendages, called styli. The styli are much smaller than the cerci, and are located just inside the cerci. The styli are very small and are barely visible without magnification.

The female roach produces eggs capsules, also known as oothecae. One *Blaberus* ootheca is about ½ inch long and contains 20 or more compartments, each with an egg. Most other species of roaches deposit their egg capsules long before they are ready to hatch. This is not so in *Blaberus,* so the egg capsules are rarely seen. The females hold the egg capsule within their bodies, where they eventually hatch. Thus it appears that the female "gives birth" to 20 or more young nymphs.

MILKWEED BUGS

The large milkweed bug is ideal for your 4-H entomology project. It is brightly colored and easy to maintain. It requires little space, is easily observed, creates no offensive odor, is resistant to diseases and parasites, and has a fairly short life cycle. This species is widely distributed throughout the United States and can be readily collected during the proper season.

Obtaining the insects. Milkweed bugs are collected from their host plants, milkweeds (*Asclepias* species), which commonly grow in pastures and along roadsides. The plants are often 4 to 5 feet tall. Their stems and large, fleshy leaves contain a milky juice, or latex. The seeds are borne in pods which turn from green to brown as they mature. When the pods are fully ripe, they split open, releasing the seeds. A tuft of soft, silky hair (down) is attached to each seed and acts as a parachute, helping the mature seeds drift with the wind. In the Midwest the pods appear in August and September. Therefore, late summer and early fall are the best times to search for milkweed bugs.

The bugs begin to appear on milkweed plants as the maturing pods change from green to brown. The larger milkweed bug does not overwinter in Michigan and must reinvade the state each year from south of the Ohio River valley. Adults and older nymphs will be found feeding on milkweed pods and the seeds they contain. You will find more bugs on pods which have begun to split open. The bugs are easy to see because of their bright reddish-orange and black markings, and they are easy to collect by hand. Collect both adults and nymphs, and place them in your collecting container. You will also need to collect a lot of milkweed pods to feed your bugs over the next year.

Special strains of large milkweed bugs that are able to survive on unsalted sunflower kernels are now available through biological supply houses. The advantage of buying these bugs is that you don't have to collect milkweed seed to use as food.

Habitat requirements. The large milkweed bug adapts well to rearing in glass or plastic containers. Fish bowls or gallon jars covered with screening or cheesecloth are quite suitable.

The bugs are fully capable of flying, but in captivity they seem to prefer crawling around the container, and will readily climb the vertical glass or plastic walls. It's a good idea to ring the mouth of the container with a thin layer of mineral oil, petroleum jelly or furniture wax. This will keep the bugs from escaping when the cover is removed for housekeeping, etc. The bottom of the container should be lined with material for the bugs to crawl on; paper towels cut to the same dimensions as the container will work well. Keep the cage clean and avoid overcrowding.

Milkweed bugs require milkweed seeds for proper growth and development (unless of course, you are using a sunflower seed strain of the bug). Since milkweed seeds are not available commercially, you'll have to collect your own supply of pods and seeds. This is easily done when you collect your bugs. Pods which have recently split open are just right for collecting, but you can take green pods as well. After the pods are dry, separate the seeds from the pod and down. The dry seeds can be stored indefinitely at room temperature.

Generation after generation of milkweed bugs will develop on a diet of seeds (milkweed or sunflower, depending on the strain) and water. Used seeds should be discarded periodically.

Milkweed bugs need a water source. The most convenient way to water them is with a vial and wick fountain (fig. 4, page 7). Soiled wicks should be replaced frequently.

Small balls of cheesecloth are suitable sites for egg laying (oviposition). They can be easily removed and transferred to other containers for starting new colonies. The eggs will hatch right in the cheesecloth and the young nymphs will crawl out.

Life cycle. The oval, yellowish eggs are laid in clusters of 10 to 50. The newly laid eggs look very much like miniature jellybeans. The eggs hatch within 1 to 2 weeks when held at 70 to 80°F. They change from yellow to reddish orange during incubation.

Newly emerged nymphs are bright red and about the size of a pinhead. They crawl about actively looking for food almost immediately after hatching. The nymphs grow fairly quickly through their five nymphal stages (instars). Wingpads appear early in development.

Milkweed bugs reach adulthood after the fifth nymphal molt. Fully developed wings are characteristic of the adult stage. The male and female can be distinguished by examining the ventral abdominal surface (fig. 5). In the male, the second abdominal segment (counting from the end closest to the thorax) is unspotted, the third segment bears a wide black band and the fourth segment has a somewhat nar-

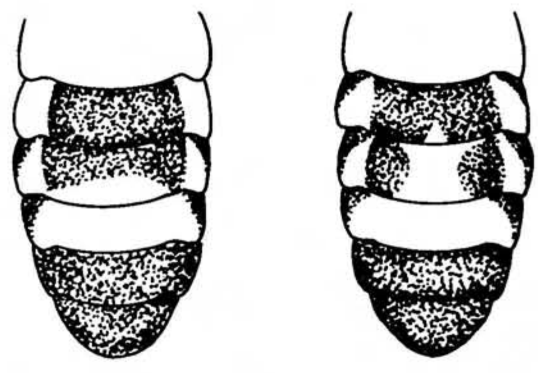

Figure 5. Underside of abdomen in adult male and female larger milkweed bugs.

row black band. The female's second abdominal segment has two black spots, the third segment has a wide black band (like the male) and the fourth has two black spots (instead of the narrow band like the male).

Large milkweed bugs mate in an end-to-end position. They couple at any hour of the day or night, and mating pairs may remain attached for 30 minutes or more. If the colony is kept at about 80°F, the eggs will develop to adulthood in about 25 to 30 days.

MEALWORMS

Mealworm larvae are excellent fish bait and can be used either alive or preserved. The yellow mealworm, *Tenebrio molitor,* is the species most frequently reared and used for bait. These beetle larvae are also used as food for exotic pets, such as lizards and tarantulas, and therefore can often be purchased in pet shops. They are also sold by bait dealers and biological supply companies.

Habitat requirements. Any large glass or plastic container will work for rearing mealworms. Your mealworms will live well in a mixture of either graham flour and meat scraps or wheat bran with a small amount of dry brewer's yeast. Wheat bran alone seems to be an inadequate staple diet; the larvae will grow larger if you add yeast. Place 3 to 6 inches of food in the container.

Maintaining an adequate moisture supply is essential for mealworm survival; too little or too much moisture is equally bad. If there is too little moisture available, the larvae will grow slowly and will be small. If there is too much moisture, the food becomes moldy and poisons the larvae. To maintain suitable moisture levels, place either a piece of cabbage, carrot or potato on top of the food. Replace it as needed. You also need to supply drinking water to the larvae; use a vial and wick fountain (fig. 4, page 7). Be sure to keep the fountain clean and don't let it leak large amounts of water.

When the larvae are nearly full-grown (about ¾ inch to 1 inch long), place corrugated paper, burlap cloth or crumpled paper towels in the container. Let the adult beetles emerge from these hiding places before disturbing them. Don't keep too many adults in one container. Crowding will eventually reduce the population, because the adults may begin to eat the eggs. Remove some of the adults when the colony has more than two or three adults per square inch. You can use these surplus adults to begin additional colonies, if you wish.

Life cycle. Larval mealworms molt 9 to 20 times during their development. If your mealworms are well-fed, warm enough (about 80°F), not overcrowded, and are exposed to sufficiently humid conditions, they will complete their development in about 5 months. On the average, the adults live for 84 days. Each female lays about 275 eggs.

FLOUR BEETLES

Habitat requirements. Any medium to large glass or plastic container is suitable for rearing flour beetles. Fill the container with an inch or two of white flour, finely ground whole wheat flour or cornmeal. No water source is needed.

Avoid overcrowding your cultures. Periodically transfer some beetles to a fresh food medium. The beetles should be transferred with some care because they are fairly delicate. Avoid using an aspirator to transfer the beetles, because they emit a disagreeable odor when disturbed. A small brush, spoon or spatula works better.

Life cycle. Two species of flour beetles commonly infest stored food products. They are the confused flour beetle *(Tribolium confusum)* and the red flour beetle *(Tribolium castaneum).* The species are very similar in size and appearance, but they can be easily distinguished by the difference in their antennae. The red flour beetle has an abrupt, distinctly three-segmented antennal club, whereas the confused flour beetle has a gradually swollen antennal club.

Flour beetle eggs are very small (several would fit on the head of a pin). The whitish larvae are very active and burrow in the food medium. They pass through 6 to 11 instars, depending on the quality of their food and the temperature. You can determine the sex of the beetles as soon as they reach the pupal stage, but because they are so small you will need to use a low power microscope or a high power hand lens to do so. Examine the underside of the terminal abdominal segment. The females have a pair of small appendages. The males either have much smaller appendages or none at all.

Flour beetles average 3.4 mm in length. Although adults may live for up to 2 years, their average lifespan is only 6 months. The time it takes them to complete development, from oviposition to adult emergence, varies with the environmental conditions. At 80°F and 75 percent relative humidity, the process takes about 40 days.

WAX MOTH LARVAE (WAXWORMS)

The greater wax moth, *Galleria mellonella,* is a pest in honey bee combs, but certain growth characteristics make it suitable for rearing in mass cultures. You can make many valuable observations on the life cycle and biology of insects in your wax moth culture. Also, mature larvae can be harvested and used or sold for fish bait and pet food.

Obtaining the insects. Cultures can be started from any stage, but the usual procedure is to collect larvae from infested combs or to buy them from a biological supply company. Rear the larvae in a large glass or metal container (they can chew through wood and soft plastic).

Habitat requirements. In nature the larvae feed on the pollen, honey and beeswax in honey combs. When rearing waxworms in large numbers it is easier to prepare and use a manufactured diet. One such diet, which is inexpensive, easy to use and that produces favorable results, is made with granular dog food and honey. The food should be prepared as follows. Mix seven parts granular dog food and one part water, then add two parts honey. Mix the ingredients thoroughly and allow them to stand for at least a day before using. The dog food granules should be soft, but not sticky.

Wax moth cultures will be most successful if you provide them with fairly constant conditions of 90 to 95°F and 75 to 85 percent relative humidity. Add food to the container as the larvae eat it. A continuous cycle of larvae can be obtained by allowing female moths to deposit their eggs on the food in the container. Transfer some adult moths or a few larvae to a fresh container occasionally.

When mature larvae are ready to pupate, they will crawl into any available crevice or hollow to spin their cocoons. If you want to "harvest" waxworms, you can take advantage of this behavior by furnishing the culture with a pair of boards with a ¼-inch gap between them (nails or screws and a few washers can be used to hold the boards apart). Larvae will crawl into this space and can be collected daily. They can be counted and allowed to crawl into rolls of corrugated cardboard strips for holding.

Once the mature larvae have tunneled into the corrugated strips they can be placed in a cool storage area to halt further development. Do not place them in a refrigerator (it's too cold). At temperatures near 60°F the larvae won't pupate for 2 or 3 months.

Life cycle. Under the best temperature and humidity conditions, the life cycle (egg hatch to adulthood) of the greater wax moth takes about a month. If conditions are not favorable, development may take much longer. The larvae pass through seven instars. They feed actively in all instars but grow the most in the final two. The mature larvae spin cocoons and pupate. The adults emerge from these cocoons within a week or two.

BUTTERFLIES AND MOTHS

Obtaining the insects. You can start a moth or butterfly rearing program at any stage in the life cycle of these insects. Eggs and pupae (cocoons) can be purchased from biological supply companies or Lepidoptera breeders. Larvae can be collected in the field if you know where to look. Also, females can be used to attract and capture males, and then

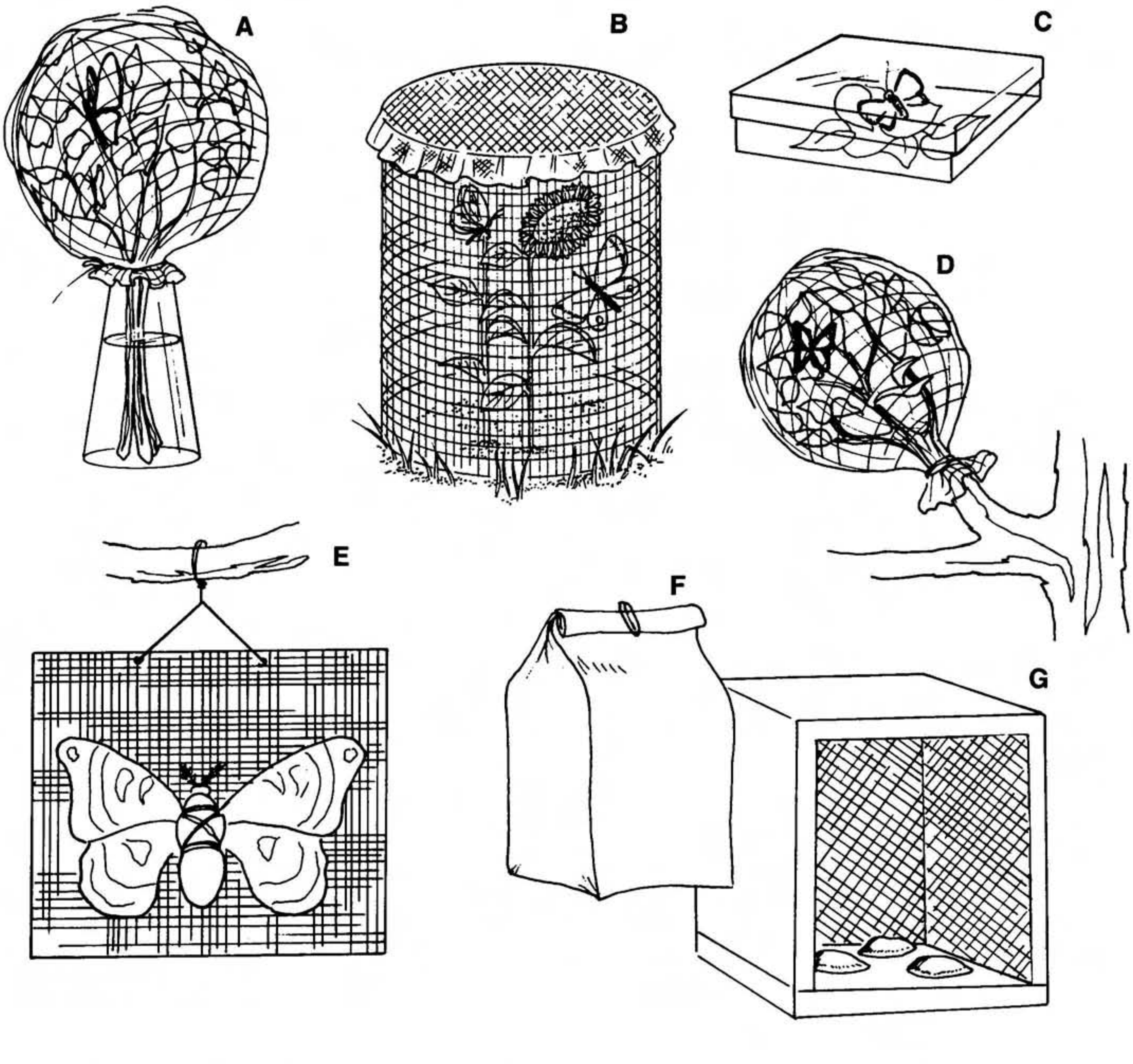

Figure 6. Techniques for rearing Lepidoptera: a) bouquet of foilage set in a bottle of water and covered with nylon netting, b) screen cage with plant growing inside, c) plastic box with leaves, d) nylon sack tied over a plant branch, e) female moth tied to a screen to attract males, f) paper sack for use as an egg laying chamber, g) emergence cage.

you can breed your own butterflies or moths. Several techniques for rearing butterflies and moths are illustrated in fig. 6.

Life cycle. After the males and females have mated, place the females (distinguished by their larger body size and narrower antennae) in paper bags for oviposition. Some species will glue their eggs to the inside of the sack, and others will drop them to the sack's bottom (they may look like a sprinkling of sugar in the sack). After the eggs are laid, remove them from the sack and place groups of 20 eggs into separate hatching containers. If the eggs are glued to the sack, cut the sack around them and place the paper discs in the hatching containers. Any half-gallon or larger container will do.

When the eggs hatch, place several leaves of the appropriate food plant into the container (table 1 or 2, pages 17 and 18). Make sure the leaves you use haven't been treated with pesticide! Your container should have a screen or cheesecloth cover that prevents escape but provides adequate ventilation. If you use an airtight cover, moisture will build up and the leaves and larvae may mold. After the larvae start feeding, keep them supplied with plenty of fresh leaves. Remove any uneaten and dried leaves frequently.

If the larvae get large, or if you have many larvae, it may be necessary to transfer them to a larger container or to cages. Food plants may be placed in bottles of water to keep them fresh longer. Provide fresh food, keep the container clean and uncrowded, and provide plenty of ventilation if you want your rearing efforts to succeed.

Do not disturb the larvae once they have begun to spin cocoons or form chrysalises. You may need to supply them with sticks or other objects for chrysalis or cocoon attachment. At this point it is necessary to determine whether the species you are rearing overwinters (hibernates) in the pupal stage. This will determine whether the adults will emerge in a week or two, or whether the pupae (cocoons) must be exposed to cold temperatures before the adults emerge. Life cycle information for many common species of butterflies and moths is contained in tables 1 and 2 (pages 17 and 18). For species not listed in either table, refer to one of the books listed under "References" on page 35.

Pupae (cocoons) can be stored in any protected place that is exposed to cold temperatures, such as a breezeway, garage, porch or outdoor rearing cage. Many species will respond to a short "artificial" winter. Place the cocoons and a single green leaf (to maintain proper moisture) into a container and put the container in the refrigerator for 8 to 12 weeks. Remove the cocoons from the refrigerator and let them warm up gradually if you can. Then place them in a rearing cage lined with cheesecloth or screening (to provide footholds for adults to hang from while their wings expand). Do not disturb the emerging adults until the wings appear to be fully expanded and hardened; this usually takes 24 to 48 hours.

Some moths, such as sphinx moths, pupate in the ground. After the last molt, the larvae should be transferred to a container that has several inches of peat moss in the bottom. The mature larvae will crawl into the moss and can be left there until they emerge on their own.

Table 1. Quick Helps for Butterfly Rearing.

Butterfly Species	Larval Food Plants	Egg Color	Days to Maturity Egg	Days to Maturity Larva	Adult Activity
Eastern black swallowtail	carrots, parsley, parsnip, celery, Queen Anne's lace	yellow white	5-7	24	May to Sept.; 2-3 broods
Spicebush swallowtail	spicebush, sweet bay, sassafras, prickly ash	yellow white	5-7	21	May to Sept.; 2-3 broods
Tiger swallowtail	cherry, ash, birch, lilac, aspen, willow, hornbeam	yellow white	5-7	22	April to Oct.; 2-3 broods
Common sulphur	clover, vetch, trefoil, alfalfa	white	5-6	21	April to Oct.; 3-4 broods
Cabbage	cabbage, collards, broccoli, winter cress, nasturtium	yellow white	5-6	14	May to Sept.; unavailable
Monarch	milkweed, dogbane	yellow white	7	10	June to Sept.; 2-4 broods
Great spangled fritillary	violets	yellow white	3-4	14	May to Sept.; 1-2 broods
Baltimore	turtlehead	yellow orange	21	hibernate	June to July; 1 brood
Questionmark and Comma	elm, nettles, hops	green	5-7	21	June to Aug.; 2 broods
Buckeye	plantain, Gerardia	green	5	14	April to Sept.; 2-4 broods
American painted lady	everlasting	green	3-5	21	May to Sept.; 2 broods
Painted lady	thistles, nettles	green	4-5	21	May to Sept.; 2-3 broods
Red admiral	nettles	green	4-5	21	May to Sept.; 2-3 broods
Milbert's tortoiseshell	nettles	green	4-5	14	May to Sept.; 3+ broods
Mourning cloak	willow, poplar, elm, hackberry	yellow brown	14	21	June to Sept.; 2-3 broods
Viceroy	willow, poplar, birch, cherry	brown	4-5	18	June to Sept.; 2 broods
Hackberry	hackberry	green	4	30	June to Sept.; 2 broods
American copper	sorrel	green	4	14	May to Oct.; 4-5 broods

Table 2. Quick Helps for Moth Rearing.

Moth Species	Larval Food Plants	Egg Color	Days to Maturity Egg	Larva	Adult Activity
Cecropia	apple, willow, maple, box elder, cherry, lilac	ivory	10	60	May to June
Io	willow, cherry, oak, hickory, plum, ash, poplar, linden, elm	white and yellow	10+	40	June to Aug.
Promethea	cherry, sassafras, willow, poplar, ash, apple, pear, lilac, plum	pinkish	11	42	May to June
Polyphemus	elm, maple, cherry, oak, linden, apple, box elder, hickory, birch	white	7	48	May to June
Cynthia	ailanthus, cherry, willow, ash	white	7	42	July
Luna	walnut, birch, oak, hickory, butternut, beech, willow	white and gray	15	48+	May to June
Imperial	spruce, pine, cherry, birch, alder, elm, maple, hickory	yellow	13	42	July
Tomato hornworm	tomato, potato	pale green	7	40+	July
Bumblebee	vibernum, snowberry, hawthorn	green	7	35-42	June to July
White-lined sphinx	grape, apple, dock, chickweed, purslane, weeping willow	yellow green	6	30	July
Twin-spotted sphinx	apple, elm, ash, willow, birch	greenish	6	30	June to July
Underwings (Catocala)	plum, apple, cherry, willow	various	(overwinters)		July to Sept.
Virgo tiger	dandelion, plantain	white	*	49	July to Aug.
Garden tiger	dandelion, plantain, dock	white	*	56	imported
Four-horned sphinx	elm	green	*	35	July
Laurel sphinx	privet	green	*	35	July
Pen mark sphinx	ash, cherry	green	*	40	July
Oak silk	oak, crab apple, hawthorn	brown	7	28+	imported

*Information is unavailable.

ANTS

Ant "farming" has been a fascinating hobby for many generations of nature enthusiasts. Ants are especially interesting because of their social habits. Ants live in colonies where there is a division of labor. The tasks necessary to maintain the colony are divided among three groups or castes of ants.

The workers are responsible for building, maintaining and defending the nest. They also gather food and care for the immatures (larvae and pupae). A single queen lays most of the eggs but she may be assisted by supplemental (auxiliary) reproductive females. At certain times males are also present in the colonies. Because of their complex social system, ants are highly successful insects that inhabit virtually every environment.

Obtaining the insects. As with many other insects mentioned in this manual, you can either buy your ants or collect your own. Ants can be obtained just about any time of the year, but late July through early September is the best time because you are most likely to find winged, mature ants in or near the nests. All you need to collect ants is a shovel, trowel, kitchen strainer and large (at least gallon-sized) pail or other container with a lid.

Find an ant hill, preferably a small one in loose, sandy soil. If there is a large mound, remove it with the shovel. Dig into the heart of the nest. Use the trowel and strainer to collect ants and place the ant/soil mixture in your container. Fifty workers should be enough to stock the average artificial ant nest (12 inches by 12 inches). Find and capture the queen if you can; she'll be bigger than the other ants in the nest. Also collect samples of any other life stages you see, such as larvae, pupae ("ant eggs" to the nonentomologist) and winged reproductives.

Place the ant/soil mixture in the artificial nest. Remove any large clumps of soil, rocks, vegetation and other debris. Cover the glass faces with cardboard and leave the nest undisturbed for several days. If you don't cover the glass with an opaque material, the ants are likely to construct their galleries in the center of the nest and you won't be able to see most of their activity. Once the colony is established, keep the glass covered when you aren't observing it, or cover the glass with red acetate to simulate darkness.

Habitat requirements. Ants are easily reared in just about any kind of container, but if you want to observe their activity you will need to use an artificial ant nest or ant farm. Ant farms are available from many biological supply companies and hobby shops, both assembled and as kits. The typical ant farm is nothing more than two panes of glass or plastic 1 to 3 inches apart and filled with sand or soil. You can easily construct your own ant nest by studying figure 7.

Most ants are omnivorous and will eat just about anything. You can feed them dabs of honey thinned with water, molasses (also thinned), fruit syrup, dead insects, or crumbs and food scraps from the dinner table. Periodically remove any unused food to prevent mold. Water your ants by placing two small pieces of wet sponge in the nest. Many nests are built with special holes in the lid so that you can feed and water the ants without opening the entire lid.

The long-term success of your ant farm will depend on whether your colony has an active queen or supplemental reproductives. If your

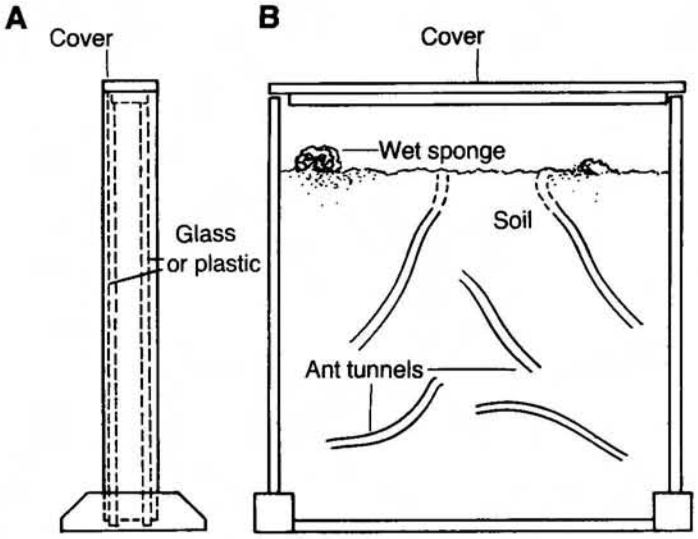

Figure 7. Typical artificial ant nest or "ant farm": a) end view, b) front view.

colony has no queen it may die out each year, but this is really no problem because you can replace the ants easily.

Once your ant nest is well-established, you may want to try some other interesting observations. You can connect your colony to a separate feeding chamber or to a captive colony of ant lions (a predator of ants) by attaching a length of ⅜-inch to ½-inch plastic or rubber tubing between them. Now you can observe ant foraging behavior or predator/ prey interactions.

SPIDERS

Although spiders are not insects, they are often reared by 4-H'ers interested in entomology. Spiders are exciting to keep and observe, even temporarily. All spiders are predatory, and watching their diverse food gathering and feeding habits is very interesting. There are a few problems with keeping spiders alive. Since they are predatory you must have a supply of living insects to feed them (they will not accept dead insects). For this reason many people who rear spiders, especially tarantulas, also rear crickets, cockroaches or mealworms as food sources. Spiders are definitely inclined to eat each other; therefore, they must be well-fed or kept in separate containers.

Obtaining spiders. Like insects, spiders can either be purchased or collected in the wild. Many native Michigan spiders can be successfully collected and reared. Many people are interested in keeping tarantulas, which can be collected in the southwestern United States and Mexico. Most people buy theirs from a biological supply company or a pet shop, however.

Habitat requirements. The type and size of the container is relatively unimportant, as long as it is big enough to let the spider move around freely, and small enough to regulate the humidity if necessary. If your spider is one that normally builds a web to catch its prey, the container must be large enough to hold a web. A gallon jar with several twigs or branches inside to support the web will work well for web-building spiders.

An adequate supply of moisture, both in relative humidity and drinking water, is critical for most species of spiders. Placing a piece of wet absorbent cotton in a shallow dish allows spiders easy access to moisture without the risk of drowning. You can also use a cotton-stoppered, water-filled vial (fig. 4, page 7). Be sure to change the cotton every week. The relative humidity of the atmosphere in the container appears to be very important for many spider species. The natural habitat of your spider can serve as a clue to its humidity requirements. Those species which live near water or in the ground require higher relative humidities than do other species. Wet the soil in your container so that it remains slightly moist to the touch. Do not overmoisten it!

Spiders are predators, which means they require live prey. Lack of or improper food is usually the reason spider raising efforts fail. The feeding problem may be particularly acute with spiderlings (young spiders) that have just emerged from the egg sac. The young of most spider species need food immediately in order to prevent them from eating each other. It is often hard to find prey small enough for the young of some spider species. If you have many spiderlings in a single container you can solve this problem by allowing them to eat each other until some are big enough to accept larger insect food. Another solution is to rear a suitable small insect species, such as flour beetles. The larvae of flour beetles work quite well as spiderling food.

If you plan to rear spiders over the winter months, you have almost no choice but to start a culture of some insect species as a constant food supply. Wingless fruit flies, mealworms, crickets and lepidopterous larvae (caterpillars) all work well, especially for larger spiders.

Spiders, like insects, are subject to a variety of diseases. No matter how careful you are, you will still lose some spiders to bacteria and fungi. Healthy spiders have the best chance of avoiding disease, so be sure that your spiders are well-fed and well-watered. Rearing containers should be thoroughly washed and dried between uses. Change the cotton of your water fountain frequently, especially if it has been contaminated by the juices of insects the spider has killed. These juices form a very good medium for the growth of many fungi.

Tarantulas. Tarantulas require nearly the same conditions as other spiders. A terrarium with sand in the bottom makes an ideal container. Never place more than one tarantula in a terrarium, because they are strongly cannibalistic!

Most spiders only live for a year or so, but female tarantulas may survive for up to 20 years. When you buy a tarantula, try to get a female or an immature male, because mature males will only live for another year or so! Look at the "knee joint" of the first pair of legs. If the joint has a small pair of thumblike projections, then the spider is a mature male. Don't buy that one if you want a long-term pet.

Contrary to popular belief, tarantulas are not dangerous, although they will bite if handled roughly. The bites are painful (like a bee sting) but not fatal. Although tarantulas are easily handled, the risk of hurting the spider is great, and you should only handle your spider when absolutely necessary.

Tarantulas need both food and water. Hungry tarantulas will try to eat just about anything that moves and is smaller than they are (spiders, large insects, small snakes, lizards, toads and baby mice). They can also be tricked into eating canned dog food or ground beef. Do this by forming a small ball of meat around the end of a piece of thread and then jiggling it in front of the spider. When the spider grabs the bait, keep jiggling the string while you gently pull the string out of the meat. The spider will think the "prey" is struggling to get away and should then really hold on to it.

One large insect a week is enough for most tarantulas. During spring, summer and fall most tarantula species should be fed every 4 or 5 days. During the winter the spiders seldom eat, but it's a good idea to offer them food once every other week. It is impossible to overfeed tarantulas; they will only eat according to their needs. Water can be provided by placing moist cotton in a shallow dish and putting it in the spider's terrarium.

OTHER ARTHROPODS

If you can duplicate the natural conditions (food, water and environment) required for growth and survival, there are many other arthropod species you can rear. More information is contained in "References" (page 35). Some other arthropods you can rear are:

- Isopods (sowbugs, pillbugs, etc.)
- Millipedes
- Centipedes
- Scorpions
- Giant whipscorpions (vinegaroons)
- Dragonflies and damselflies
- Mole crickets
- Grasshoppers
- Walkingsticks
- Praying mantids
- Termites
- Earwigs
- Tent caterpillars
- Grain, meal and flour moths
- Ant lions
- Ladybird beetles
- Ground beetles
- Passalid beetles (bessbugs)
- Bean and pea weevils
- Wood-boring beetles
- Hide and carpet beetles
- Mosquitoes
- Fruit flies *(Drosophila)*
- House flies

Reared Insects as Projects

To conduct an insect rearing project, you may take two approaches: long-term or short-term rearing studies.

Long-term. Select one or more insect species and try to rear them through several generations. Here are some items that should be pat of your project:

Record notebook. Keep a journal of everything you did, the type of container or cage you used, the type and amount of food you fed the insects and the rearing conditions (temperature, humidity, light, etc.).

Reproduction rate. Count or estimate the number of individuals in your culture at regular intervals (weekly or monthly).

Problems. Describe any problems you encountered, whether solved or unsolved! Report the problems you ran into (like insect diseases, parasites, starvation or accidents) and tell how you handled these situations.

Life cycle. Collect and preserve representative specimens from each life stage to show the complete life cycle of the insect species you studied. Keep notes on the life cycle of your insects and how long it takes them to complete their development at certain temperatures.

Educational displays. Prepare a notebook, picture album, display or slide program so you can share what you learned from your project.

Short-term. Even if you are only able to observe insect cultures (either your own or someone else's) for a short period of time, you can still conduct a study project. Here are some of the items you may want to observe and report on.

Life stages. Which are present? Which are absent? How much time is spent in each stage? How active are the various stages?

Requirements for life. What are they, and what evidence do you see to support your conclusions?

Reproduction. How do the insects mate and reproduce?

Field Observations of Live Insects

You can discover many interesting facts about insect life cycles, behavior and ecology by observing insects in their natural habitat. Your observations could provide insight into some of the many unanswered questions about insects. The following information is intended to stimulate you to conduct your own field observations of living insects. Therefore, only basic information and a few examples are given. The rest is up to you!

KEEPING A FIELD NOTEBOOK

Every good field observer keeps a notebook. This is very important in preserving your observations. You should not rely on memory alone for an accurate accounting of your observations. You must train yourself to write everything down. Some observers write everything down while they are in the field. Others take notes and then write a full account of their observations once they are at their home, office or laboratory. The method you choose will depend on the complexity of the insect activity you are observing and your ability to recall facts. You may be able to use the **4-H Entomology Record and Report** (4-H 1393) to record some of your field observations.

To improve the accuracy of their recorded observations, some entomologists use tape recorders and even computers to record extremely complex, varied or abundant observations in the field. They can then transcribe their recorded observations at a later, more convenient time.

Not all observations are best recorded as words. Some observations are better recorded as photographs. You've no doubt heard the old saying, "A picture is worth a thousand words!" Well, there is a considerable amount of truth to this old saying, because many insect activities are best captured for later study with photographs. You may also be able to use sound recordings to gather information on those insects which "sing" or make other sounds.

No matter how you record your field observations, there are a few essential items you should always include.

Date month, day, year

Location state, county, city and specific location of your observations

Conditions day or night, temperature, weather, host plant or animal, traps or special techniques used, etc.

Observations species being observed, detailed account of your observations of insect activity

Observers list all observers

Date July 28, 1989

Location Crystal Falls, Iron Co., MI; on riverbank below Paint River dam.

Conditions 3:15 p.m., 83 °F, humid, sunny; using aerial net.

Observations Watched Eastern blue darner dragonflies skimming the river, one or two individuals at a time. Caught one male and two females. Some mating activity underway.

Observers Gary Dunn, Rebecca McKee and Susan Seitz

FIELD OBSERVATION PROJECTS

Insect development and life cycles. The following section contains suggestions for field observations on insect development and life cycles. Remember, these are just suggestions to get you started. There are many other projects you could conduct if you just use your imagination.

1. Keep a notebook of your observations on the life cycles of various insect species. What time of year do you see the various insect life stages? Are they more or less abundant than in previous years? What are the effects of natural enemies such as predators, parasites and diseases? What is each species' preferred food source? Do the habits of the adult and immature insects differ?
2. Photograph the life cycle of an insect species. You can also collect and preserve a representative specimen of each life stage and both adult sexes.
3. Construct and set out trap nests for bees and wasps. This technique is used to attract and study the species of solitary bees and wasps which normally nest in hollow twigs and branches.

   Most species have a single generation each year, but some have two or three. Bees stock their nests with pollen mixed with nectar. Wasps, however, use animal prey such as caterpillars, spiders, aphids, crickets and leafhoppers. The female finds the nest, makes the cells and provides food for each cell. She lays one egg on the food and makes a cell partition of mud or leaves. She continues laying eggs and building partitions until the nest is filled. The eggs hatch in 3 or 4 days and the larvae feed on the pollen or the insects until the food is gone. The larvae then spin cocoons and hibernate for the winter. The adults emerge the following season.

   Trap nests (fig. 8) can be made by cutting narrow strips of soft wood (6 inches by ¾ inch by ¾ inch). The long axis of the strip should be oriented with the grain, not across it. Cut a groove into each strip, then seal one end of each groove with wood filler (putty or caulking). Number each nest (using permanent ink), then wrap each one with a piece of clear plastic (cellophane). Put a cover strip in place to darken the nest; these can be held in place with elastic bands. The nests are usually bundled together in groups of 9 or 12. Place bundles of nests horizontally in different parts of a yard, farm, field or woodlot. You can remove the cover and look through the plastic without harming the inhabitants.

   Keep a notebook of your observations, recording information separately for each numbered nest. Inspect the nests frequently and record your observations of the bee or wasp activity. Record the dates for starting and finishing the cells. Check the position, size and shape of the eggs. Check for larvae, parasites and cocoons. After the larvae spin their cocoons, you can put them in an emergence cage and wait for the adults to appear.

Insect behavior. The following section contains suggestions for field observations on

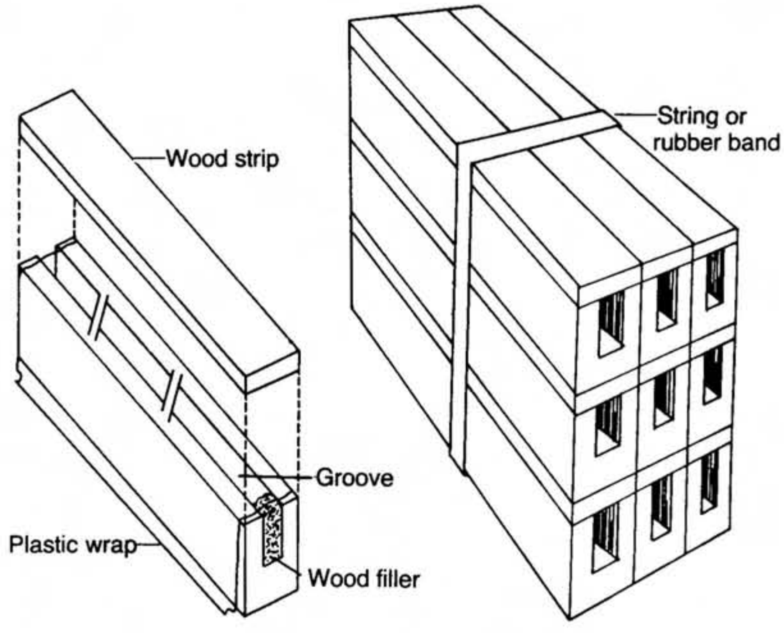

Figure 8. Trap nests for bees and wasps: a) individual trap nest, b) nine trap nests bundled together for placement in the field.

insect behavior. Remember, these are just suggestions to get you started. There are many other projects you could run if you just use your imagination.

1. Keep a notebook of your observations on the behavior and daily activities of various insects species. Here are some examples:
   Aphid colony. Record population increases. How does this effect the number of winged individuals? How do they react to their natural enemies? What is their relationship with various ants and leafhoppers?
   Ant nest. What happens when two ants meet? What type of food are they gathering? Do the workers cooperate when gathering food? Do they use pheromone (odor) trails? Is there any nocturnal activity? Are there different types of nest structures? How many individuals are there in the colony?
   Solitary bees. Can these ground nesting bees find their nests if you change nearby landmarks? How frequent are their foraging trips? What type of food do they gather?
   Bark beetles. What tree species do they attack? Do they attack healthy trees? What do the larval galleries look like? Are the patterns different for each species? Are they vertical or horizontal?
2. Take photographs to illustrate unique insect activity or behavior.
3. Record insect songs and other sounds. Capture specimens for matching a species to each song.
4. Use an ultraviolet (UV) blacklight to observe the behavior of nocturnal insects. What groups of insects are attracted to the light? What happens if you place the trap at different heights? What happens if you run the light at different times of the night (10 p.m. to midnight versus 3 to 5 a.m.)? Is the catch different in numbers and species in different months? How many pest versus nonpest species are attracted to the light?
5. Participate in a study of monarch butterfly migration. Contact the Xerces Society, 10 SW Ash Street, Portland, OR 97204, or the Lyman Research Lab, MacDonald College, McGill University, Ste. Anne de Bellevue, Quebec, H9G 3M1, Canada, for information on how you can get involved.
6. Set out various kinds of bait (such as sugaring bait, rotten fruit, spoiled meat or cheese) and observe what insects are attracted to it. Which insects arrive first? How soon after the bait is set out do they arrive? What insects arrive second, third, etc.? What time of day are the various insects active?
7. Obtain different insect pheromones (insect odors and sex attractants) from a garden shop or pesticide distributor and use them to observe insect behavior. How specific is the attraction? What are the effects of wind, temperature and humidity on the attraction? Can you make a population estimate from a pheromone trap?
8. Observe insect activity at a flowering shrub or in a flower garden. What insect species are attracted to the flowers? What time of the day or night do they come? Which species of insect is most abundant? Do marked individuals revisit the same flowers? What types of predators or parasites are present? Do all the flowers on the same plant get equal attention? Which plants are most attractive to the insects? (Hint: You can use this information to plan a butterfly garden!)
9. Observe the mating behavior of lightning bugs (fireflies). Can you determine the specific flash pattern for each species? Do the males and females of the same species use the same flash pattern? What are the effects of weather on this behavior? What time does the flashing begin? Does each species fly at the same height? Are there any lightning bugs that mimic other species' flash patterns? If so, why?

Insect populations and communities. The following section contains suggestions for field observations on insect populations and communities. Remember, these are just suggestions to get you started. There are many other projects you could undertake if you just use your imagination.

1. Estimate insect populations using a mark and recapture technique. Capture a representative sample of a selected insect species (preferably with some type of trap) over a measured amount of time. Mark the captured individuals with nail polish or enamel model paint, and release them back into the sample area. Repeat the capture process

over the same time period as before. Count the number of marked and unmarked individuals and use this information in the following formula (known as the Lincoln Index).

P = **A** × **N** ÷ **R**

P is the total population.

A is the number of marked individuals released from the first trapping period.

N is the total number of recaptured individuals.

R is the number of marked individuals recaptured.

2. Observe aquatic insect populations. You may want to make a simple waterscope to observe insect activity beneath the surface. Remove the top and bottom of a large waxed cardboard carton (a half-gallon milk carton will do). Stretch a piece of cellophane wrap across one end and hold it in place with elastic bands. To use your waterscope, put the cellophane end (the "lens") into the water and look through the scope.
3. Attract corn borers for study. Plant sweet corn early in the season, so that the corn plants are 24 inches tall in late June. Plant a second sweet corn crop so that it is about 24 inches tall by August 1. You should have no problem attracting significant numbers of corn borers to your unprotected corn. If you plant corn on the same land for several years on the same schedule, you should have an abundance of borers for study or harvesting. Don't plow the land (corn borers overwinter in corn stubble and soil), and don't collect all of the corn borers from any one crop. Corn borers also make good fish bait.
4. Observe nocturnal insects. Create an insect terrarium stocked with live insects collected at lights, from pitfall traps or by hand. Use an assortment of species, including both predators and plant feeders. To watch the insects without disturbing their night behavior or activity, illuminate the terrarium with red light (a flashlight covered with red acetate will do nicely). Record your observations.
5. Observe insect locomotion. How do insects move? How do they use their wings, legs and/or bodies to get from one place to another?
6. Observe insect distributions. What is the distribution pattern for selected species? Does the pattern bear any relationship to the habitat limitations? Is there evidence of a dispersal stage? What is the means of dispersal?

Experimenting With Live Insects

You can discover many interesting facts about insect life cycles, behavior and ecology by experimenting with live insects under carefully regulated artificial conditions. Your experiments could provide insight into some of the unanswered questions about insects.

The following information is intended to encourage you to conduct your own experiments with living insects, so only a little bit of background information and a few examples are given to get you started. The rest is up to you!

THE SCIENTIFIC METHOD

Science can be described as a methodical approach to seeking answers to questions about the world. The way people ask and answer these questions is called the scientific method. The purpose of the scientific method is to distinguish facts (things which can be proven) from beliefs (things which are only ideas or opinions, and may or may not be true). Complete honesty in the search for facts is an essential foundation for scientific investigation.

The scientific method uses five basic steps.

1. Clearly define your objectives. What is the specific question or problem you wish to address?
2. Collect preliminary information. What facts are already known about your question or problem? Ideas or opinions which are not necessarily established facts that you have gathered from other people may be helpful.
3. Form a hypothesis. This is your "best guess" about the outcome of your experiment.
4. Test your answer with a carefully designed experiment. Does the experiment reveal that your answer works under all conditions?
5. Revise the hypothesis and test again. If your hypothesis is still valid after repeated experimentation you may now consider it a scientific theory. When a theory is fully tested and proven through additional experimentation, it may then be raised to the rank of scientific law—the ultimate in scientific fact!

Conducting a scientific experiment requires good managerial skills. This means you must be able to make and carry out decisions in a manner that allows you to accomplish your objectives as quickly and accurately as possible. Set your goals and then conduct your work in an organized, thorough manner. Learn to be a keen observer. As you gain experience in conducting experiments your skills will improve.

Many scientific studies show that certain events happen as a result of something that occurred earlier. This idea is referred to as "cause and effect." In scientific studies, observations (data) may be collected on factors that lead to a certain result. These data can be used to predict quite accurately the results that might be expected in a future situation. For example, a farmer may be able to estimate rather closely the number of bushels of corn a certain field will produce using information (data) obtained previously on soil type, fertility, drainage, pests, weather and corn variety.

Sometimes coincidences occur which seem to be easily linked by a cause and effect relationship. You must be careful not to make assumptions which may not be true. Experimentation must be used to determine if a true cause and effect relationship actually exists. For example, you may go collecting insects along a stream and collect two specimens—a 10-spotted dragonfly and a monarch butterfly. Is it correct to assume that there is a cause and effect relationship between the stream and the appearance of these insect species there?

If you make such an assumption, you would predict that the best place to collect these two species is near streams. A study of the habits of these insects would show that only the dragonfly is attracted to water, and that the monarch must have been attracted to the area for some other reason. Additional observation is necessary to determine the true cause and effect relationship in the monarch's appearance at the stream, if there is any. It could be due to chance, the presence of the proper host plant, the weather or some other reason.

Using the scientific method. When you select an experimental project, be sure the topic really interests you. Would you really like to explore it in detail? Unless you're really interested in throughly exploring a particular topic, it is unlikely that you'll carry the project through to its conclusion. Do not, however, abandon an idea without seriously considering the possibilities and doing some initial research on the topic. Often as you learn more about the project, it becomes more appealing.

Try to think all the way through your project before you actually begin work. Consider the equipment and materials you will need. Will you be able to get everything you need? If not, are there any substitutes you can use? Although there will probably be some unexpected problems, try to anticipate as many of them as possible and decide how you could handle them. Plan carefully and keep in mind the time factor. Will you have time to complete the project and prepare your results before any deadline you have?

After you have selected your project, follow the scientific method. State your objectives clearly and concisely. Gather facts and background information on your project. Formulate your hypothesis. Gather data; be sure it is reliable and that you have adequate controls. If you have any doubts, see if you can duplicate your data in additional runs of your experiment (this is called replication). Keep a notebook that contains each procedure and the results. If possible, take pictures of the experiments as they progress.

The final step is to prepare a report on your experiment to share with other entomologists. If you took good notes as your experiment progressed, your job will be greatly simplified. Your data can be presented with words, tables, graphs, illustrations or photographs. Your report should be so complete that anyone reading it would be able to follow your directions and duplicate your results. You may want to consider publishing the results of your experiment in an entomological journal for others to read. One journal that specializes in publishing investigations by young entomologists is the **Y.E.S. Quarterly** of the Young Entomologists' Society (see "References," page 35).

You may want to inform other entomologists about your experiments in other ways, too. You could give an oral presentation or prepare an exhibit showing the highlights of your experimental design and your results. Such presentations and exhibits will be greatly enhanced by any photographs, scientific illustrations or other visuals you have.

SCIENTIFIC ILLUSTRATION

Illustrating your entomology reports, displays and posters yourself can be a very satisfying way to clarify important points and to add visually interesting details to your work. Doing your own illustrations can heighten your awareness of detail and improve your powers of observation of the natural world. This section could help you begin your career as an amateur, or even professional, scientific illustrator.

Materials. The equipment necessary to make pencil drawings is simple and inexpensive. You can purchase everything you need fairly inexpensively at a local stationary or art supply store.

Pencils are rated in degrees of hardness. The most common art pencils, and the ones you will probably use the most, range in hardness from 5B (very soft) to HB (medium) to 5H (very hard). There are several varieties of art erasers on the market. A standard "Artgum," or plastic or kneaded rubber erasers will handle most of your erasing needs. Try a variety of eraser types to determine which you like best.

Erasing will be less frustrating if you avoid using a common pink pen or pencil eraser, or one that comes on the end of a pencil. These erasers contain too much grit and will tear up the surface of your drawing paper.

For your rough sketches and preliminary drawings, you can use inexpensive sketching paper or typing paper. Graph paper is helpful for doing measured, scale drawings. For your final drawings, use a high quality 100 percent rag paper that is acid-free. This paper is a bit more expensive because it is "archival quality" and will preserve your drawings for years. Make sure the surface of the paper you use for your final drawings has a fine texture and is not perfectly smooth.

Other helpful items for your equipment list are dividers, straight edges (such as rulers, triangles, T-squares, etc.), french curves and correction fluid.

Drawing. Choose your first subjects carefully. Begin with large insects, either larvae or adults. The larvae of the Cecropia moth (or any other silkmoth species) or the tomato hornworm make excellent subjects. Grasshoppers, walkingsticks, moths, butterflies, cockroaches, scarab beetles, stink bugs and many other large insects are also good starting material. Stay away from subjects with complex structures or those that are highly colored or textured, they will be too frustrating for your first efforts.

You'll probably want to use preserved specimens for your first efforts in order to avoid the frustrations of dealing with live insects. If you are using specimens that have been preserved in alcohol, remember that they have probably shrunk and changed color. For that reason you may want to refer to photographs or live specimens as you work. This section will describe how to draw a monarch butterfly *(Danaus plexippus)* that is 3 inches wide and 2½ inches long.

Pose live caterpillars on twigs for observation. Adult insects should be killed and then positioned on lumps of modeling clay. The insect's claws can be pressed into the surface of the clay to hold the legs away from the body. The wings of butterflies and moths should be spread.

Select a clean sheet of paper and pin or tape it to a wooden drawing board or other smooth surface. For starters, lightly draw a 6-inch by 6-inch square in the center of your paper with a 3H pencil. These lines represent the extreme limits of the image you are drawing. Draw a vertical line through the center of the square. If you are drawing a butterfly or some other bilaterally symmetrical insect, the insect's body region should lie on this line (fig. 9c).

Your illustration probably won't be the same size as the insect you are observing. A life-size drawing of most insects would be too small to allow you to include much detail. Therefore your drawing should be proportionally larger than the subject. You may decide to make your drawing of that 3-inch wide by 2½-inch long butterfly twice the insect's normal size. That means the image will end up being 6 inches long by 5 inches wide. Indicate the proportional increase (2X) in the upper right-hand corner of your drawing. Some insects, such as the Cecropia moth, may be large enough that enlargement is not necessary. If so, indicate this by writing "actual size" in the upper right-hand corner. After you decide on the proportion of your drawing, all measurements must be adjusted to the same scale by multiplying by two, three, four or whatever proportion you are using.

Now that you have decided on the size of your drawing and laid out the pencil square, you can begin transferring the butterfly's image to the paper. Use a pair of dividers to find the distance between the front of the head and the tip of the abdomen; indicate these points on the central line of your paper (remember to double the figures). Next indicate the point at which the thorax and abdomen join. Do the same for the head and thorax. Now use a 3H pencil to lightly draw in the body region. Use the dividers to find the butterfly's wing size (fig. 9a), transfer the dividers to your ruler to find the actual size (fig. 9b), then double that figure on the drawing (fig. 9c). This "point of reference" technique helps you outline your drawing. By using body divisions, wing demarcations, etc., you should be able to make an outline of the insect.

Once the rough outline is completed, you can begin the final outline work. Bring the specimen close to your paper so you can clearly see the fine points you are adding. Add the outline and wing variations of your butterfly with a 2H pencil (fig. 9d).

After you have done the basic anatomy, indicate the color pattern. You can create a series of tones with your pencils to represent the butterfly's colors. The soft 4B pencil is good for dark colors; other pencil grades can indicate other shades. Use the side of your pencil point to begin to lay in the dark color pattern of the wing (fig. 9e). Continue to build up the detail of the colors.

After your drawing is completed (fig. 10, page 32), you can erase the points of reference and other pencil lines used to help indicate the butterfly's size. Make sure any smudges have been removed or covered with correction fluid.

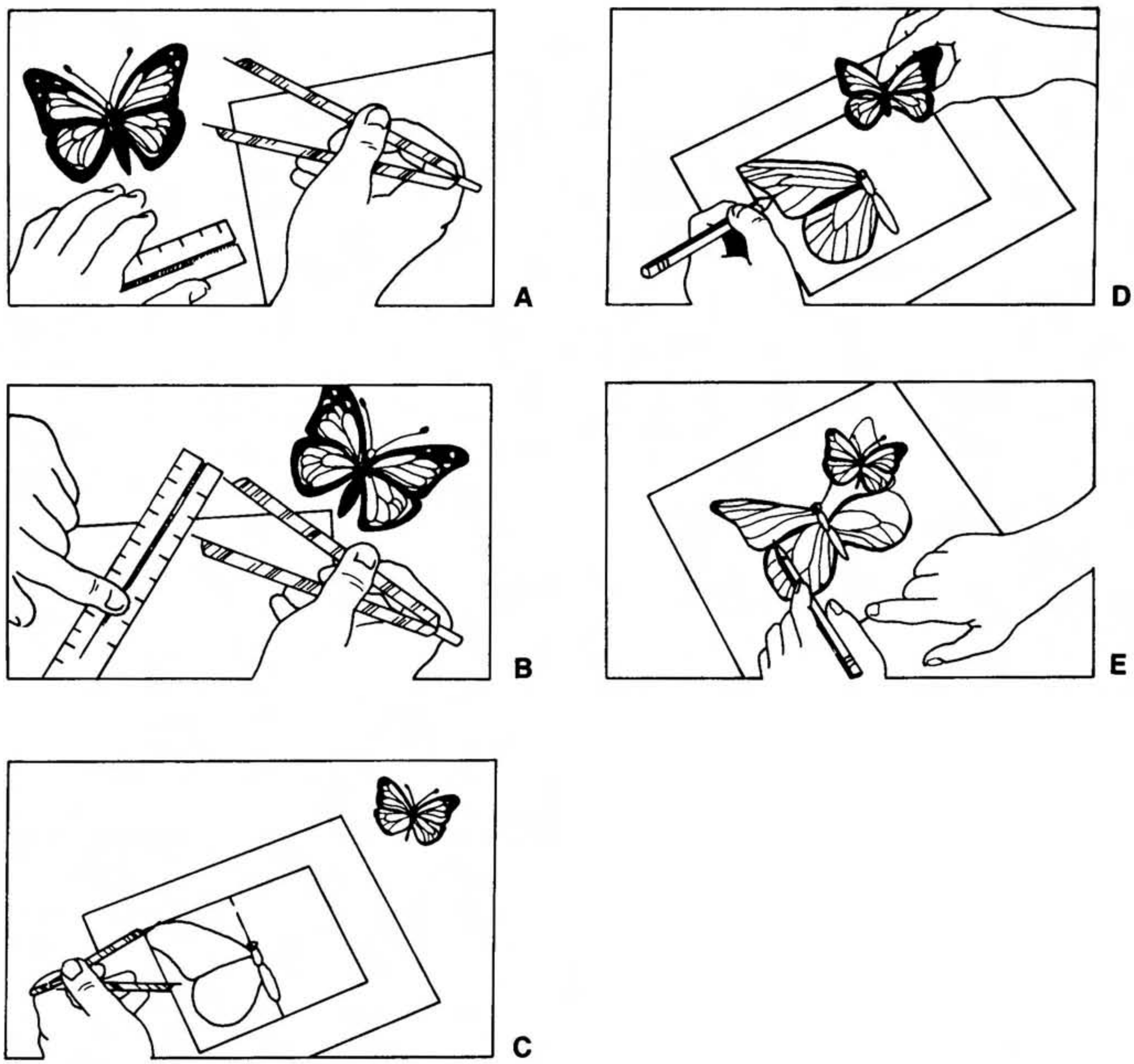

Figure 9. Drawing a monarch butterfly *(Danaus plexippus):* a) using dividers to measure wing size of specimen, b) transferring measurement to ruler to determine size, c) using points of reference to lay out a rough outline, d) addition of detail (note that the specimen is nearby for referrals on fine points), e) applying color tones with a soft pencil.

Matting the drawing. You are now ready to mat your finished illustration of the monarch butterfly. Matting creates air space between the artwork and the glass of the frame to prevent water spotting from condensation, mold growth, etc. Matting also makes your work look more "finished" and professional. A list of suggested materials you will need to mat your illustration follow.

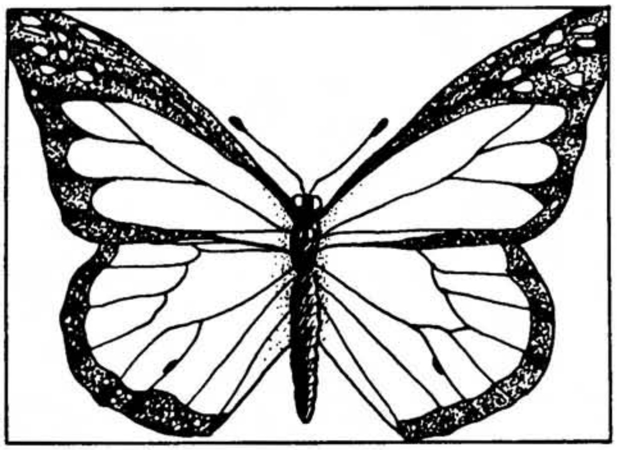

Figure 10. Final drawing of the monarch butterfly *(Danaus plexippus)*.

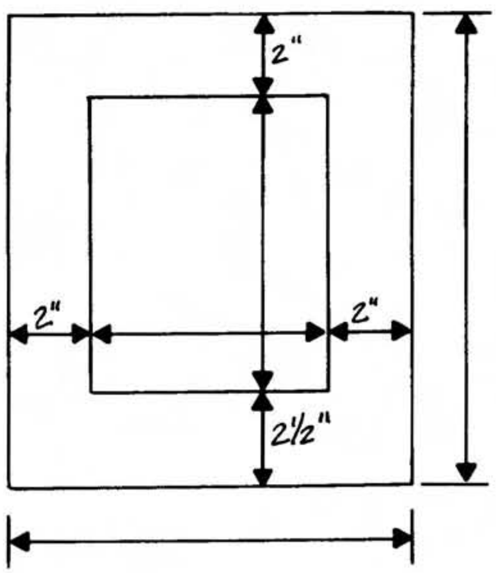

Figure 11. Measuring and cutting mats.

- Mat board
- Backing board
- Pencil and kneaded eraser
- Glue stick, library paste or homemade starch paste
- 10 percent rag or rice paper
- Linen or book tape
- Scrap board to cut on

You will also need the following tools:
- Mat cutter (Dexter, X-Acto or other brand)
- Metal-edge ruler, T-square
- Scissors

Measure the image area of your drawing to determine the size of the mat "window." Use two L-shaped pieces of cardboard to help you decide on the window size. Next decide on the width of the mat border. A typical mat width is 2½ inches on the top and sides, and 3 inches on the bottom. This can vary depending on the size of the artwork and your personal preference.

Calculate the outside measurements of the mat. It's best to make the measurements in even inches because most readymade frames are in even inches. Make a diagram of your mat showing all the measurements you have decided on. Transfer the measurements to the back of the mat board with a soft pencil (HB or 2B) (fig. 11, page 32).

Cut the mat window using an X-Acto knife, utility knife, Dexter mat cutter or other mat cutting tool. Make sure the cuts run exactly over your pencil marks. Cut just slightly past the corners of the mat window. Marking and cutting from the back side of the board prevents dirt and marks from getting on the good side. After you cut the window, cut the outside dimensions of the mat.

Cut another backing board the same size as the outside edge of the first board. (A backing board such as Fome-cor works well because it is light and relatively acid free.) Arrange the drawing on the backing so that it is straight when the mat board is laid over it.

Attach the drawing to the backing using linen tape hinges or other framer's acid-free tape, or use 100 percent rag paper hinges with starch paste (fig. 12). Tape in only a few spots along the top of the artwork, using 1- to 2-inch pieces of tape. Hinge the mat to the backing board either on the side or on the top. Your illustration is now ready for framing.

Helpful Hints

1. A pencil sharpener makes an excellent point for most drawing needs; however, to make fine lines, use a piece of sandpaper to create a sharp point. Be careful though, because if you press too hard with a very sharp pencil you may cut the paper. Sandpaper may be used to flatten a pencil lead for shading.
2. Small french curves are good for making smooth, curving lines. Practicing with these curves will make drawing much easier.
3. Your imaginary light source should come from the upper left-hand corner of the drawing paper when you are shading a three-dimensional scientific drawing, such as a dorsal (top) view of a grasshopper. This means that your highlights are in the upper left of the drawing and the shadows in the lower right. You can practice shadow techniques by outlining the subject, then constructing a cross section of the area to be shaded. With a cutaway section you can see where the light falls and where the shadows begin and end (fig. 13).
4. Practice using different grades of pencils to create a full range of tones (variations in shades of black) in your drawings. For dark colors or shades, use a 3B pencil; for light tones use a 2H pencil. Each degree of hardness will produce a different tone.
5. Don't try to put a soft pencil shading (such as a 3B) over a hard pencil shading (like 3H) to make it darker. The hard pencil produces a smooth surface and the soft pencil won't have much of an effect.
6. Make all outlines in light pencil first, then go over them again to make them darker if you have to.
7. You can create a uniform tone in a portion of your drawing by smudging your soft pencil (3B) shading. Use a piece of tissue paper over your finger tip or a smudging stick (available from art supply stores) to smear or smudge the soft pencil. Lay another sheet of paper over any portions of the paper you want to mask from being smudged.
8. Observe other people's work whenever possible. Use your public library to find books on insects, zoology, biological sciences and nature study. Such books contain drawings you can learn a great deal from.

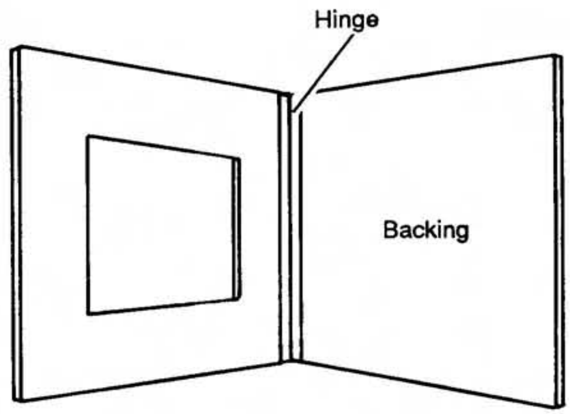

Figure 12. Hinging the mat to the backing.

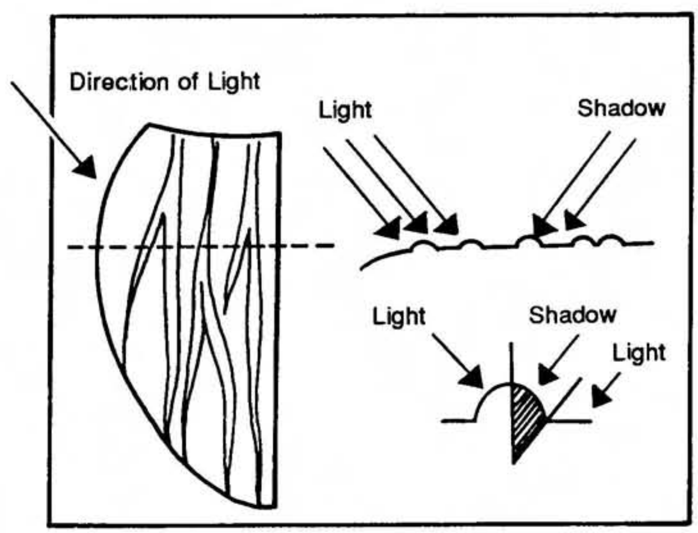

Figure 13. A method for determining shadow effects by constructing a cross section of the subject.

ENTOMOLOGY EXPERIMENTS

The following section contains suggestions for entomological experiments in insect development and behavior. Remember, these are just suggestions to get you started. There are many other experiments you could conduct; just use your imagination.

Insect Development

1. Determine the effects of temperature, relative humidity, food quality or quantity on the growth and development of various insect species. How quickly do the insects grow under each condition? Prepare a chart of growth rates (size or weight) under various conditions.
2. Determine the strength of an insect. How far can an insect jump? You can make an insect jumping arena by drawing a series of concentric circles (at measured distances) around a center point. Place an insect on the center point and record the distance of each jump. Compute the minimum, maximum and average jump for each individual of a species. Compare different species. How much weight can an insect lift? Prepare a weight lifting table (fig. 14, page 34). Test different insects (individuals and species) by adding weights to the container at the end of the string (and don't forget to add in the weight of the container). Does the table's surface affect the insects' ability to pull ("lift") the weight? Compute the average and maximum weight lifting ability for each species.

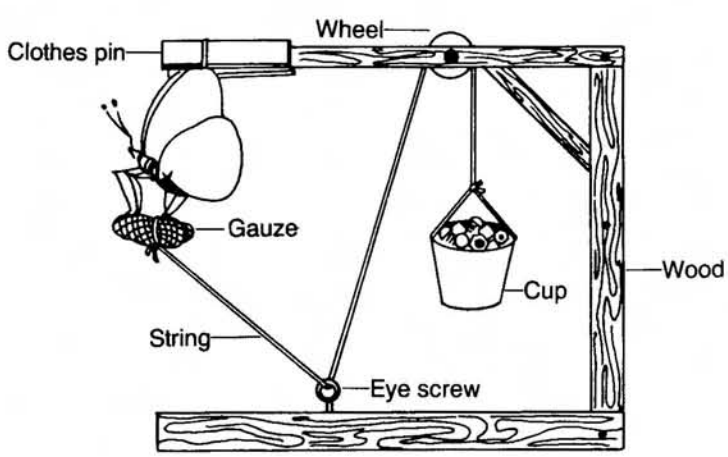

Figure 14. Weight lifting apparatus for testing the strength of insects.

Insect Behavior

1. Determine the effect of ultraviolet blacklight on the behavior of nocturnal insects. What is the relationship between insect activity at the blacklight and the temperature, the relative humidity or different intensities of moonlight? What happens if you run the light at different intensities? What happens if you change the color of the light?
2. Experiment with the trail making abilities of ants. What changes in ant behavior take place if you move their pheromone (odor) trail? (Hint: Allow ants to lay down a pheromone trail across a small piece of paper in a larger test chamber. Rotate the paper to break the trail and then make your observations.)

References

BOOKS

A few of these books are no longer in print. This means you will not be able to go to a local bookstore and order them. However, all these books are available at larger public libraries, so the information they contain is still accessible.

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Zweifel, F.W., 1961. *A Handbook of Biological Illustration.* Phoenix Science Series, University of Chicago Press, Chicago, Ill.

PERIODICALS

Amateur Entomologists Society Bulletin. A.E.S. Registrar, 355 Hounslow Road, Hanworth, Feltham, Middlesex, TW13 5JH, England.

Y.E.S. Quarterly. Young Entomologists' Society, Department of Entomology, Michigan State University, East Lansing, MI 48824-1115.

APPENDIX A—COMPANIES THAT BUY LIVE ARTHROPODS

Carolina Biological Supply Co.
2700 York Rd.
Burlington, NC 27215

Sigma Chemical Co.
P.O. Box 14508
St. Louis, MO 63178
—fireflies only

Wards Natural Science Establishment, Inc.
P.O. Box 92912
Rochester, NY 14692-9012

APPENDIX B—CLASSIFICATION OF COMMONLY REARED ARTHROPODS

Common Name	Order	Family	Scientific Name
Large milkweed bug	Hemiptera	Lygaeidae	*Oncopeltus fasciatus*
Confused flour beetle	Coleoptera	Tenebrionidae	*Tribolium confusum*
Yellow mealworm	Coleoptera	Tenebrionidae	*Tenebrio molitor*
House cricket	Orthoptera	Gryllidae	*Acheta domestica*
House fly	Diptera	Muscidae	*Musca domestica*
Giant cockroach	Orthoptera	Blaberidae	*Blaberus gigantae* *Blaberus craniifer*
Greater wax moth	Lepidoptera	Pyralidae	*Galleria mellonella*
Tarantulas (USA)	Araneae	Theraphosidae	*Dugesiella* spp. *Aphonopelma* spp.
Chinese mantid	Orthoptera	Mantidae	*Tenodera aridifolia*

APPENDIX C—SOURCES OF LIVE ARTHROPODS

Orthoptera

American cockroach .... American, Carolina, Wards
Blaberus cockroach .... American, Carolina
German cockroach .... American, Carolina
Chinese mantid .... American, Wards
House crickets .... Carolina, Armstrong's, Wards
Grasshopper .... Carolina

Dermaptera

Earwigs .... Carolina

Isoptera

Subterranean termite .... Carolina, Wards

Hemiptera

Large milkweed bug .... Carolina, Wards

Lepidoptera

Miscellaneous butterflies	Carolina, Wards
Painted lady butterfly	Carolina, Insect Lore
Greater wax moth	Carolina
Silkworm	Carolina, Insect Lore

Coleoptera

Dermestid beetle	American, Carolina, Wards
Mealworm	Carolina, Lemberger, Rainbow, Wards
Ladybird beetles	Carolina, Natural Pest Controls
Bessbugs (passalids)	Carolina
Confused flour beetles	Carolina

Diptera

House fly	American
Blow flies	Wards
Mosquitoes	American
Drosophila fruit flies	Carolina, Wards

Hymenoptera

Ants	Carolina, Wards
Parasitic wasps	Carolina, Natural Pest Controls

Other arthropods

Tarantula	Carolina

Addresses for Firms Listed Above

American Biological Supply Co.
1330 Dillon Heights Ave.
Baltimore, MD 21228

Armstrong's Cricket Farm
P.O. Box 125
West Monroe, LA 71294-0125

Carolina Biological Supply Co.
2700 York Rd.
Burlington, NC 27215

Insect Lore Products
P.O. Box 1435
Shafter, CA 93263

William Lemberger Co.
P.O. Box 2482
Oshkosh, WI 54903

Natural Pest Controls
8864 Little Creek Dr.
Orangevale, CA 95662

Rainbow Mealworms
126 East Spruce St.
Compton, CA 90220

Wards Natural Science Establishment, Inc.
P.O. Box 92912
Rochester, NY 14692-9012

APPENDIX D—SOURCES OF REARING SUPPLIES AND EQUIPMENT

Albany International
P.O. Box 537
Buckeye, AZ 85326
—pheromones

American Biological Supply Co.
1330 Dillon Heights Ave.
Baltimore, MD 21228
—cages

BioQuip Products Inc.
P.O. Box 61
Santa Monica, CA 90406
—cages

BioServ, Inc.
P.O. Box 450
Frenchtown, NJ 08825
—artificial diets and rearing containers

Carolina Biological Supply Co.
2700 York Rd.
Burlington, NC 27215
—cages, containers and artificial diets

Wards Natural Science Establishment, Inc.
P.O. Box 92912
Rochester, NY 14692-9012
—cages, containers and artificial diets

4-H Youth Programs
Cooperative Extension Service
Michigan State University