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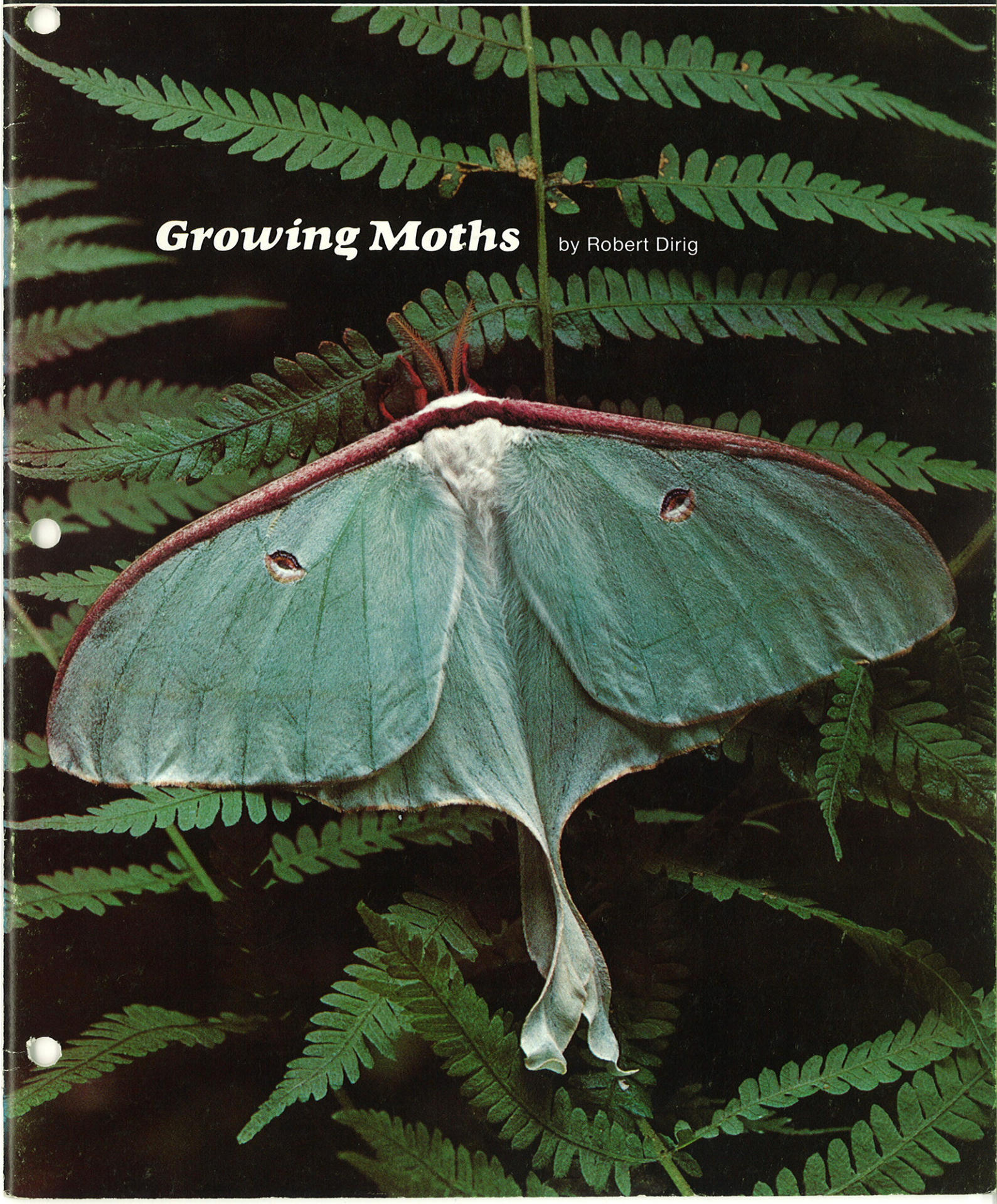

Growing Moths

by Robert Dirig

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Contents

Gratitude is expressed to the following people for critically reviewing the manuscript and figures, and offering valuable suggestions: Professors Warren T. Johnson, John G. Franclemont, and Verne N. Rockcastle; also David Shaw, Mark H. Evans, Charles Duquette, John F. Cryan, and Fran Cryan.

Figures 9, 19, 21, 24, 25, 38, 39, and 40 by John F. Cryan. Figures 5, 8, 10, 35, 41, 42, 47, and 48 by Howard H. Lyon. Figures 22, 43, 44, and 45 courtesy Plant Pathology Department, Cornell University; Figure 26 courtesy Colleen Seeley. All other figures are by the author.

In Figure 23, wu larva was redrawn from *Illustrations of the North American Species of the Genus* Catocala, by Barnes and McDunnough, 1918, plate XIII, fig. 14; rw and tm redrawn from *Butterflies and Moths* (A Golden Nature Guide), by Mitchell and Zim, 1964, pages 108, 111; cm redrawn from *The Moth Book,* by Holland, 1903, Plate I, number 8. Other larvae drawn from original sketches.

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I. INTRODUCING MOTHS

Among the nocturnal (night-flying) insects, the moths are most spectacular, both in size and coloring. On a warm June night, have you ever had a big, velvet-winged moth almost brush your face? Have you ever found a huge, green, winged creature with long "tails" on its hindwings clinging to a branch or tree trunk in your back yard or at a woodland's edge? Have you ever disturbed a plain-looking moth settled near a light and been startled at the flash of two huge eyespots (see figure 46), or of bright pink, yellow, red, orange, or crimson as the hindwings were suddenly revealed? Were you ever surprised by a late hummingbird's buzzing near an evening primrose at dusk, when most hummingbirds should be roosting, and then saw the two uplifted antennae that meant it was a moth? Have you ever wondered what it would be like to be a moth and see in the dark as plainly as people do in daylight? What manner of creatures are about? What are they doing? Where do they go when the sun comes up? What is the pattern of their lives?

Questions like these have prompted great naturalists and scientists, as well as enthusiastic amateurs and beginners, to spend many hours of enjoyment while seeking the answers. By keeping moths alive in captivity and studying their behavior and life cycles, many fascinating things may be learned about their diurnal (daytime) as well as nocturnal habits. In fact, keeping and growing moths is often fun!

The purpose of this booklet is to tell you how to find, catch, grow, and study living moths. Suggestions for making exhibits illustrating the dramatic life histories of these night fliers and for teaching others about them will also be given, as will a list of books that may help you further.

Project requirements for this part of the 4-H ENTOMOLOGY PROJECT are detailed on page 32.

What Is a Moth?

Before reading about the actual growing of moths, one needs to know a few general things about this group of insects and some important words that will be used throughout the rest of this booklet. If you can find a living moth and put it in a jar, or if you have a pinned one handy while you read this, it will help. A 10× or 20× hand lens will also aid you in seeing some of the structures mentioned.

Moths belong to a huge group of invertebrates called insects, characterized by three main body divisions (head, thorax, abdomen), six legs, and usually four wings. Moths and their close relatives, butterflies and skippers, are separated from all other insects by the tiny, shingle-like, overlapping scales that cover their wings, giving them

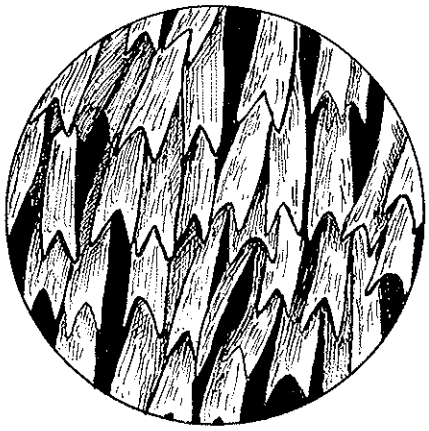


Figure 1. Wing scales of the polyphemus moth (magnified 40 times).

their beautiful colors (figure 1). If you ever have a chance, examine a moth under a microscope. For the moment, look through your hand lens at your moth's wings to see the scales. Are they rectangular, triangular, pointed, or forked? Are they the same size and shape on all areas of the wings? Are there any scales on the *under*sides of the wings? Are there any on the body?

The wing scales of moths, butterflies, and skippers caused *taxonomists* (scientists who classify or determine relationships among living things) to place these together in a large group called the *Lepidoptera*. This term was formed from two ancient Greek words meaning "scales" and "wing," so Lepidoptera means "scaly-winged insects." Now it should be easy for you to guess what a lepidopterist does.

Let's take a close look at a moth. Again, you will need your hand lens and a specimen. Refer to figure 2 as you read the next few paragraphs about the parts of a moth.

On the *head* are two large compound eyes, each formed of hundreds of tiny, individual, light-sensitive units. In some but not all kinds of moths, a long proboscis, or hollow "mouth" like a drinking straw, is coiled in against the head. Moths that feed suck up fluids (usually nectar) through this, but species that take no nourishment as adults have a tiny, useless proboscis (see figures 3 and 4). Some moths have beautiful feathery antennae; others have antennae more like a thread. However, no moths occurring naturally in New York State have prominent knobs at the tips of their antennae—as all our butterflies and skippers do.

Four wings and six legs are fastened to the middle body part, the *thorax*. The scales which cover the wings and give them their colored patterns have already been mentioned. Sometime, before discarding an old, damaged specimen, rub off all the scales on part of a wing with your thumb and forefinger to reveal the wax paper-like wing membrane supported by a framework of stiff

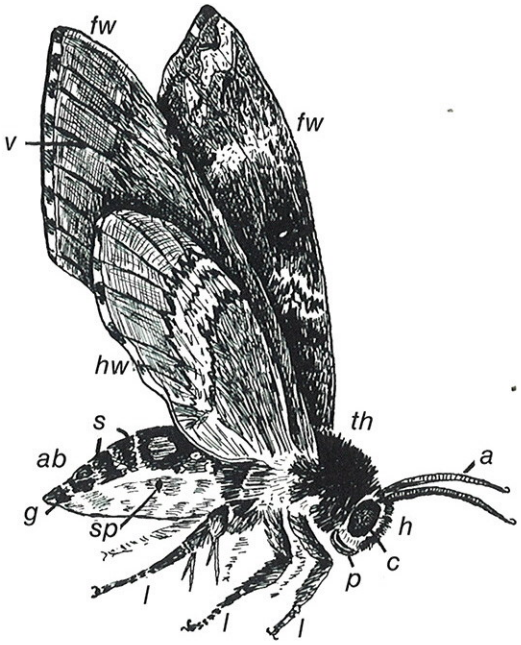


Figure 2. Parts of the moth.

h—HEAD
a—antenna
c—compound eye
p—proboscis
th—THORAX
fw—forewing
hw—hindwing
v—wing vein
l—leg
ab—ABDOMEN
s—segments
sp—spiracle (beneath "furry" covering)
g—genitalia

Figure 3. The hummingbird clearwing sphinx feeds as an adult. Here its proboscis is shown rolled (left) and extended.

veins. The arrangement of these veins is important in classifying moths.

All moths have jointed legs, some with spines or barbs along their length. The feet usually end in two hooks, called tarsal claws, which help the resting moth cling to a wall, tree trunk, leaf, rock surface, or whatever.

The rearmost body division, the *abdomen,* is formed of several parts or segments (how many?). The abdomen is often very stout and "hairy." Inside it are most of the digestive tract, the breathing tubes (tracheae), and the sexual organs. If the moth is a female, the abdomen may also contain hundreds of eggs.

Most moths fly at night, but a few kinds, such as the hummingbird clearwing sphinx (figure 3) and eight-spotted forester (figure 5), are diurnal. The wasplike aeg-

Figure 4. The royal walnut moth does not feed as an adult. Its probosicis is barely developed and non-functional.

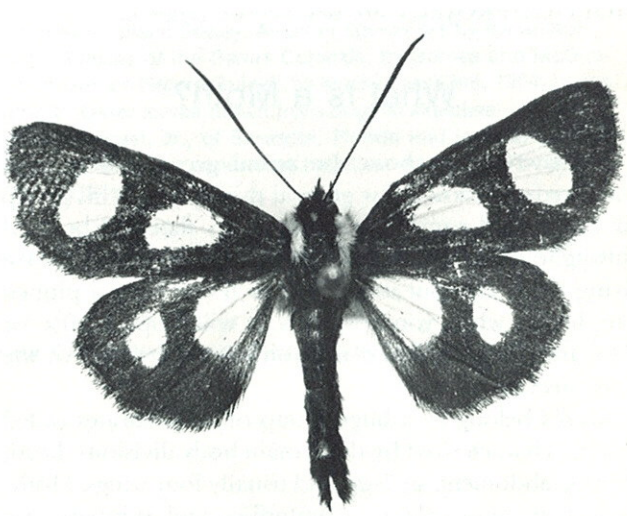


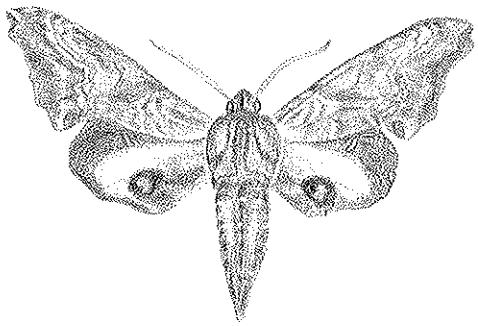
Figure 5. Eight-spotted forester moth.

erid moths, whose larvae are wood-boring, are also day fliers. Moths usually have stouter bodies and more "hair" than butterflies. Differences in antennae have already been noted. Details of the life cycle also vary slightly.

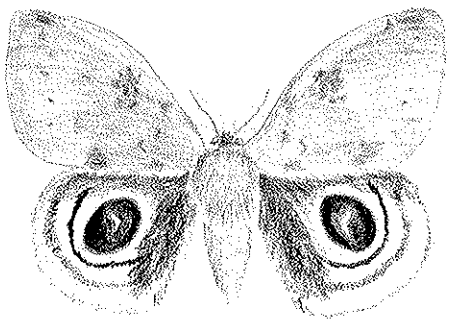
Kinds of Moths

In order for the examples used in this booklet to be meaningful, you need to know something about a few large, general groups of moths. We are concerned only with the more spectacular families or genera that most people would want to rear. Some of the small, drab, or less-known groups are ignored. The five groups considered in this booklet are described in figure 6.

Figure 6. Moths: *a.* sphinx, *b.* giant silkworm, *c.* tiger, *d.* underwing, *e.* regal.

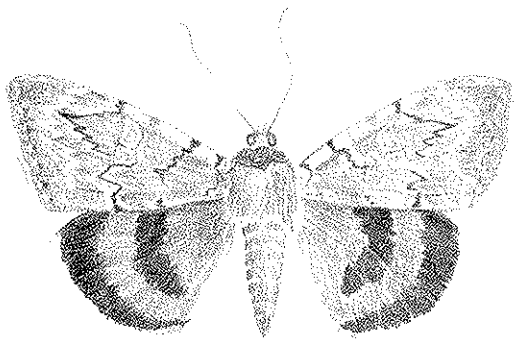


a-SPHINX. Medium- to large-sized, stout-bodied moth with long, narrow, often plain forewings and much smaller hindwings that may be brightly-colored or bear eye-like markings. Antennae always threadlike. About 30 common species in New York.



b-GIANT SILKWORM. Usually very large, striking moth with stout body and always with ferny, branched antennae. The 8 species that occur in New York have either eye-like markings or clear, unscaled areas on their wings. Very colorful. Largest New York moth.

c-TIGER. Small- to medium-sized, often brightly-colored moth with stringlike or slightly branched antennae. Common. Less spectacular than some groups. Fifteen common kinds in New York.



d-UNDERWING. A large, spectacular subgroup of a huge moth family called *Noctuidae.* Barklike forewings cover the hindwings ("underwings") when the moth is at rest (see fig. 13). When it flies or is disturbed, the colorful hind-wings are exposed. These are predominantly black (in a few kinds, wholly black), vividly banded with red, orange, pink, yellow, or white, depending on the species. Antennae always threadlike. About 50 kinds in New York.

e-REGAL. Small, medium-sized, or very large moth, with ferny or stringlike antennae. Colorful, spectacular. The large species (regal, imperial) are uncommon in New York. About 7 kinds recorded in the state. This is a giant silkworm subgroup.

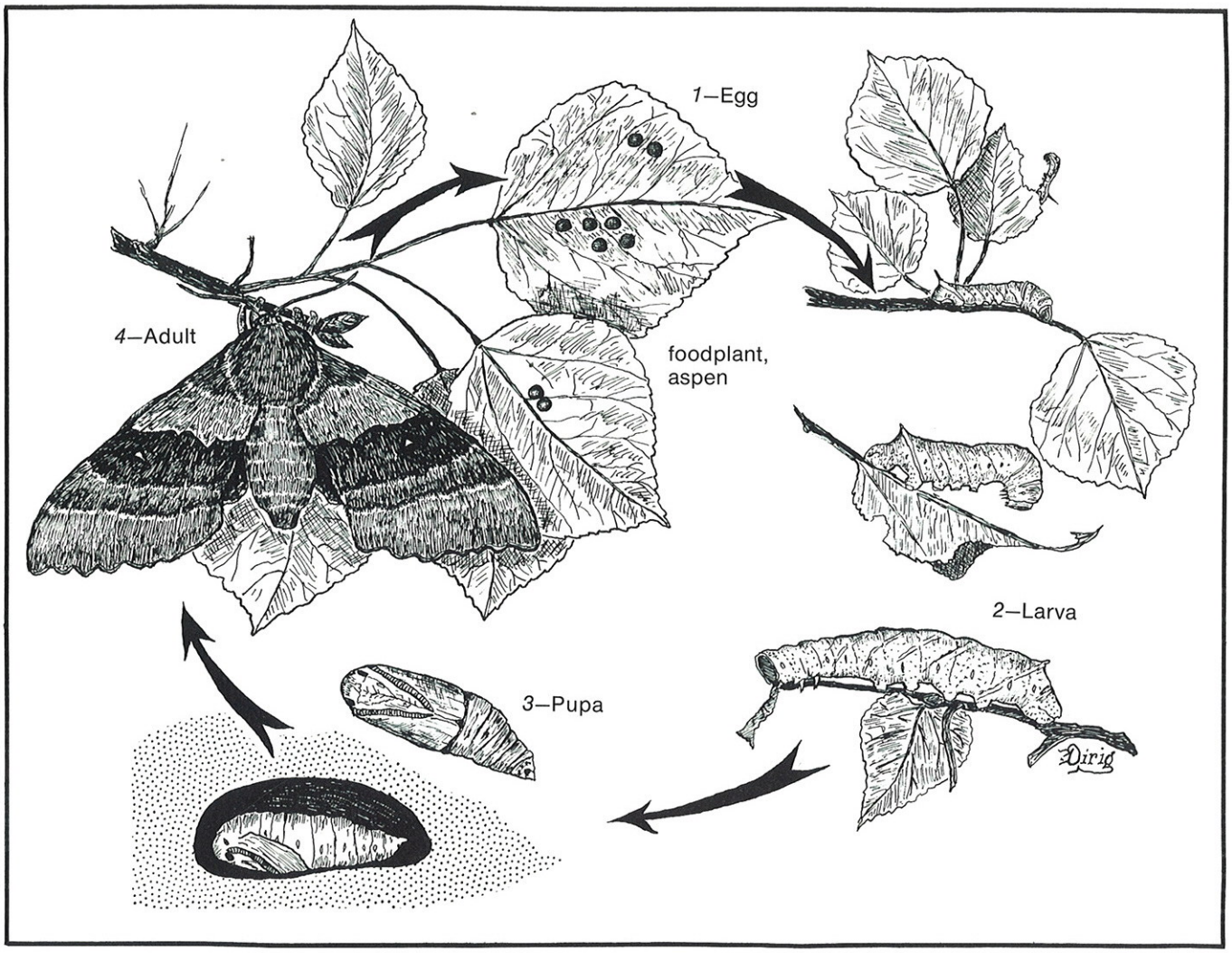


Figure 7. Life cycle of modest sphinx moth. Il moths undergo 4 different stages in their lives—egg, larva, pupa, and adult. The modest sphinx's caterpillar pupates in the soil, but some other moths' larvae spin cocoons at or above the ground surface. See Section V for duration of each stage.

Moth Life Cycle

Any moth undergoes four very different stages in the course of its life (see figure 7). These periodic changes in form are called *metamorphosis*. The *egg* or *ovum* (plural, *ova*) is usually thought of as the first stage, because it is the beginning of a new individual. From the egg hatches a tiny *larva* (plural, *larvae*), commonly called a *caterpillar,* which almost always feeds on leaves and grows for a period of time—usually at least a month, and frequently six or eight weeks. When mature, the caterpillar either spins a silken cocoon or burrows under dead leaves or into the soil. Then it changes into a *pupa* (plural, *pupae*). After a rest period varying in length depending on the kind of moth and season, the *adult* or *imago* (plural, *imagines*) emerges. This is the familiar, winged creature you see flying around lights at night. Egg, larva, pupa, and adult: Metamorphosis is completed. The moths mate and the females lay eggs to start the series of four stages over again. Some moths undergo two or three complete broods in a year, but several of the largest complete only one. The carpenterworm is a New York moth that requires three or four years to complete a *single* brood.

Passing the winter poses no real problem for moths because Nature has "programmed" each kind to become dormant in a certain stage of its life. The giant silkworms hibernate as pupae encased in elaborate silken cocoons (hence their name). Sphinxes and regal moths also overwinter as pupae, but almost always in a pupal chamber that the full-grown caterpillar has made in the soil beneath the frost line. Many types of tiger moth caterpillars pass the winter partly grown, resuming their feeding after the snow melts in the spring. An example is the familiar "banded woolly bear" larva of the Isabella tiger moth, which you probably have seen crawling on roads or sidewalks in autumn. Some moths, including under-

wings, the buck moth, and the destructive Eastern tent caterpillar and gypsy moths, pass the winter as unhatched eggs glued to branches or trunks of their foodplant trees. You may be surprised to learn that some New York moths overwinter as adults. The dot and dash swordgrass moth (figure 8), a close relative of underwings, is one of these.

Moths may pass winter in any one of the four life stages, but each species hibernates in one particular stage only. How to handle hibernating eggs, larvae, and cocoons or pupae is discussed further on in this booklet.

Figure 8. Dot and dash swordgrass moth.

II. FINDING AND CATCHING MOTHS

To many people, moths are ugly, fluttery brown things that make sitting on a lighted porch on a summer evening unpleasant; or nasty creatures that eat holes in winter woolens. It is unfortunate that people have such a narrow view of these interesting insects. Of course, the larvae of clothes moths do eat woolen goods and furs. But the thousands of other "innocent" moth species should not be condemned because one or two kinds damage human belongings. If people took a good look at the "flutterers" around their lights, they would discover some of the most intricate geometric patterns to be found in Nature on the wings of these small "miller" moths.

I would not recommend your looking in a winter clothes closet if you expect to collect many different kinds of moths, but a porch light *is* a good starting point, particularly on warm, muggy evenings. Check the walls, ceiling, floor, and posts near the light carefully, every half hour or so. Many moths are attracted to lights and will settle nearby. Tiger moths, some sphinxes and underwings, a few regal moths (such as the rosy maple), and an occasional giant silkworm will turn up. Some may be fluttering near the bulb, but if you look for individuals that have settled, you will also be rewarded.

Various types of all-night lights attract moths, such as street lights, those at garages or restaurants, and lights near restrooms at campsites. If you investigate these, or even check them in the morning, some interesting specimens can be obtained.

Using a Blacklight

If you become seriously interested in collecting and raising moths, you may want to invest in a *blacklight* (figure 9). This is a type of fluorescent bulb which emits both dark purplish rays that people can see, and *ultraviolet* rays, that are invisible to the human eye. The power of these ultraviolet rays to attract moths and other night-flying insects is amazing.

I have used a blacklight to attract moths for many years with excellent results. Perhaps I can best explain how one is set up and used and what results to expect by telling you about some of my experiences. When I first started to collect and grow moths I used a porch light to attract them. Results were fair, but the big moths, the ones I wanted most, were few and far between. When I learned that a blacklight existed, I immediately wanted one. My parents gave me one as a birthday gift. That was in August, too late in the year for many moths to be flying. I could hardly wait until spring.

Winter came, then, slowly, March and April. At last, in late May, I could set up the light in the backyard, facing an old sheet (see figure 9). The sheet served as a reflective surface, as did the whole side of our white house. An extension cord plugged into an outdoor socket provided electricity.

Our backyard was bordered by a grove of small trees,

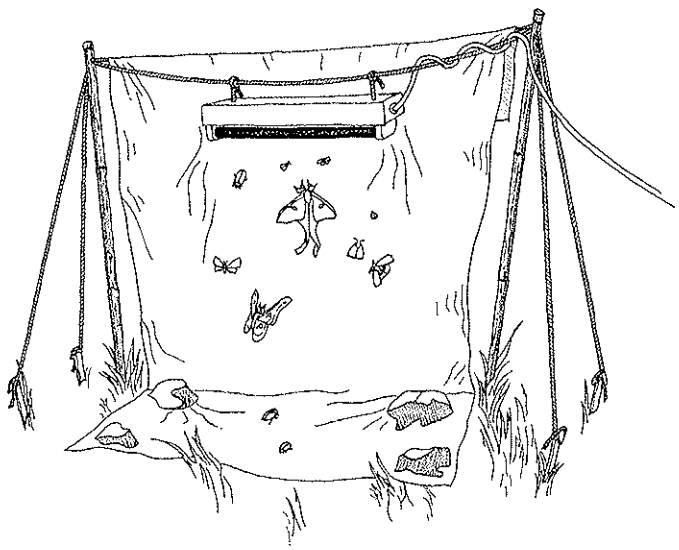


Figure 9. Blacklight set up facing a sheet. Badminton poles were used for support, although wooden stakes would have worked as well.

and nearby were several different habitats—hedgerows along roads and stone fences, open fields, growing-up fields, mature woodlands, swamps, ponds, and streams. With this diversity of places for moths to live, I had high hopes.

The light was turned on at dusk and left on all night. I had read that most of the big moths fly very late, between 1:00 a.m. and dawn. Hence they are rarely seen and are considered scarce by most people although most are rather common. The light was checked periodically until bedtime, and then I set my alarm for 4:00 a.m. so I could get up just before dawn and see what had been attracted. That first night I caught three perfect polyphemus moths (a gigantic brown moth with striking black, yellow, and blue "eyespots" on its wings, see figure 43) plus an assortment of smaller, colorful species. Altogether, on that one night in late May, I attracted more moths than I had in a month using our regular porch light.

Throughout June and the whole summer, I had spectacular success. I remember "record" nights in June when 28 polyphemus were attracted, or 5 lunas, or 11 ios, or 7 cecropias. Sphinx moths abounded; the catch included many individuals of fifteen species. Over a dozen kinds of both underwings and tiger moths were found resting near the light during their flight seasons. My parents, sister, and brothers became as excited as I at each new species. When we captured two or three *Arctia caja* (garden tiger) moths (figure 10) in August, as far south as they have ever been recorded, we felt really great!

That summer, my moth collection grew by leaps and bounds. Different types of moths fly at different times of the year and under different weather conditions, so the light was run each night, all night, rain or shine, from late May through late September. At least one or two specimens of all the different kinds attracted were saved, even the the smaller, less colorful ones. (The latter resulted in an interesting "Little Moths of New York State" display.)

We checked the sheet, house walls and foundation, fern clumps and flowers in the border, and the lawn near the light, using a high-powered flashlight. Some moths had settled with their wings flattened against the surface of the house or a nearby tree trunk. These were collected by holding an open glass jar a little below the resting moth, and slowly moving it up until its edge touched the wing tips, as shown in figure 11. When thus disturbed, the moth almost always sprang back into the jar in its first rush to escape, and was easily captured. If a prize underwing had settled near the peak of the house or too high on the wall to be reached from the ground, a chair or ladder helped. Sometimes the moth, if disturbed with a net, would drop lower and resettle where it was more easily caught. Some moths, such as cecropias and polyphemus, rested with their wings up over the thorax, as many butterflies do. These were simple to capture by grasping the thorax carefully but firmly between the thumb and forefinger (figure 12), and transferring to a jar or paper sack.

Figure 10. Garden tiger moth.

Figure 11. How to catch a resting moth using a bottle.

On some warm, humid nights in midsummer the yard was so full of moths and other insects that we felt "crawly" when we got back in the house. Without a blacklight we never would have imagined how abundant some formerly "rare" moths really are.

Needless to say, the bird population in the area thrived that summer because of the great concentration of insect food available near the light in the morning. Catbirds and chipping sparrows would scream at me just at dawn when I caught them, and they caught me, "poaching" on each other's territory. This may sound funny, but finding beautiful polyphemus, luna, and

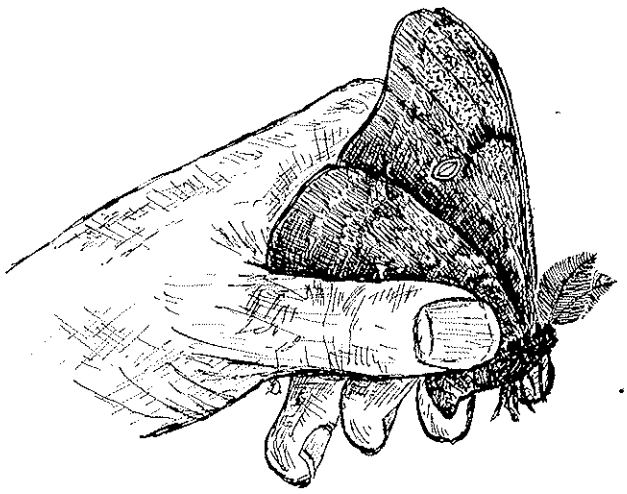


Figure 12. How to catch and hold a moth with your hand.

cecropia wings in little piles beneath favorite bird perches soon taught us that the early person gets the moths.

My blacklight was not the kind used with posters (these work no better than a porch light), but a special kind with a white, not black, tube, made especially for entomologists. These are available for about $10.00 (bulb, fixture, and cord) from BioQuip Products, P.O. Box 61, Santa Monica, California 90406; or from the American Biological Supply Company, 1330 Dillon Heights Ave., Baltimore, Maryland 21228. A blacklight is the most important investment a would-be moth rearer can make, because it lures the wild females from which you can obtain eggs to get a stock started. Portable, battery-operated models are also available from the two companies mentioned, priced between $30 and $80.

Sugaring

Another time-honored method of collecting moths is "sugaring" or "baiting." This sometimes works well for moths that feed, but regal moths, giant silkworms, some sphinxes, and most tiger moths do not take any nourishment as adults and therefore will not be attracted. Underwings (figure 13), however, usually come quite readily to baits.

Many recipes for the bait are given in some of the moth books listed near the end of this booklet. Here is one used by two teenagers who have enjoyed great success in capturing underwings in central New York.

Pour the contents of 2 small (12 oz.) bottles of unsulphured molasses into a saucepan. Add 1 or 2 cups of chopped up peaches, bananas, apples, or other fruit (the more nearly spoiled, the better). To this, add about 4 oz. of stale beer or other alcoholic beverage and ¼ cup of

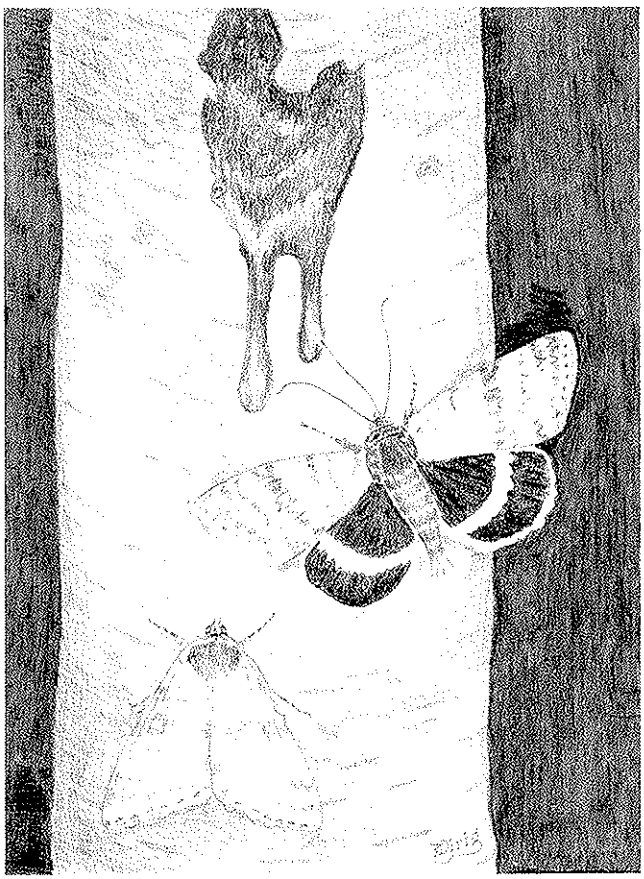


Figure 13. At the next baited tree (a white birch), one—no, two—white underwings *(Catocala relicta)* show up in your flashlight beam. The moth settled higher on the trunk has more heavily marked forewings than the lower one. This variation is common in *relicta* but not in most other *Catocala*.

brown sugar. Heat until it boils and the fruit is thoroughly cooked. Remove from the heat and let the mixture cool until evening.

Half an hour before dusk carry the bait to a woodland edge near a pond or stream, where there is a diversity of habitats and tree species (see list of underwing foodplants on page 31). With an old paintbrush, apply the bait generously to tree trunks, posts, and boulders at breast height. Dab a little every 10 feet or so, following a definite route. Then wait until dark. Take along a friend—four hands are better than two.

Sugaring is profitable throughout August and early September, especially on warm, humid nights. Underwings are particularly active when these conditions prevail.

As soon as it is dark, start checking the baited trees (figure 14). If conditions are right, small moths, ants, some beetles, and other insects should appear, as well as the huge, beautiful underwings. The wariness of the latter adds a challenge to trying to catch them, and finally having one safe in a bottle or plastic box is very exciting. There are so many different kinds, looking so much

Figure 14. The "Gruel Fiend."

alike, that you often are not sure which species you have until the catch can be closely examined indoors. (Sometimes, identification is difficult even then.)

My young friends use an original method to catch the underwings lured to their bait (figure 15). One has made a special net with a slightly curved rim, so it will fit tightly against the rounded trunk of a tree. When an underwing is discovered on a baited tree, one person "spotlights" with a flashlight beam directly on the moth. The other advances quietly from the side, carefully clamping the special net over the trunk and quickly gathering the netting to imprison the struggling moth. It can then be transferred to a killing jar or other container. Not all underwings seen will be captured. They are very wary.

Each person or sugaring team develops its favorite bait recipe and techniques. Sugaring can be a lot of fun, and

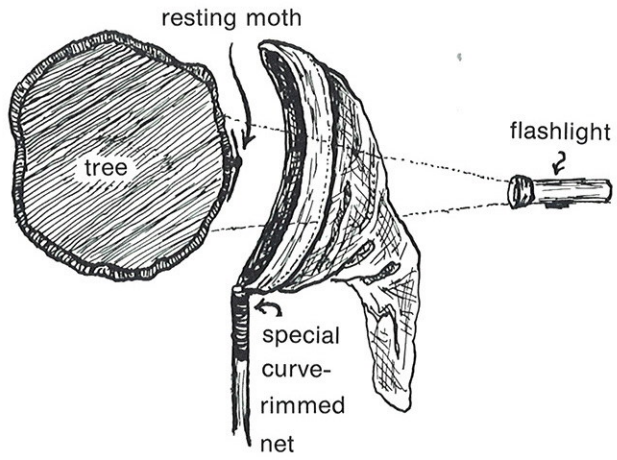


Figure 15. Special net used to catch underwings attracted by "sugaring."

is probably the best way to capture many underwing females. Butterflies have a sweet tooth too, so check the baited trees the next day to see if any anglewings, vanessids, swallowtails, wood nymphs, or other kinds have been attracted by the remnants of last night's "feast."

III. BEGINNING A LIFE-CYCLE STUDY

Male or Female Moth?

You might think that determining the sex of moths is difficult, if not impossible. Actually, among the five groups dealt with in this booklet, it is usually quite easy. If you wish to study all the life stages of moths, you must learn to immediately recognize a female when one is caught, so it can be saved to lay eggs, and not killed for a specimen.

Generally, a female moth will have a stouter abdomen than a male. In her abdomen are the 200-300 or more eggs she can lay if a bird, bat, mouse, or young collector doesn't catch her first. Having a bigger body makes her heavier, which requires a larger wing area to support her weight. Hence, female moths are usually bigger than males of the same species. Finally, her antennae are usually thinner or less feathery than her mate's.

Figure 16 shows the five groups of moths mentioned on page 5, illustrating *specific* differences of the female and male in each case.

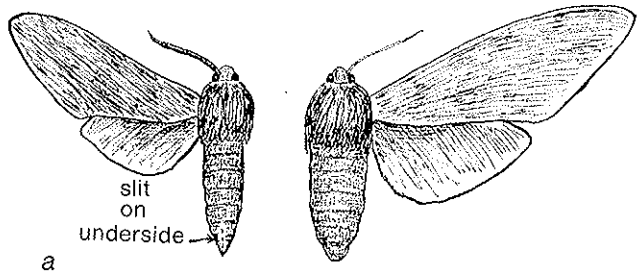
Some moths are *sexually dimorphic*. This means the female and male differ drastically in markings or coloring or both (*dimorphism* means two forms). Examples of sexually dimorphic moths pictured in this booklet are the imperial (figure 17), the io (figure 6b, male; figure 46, female), and the promethea (figure 40, male; figures 18 and 39, female). *Seasonal dimorphism* occurs in some moths, such as luna, where spring-flying adults differ noticeably from those of the midsummer brood in color or markings or both.

Getting and Handling Eggs

A common mistake beginning moth rearers make is thinking that a female *and male* are needed in order to get fertile eggs. This is, of course, true with newly-emerged adults, but almost any female moth you catch flying outdoors will already have mated and will give you fertile eggs. Therefore, catching a male in order to mate with the female is a waste of time. During ten years' experience in growing moths, mostly from wild-caught females, I have only twice captured an infertile female among hundreds saved for egg-laying.

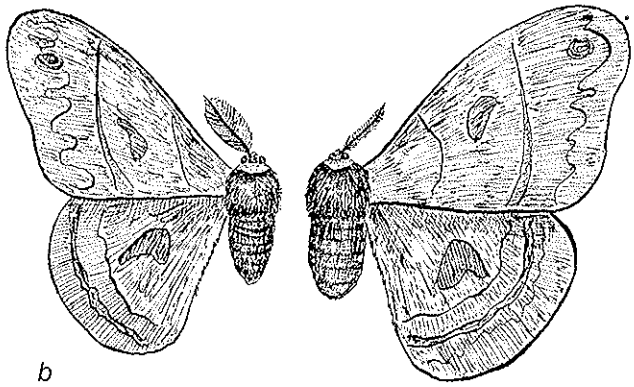
Assuming you have a female moth, how do you get

Figure 16. Male (left)–female differences: *a.* sphinxes, *b.* giant silkworms, *c.* tiger moths, *d.* underwings, *e.* regal moths.



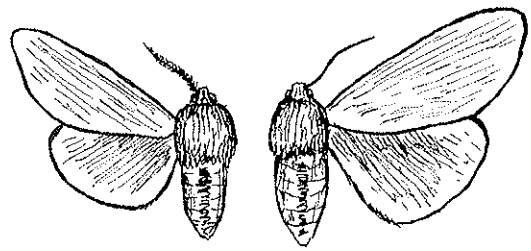
a

SPHINXES: *Male:* thicker antennae, narrower body with a slit at the end of the abdomen which the female lacks. *Female:* larger, antennae narrower, with a fuller, heavier body. Difficult to tell sex in a few species.



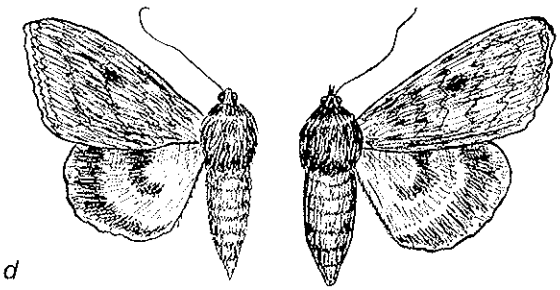
b

GIANT SILKWORMS: *Male:* slightly smaller; antennae huge, feathery, beautiful! Abdomen much smaller than female's. *Female:* antennae narrower, but branched; abdomen huge. Very easy to tell sex.



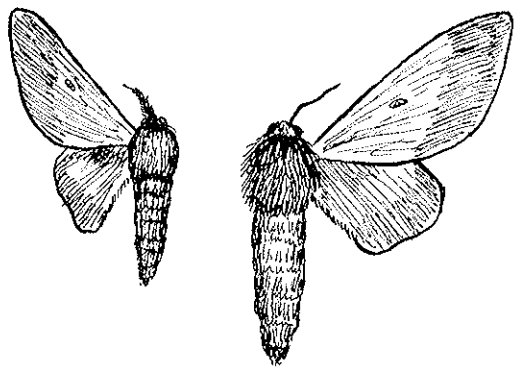
c

TIGER MOTHS: *Male:* slenderer body with slightly-branched antennae. *Female:* body much fuller, larger, antennae threadlike. May be brighter in color. Usually easy to tell sex.



d

UNDERWINGS: *Male:* similar in size, abdomen more slender. *Female:* may be brighter in color; body fatter. Antennae whiplike in both sexes. Usually difficult to tell sex.



e

REGAL MOTHS: *Male:* may be $\frac{1}{3}$ or $\frac{1}{4}$ smaller than the female! Antennae ferny near base. Body more slender and colors are brighter. *Female:* larger, paler, with stringlike antennae and a *huge* body; more rounded wings. Easy to tell sex.

Figure 17. The imperial moth is sexually dimorphic. The slightly smaller male has more extensive purple areas on his yellow wings and a heavier peppering of black dots. This pair is shown on the trunk of a pitch pine, one of the larval foodplants.

eggs? Nearly all varieties will easily lay large numbers of eggs if confined in a brown paper grocery bag, with the top rolled over two or three turns and fastened shut with a clamp clothespin (figure 18). If you want to watch the female lay some eggs, keep her in a gallon glass jar containing several long paper strips.

Most female moths glue their eggs to the inside of the bag in rows or bunches with a special abdominal cement that wipes onto them as they are laid. A few kinds, such as the *Apantesis* group of tiger moths, drop their white, salt-grain-like eggs loose on the bottom of the sack. When you have all the eggs you need (two dozen is plenty for a start), release the female, give her to a friend who raises moths, or keep her for your collection.

Moth eggs are very interesting. All fertilized eggs have a hard shell, and contain a developing embryonic caterpillar. Fertilization is accomplished as each egg is laid, when a drop of fluid deposited in the female's abdomen by a male brushes onto the egg, and sperm enter it.

The eggs may be pale blue, green, grey, white, yellow, brown, pinkish- or orangish-white, maroon, black or even multicolored, and are usually no larger than the head of a common pin. They may be deposited singly, in small patches, in curved rows, or in masses. Hatching time varies as much as color. For each species it is different, but most moth eggs will hatch within 3-14 days after laying, with 5 or 7 days being average. (Some eggs will not hatch until the following spring.) As hatching time approaches, the egg usually resembles a tiny donut or life saver, with a hollow, but not a hole. If the shell is transparent, as it is with sphinx and regal moth eggs, the tiny caterpillar can be seen curled up inside a few hours before hatching. *Almost all eggs will turn darker a few hours before the larvae eat their way out of the shells*—your clue to watch closely. If the egg walls collapse and the eggs shrivel and dry up, they are infertile.

From the minute you put a female moth in a sack to lay eggs, you have a serious commitment to watch her and her eggs closely. It is not fair to remove the moth from a wild population, confine her in a sack, let her die there, allow her eggs to hatch unnoticed, and leave the young caterpillars to die from neglect. Growing moths successfully requires a certain amount of self-discipline, patience, and responsibility.

The easiest way to watch the eggs is to remove them from the sack by cutting away the little piece of paper they're glued to. Don't try to pull the glued eggs off the

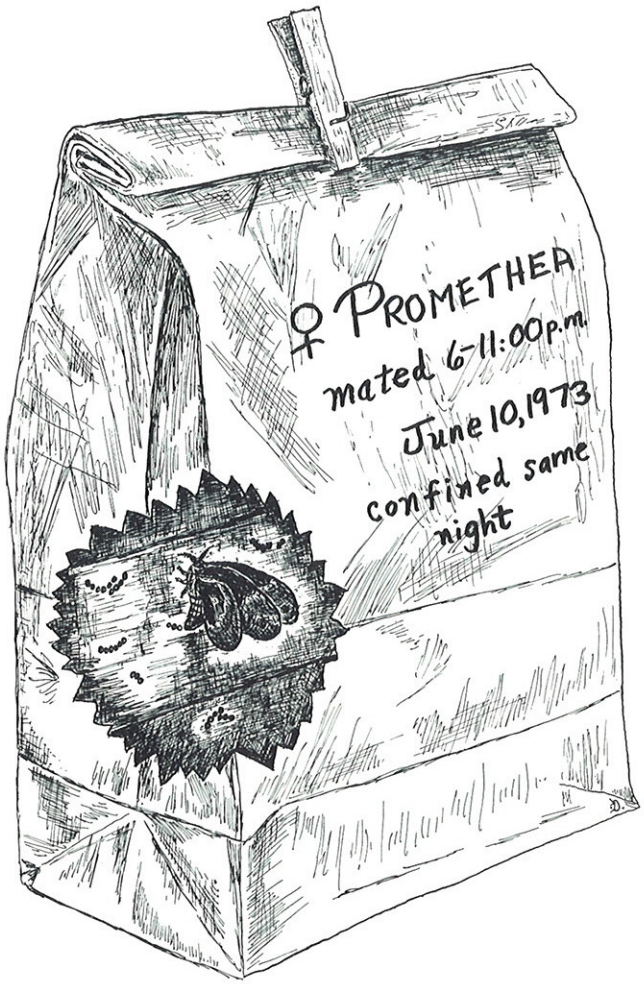


Figure 18. Female moth ovipositing in bag.

paper; you will most likely break the shells and kill the embryo. Keep the eggs in a small, snap-top, clear plastic box or empty pill container. Since hatching time varies, look at them several times a day. This is most easily done if you tape the container to a door, mirror, cupboard, or refrigerator—some place where the eggs will be seen often during the day and their hatching noticed soon after it happens. *No leaves should be put in with the eggs, nor should they be "watered." This almost always reduces hatching or kills the developing caterpillars.*

While waiting for your ova to hatch, check in the table on pages 29-31 or in a moth book to find out what plant or plants the caterpillars will eat. Each kind of moth has just one or a very few foodplants. The larvae of most sphinxes, underwings, giant silkworms, and regal moths feed on leaves of trees. Many tiger moth caterpillars, however, eat *herbaceous* (nonwoody) plants, such as the familiar lawn and garden weeds, plantain and dandelion. It is important for you to learn to recognize these different trees, shrubs, and common weeds if you expect success in moth-rearing. (See references, page 37). It is urged that you enroll in the "Know Your Trees" and "Know Your Weeds" 4-H projects before or at the same time you undertake this part of the Entomology Project. Find a good supply of the foodplant nearby, so it will be handy when the little caterpillars appear.

Eggs that hibernate may be kept in a plastic pill bottle or other closed container in a regular refrigerator over the winter (35-40°F).

IV. KEEPING CATERPILLARS, COCOONS, ADULTS

Larval Care

The caterpillars that crawl from the eggshells are very tiny. Some eat only enough of the shell to get out. Others eat the rest of the shell after hatching, before starting their first meal of leaves.

Many young moth caterpillars do not begin eating foliage until 12 to 24 hours after hatching, so if you forget to look at the egg bottle one day, and find the caterpillars crawling around inside the next, do not be alarmed. They cannot, of course, live much longer than 24 hours without food, and should be transferred to fresh leaves as soon as possible after hatching.

How you keep the caterpillars will depend on the time and space available to care for them. They may be raised either inside or outdoors. If you want to watch the daily changes in their development, growing them indoors is preferable. This is more work than feeding outside (where they need to be checked only every four or five days), but you will be rewarded with a more intimate knowledge of the moth's life.

For growing *indoors,* keep the caterpillars in refrigerator food storage boxes with tightly-fitting lids, made of transparent, durable plastic (figure 19). Put a facial tissue or paper towel on the bottom, to catch the small, dry pellets of waste material (called *frass*) that caterpillars expel and to absorb some of the moisture evaporating from the foodplant leaves placed in the box on top of the paper towel.

The plastic boxes range in size from about $4\frac{1}{2} \times 2\frac{1}{2} \times 3\frac{1}{2}$ inches to $14 \times 10 \times 4$ inches. They may be obtained from hardware stores or from the housewares department of many supermarkets. For nearly full-grown caterpillars, clear plastic crisper chests are ideal—their intended purpose, after all, is to keep vegetables fresh, and they do a fine job with foodplant leaves. They are not very expensive, last for years, and if you tire of raising caterpillars, many other uses can be found for them.

It is unnecessary to punch or drill holes in the top to give the caterpillars air, as they require very little. If the boxes are opened at least once a day for cleaning and putting in fresh leaves, there will be no problems with "stuffiness." I have never had a caterpillar die from suffocation because of lack of air holes in the top of a feeding container.

Keep boxes of larvae out of direct sunlight. If you have many such boxes, they can be stacked on card tables in a shaded room for compact storage.

Start feeding the larvae in small boxes, where they are easy to find. A pair of featherweight, stovepipe metal forceps (see figure 20) or a small, moistened water color brush may help you in handling them at this stage. As they grow and need more space, keep them in larger boxes. When nearly full-grown, caterpillars of many kinds of moths may be three, four, or even five inches long. At most only eight or a dozen should be kept in a single large crisper box ($14 \times 10 \times 4$ inches) at this stage. Overcrowded caterpillars often become diseased

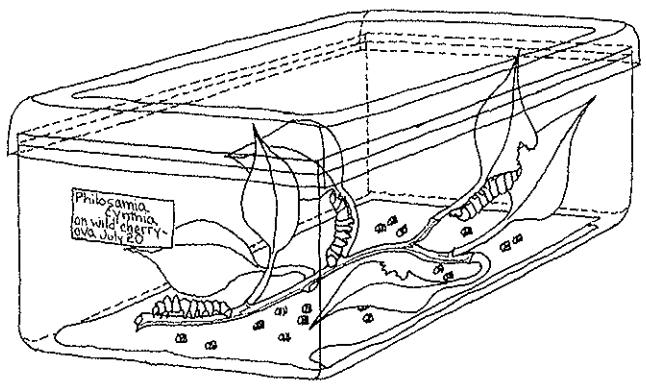


Figure 19. Plastic box method of rearing caterpillars indoors. A label can be fastened to the box to facilitate record keeping.

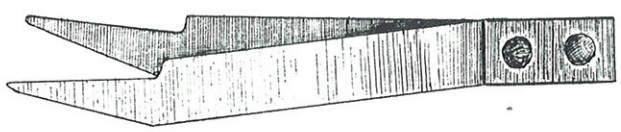


Figure 20. Featherweight, stovepipe metal forceps.

and die. Cleanliness and fresh food are also important. Wipe the condensed moisture from the inside of the box each day and, at the same time, put a new paper towel on the bottom and add freshly-gathered leaves. Containers should be thoroughly washed with hot, soapy water containing a little Clorox after one brood finishes–before you start another batch of larvae in the newly-empty box.

When deciding which of several listed foodplants to feed caterpillars, consider how close the plant or tree is to your house. It is foolish to walk four blocks to get walnut leaves if foliage from the hickory growing in the backyard will do. Feeding and cleaning larvae is a daily task and the more time and steps you can save, the better.

With certain moths, however, where foodplant preferences are very restricted, one kind may be the universal favorite. Caterpillars may refuse to even nibble leaves of the others listed. Larvae of the tuliptree silkmoth, a somewhat scarce, nocturnally active cousin of the promethea that looks very much like it, prefer tuliptree leaves, for example. Magnolia, cucumbertree, wild cherry, and lilac have been substituted in captivity, but the caterpillars do not like or grow well on these plants. In such a case, the rearer has little choice but to supply tuliptree foliage–even if the nearest source is a mile or two away. Foodplants listed in Section V of this booklet are in order of preference, the first being the favorite, in my experience.

I have found it easiest to collect all required foodplant leaves in one trip, following a definite route, taking along a list so nothing is forgotten, and snipping the leaves or branches into a large plastic bag for easy carrying. If the larvae cannot be fed and cleaned immediately after gathering the leaves, putting the bag in the refrigerator will keep them fresh for a few hours. This is not recommended as a general practice, however. Fresh leaves are always best.

Developing a daily routine will be best for you and for your unusual "pets." If you decide on a specific time to gather the leaves and clean the larva boxes each day, this will soon become habitual.

When cleaning the containers and putting in fresh leaves, it is unnecessary to see each larva crawl onto a new leaf. It is easier to snip the leaf or stem the caterpillar is clinging to away from the rest of branch, and drop it, larva and all, into the box with fresh leaves.

If it is raining and the leaves you have gathered for feeding are dripping wet, spread them out on a terry-cloth towel to dry for half an hour. Most of the water will evaporate or be soaked up. This prevents the frass from becoming very messy and also reduces heavy fogging of the interior of the plastic box. If you suspect that gathered leaves have been sprayed with an insecticide, wash them thoroughly under the faucet and dry as above, before feeding. It may be necessary to collect "safe" leaves from outside sprayed areas.

I recommend that you start with a dozen or two of each kind, particularly if you are growing several different species. The daily responsibility of properly feeding and caring for several hundred caterpillars will leave you time for little else all summer; but a dozen or two of each species are easy and fun to care for.

Do not stuff the plastic boxes completely full of leaves; this is unnatural. Larvae need room to move around. Caterpillars of two different species should not be mixed in one container. Some underwing caterpillars are *cannibalistic*. Therefore *each* larva must be kept in its own container if you want more than one big one. Tiger moth larvae, if overcrowded and improperly fed, will eat each other or newly-formed pupae.

Most books that say anything about keeping moth caterpillars caution the rearer not to change the foodplant after having once started a brood on a certain kind. In general, this is sound advice, but if you have a good reason (your supply of leaves is exhausted, or you find a suitable foodplant nearer to the house), changing the caterpillars is usually not very difficult. Simply mix leaves of the new foodplant in with the one you are now using. After two or three days of doing this, remove the original kind, feeding only the new variety. Of course, this new tree must be a known foodplant or near relative, the more closely related, the better. Some caterpillars will not change.

It may happen that you obtain eggs from a female moth but are unable to find any information on foodplants. In such a case, offer the little caterpillars foliage from characteristic trees in the vicinity, like ash, maple, apple, poplar, willow, oak, elm, or birch. With luck and perseverance, the proper foodplant will be discovered. This especially applies in the case of underwings (figure 6d). With these, try oaks, thornapple, blueberry, black and honey locust, hickory and walnut, or willow and poplar before you try other trees, as most underwing caterpillars eat these tree groups except *Catocala cerogama,* which feeds on basswood.

The time investment is substantially reduced if the caterpillars are grown *outdoors* in a "sleeve." This is a cylindrical sack of nylon marquisette (curtain material) or cloth screen, in the latter case with cloth flaps sewed on both ends for gathering and fastening shut (see figure 21). The sleeve is drawn over a branch of the foodplant tree and securely fastened on both ends with a stout thread or rawhide shoelace, with the eggs or newly-hatched larvae inside. The caterpillars will crawl onto the

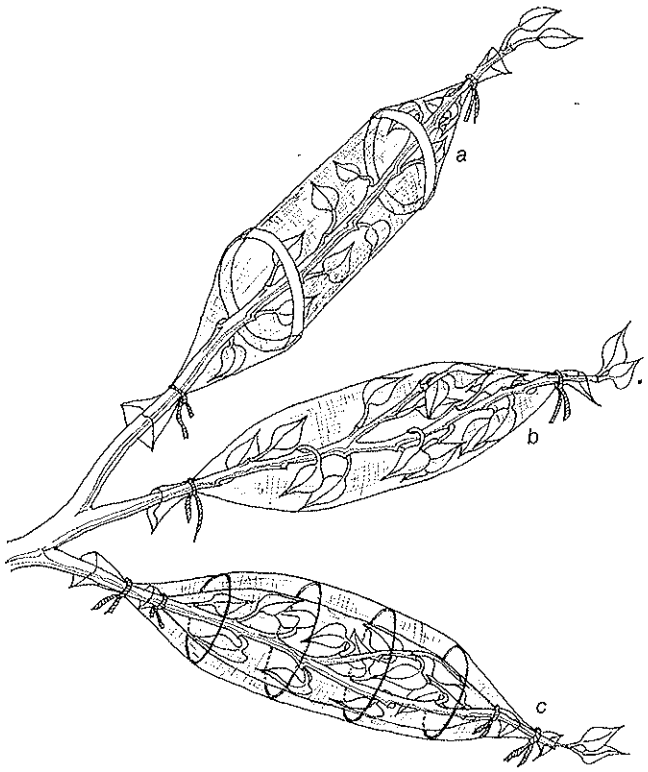


Figure 21. "Sleeving" method of rearing larvae outdoors, showing variations:

a. cylinder of screen or heavy cloth with marquisette netting on ends for tying shut.
b. simple marquisette cylinder sleeve.
c. double-sleeving (one sleeve within another) to deter stinkbug pests. Wire ribs help maintain an air space between the two.

Material may be dyed green if desired.

leaves and feed under completely natural conditions except they will be free from parasites or bird predators.

The sacks should be opened to allow accumulated frass and leaf pieces to drop out, at least once a week when the larvae are young, and every two or three days when the caterpillars are larger. As the larvae grow and need more food, they can be moved to fresh branches more frequently. Again, don't overcrowd; put no more than 12 or 15 in a sleeve three feet long and one foot in diameter. Overcrowded, hungry larvae in sleeves will sometimes chew holes in the cloth and escape onto nearby branches.

Sleeving is the most practical method for rearing large quantities of the same moth. People who sell surplus cocoons to museums, dealers, or universities almost always raise caterpillars this way. Sleeving is also the standard method used on moth farms in the United States, England, and other parts of the world.

While growing caterpillars, you may be astounded at their appetites and at how fast they grow. In the life cycle of the moth, the caterpillar's role is to eat and store food for the inactive pupal stage, and, in many cases, for the nonfeeding adult and egg stages as well. Part of the caterpillar's role in Nature is to serve as a *natural pruner* of the plants it eats. Moth caterpillars have so many enemies that they rarely survive in sufficient numbers to completely defoliate a tree or shrub, unless their natural predators and parasites are not present, as with the gypsy moth (figure 22).

As you see more and more kinds of moth caterpillars, differences in color, shape, and form will become apparent (see figure 23). Just as the egg and pupa of each species is unique, so is its caterpillar. People who have raised larvae for years can often tell which moth is being grown just by looking at the caterpillar.

Many sphinx larvae have a curved horn on the posterior (tail) end of their bodies, but in a few sphinx species this is reduced or replaced with an eye-like marking. Figure 7, on page 6, shows how the modest sphinx caterpillar's horn becomes less prominent as it grows larger. The rapid, lumbering gait of the very hairy larvae of tiger moths explains their common name, "woolly bear." Underwing caterpillars are long, slender, barklike or twiglike, well-camouflaged creatures. Regal and giant silkworm larvae are among the most beautiful. They are often gayly decorated with rows of red, yellow, orange, or blue tubercles, set against a green background. The

Figure 22. Adult gypsy moths.

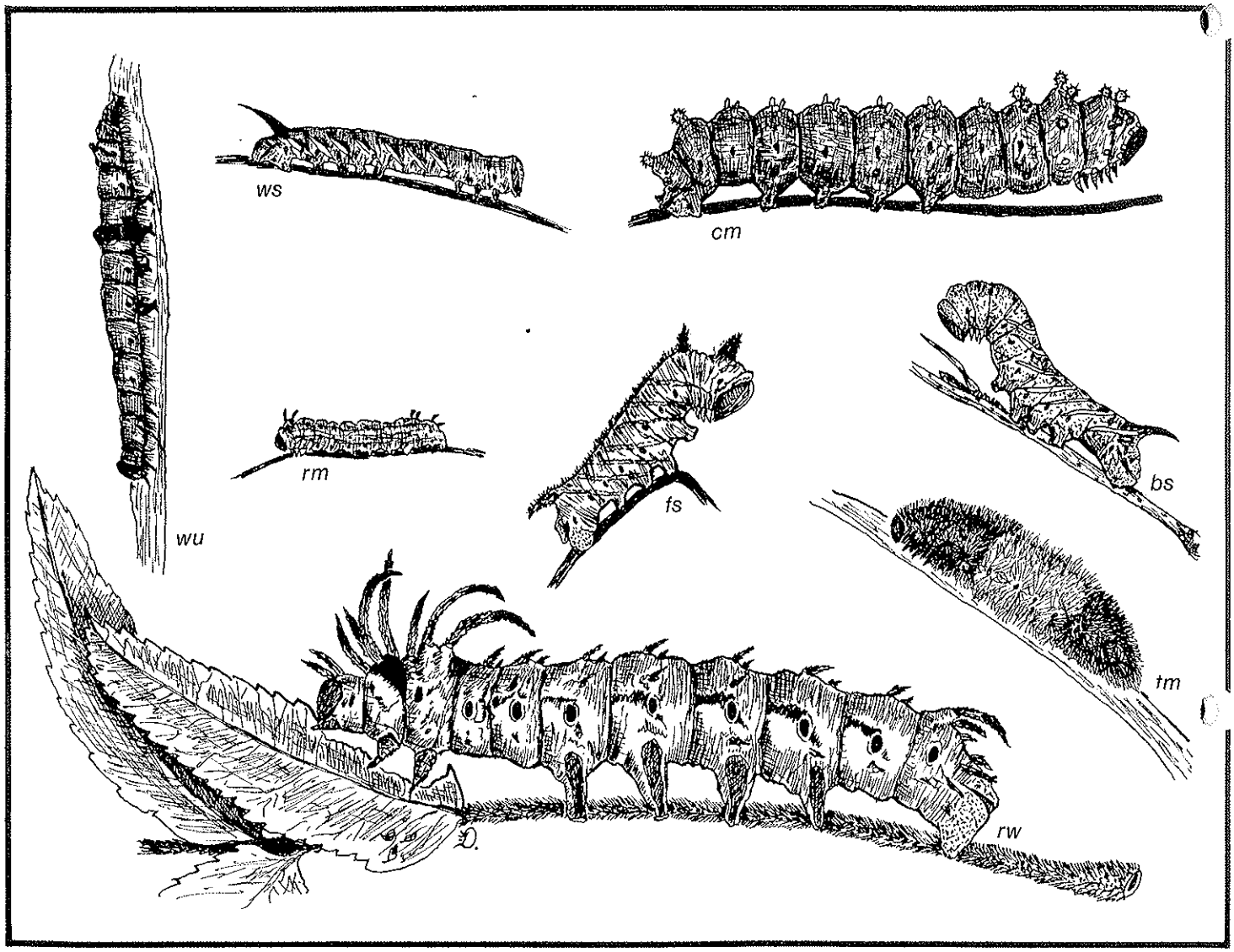


Figure 23. Larvae of some New York moths (life size):

ws—waved sphinx
fs—four-horned sphinx
bs—blind-eyed sphinx
cm—cecropia moth
tm—"woolly bear" of Isabella tiger moth
wu—white underwing
rm—rosy maple moth
rw—"hickory horned devil" of royal walnut moth

royal walnut moth's "hickory horned devil" is New York's most formidable caterpillar, although the long curved horns are harmless. When you get used to caterpillars, you may even think this horned "monster" quite handsome.

Larvae of some kinds of moths exhibit color forms. Imperial's stout, hairy caterpillars (figure 24), for example, may be dark brown or green. The four-horned sphinx's larva likewise is green or brown, or intermediate color combinations. White-lined sphinx caterpillars vary from almost wholly bright green to wholly black. Occasional individuals are marked or colored differently from others of their species. It is interesting to watch for these color variations among the larvae you grow.

Even more interesting to observe are the frequent changes in markings or color as the caterpillar sheds its skin (*molts*). It spins a small silk pad on a leaf or stem, attaches its hindmost pair of legs (*prolegs*—see figure 24) to this and waits. At this stage, the head cap is very small and the larger, new face cap can be seen under the skin of the first thoracic segment (figure 25). After several hours, the old skin splits and the caterpillar crawls out,

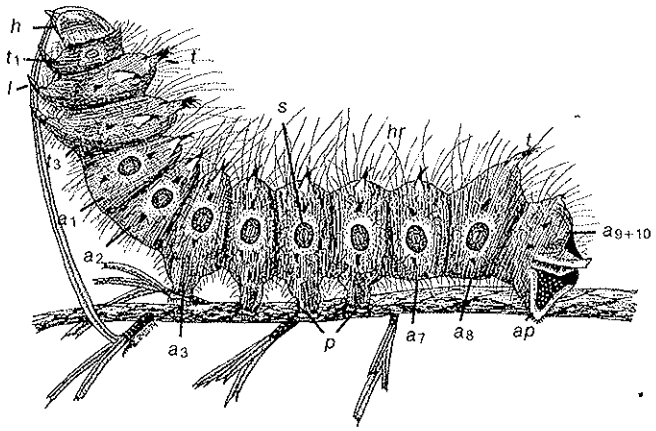


Figure 24. Parts of the caterpillar (imperial moth, life size).

h—head
t_1-t_3—thoracic segments
l—true leg
t—tubercle
a_1-a_{9+10}—abdominal segments
hr—hairs
s—spiracle
p—prolegs (false legs)
ap—anal proleg

bedecked in a new, larger one. Molting will occur about four times during the four to eight weeks it takes for most moth caterpillars to become full-grown. They should not be disturbed or pulled off the silken pad while molting.

The different stages in the development of caterpillars are called *instars*. A first-instar larva is one just out of the egg, before molting once; a final-instar caterpillar is one about to pupate; and a third-instar larva is between the second and third molt. All five instars of the promethea moth's larva are shown in figure 26.

Near the end of the last larval instar caterpillars do several things which foretell approaching pupation. They void their digestive tracts of very juicy frass, much different from the usual hard, dry pellets; they may shrink slightly; and may even change color[1] Some sphinx moth caterpillars turn pink, brown, or purple along the "back," and lunas turn rusty brown at this stage, for

[1]Do not confuse with disease symptoms—see page 20.

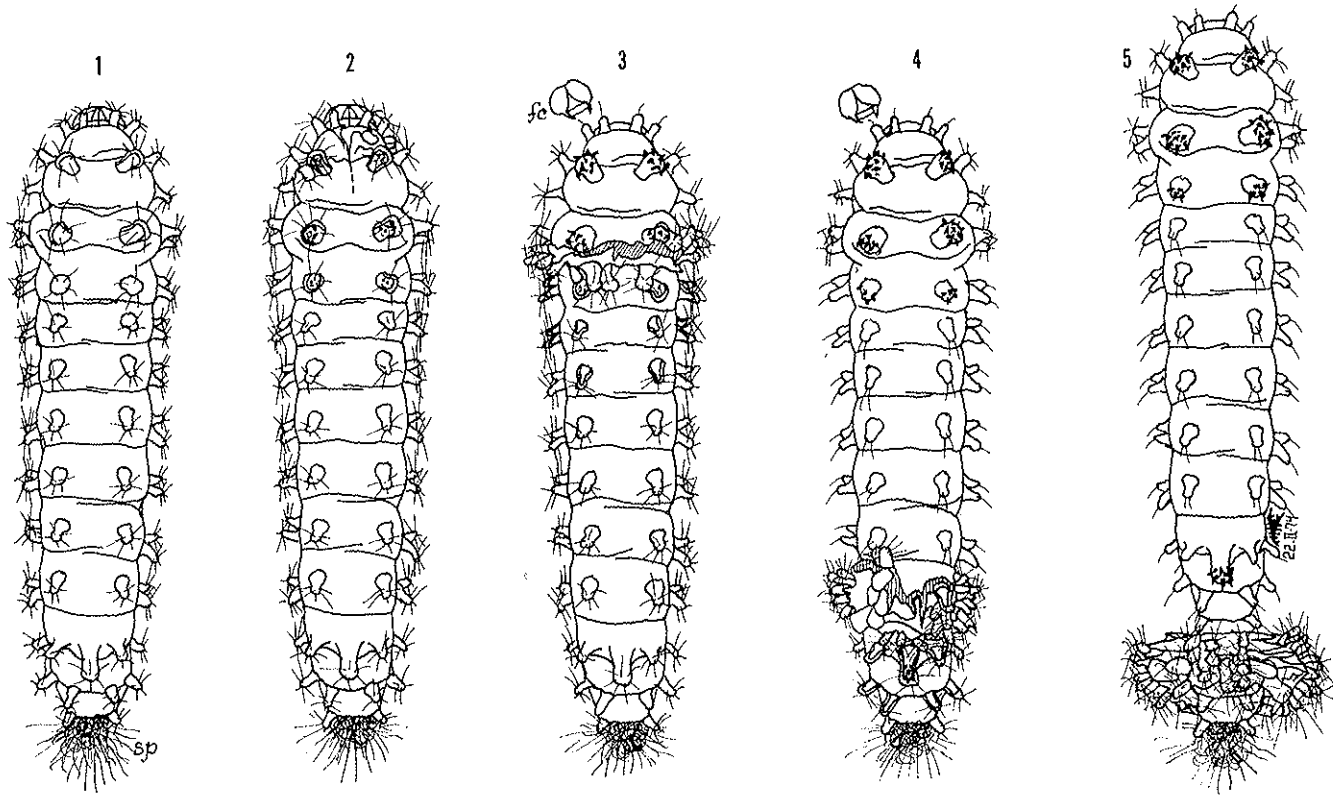


Figure 25. How a caterpillar molts:

1. The larva spins a silk pad *(sp)*, to which it fastens its anal prolegs.
2. The old skin splits along the thorax. New thoracic tubercles can be seen inside the old ones.
3. The face cap *(fc)* is shed and the old skin shuffled rearward.
4. The old skin is shuffled all the way back.
5. The caterpillar crawls out of the old skin. Compare the largest tubercles in pictures 1 and 5.

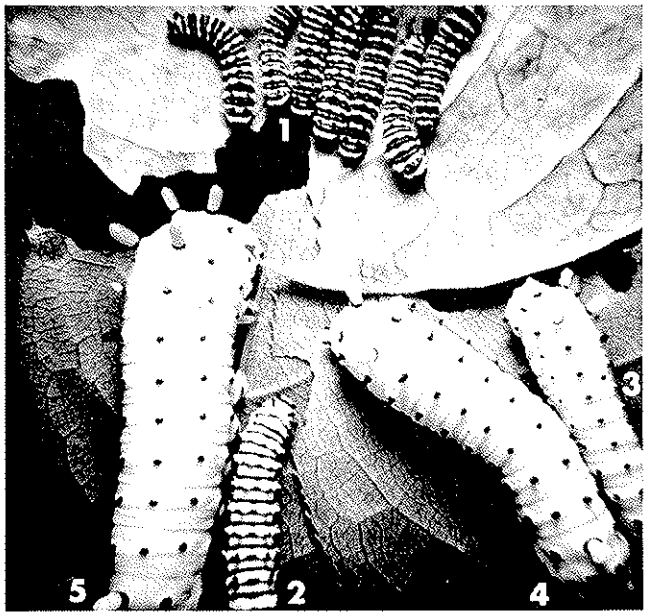


Figure 26. First through fifth instars of the promethea moth larva.

example. Many kinds appear restless, wandering all over inside the sack or box for a day or two. Sphinxes may burrow beneath the paper towel or leaves on the bottom of the box, or under frass and leaf debris in the bottom of a sleeve. Caterpillars that spin cocoons will start fastening silken threads in a corner among leaves.

Cocoon-spinners should be allowed to finish their cocoons undisturbed. Then remove most of the leaf wrappings and leave the cocoons in a protected place out in the open air for a few days. The silk will dry and harden and the pupae will form inside.

Moths that have bare pupae should be handled as follows: Put each shrinking caterpillar in a small, covered plastic box by itself with only a paper towel on the bottom. Change the paper towel as it becomes dampened or soiled while the caterpillar voids its digestive tract, but otherwise leave it strictly alone, particularly at the point of pupation. After three to eight days (sometimes more), you will see a firm pupa in the box. If you are lucky, you may notice a pupa shedding the last larval skin, and can watch the soft, green blob dry and harden into the pupal form. Pupae are very easily damaged at this point and should not be touched or handled nor should the box be jarred.

Caterpillars that overwinter in Nature are very difficult to deal with in captivity. I have tried (and failed) to overwinter *Arctia caja* caterpillars in a plastic box in the refrigerator. I think the reason for death of the larvae was drying out. Hibernating butterfly caterpillars can be overwintered if kept in the refrigerator in a tightly-closed plastic container with a piece of dampened paper towel. You should change the towel every three or four weeks.

Predators, Parasites, Diseases

Imagine for a moment a wild female cecropia moth on the first night after mating. She labors along, flapping her huge wings, weighed down by an abdomen heavy with eggs. Every few feet she lands on a cherry, maple, or birch sapling beside the road and lays a few eggs in a small patch on the leaves. This performance is repeated until she has laid over 100 eggs.

Dawn approaches. The moth lands in a thick patch of bushes and crawls down among the stems. Despite her bright colors, she is well hidden as she rests with her large wings (slightly snagged by twigs) closed together up over the thorax.

Red streaks appear in the east. The sun is up. The morning bird chorus reaches its height. Many kinds of animals begin to move about and feed. Plants spread their leaves to the sun to trap its energy in the chemical bonds of the sugars they manufacture, using carbon dioxide from the air and water from the soil. But the night creatures rest in hollow trees, beneath stones, or in other shaded spots, like the cecropia's.

Noon, afternoon, and evening pass. Again it is dark. The cecropia resumes her egg-laying; only 60 eggs tonight.

The next night, she lays 40 more, and before a week has passed, nearly 100 more, or about 300 altogether. Then she dies.

Let's assume the female cecropia laid each of her eggs on a plant the caterpillars could eat. All eggs hatched and produced a healthy larva that fed and grew to maturity, spun a cocoon, and successfully pupated. Let's further suppose that each of the 300 pupae survived the winter and produced a moth the following June. Half of the emerging moths were females, half males. Each of these 150 females mated and laid 300 eggs. In other words, 45,000 eggs were laid on trees and bushes by these female cecropias. Again, let's assume all 45,000 hatched, grew, pupated, and emerged as adults the following June. Half of these—22,500—were females. All 22,500 females mated. Each laid 300 eggs. In other words, a total of 6,750,000 cecropia eggs were placed on trees and bushes by the 22,500 females, all descendants of the original female cecropia laying her eggs just two years earlier. I need go no further to make my point: the *reproductive potential* of just one pair of moths is astounding.

Of course a situation like this would never occur in Nature. Probably only two or three from the 300 eggs would survive to the adult stage and reproduce.

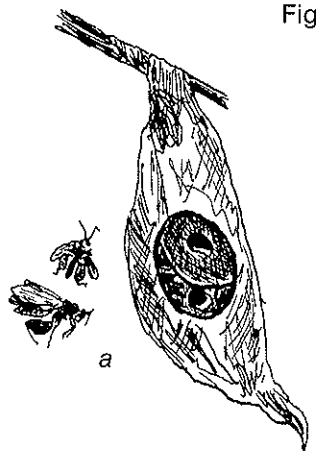
Cecropias and other moths have many enemies in all stages of their lives. The eggs may be eaten or attacked by birds, spiders, or tiny parasites. In Nature the female moth usually deposits her eggs on leaves or stems of an appropriate foodplant, but not always. If she doesn't,

the newly-hatched larvae need to crawl to find a plant they can eat. Many of these undoubtedly perish from starvation, drown in dewdrops, or fall prey to spiders, birds, or other *insectivores* (insect-eaters). The same plight may also await many of the caterpillars hatching from eggs laid on an appropriate foodplant.

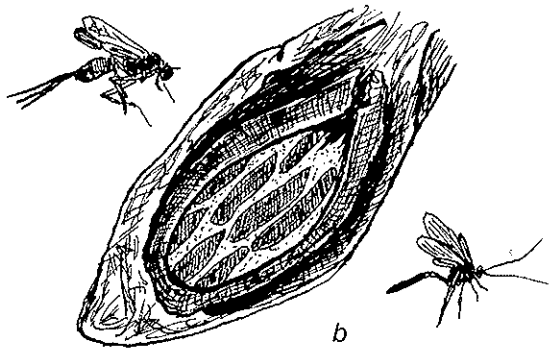
As it feeds and grows the larva may be attacked by many enemies. Parasitic wasps and flies may lay their eggs on or inside the caterpillar or on the leaves it eats. The small wasp larva or fly maggot then hatches inside the moth caterpillar's body and feeds on its tissues, gradually weakening it. Depending on the kind of parasite, the caterpillar may die before pupating, wearing a cluster of small, oblong, white wasp cocoons on the outside of its body; or it may spin a cocoon, but die before pupating, the parasites spending the winter in the cocoon and emerging the following spring, instead of the moth. Or a pupa may form, but die during the winter, producing small wasps the next spring. Probably over half of the wild cocoons you find will produce parasites instead of moths. This may be disappointing, but you should preserve these, as they have a definite scientific value. Be sure to record host moth and keep the cocoon from which they emerged, all labelled, to avoid confusion later. Figure 27 shows some common parasites of New York moths.

Predators attack the caterpillars throughout their lives. Again, birds of many kinds find a moth larva a tasty

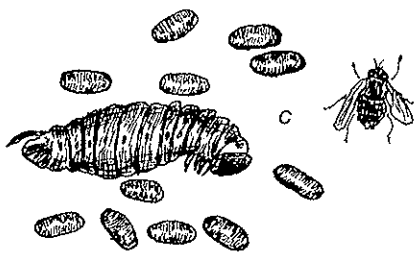
Figure 27. Moth parasites (life size).



a—cynthia cocoon, cut open to show exit holes of the adult parasites through the pupal shell. The wasps then bore through the silk (not shown) to escape. Larger wasp shown is the female. Note the enormous enlargement of hind legs. Wasps are yellow and brown.



b—cecropia cocoon cut open to reveal wasp parasite cocoons instead of pupa inside (compare with figure 30). Larger wasp shown is the female. Color of legs and abdomen red, the rest black. The same or a very similar species attacks promethea.



c—great ash sphinx larval "mummy" and puparia of 11 fly maggots that crawled from the caterpillar shell. Adult fly is grey, hairy, with brown eyes. The same or a very similar species attacks polyphemus caterpillars.

morsel. Some mammals (mice and squirrels, for example) eat caterpillars, too. Predatory insects, such as *stinkbugs* (order *Hemiptera)* may puncture a larva and suck out its internal fluids, as shown in figure 28. These can be a nuisance around sleeved caterpillars, lurking in the folds of the sack and attacking any larvae they can reach through the cloth. Double-sleeving your caterpillars (figure 21c) will safeguard them, if you find stinkbugs to be a problem. A Long Island naturalist once found a black racer snake that was swallowing a royal walnut moth's caterpillar.

Caterpillars can be knocked from their foodplants or injured during bad weather. And, of course, humans take their toll by spraying poisons on leaves caterpillars must eat, destroying habitats by cutting trees and bushes, and squashing any "worm" seen along the sidewalk.

Cocoons and pupae may be eaten by birds, mice, squirrels, moles, and other animals. The particularly conspicuous cocoons of cecropia, promethea, and cynthia may find their way into the hands of a young collector.

Adult moths themselves fall prey to birds, bats, owls, cats, and so on. I have already mentioned finding moth wings around my blacklight in the morning, after the bodies had been eaten by chipping sparrows, catbirds, robins, and other yard birds.

As if pressures from predators, parasites, bad weather, and humans are not enough, moths are also subject to several diseases caused by bacteria, viruses, protozoa, and fungi. As you rear moth caterpillars, the role of diseases in their natural control will become apparent.

In captivity, diseases often develop when larvae are not kept sufficiently clean, properly fed, or are too crowded, especially under hot, humid conditions. When disease develops in a brood, this usually means something is wrong with your rearing techniques.

Diseased larvae typically exhibit one or more of the following symptoms: they may act sluggish, refuse to eat, and (or) discharge a sticky fluid from the mouth. The frass may liquify, which is abnormal except when pupation approaches. The caterpillar may limply hang from a support by its *prolegs* (see figure 24), or may become greyish or off-color. Discolored blotches sometimes appear on the skin and may spread. All of these symptoms can develop very rapidly, even overnight. Death usually closely follows.

In the artificial conditions under which moths are reared, disease can spread rapidly, killing a whole brood of caterpillars. Therefore it is wise to immediately remove any larvae exhibiting disease symptoms and destroy them. This is hard to do, but little if anything can save an infected caterpillar and destroying it will prevent its contaminating healthy larvae. Be sure to thoroughly sterilize enclosures in which diseased caterpillars were kept before placing other larvae in the box or sack. First, wash them carefully in warm, soapy water. Next, soak in

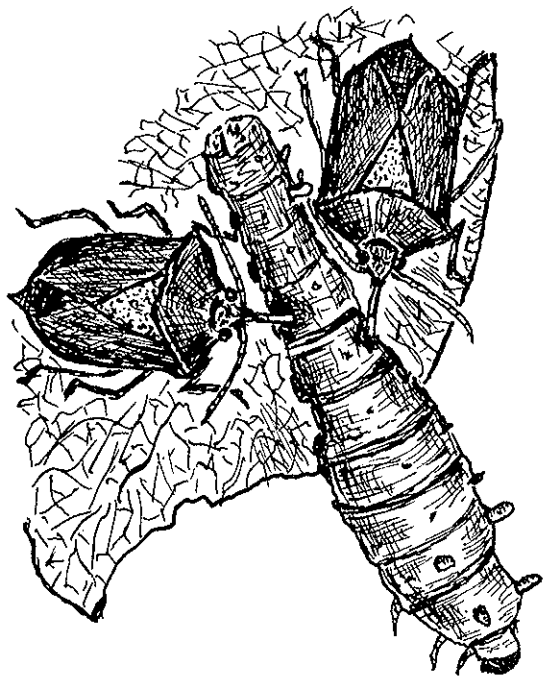


Figure 28. Stinkbugs sucking out a promethea caterpillar's internal fluids.

a solution made from one part Clorox and three parts water for at least an hour. Then rewash and rinse. This should eliminate most fungi, bacteria, and protozoa. Finally, boil the sleeves or plastic boxes[2] in water for half an hour to reduce the chances of virus-caused diseases developing in the next brood of caterpillars kept in the box. Little is known about caterpillar diseases, and it is difficult for the average person to tell which type of causal organism is responsible for the symptoms. Therefore, all four of the above steps should be followed when cleaning a plastic box that contained diseased larvae.

Because of all these things—predators, parasites, weather conditions, man's activities, and diseases— immense populations of moths do not build up. Even the most sentimental person can see that the huge number of hungry caterpillars one female cecropia and her progeny could produce in just three years without these natural controls would constitute a threat. The ravages of the gypsy moth (figure 22), an introduced pest devoid of its natural predators and parasites, dramatically point out how important these are in Nature's scheme, and what problems humans cause when they tamper with things best left alone.

Handling Pupae and Cocoons

The stage following the caterpillar should be called a *pupa. Cocoon* correctly applies only when some sort of

[2]Some kinds of plastic will melt if put in boiling water.

covering is spun or fastened around the pupa. Among our native moths, the giant silkworms spin the most elaborate cocoons. Underwings, some tiger moths, and a very few sphinxes (myron, for example) make flimsy cocoons of bark, surface litter, or leaf pieces held together with a few strands of silk. "Woolly bears" (tiger moth caterpillars) shed their larval hair and use it, with silk, to form a cocoon. Full-grown larvae of most sphinxes and all regal moths burrow into the soil and make an egg-shaped cavity in which to pupate. The bare pupa that forms there is sometimes referred to as a *chrysalis*. This term is also used to mean the pupal stage of butterflies.

Pupae are fascinating objects. If you have one handy, examine it closely as you read the following few paragraphs. Try to find the structures mentioned and illustrated in figure 29.

Just as the moth that emerges from it will have a head, thorax, and abdomen, so does the pupa. Find the places where the head separates from the thorax and the thorax from the abdomen, if you can. Creases and markings on the pupal surface show the eyes, antennae, feet, proboscis, wings, and abdominal segments of the developing moth. *Spiracles*, or breathing-pores, are evident along the sides—find these on your pupa. How many segments will the moth's abdomen have?

Some pupae, such as luna's, are smooth-surfaced. Others, like the imperial's, are rough. A few kinds have a white powder ("bloom") on their surface; the virgo tiger moth's is one of these.

If you are holding a living pupa, it may wiggle and twist its abdominal segments in response to pressure, touch, or the warmth of your hand. Lunas wiggle the most violently of all the moth pupae I have handled. Ios

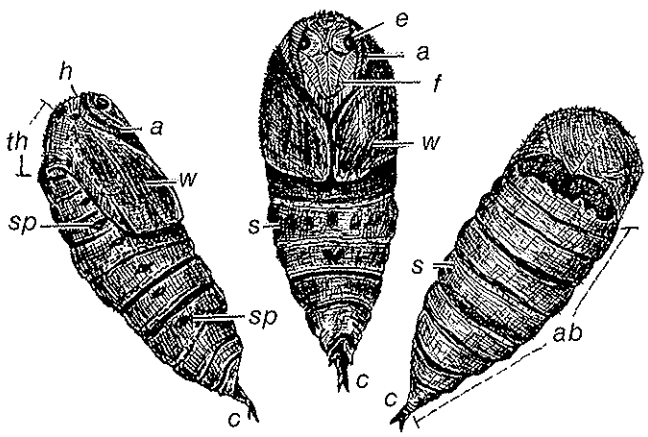


Figure 29. Parts of the pupa (imperial moth, life size).

e—eye sheath
a—antenna sheath
w—wing case
s—segment of abdomen
sp—spiracle
h—head
th—thorax
ab—abdomen
c—cremaster
f—feet

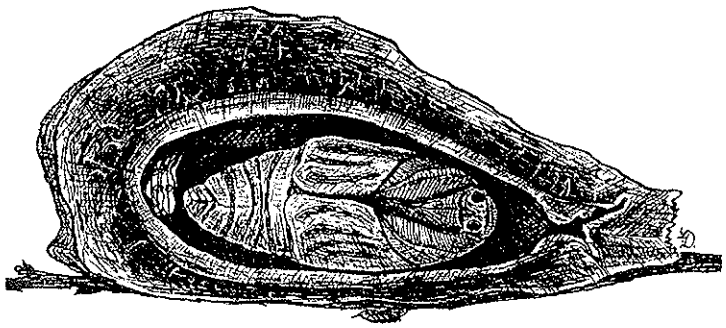


Figure 30. Cecropia cocoon cut open to show inner cocoon and pupa (life size).

are also very active. In contrast to the caterpillars, which can crawl for long distances, the movements of pupae are restricted to wiggling, and with pupae that form underground, to twisting their way to the surface just before the moths emerge. The pupa, like the egg, is essentially nonmotile.

When you grow cecropias, carefully cut open one of their cocoons lengthwise, using a pair of manicure or finely-pointed embroidery scissors, and examine its structure and the pupa inside (figure 30). You will probably be as surprised as I was to find a second, inner cocoon beneath an insulating mat of loose silk strands. Even more interesting is the one-way valve through both inner and outer cocoons that allows the emerging moth to escape. Carefully cut through the inner cocoon to see how the pupa is oriented. Is the escape valve at the head or abdominal end? Does this make sense? What is the small, dry, bumpy wad near the end of the pupa's abdomen in the inner cocoon?

Cut open a promethea or cynthia cocoon. Is there an inner cocoon? Escape valve? Notice the interesting "stem" on these cocoons, and the strong band of silk that fastens them firmly to twigs all winter and sometimes leaves them dangling for a year or two after the moth has emerged.

Also examine io, luna, and polyphemus cocoons. Do these have an inner cocoon or escape valve? Note the vein-marks left on the cocoons when you remove their leaf wrappings.

If you closely study cocoons of tiger moths or other kinds besides giant silkworms, their relative flimsiness will be evident. Seeing more and more kinds of pupae will point out the endless variations on the general pattern (see figure 31). The tomato hornworm sphinx's pupa, for example, has a raised, jug handle-like proboscis ("tongue") case. The walnut sphinx pupa's abdomen is peculiarly flattened at the end. The royal walnut moth's huge, glossy black pupa emits a pleasant, pungent smell reminiscent of incense. Some pupae, particularly those that form underground, have a prominent, sharp spine called a *cremaster* at the tip of the

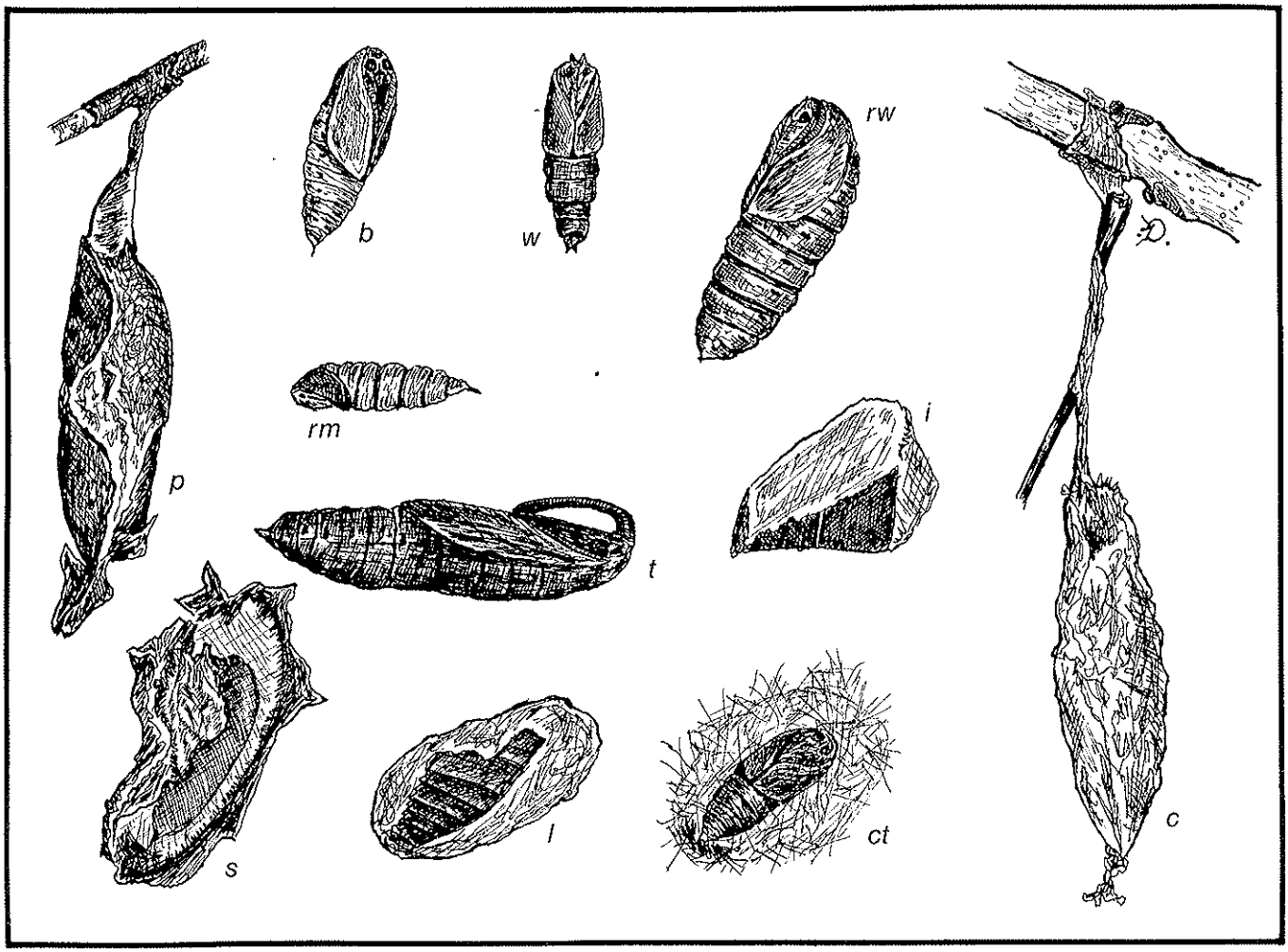


Figure 31. Cocoons and pupae of some New York moths (life size):
w—walnut sphinx
t—tomato hornworm sphinx
p—promethea
c—cynthia
l—luna
i—io
rw—royal walnut
rm—rosy maple
ct—caja tiger
s—sweetheart underwing, *Catocala amatrix*
b—bride underwing, *Catocala neogama*

abdomen (see figure 29). This helps the buried pupa move through the earth to the ground surface when the moth is ready to emerge. Similiar structures on butterfly chrysalids fasten them to silken pads so they hang freely, head-downward, while the adult develops.

Cocoons and *bare pupae* require different storage techniques and adult emergence enclosures.

After a *cocoon* is spun, leave it in a safe place in the open air for about a week to dry and harden and to allow the pupa to form inside.

Once the pupae have formed, it may be only two or three weeks before the moths emerge. This is fine if you are anxious to see them or if it is midsummer and there is time to grow another brood; but what if it is September and you'd like to save some of the pupae alive for breeding stock next spring? The cocoons would normally be outdoors all winter—in fields, along roads, or in woodlands. People, however, keep their houses at about 72°F in winter, which is drastically different than outside temperatures. Cocoons (or bare pupae) kept in a heated room during autumn and winter may produce adults prematurely. Something inside the pupa "tells it" it's summer and triggers emergence of the moth.

Emergence can be retarded until the proper season in several ways. Many people leave cocoons outdoors or in an unheated garage or other building in a place safe from mice, birds, or other animals that might eat the pupae. In late April or early May, they bring them

inside. Others find the enclosure formed when an aluminum storm window is fastened over a regular window a handy "outdoor" cage for overwintering cocoons. But I usually simply pack cocoons in one of my plastic-larva boxes and put them in the refrigerator (not the freezer) until spring. Most of the leaf wrappings and any bits of frass that have been fastened to the cocoon are removed to prevent mold. During storage, the box should be opened once a month to wipe out condensed moisture and let in fresh air. *Stored cocoons should not be dampened, regardless of what it may say in other books!* Just leave them alone. (If you think the air in the refrigerator is too dry, keep an open dish of water inside to evaporate and increase the humidity.) Refrigerating cocoons has worked very well for me and eliminates the possibility of mice, squirrels, or birds breaking into an outdoor storage area.

In New York State the wild giant silkworms and most other cocoon-spinners are on the wing from early June through mid-July. If you want captive moths to emerge at the same time their wild counterparts are flying, remove the cocoons from the refrigerator between May 10th and 15th. In two to four weeks after this sudden "spring," the moths will appear.

Sometimes cocoons are purposely removed from cold storage much earlier in the year so the adults will come out in midwinter. This is quite a novelty in the science classroom, for a public presentation, or for showing visitors.

The cocoons you take from the refrigerator or bring inside should be placed in an *emergence cage* made from a cylinder of window screen about one foot in diameter, with cloth flaps sewed on both ends for gathering and tying shut (figure 32). A temporary emergence cage can be as easily made by gluing cheesecloth or burlap pieces to the inside of a pasteboard box, setting it on end, putting the cocoons inside, and taping a piece of transparent plastic over the front (figure 33). Again, *do not dampen the cocoons*. If the air is somewhat humid, they will be fine as long as they are kept out of direct sunlight. "Watering" cocoons very often greatly reduces the number of successful emergences or produces cripples.

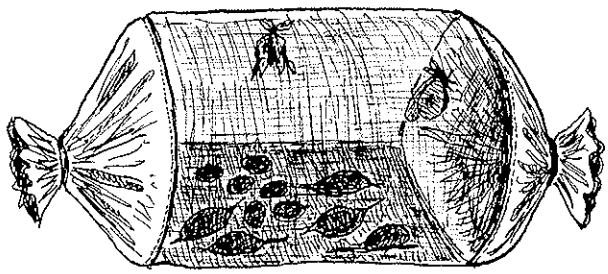


Figure 32. Emergence cage for cocoon-spinning moths. Made of screen with cloth flaps over the ends for tying shut.

Figure 33. Temporary emergence cage for cocoon-spinning moths. Made from burlap-lined pasteboard box with transparent plastic fastened over the front.

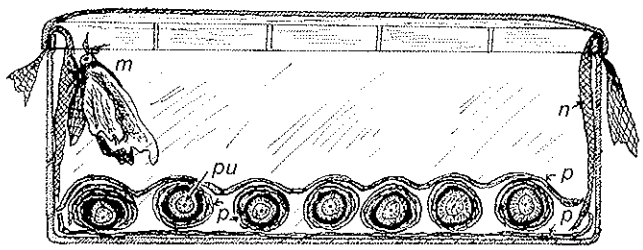


Figure 34. Emergence chamber for bare pupae

p—wet paper towels
pu—pupa rolled in wet paper towel
n—netting held in place by cover
m—expanding moth

The *bare pupae* of sphinxes and regal moths should be handled differently. After they have formed and hardened, roll each one in a strip of facial tissue or paper towel and store in a small plastic larva box; or bury in sterile peat moss or potting soil (obtainable from a greenhouse) in a plastic box. Tape the box shut and put it in the refrigerator or in a cool basement or attic until spring. About mid-May, remove the pupae from cold storage. Prepare an emergence chamber from a large crisper chest used to feed larvae, as follows: Fasten a piece of cheesecloth or nylon net (for the emerging moths to climb up on) inside the box, held in place with tape, as shown in figure 34. Put three or four layers of absorbent paper towelling on the bottom, hold under the faucet until they are saturated, and, tipping sideways, dump off the excess water until no more will run out.

Saturate another paper towel and tear it into two-inch wide strips. Roll each pupa individually in one of the

dampened strips and lay on the bottom of the box, on the wet towels. Place another damp towel over all the pupae and close the cover tightly to keep the moisture in. Remove and discard all paper towel pieces inside the emergence box and repeat the above procedure, once or twice a week, until the adults appear. This will be three or four weeks for some sphinxes, such as modesta, a month or more for imperials, and perhaps two months for royal walnut moths. Rarely will all pupae produce an adult, but this method is the most successful and easiest to use of all I have tried or heard of. Pupae overwintered in an unheated room or building have a higher percentage of adult emergences than those kept in a refrigerator all winter. Rearing adults from overwintered bare pupae is difficult, but the rewards that come with success are worth all the trouble.

As you grow more and more kinds of moths, experience will teach you that some double-brooded sphinxes and other moths with bare pupae, like the rosy maple, will emerge in two to three weeks if left in a screen emergence cage with cocoons. You will learn that cecropia adults will not emerge unless the cocoons have been chilled for several months. Some but not all prometheas and cynthias will emerge at midsummer as the second brood, but a cold treatment will be needed to produce adults from the rest. Sometimes, if a pupa is still alive at the end of the summer, it may be chilled again over the winter and will produce an adult the second spring. Even veteran rearers are still learning things like this. Don't be afraid to experiment and try new methods or ideas of your own.

It is always nice to supplement your reared stock with wild-collected cocoons. Fringes of bushes or small trees along country roads, fences, railroads, or waterways are good places to look for cocoons. The large ones of cecropia (see figure 35) are conspicuous on the branches of beech, birch, cherry, sassafras, elm, apple, willow, plum, maple, and several other trees. Prometheas dangle from the branches of spicebush, sassafras, tuliptree, and wild cherry. Very similar cynthia cocoons hang in company from the stout twigs of ailanthus trees where they grow in vacant lots in cities near the Atlantic. Less often found are cocoons of polyphemus, luna, and io. Tiger moth cocoons occasionally come to light beneath stones or boards, and sphinx pupae can be found washed out along ditches after a heavy rainstorm. When chance presents you with these opportunities, it is good to take advantage of them.

Only some of the cocoons or pupae you find will be alive. A cocoon containing a living pupa is heavy, sometimes weighing as much as two or three quarters (25¢). If the cocoon is tipped or gently shaken, a solid bump results as the living pupa slides from end to end inside. A cocoon with a dead or parasitized pupa will, in contrast, be much lighter than one quarter in weight. It may produce a dry, crackly rattle if gently shaken. This will

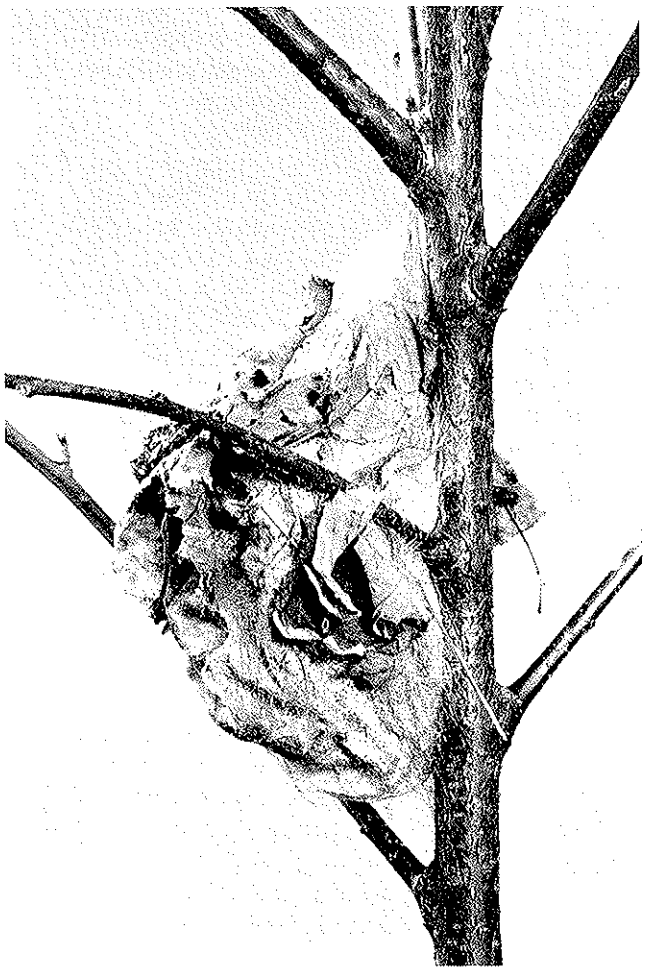


Figure 35. Wild cecropia cocoon as found.

also be true if the moth has emerged or if the larva was able to spin its cocoon, but failed to pupate properly. A living bare pupa will also be heavier than a dead one, and the segments of its abdomen can be moved easily with gentle pressure from your fingers. A dead one will be stiff.

After finding a wild cocoon that indicates by its light weight that no moth will emerge from it, cut away the silk and examine the inside. Often a plug of parasite cocoons will fill the cavity the pupa would normally occupy. If you keep these, interesting wasps may emerge by boring small holes through the side of the cocoon (see figure 27).

At times it is helpful to know if your cocoons will produce male or female moths. In general, cocoons of females will be *heavier*. Giant silkworm *pupae* may be easily sexed in the same way the moths are, by looking at the antennae (see figure 36).

Since emerging and expanding moths often spray a chalky-white or pinkish waste fluid (the *meconium)* from the abdomen, it is a wise precaution to put paper towels beneath your emergence cage and between the cage and

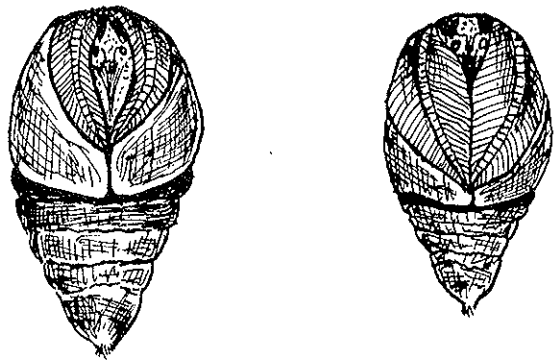


Figure 36. Female-male pupa differences: The male polyphemus moth pupa's large antennae and smaller size (right) separate it from the female. Size and antennae differences make sexing of some giant silkworm pupae easy.

the wall, to soak up this liquid so it doesn't mar the wallpaper or table top.

Care of Adults

One of the most miraculous of Nature's spectacles is the emergence and expansion of a moth. If you watch your cocoons closely, you may be lucky enough to witness this event.

Inside, the moth breaks out of the pupal shell and bumps its head against the wall of the cocoon, at the same time secreting fluid which helps to soften and dissolve the silken threads. Some cocoons, such as polyphemus', become wet on one end about an hour before the moth emerges. If you notice this, wait and watch for an hour and see what happens. Some moths, such as luna, also use sharp spines (called cocoon cutters) at the base of the wings to cut or weaken the cocoon. Even moths that spin cocoons with escape valves must break a few silk threads before they can crawl out.

After about an hour of pushing, the moth appears—a strange, bedraggled creature with thumbnail-size wings, and six furry "tarantula-feet" that carry it in a frantic search for a place where its soft wings can hang down to expand without injury. You will be able to tell immediately whether it is a male or female by the antennae.

The moth must find something to crawl up on. If it fails to suspend itself properly, a moth that may have waited 360 days for this moment will be doomed in half an hour to a brief life of terrible disfigurement as its wings harden, crumpled and useless. This may seem harsh, but it is Nature's way of weeding out the weaker individuals.

Almost always, however, the moth will climb up the screen, cheesecloth, or burlap, clinging with its feet, and settling in such a way that the stubby wings hang freely downward without touching anything. Then, the tiny, intricately patterned wings enlarge, rapidly at first, then more slowly, while the big, heaving abdomen shrinks as its fluids pass into them (see figure 37). In half an hour, when expansion ends, they are ten times their original size. The resplendent moth rests quietly for a few hours to let its huge, limp appendages dry and harden before testing them.

Metamorphosis is complete. The eggs hatched, the caterpillars grew and pupated, and finally the moths have emerged. Now the cycle will continue. The adults, many of which live only about a week and eat nothing, will mate, and the females will deposit their eggs and die. But their offspring will live on to produce new moths at midsummer or next spring.

If you want to raise the moth again, you will have to pair the adults in captivity. Put a newly-emerged male and female in a screen enclosure like your emergence cage, or let them cling to the inside of a piece of netting fastened over the top of a cardboard box. Hang or set this mating enclosure outdoors at dusk, in a place safe from cats, and leave all night. Almost invariably, the moths will mate sometime during the night, and their bodies will seem to be stuck together the next morning (see number 6 in lower right corner of figure 43, page 33). When they naturally separate, usually before the following night, put the female in a paper sack (figure 18), and she will lay 200-300 or more fertile eggs. Certain moths, such as io, may only stay together for an hour or two, so unless you actually observe the pairing, you won't be sure about fertile eggs with these. Some moths are easier to pair than others.

If you need a male for mating purposes but have none, don't give up. Tie one end of a 2-foot-long piece of yarn or stout thread securely but not too tightly around the female moth's thorax, as shown in figure 38 (use method b with giant silkworms and regal moths only). After dusk, tie the other end of the string to a tree or bush in your yard, and set the moth gently in the leaves so she can cling comfortably with her feet, or use a small, open-ended cage (figure 38c). By morning, a male should have found her. After they separate take the female indoors to keep cats or birds from catching her. This method will work only if the moth occurs naturally in your area and males are flying.

Sometimes when I have had female moths tied out, I have set my alarm for 2:00 or 3:00 a.m. and gotten up to watch a "moth carnival" in the backyard. The larger antennae of the male moths can sense a very powerful "perfume" *(pheromone)* the female moth releases—which humans can't detect—and they "home in" on it (figures 39, 40). An unmated, tied-out female may sometimes attract 15 or 20 males of her species from more than a mile away! Imagine how exciting it is to have that many huge, tan polyphemus moths with blue, yellow, and black eyespots on their wings (figure 43); or delicate

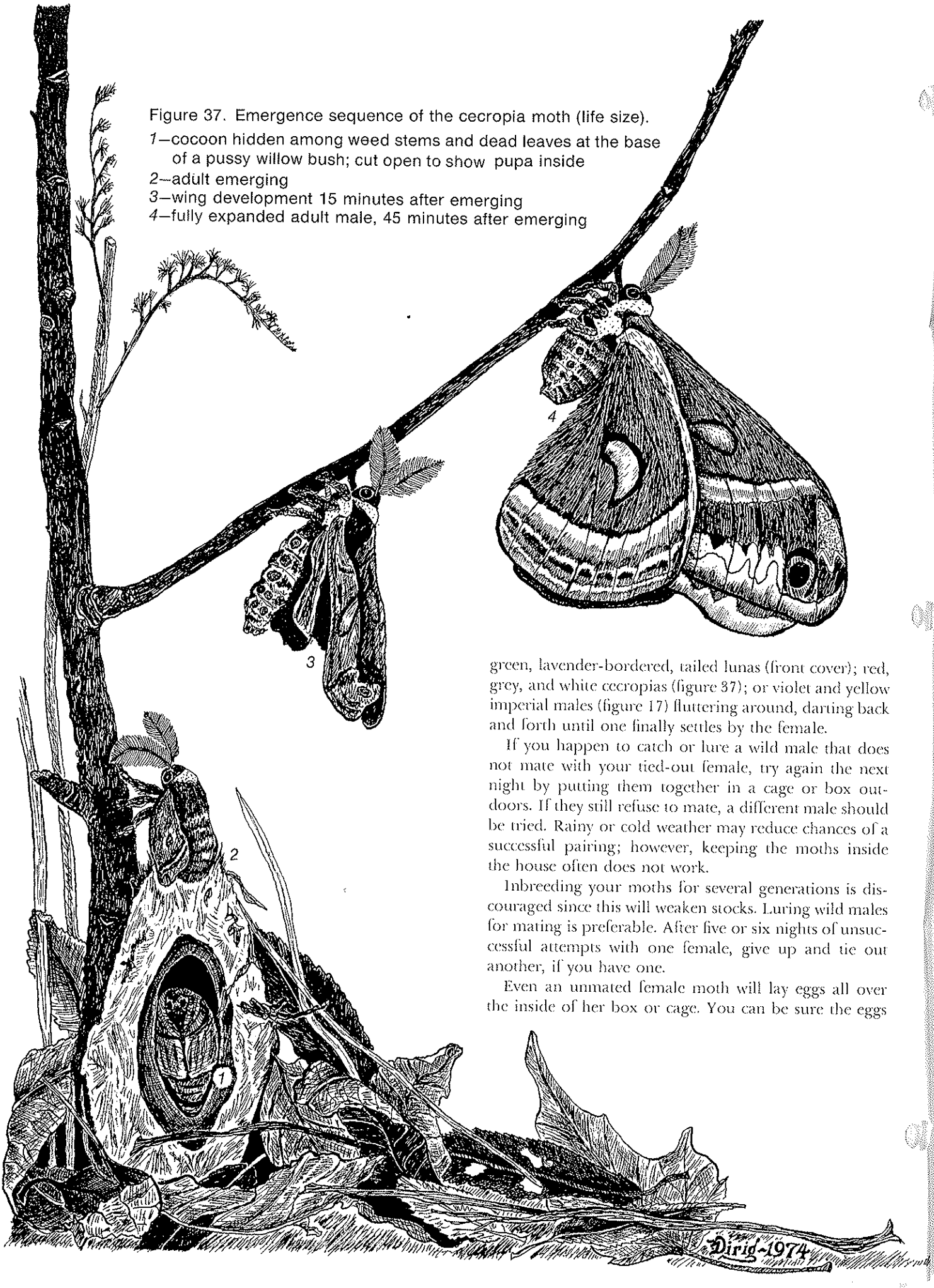


Figure 37. Emergence sequence of the cecropia moth (life size).
1—cocoon hidden among weed stems and dead leaves at the base of a pussy willow bush; cut open to show pupa inside
2—adult emerging
3—wing development 15 minutes after emerging
4—fully expanded adult male, 45 minutes after emerging

green, lavender-bordered, tailed lunas (front cover); red, grey, and white cecropias (figure 37); or violet and yellow imperial males (figure 17) fluttering around, darting back and forth until one finally settles by the female.

If you happen to catch or lure a wild male that does not mate with your tied-out female, try again the next night by putting them together in a cage or box outdoors. If they still refuse to mate, a different male should be tried. Rainy or cold weather may reduce chances of a successful pairing; however, keeping the moths inside the house often does not work.

Inbreeding your moths for several generations is discouraged since this will weaken stocks. Luring wild males for mating is preferable. After five or six nights of unsuccessful attempts with one female, give up and tie out another, if you have one.

Even an unmated female moth will lay eggs all over the inside of her box or cage. You can be sure the eggs

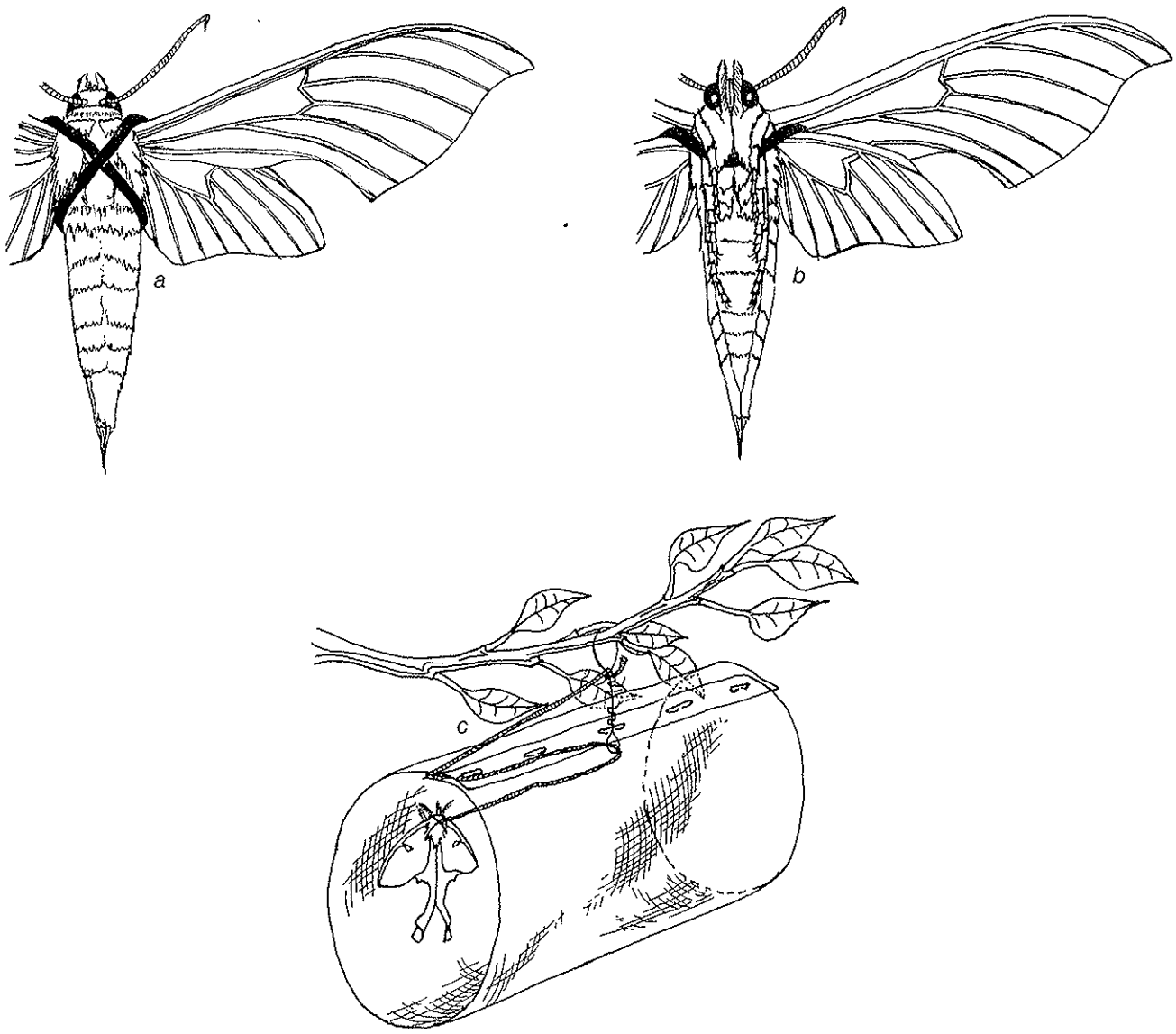


Figure 38. Ways to "tie out" a female moth.

a—yarn criss-crossed around thorax, tied beneath
b—yarn passed between forewings and hindwings and tied above or below
c—female secured in an open-ended screen cylinder. Males can enter, but birds are frightened by the screen

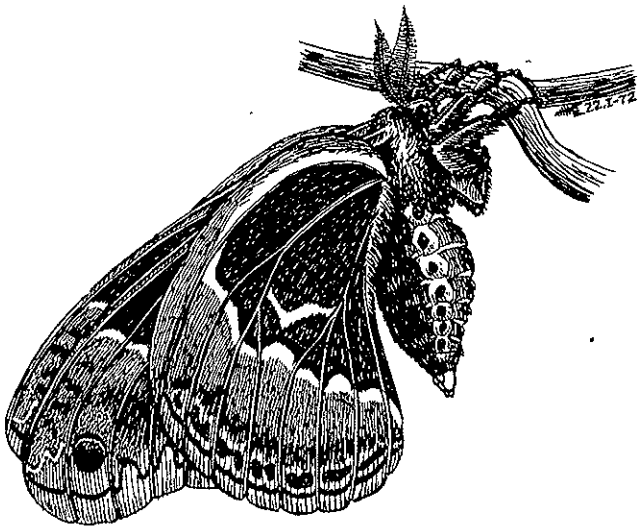


Figure 39. Female promethea "calling."

are fertile only if you have seen the male's and female's abdomens stuck together for at least half an hour, and sometimes up to 24 hours. Pairing adults should not be disturbed until they separate naturally.

The types of mating enclosures described work for most of the moths considered in this booklet. In general, large moths need roomier cages than small ones. Rosy maple moths, for example, will pair in a tiny cylindrical cage 4 inches in diameter and 6 inches high, but even one imperial adult would be very uncomfortable in such a small space.

Giant silkworms are probably easiest to pair in captivity. Regal and tiger moths and sphinxes are more difficult. It can be done with underwings, but is tricky. For the last four, it is easier to let Nature take care of this and then catch the wild female.

The following table provides helpful information on special requirements for different types of moths.

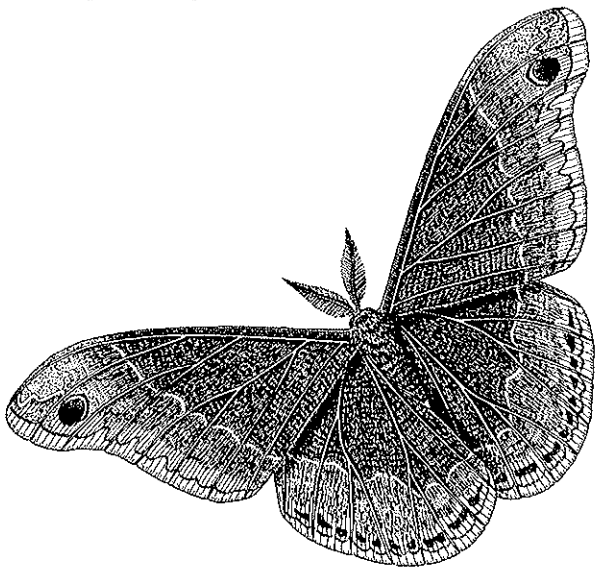


Figure 40. Male promethea approaching.

V. HINTS FOR GROWING SOME WELL-KNOWN NEW YORK MOTHS

(All times and dates are approximate. If the moth, its immature stages, or foodplant are illustrated in this booklet, figure numbers have been given to facilitate cross-referencing.)

Moth—Common and Latin names	Common N.Y. foodplants; Use of first is recommended	Egg color, Hatching time (days)	Larval period (days)	Pupa	Adult flight season(s) (N.Y.)	Overwinters as	Notes and special requirements
Tomato hornworm sphinx *Manduca* (or *Protoparce*) *quinquemaculata*	Tomato; possibly potato, eggplant, nightshade	Green 7	36	Bare (fig. 31)	June, Aug.	Pupa in ground	Odd, raised proboscis case on pupa
Waved sphinx *Ceratomia undulosa*	Ash; probably also lilac, privet, forsythia	Green 5-8	36-45+	Bare	June, Aug.	Pupa in ground	Very common moth; larvae found crawling on ground at pupation time
Four-horned sphinx *Ceratomia amyntor*	Elm, birch (fig. 43), basswood	Green 4-6	35-40+ (fig. 23)	Bare	June, Aug.	Pupa in ground	Larva rough, brown or green with 4 "horns" near head
Great ash sphinx *Sphinx chersis*	Ash; possibly also lilac, privet, forsythia	Green 6-7	29-40	Bare	June, July-Aug.	Pupa in ground	Larvae often found as they crawl down to pupate. Parasites shown in fig. 27
Modesta sphinx *Pachysphinx modesta* (fig. 7, female)	Aspen (fig. 7), cottonwood, willow	Greyish, then maroon 4-7 (fig. 7)	30-60 (fig. 7)	Bare (fig. 7)	June, Aug.	Pupa in ground	A common, huge moth. Easy to grow
Small-eyed sphinx *Paonias myops* (fig. 6a, male)	Cherry, birch (fig. 43)	Green 7-15	35	Bare	June, Aug.	Pupa in ground	Common, easy to grow
Twin-spot sphinx *Smerinthus jamaicensis* (or *S. geminatus*)	Cherry, birch (fig. 43), willow, poplar (fig. 7)	Green 7	25-35	Bare	June, Aug.	Pupa in ground	Usually common
Blind-eyed sphinx *Paonias excaecata*	Birch (fig. 43), willow, cherry	Green 4-10	35-45 (fig. 23)	Bare	June, Aug.	Pupa in ground	Usually abundant
Walnut sphinx *Cressonia juglandis*	Hickory, walnut, butternut, hop hornbeam, blue beech	Green 8	47-52	Bare (fig. 31)	June, Aug.	Pupa in ground	Abdominal end of pupa oddly flattened; female much lighter in color
Myron or hog sphinx *Darapsa myron*	Grape, Virginia creeper	Green 9	23-31	In loose cocoon	June, Aug.	Pupa at ground surface	Very unusual for a sphinx moth to make a cocoon. Larva variable; turns pink or lilac when ready to pupate
White-lined sphinx *Hyles* (or *Celerio*) *lineata*	Grape, dock, apple, purslane, etc.	Bright yellow-green 6	30-33	Bare, rarely in loose cocoon	June, Aug.	Pupa in ground	Larva very variable in color, sometimes spins a slight cocoon

Moth—Common and Latin names	Common N.Y. foodplants; Use of first is recommended	Egg color, Hatching time (days)	Larval period (days)	Pupa	Adult flight season(s) (N.Y.)	Overwinters as	Notes and special requirements
Cynthia *Samia* (or *Philosamia*) *cynthia*	Ailanthus; also cherry, ash, lilac, basswood, willow	Yellow-white 7-21	37-42+	In hanging cocoon on foodplant (fig. 31)	July	Pupa in stout cocoon	Introduced from Asia; now common in cities near Atlantic. Single brooded. Parasites shown in fig. 27
Cecropia *Hyalophora cecropia* (figs. 37, 41)	Cherry, willow, maple, elm, birch (fig. 43), beech, etc.	White-brown 10-15	35-60 (fig. 23)	In huge cocoon (figs. 30, 35, 41)	June	Pupa in cocoon on foodplant	Must chill pupae to get adults to emerge. Sleeve larvae—difficult to grow indoors. Parasites shown in fig. 27
Polyphemus *Antheraea* (or *Telea*) *polyphemus* (figs. 43, 47)	Elm, maple, birch (fig. 43,), oak, hickory	Beige with brown edge 7	48-50	In sealed cocoon (fig. 43)	June-mid-July	Pupa in cocoon—usually on or near ground	Common, easy to grow. Partially double-brooded
Promethea *Callosamia promethea* (fig. 40, male; figs. 18, 39, female)	Cherry, spicebush, sassafras, tuliptree, lilac, chokecherry	Pinkish-white 11-12	42-54 (figs. 26, 28)	In hanging cocoon (fig. 31)	June, Aug. (?)	Pupa in hanging cocoon	Find cocoons wild. Moths fly 4:00-7:00 p.m. Female and male very different. Partially double-brooded
Luna *Actias luna* (front cover, female)	Hickory, butternut, walnut, oak, birch (fig. 43), sweetgum, persimmon, beech	Pepper and salt 14-15	30-55	Flimsy cocoon (fig. 31)	June	Pupa in cocoon, on ground	Easy to grow. Larva turns rusty before spinning. Double-brooded in captivity
Io *Automeris io* (fig. 6b, male; fig. 46, female)	Cherry, willow, shadbush, corn	White with black dot, bunches 10+	40-57 (fig. 48)	Flimsy cocoon (fig. 31)	June-early July	Pupa in cocoon on ground	Larva with *stinging spines*. Black dot on top of eggs only if fertilized. Female (pink) and male (yellow) very different
Rosy maple *Dryocampa rubicunda* (fig. 6e, male)	All maples	Yellow, bunches 10-13	28-37 (fig. 23)	Bare (fig. 31)	June-Aug.	Pupa in ground	Female much paler. Adults emerge from pupae in 2-3 weeks. Very common, easy to grow
Royal walnut *Citheronia regalis* (fig. 4, male)	Staghorn sumac, walnut, hickory, ash, sweetgum	Yellow, huge 9-14	37-42 (fig. 23)	Huge, bare, shiny, black, (fig. 31)	July	Pupa in ground	Rare in N.Y. Larvae spectacular. Pupae have pungent smell
Imperial *Eacles imperialis* (fig. 17)	Spruces, pines (wild or cultivated); sassafras, sweetgum	Huge, yellow 13	42-57 (fig. 24)	Huge, rough, bare, black (fig. 29)	July	Pupa in ground	Not common in N.Y. Female and male differ in markings. Grow best on conifers. Larva brown or green
Acraea tiger *Estigmene acraea*	Plantain, probably dandelion	Masses, yellow 5-7	over winter	In loose cocoon of hair and silk	June, Aug.	Nearly full-grown caterpillar	Difficult to overwinter larvae

Moth--Common and Latin names	Common N.Y. foodplants; Use of first is recommended	Egg color, Hatching time (days)	Larval period (days)	Pupa	Adult flight season(s) (N.Y.)	Overwinters as	Notes and special requirements
Isabella tiger *Isia isabella*	Plantain, dandelion	Yellow 7-10	Aug.-May (fig. 23)	In loose cocoon of hair and silk	June-July	Nearly full-grown caterpillar	Difficult to grow from egg to adult
Garden tiger or caja *Arctia caja* (fig. 10, male)	Dandelion	White, mass 7	56 or Aug.-July	In loose cocoon of hair and silk (fig. 31)	Aug.	Half-grown larva	Larvae kept in house at 70°F. may pupate. A rare and beautiful moth
Virgo tiger *Apantesis virgo* (fig. 6c, male)	Dandelion, plantain	Yellow-white loose 7	50 or Aug.-July	Bare with white powder on surface	July-Aug.	Partly-grown larva	Larvae will pupate if kept indoors at 70°F.
White underwing *Catocala relicta* (white and black hindwings) (fig. 13)	Willow, poplar (fig. 7), white birch (fig. 43)	Brownish-grey, over winter	May-July (fig. 23)	Flimsy cocoon	Aug.-Sept.	Unhatched egg	Female with darker forewings. Overwinter eggs in refrigerator. Larva cannibalistic
Sleepy underwing *Catocala concumbens* (rose pink and black hindwings) (fig. 6d, male)	Willow, poplar (fig. 7)	Brownish-grey, over winter	May-July	Flimsy cocoon	Aug.-Sept.	Egg	Keep larvae separate--cannibalistic. Eggs in refrigerator over winter
Yellow-banded underwing *Catocala cerogama* (yellow and black hindwings)	Basswood	Brownish-grey, over winter	May-July	Flimsy cocoon	Aug.-Sept.	Egg	Larva cannibalistic. Keep ova in refrigerator, Sept.-May
Other underwings-- *Catocala* spp.	Oak, hawthorn, blueberry, hickory, walnut, willow, poplar (fig. 7), cottonwood, honey locust, black locust	Brownish-grey, over winter	May-July	Flimsy cocoon (fig. 31)	Aug.-Sept.	Egg	Life history work needed. Several incompletely known. Keep careful records, preserve each stage, record foodplant

VI. EXHIBIT AND PROJECT SUGGESTIONS

Minimum requirements for completion of this part of the Entomology Project are that you:

1. Rear at least four species of New York moths from egg to adult
2. Keep time data and records as outlined below
3. Preserve all four stages of each moth grown in a Riker mount
4. Grow moths belonging to at least two of the five groups shown in figure 6, page 5

You need not limit yourself to the above, however. Once started, it is difficult to stop. The life history of each species is like an unsolved mystery until you have grown the moth.

Exhibits of the Moth Life Cycle

Probably the easiest and most useful display of this type is made by saving a few eggs, a larva, a cocoon or pupa, female and male adults, and a few pressed leaves of the foodplant, all labelled, in a Riker mount[3] (figure 41). This is a shallow, glass-topped, cotton-filled cardboard box that is often used for displaying adult Lepidoptera, but is also ideal for housing a life-cycle exhibit.

Preserve the eggs by putting them in 70% (rubbing) alcohol overnight, or use the shells of hatched eggs. Drop a mature larva in boiling water, leave about half a minute, and then transfer to a small vial[3] of 70% (rubbing) alcohol. (If a living caterpillar is dropped directly into the alcohol, it will usually turn black and look unsightly. Dropping into hot water first prevents this.) A cocoon or pupa case from which the moth has emerged works fine—it is unnecessary to kill a pupa. Adults should be pinned using the standard method, but remove the insect pin through the thorax *immediately* after setting the

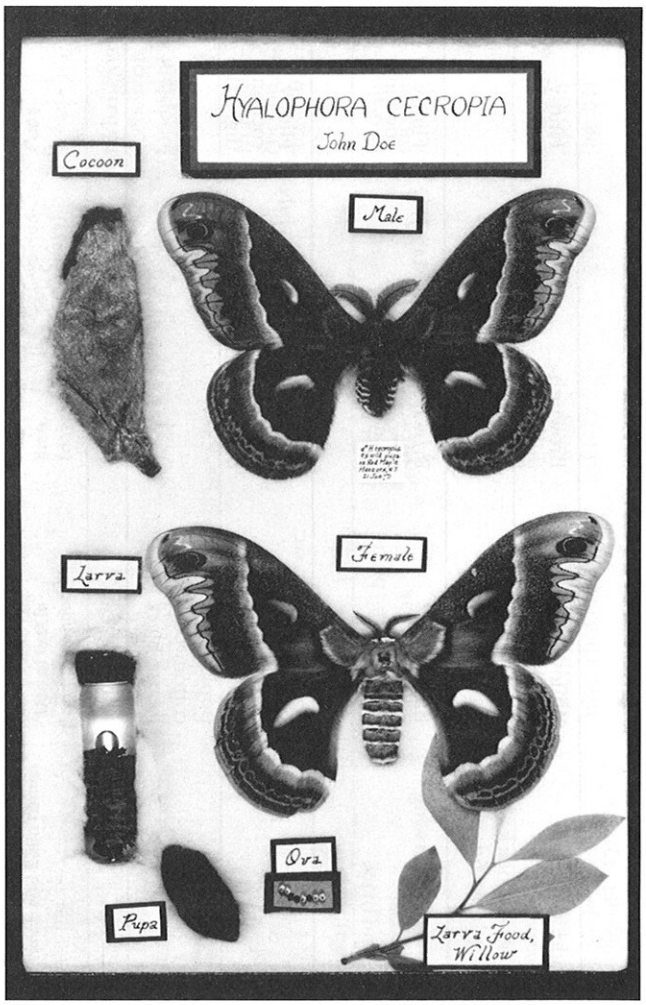


Figure 41. Cecropia Riker mount, front.

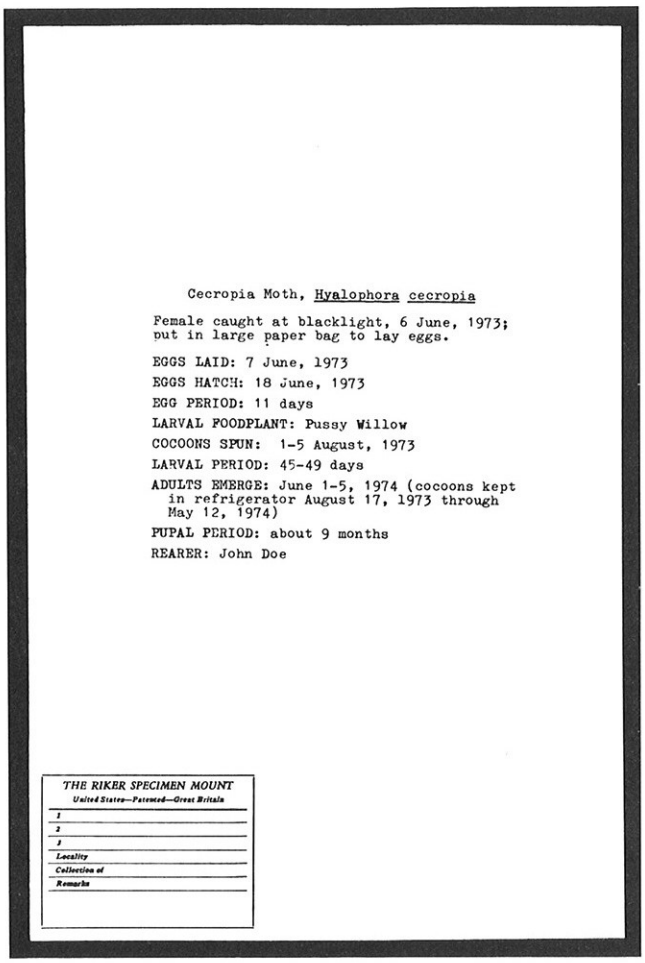


Figure 42. Cecropia Riker mount, back, with data sample.

[3]See page 38 for the addresses of companies that sell Riker mounts and vials.

wings, since a Riker mount is too shallow to accommodate it, and you will have difficulty removing it after the moth has dried. Time and locality data should either be written on the back of the mount or typed on a small piece of paper and glued to the back. Include where and when the female moth was caught; dates ova were laid and hatched, larvae made cocoons, and adults emerged; plus brief notes on rearing procedures, parasites, or other interesting observations. An example of a properly prepared record is shown in figure 42. This information should be written down as it happens—don't trust your memory. Preserving a life cycle in this way provides a display or teaching aid and something of scientific value.

More elaborate, museum-quality exhibits may be put together in a glass-topped case, recreating the moth's natural habitat by pinning or gluing dried plants or other constituents to a styrofoam pinning base. When well done, this kind of exhibit is beautiful to look at and ecologically accurate. Figure 43 shows such a display prepared by a New York State 4-H member.

For a fair, school science classroom, museum, or nature center, displays of *living* moths in various stages are unusual enough to attract much attention. A "moth corner" or even an outdoor, screened, "moth house" can be very effective during the June and August emergence seasons. Permanent displays of preserved ova or cocoons/pupae of different types of moths will enhance such an area. Close-up photographs of caterpillars can be used to create a striking bulletin board or wall exhibit. A few nature centers maintain exhibits of living larvae feeding on their foodplants in small fish tanks set into a plywood wall panel lighted from behind, with explanatory material alongside. Such live exhibits prove real highlights wherever used and are not too difficult to

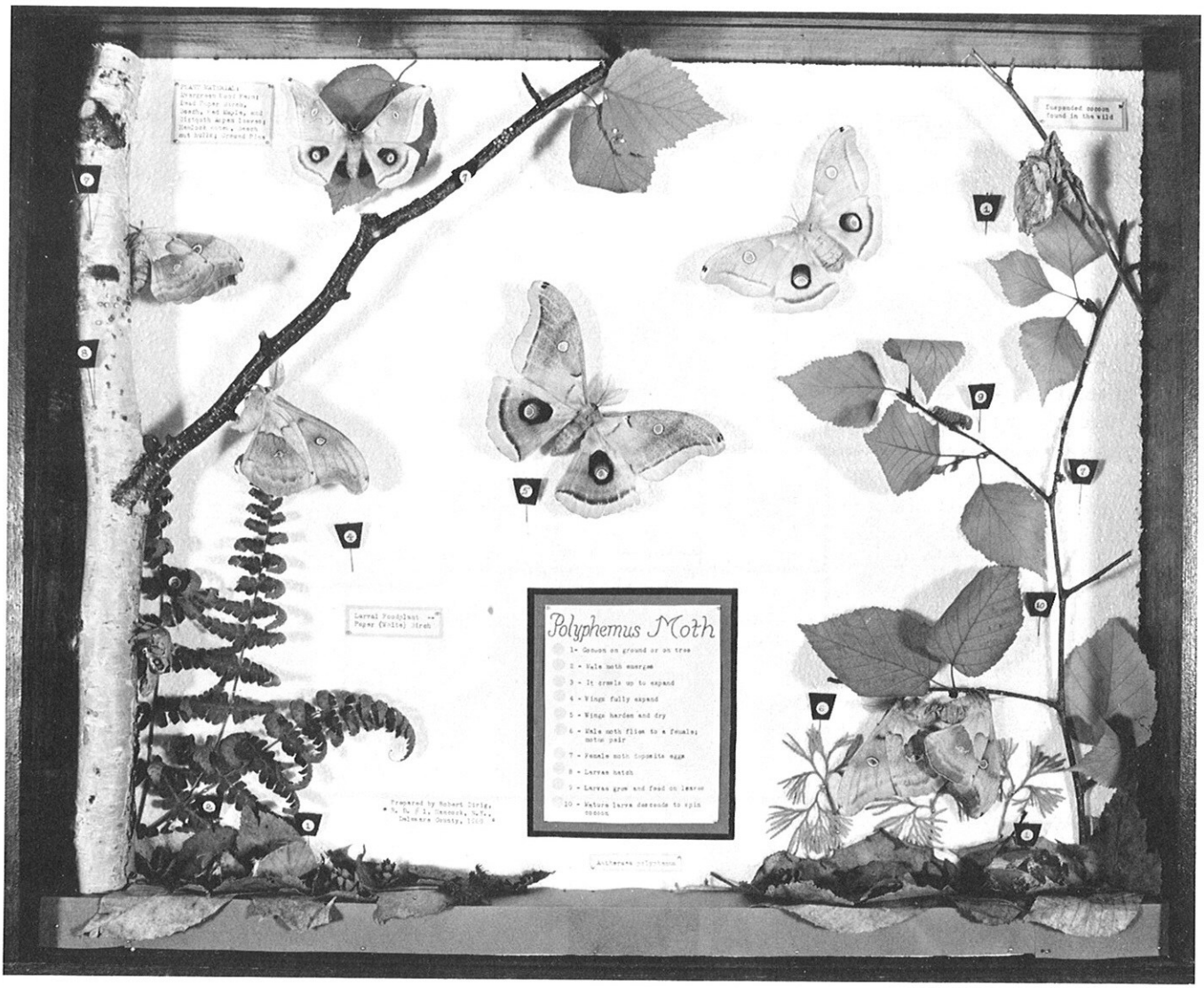


Figure 43. Polyphemus life-cycle case.

set up and maintain for someone with the necessary know-how.

Exhibits Using Adult Moths

Exhibits of mounted adult moths you grow or attract with a blacklight and baits are fun to prepare and interesting to look at. Collections of a single moth family or group, such as silkworms, sphinxes, or tiger moths, are sometimes put together (figure 44). Displays of underwings are very interesting, especially if one is mounted on a piece of bark with its wings closed so no bright color shows, to demonstrate their protective coloration (see figure 13). Collections of some of the smaller moths not considered in this publication can be interesting and beautiful (figure 45).

Collections of moth parasites (figure 27) are fascinating to make and study as well as scientifically valuable. A case of several well-camouflaged moths arranged on natural backgrounds, such as the female io shown in figure 46, is eye-opening for many who see it at a fair, school, or museum. The possibilities for exhibits using moths are limited only by your imagination. The few photographs of 4-H members' exhibits shown in this booklet may give you further ideas.

Some places to exhibit moth collections and displays have been mentioned in the preceding few paragraphs. In addition, local librarians, store or bank window managers, hobby show directors, and elementary, junior high or high school teachers are on the lookout for interesting educational displays. Properly prepared collections shown at 4-H club meetings encourage beginners or awaken interest in other members. Through exhibiting your collection at county and state fairs, the general public will be able to see these beautiful insects; and cash prizes may be won, which can help finance your project. Some 4-H members with extensive moth collections set up mini-museums in a room or hall of their homes, so friends, relatives, visitors, and the family can enjoy their beauty every day.

Experiments and Special Projects Using Moths

Many special project or experiment possibilities present themselves:

1. Using foodplants listed in Section V and in some of the books mentioned later in this section, see if larval, pupal, and adult sizes vary with different plants fed to the

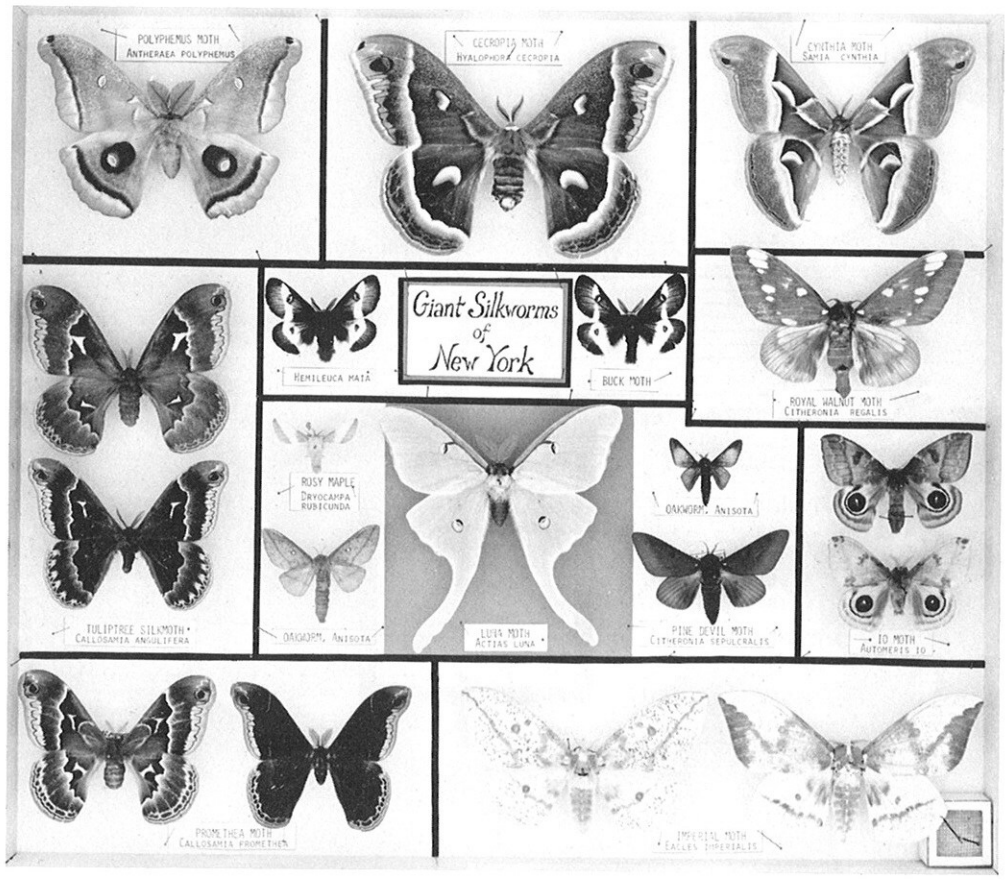


Figure 44. Exhibit of New York giant silkworm moths.

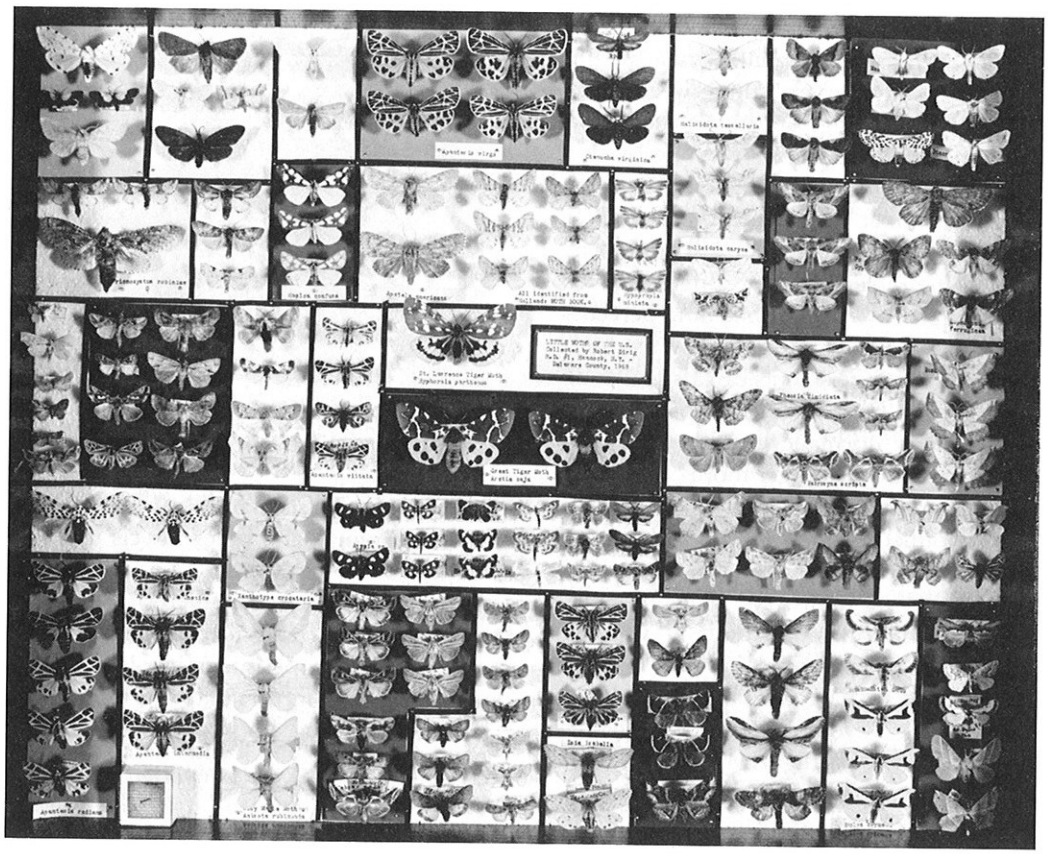


Figure 45. Exhibit of small moths.

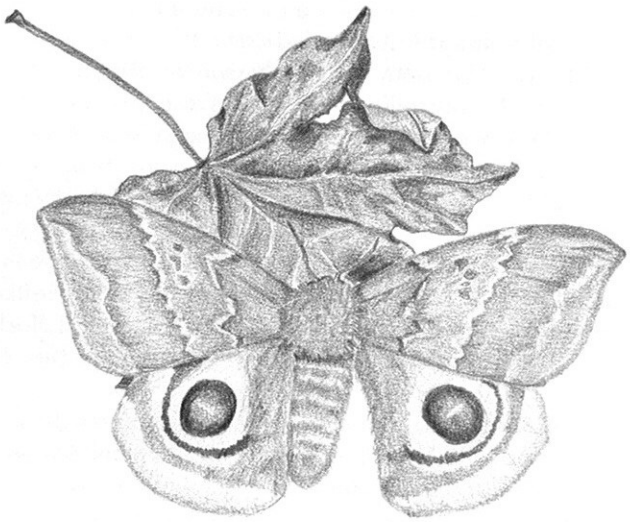


Figure 46. Female io moth on leaf, showing camouflage.

caterpillars; or if larvae refuse to eat certain listed plants. Record results.

2. Moths classed as "general feeders" (those with very wide foodplant ranges), such as io, imperial, white-lined sphinx, and caja tiger, might be fed all recorded foodplants and as many others as you have available, to see just what plants are acceptable. Keep written records.

3. Will larvae of a moth that is very *restricted* in foodplant choice, such as the myron sphinx's which feed only on grape and Virginia creeper leaves, eat "foreign" foliage if it is dipped in a watery mixture made from the leaves of its normal foodplants? To find out, shred a large number of grape or Virginia creeper leaves and put them in an electric blender with a very little water. A soupy mixture should result. Dip some "foreign" leaves (apple or dogwood, for example) in this fluid and offer them to the caterpillars. What happens?

4. Records of the seasonality or flight seasons of moths in your area are always scientifically valuable.

5. You may want to try crossing some closely-related moths, such as the eastern cecropia with one of its western relatives, Glover's or ceanothus silk moths. Resulting hybrids, with intermediate characters, are very interesting. A cross of io × luna or cynthia × polyphemus would be difficult to obtain, and would almost surely produce infertile eggs, but with very close relatives, at least one generation may survive. This type of study makes a good science fair project.

6. Experiment with new plants (closely related to listed foodplants) to see if caterpillars will eat them. In this way, you may be the first to record acceptance of a new foodplant in captivity. Try lilac, forsythia, and privet with caterpillars that normally eat ash, for example.

7. Determine the effects of cold on egg hatching. Keep batches of 25 newly-laid eggs from one female in the refrigerator for one week, two weeks, three weeks, and four weeks. Leave another 25 eggs out in the room as a control, and another 25 in the freezer for one or two weeks. Record the temperature inside the refrigerator and freezer and in the room at a certain time each day. It is hypothesized that the eggs in the freezer will not hatch; and that those left in the refrigerator for longer periods (3-4 weeks) will have a greatly reduced hatching percentage upon removal relative to unchilled eggs. Why don't you find out? Temperature experiments can also be done with larvae to test growth rate or on the initiation or breaking of pupal *diapause* (dormancy).

8. Experiment with underwings, tiger moths, and other groups not often bred in captivity, using the basic framework outlined in this bulletin, to try to find convenient, successful methods. Methodology in moth rearing is constantly being adapted or improved, often by amateurs. There is much you can contribute, if you are willing to experiment and keep careful records.

9. It is always exciting to have an unusual freak or variation emerge from one of your cocoons. Imagine my surprise when this *gynandromorph* (figure 47), partly male and partly female, as is apparant from the antennae, emerged from a polyphemus cocoon I had raised. Rarely, a moth with blurred or doubled eyespots or with markings lacking or out of place will show up.

10. Tag or in some other way mark several male giant silkworms and release them downwind, 1, 2, 3, 4, and 5 miles from tied-out females of the same kind. Record which males were released at which distance from the females (perhaps number or color code them). Watch to see if any released males are attracted; if so, from how far away?

11. Reports on all ten of the above experiments or activities (and similar ones you think of yourself) are worthy of publication as a scientific paper or note. Such information is valuable and sought by organizations such as the Lepidoptera Research Foundation, the Lepidopterists' Society, and the Teen International Entomology Group for their publications. Your science or biology teacher can help you prepare a paper and offer advice on submitting it to the Lepidopterists' Society *Journal* (c/o T.D. Sargent, Editor, Dept. of Zoology, Univ. of Mass., Amherst, MA 01002); *The Journal of Research on the Lepidoptera* (1160 W. Orange Grove Ave., Arcadia, CA 91006); or the *TIEG Newsletter* (315 Plant Science, Cornell University, Ithaca, NY 14853). Activities (1) through (7) might become International Science and Engineering Fair (ISEF) entries or special credit projects for a school science course (again, your teacher can help). Perhaps this small exposure to elementary science research will give you an appetite for this type of thing resulting in your following an entomological or biological science curriculum in college. Many great naturalists, biologists,

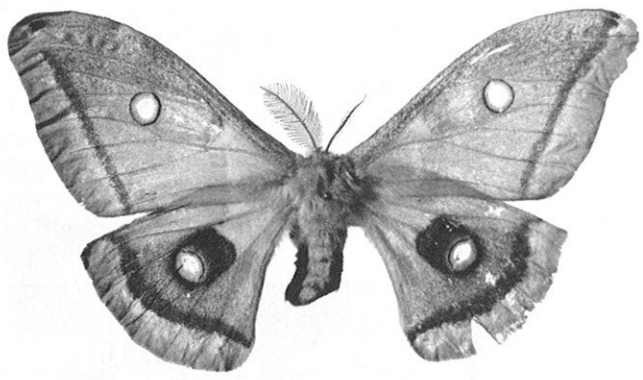


Figure 47. Polyphemus gynandromorph.

and lepidopterists started out this way by growing and studying moths and other insects that turned up in their backyards.

If you become really interested in this type of research perhaps your science teacher can help you design a more sophisticated experiment involving moth hormones or environmental factors that affect development. Reference to the following book or articles may give you some ideas:

Farb, Peter
1962. *The Insects*. N.Y.: Time, Inc., pages 66-69.

Truman, J. W.
1970. The eclosion hormone: Its release by the brain and its action on the central nervous system of silkmoths. *American Zoologist* 10:511-512.
1971. The hour-glass behavior of the circadian clock controlling eclosion of the silkmoth *Antheraea pernyi*. *National Academy of Science, Proceedings* 68:595-599.
1971. Physiology of insect ecdysis. I. The eclosion behavior of saturniid moths and its hormonal release. *Journal of Experimental Biology* 54:805-814.
1972. Physiology of insect rhythms. II. The silkmoth brain as the location of the biological clock controlling eclosion. *Journal of Comparative Physiology* 81:99-114.
1973. How moths "turn on": A study of the action of hormones on the nervous system. *American Scientist* 61:700-706.
1973. Physiology of insect ecdysis. II. The assay and occurrence of the eclosion hormone in the Chinese oak silkmoth, *Antheraea pernyi*. *Biology Bulletin* 144:200-211.

Truman, J. W., and Riddiford, L. M.
1970. Neuroendocrine control of ecdysis in silkmoths. *Science* 167:1624-1626.

Truman, J. W., and Sokolove, P. G.
1972. Silkmoth eclosion: Hormonal triggering of a centrally programmed pattern of behavior. *Science* 175:1491-1493.

You ought also to relate this 4-H project to others. Taking "Know Your Trees" and "Know Your Weeds" will help you learn to recognize moth larval foodplants. Through the "Woodworking" project you can learn to make your own display cases. Moths are good photographic subjects and may also be used in some crafts or for making room decorations. As part of ornamental horticulture, plant trees or shrubs that will help you with moth-feeding—weeping willow, boxelder maple, Chinese elm, paper birch, and flowering crabapple are handy to have. Several projects can be related to this one.

Other 4-H entomology leaflets presently or soon to be available from Cornell University will help you, including those on pinning Lepidoptera; making a display case, killing jar, and aerial net; scientific names; photographing insects, and raising butterflies. In addition, the following books will help you.

Helpful References

Books on moths in general—good for identification of common species, and offering brief information on rearing:

Butterflies and Moths, R. T. Mitchell and H. S. Zim. A Golden Nature Guide, Golden Press, N.Y., 1964, 160 pp. Available in most bookstores. Excellent for beginners, the first book to buy. Color pictures of some common species, geographic range, foodplants, brief life history information, some larvae and pupae pictured. About $1.50.

The Moth Book, W. J. Holland. A 1968 Dover paperbound reprint, showing nearly 1500 well-known N.A. moths in color; over 500 pp. Range, foodplant information; some larvae and pupae pictured. Strongly recommended. Available through Dover Publications, Inc., 180 Varick St., N.Y., N.Y. 10014. $5.00.

Books specifically concerned with rearing moths:

There are very few of these, and unfortunately, most are no longer in print, but may be available in some good public or university libraries, can be found for you by out of print book companies, or perhaps borrowed from someone lucky enough to own a copy. Much of the material given in these books is similar to that presented in this booklet. These books are all highly recommended with hopes that you will be lucky enough to run across one or more of them.

Caterpillars and Their Moths, I. M. Eliot and C. G. Soule. Out of print, published in 1902, 302 pp. Excellent descriptions and black and white photographs of many common moths, plus rearing directions, notes on finding stages wild, and a description of their fascinating "Crawlery" (caterpillar-keeping room).

Moths of the Limberlost, G. Stratton Porter. Out of print, published in 1912, 370 pp. Beautiful book, superbly illustrated with black and white photographs and watercolor paintings; about growing well-known moths of northern Indiana, many of which also occur in N.Y. About $10-20 from out-of-print book companies.

Moths of the Woodside, C. Seeley. Out of print, published in 1963. 40-page booklet with photographs and drawings; an excellent introduction to growing moths and making a moth collection.

Moths and How to Rear Them, Paul Villiard. Just recently out of print, published in 1969, 242 pp. This book has an excellent introduction on rearing methods and much helpful information on individual moths, including many black and white photographs. Species considered are worldwide, however, not just North American. A basically sound book with a few factual errors in the text. Some bookstores may have unsold copies at about $10.00; should be in many libraries.

Wild Silk Moths of the United States, M. M. Collins and R. D. Weast. 1961, 138 pp. An interesting, useful book on well-known giant silkworms, with notes on rearing, parasites, diseases, hybrids, studies, and so on. Available for $4.25 from Merle Collins Foundation, 13601 Preston Road, Suite 509W, Dallas, Texas 75240.

Collecting Cocoons, L. J. Hussey and C. Pessino. 1953, 73 pp. Very good simplified material for beginners on moths, their life cycle, and finding and hatching cocoons. Interesting pictures. Should be available in many libraries, perhaps in children's sections. Still available for $3.50 from Thomas Y. Crowell Co., Inc., 666 Fifth Ave., N.Y. 10019.

A Silkmoth Rearer's Handbook, W.J.B. Crotch. 1969 reprint of 1956 edition, 165 pp. A British paperbound book about growing giant silkworms of the world. The introductory chapters on rearing methods apply generally, and are of interest, as is the information on American species included. Available for $7.00 from Entomological Reprint Specialists, P.O. Box 77971, Dockweiler Station, Los Angeles, California 90007.

Insects As Pets, Paul Villiard. 1973, 143 pp. This new book has a chapter about growing moths and butterflies, which is useful as far as it goes. Available for about $5.00 from Doubleday and Company, Inc., 501 Franklin Ave., Garden City, N.Y. 11530.

[Many books concerned with moth identification, or with moths in general, will have notes on rearing in their introductory chapters, but this information is rarely sufficiently detailed to be of much practical use to the rearer.]

Books to help you identify moth larval foodplants:

Know Your Trees, J. A. Cope and F. E. Winch. The 4-H *Know Your Trees* project manual, specific for New York tree species. Excellent, available from your local 4-H Office, or from the Mailing Room, Bldg. 7, Research Park, Cornell University, Ithaca, N.Y., 14853, for 50¢. (Catalog No. J 85).

Field Book of American Trees and Shrubs, F. S. Mathews. Available from G. P. Putnam's Sons, 200 Madison Ave., N.Y., N.Y. 10016, for about $6.00. Excellent illustra-

tions, descriptions, range maps. This and similar books are available in many libraries.

Field Book of American Wild Flowers, F. S. Mathews. Available from the same place as above listing, at the same price. Good for identifying the weeds or herbaceous plants which some moth caterpillars eat.

Probably the best way to find out how to grow moths is to talk to people who have done it already and watch them to learn their methods. You will soon contact fellow moth-rearers and can share experiences. Joining TIEG or the Lepidopterists' Society (addresses on page 36) will help you make these contacts. Many teenage entomologists interested in moths live in New York State.

In addition, several dealers who sell living cocoons, eggs, larvae, or adult moths to collectors and rearers live in the United States. You may want to send a self-addressed, stamped envelope to the following people for price lists of available species:

Mr. Max Richter, Butterfly Farm & Museum, E. Durham, N.Y. 12423.

Michael A. Zappalorti, The Insect Farm, 123 Androvette Street, Staten Island, N.Y., 10309.

Butterfly Breeding Farm, 389 Rock Beach Road, Rochester, N.Y. 14167

Duke Downey, Box 558, Sheridan, Wyoming 82801.

Some of these people can also supply you with Riker mounts and other collecting materials, as can:

The American Biological Supply Co., 1330 Dillon Heights Ave., Baltimore, Maryland 21228;

WARD'S Natural Science Establishment, Inc., P.O. Box 1712, Rochester, N.Y. 14603.

VII. SUGGESTIONS FOR TEACHING ABOUT MOTHS

The 4-H member, leader, junior or project leader, or parent reading this section will find it of help in preparing public presentations or lessons for a club. School teachers, museum workers, teacher-naturalists, scout leaders, or members of the general public who use this booklet may also find these suggestions applicable.

Adult moths, especially giant silkworms and regal moths, never fail to attract attention and comment, because of their large size and great beauty. When available, these are good attention-getters to use during your presentation. It is preferable to use *living* moths and other stages whenever possible. Displays of dead specimens may be substituted, but in general, audiences respond better to living, moving examples. Displays will help as accessories, though, especially those in Riker mounts that can be passed around or handled by children.

A very practical consideration a teacher or 4-H member may advance is that most of the huge, spectacular moths fly only in June and July, and therefore are not available as adults during the school year or winter 4-H teaching/presentation season. This can be remedied by removing a few hibernating cocoons or pupae from the refrigerator five or six weeks before the adults are needed, and forcing the moths to emerge in a warm room. If the moths appear earlier than needed, put them in a plastic box in the refrigerator. This will cause sluggishness, prevent battering, and keep them alive for about a month. The moths will revive when brought out into a warm room, and can be shown to an audience as needed, and kept in the refrigerator at other times.

It is always wise when beginning a moth lesson to carefully define what you plan to do or cover. Start with basics and build from this foundation. Be sure your audience knows what a moth is (insect, Lepidoptera, and so on), for example. Take one small facet at a time and do it well. An entire session for beginners might be spent just looking at moths (pages 3, 4) letting students find out for themselves how many eyes, antennae, legs, wings, and other parts they have. Succeeding lessons on the moth life cycle, or even on each stage, would be appropriate. A lesson might be taught on how moths hibernate (page 6), or kinds of common moths (page 5), and so on. Having each member of a class or group cut open and examine an old cocoon can be extremely exciting, especially if some contain dried-up pupae, dead larvae, or parasites. An outdoor field trip to search for wild cocoons in winter sounds good in theory, but its success would depend on how abundant they are in your particular area. Trips in many areas will end in disappointment.

Actually growing a moth through all four stages is very interesting for a whole class or club to pursue but is practical only in late spring, summer, and very early fall. The banded "woolly bear" caterpillars (figure 23) children find in autumn are fine for temporary study, relating well to lessons on the life cycle, hibernation, or larval stage; but it is nearly impossible for the average person to successfully overwinter them, and since they will die if kept indoors for very long, they should be released after their utility as lesson material is over. In late March, ova of some species may be available, but there is rarely time to finish a whole cycle, and this leaves the students hanging. For this reason, I recommend growing either the cabbage or clouded sulphur *butterfly*[4] in the classroom to demonstrate the life pattern of Lepidoptera, since the stages are the same, metamorphosis is over within 30 days, foodplants are readily available, and wild females are abundant throughout September and October and in April and May in New York—in plenty of time to finish before the school term ends.

The hatching of moths from cocoons can be fascinating for a class or group to watch. It is sometimes possible

[4]See *Growing Butterflies,* the sequel to this publication, for directions.

to obtain pairings from hatched moths as early as April, but be sure that leaves of an appropriate foodplant have developed before the little caterpillars appear—very few readily available moths will eat evergreens.

The widespread prejudice towards moth caterpillars is largely due to their formidable, spiny appearance. This is almost always a sham; but the "dangerous" guise of a very few kinds should be respected. Among the moths considered in this booklet, only two have larvae with stinging tubercles. The branched spines of the beautiful io moth caterpillar (figure 48) and buck moth larva are severely urticating. These species should be carefully handled to avoid a painful rash or irritating itching sensation. Other New York moths with urticating caterpillars are the saddleback caterpillar moth, spiny oak-slug, hag moth, and skiff moth. The larvae of these species are brightly marked or oddly shaped, but the adults are small and drab, and probably would not often be encountered. The hairs of "furry" tussock moth caterpillars are irritating to some people. Thoroughly washing your hands after handling potentially irritating caterpillars may reduce chances of a rash developing.

The 28-minute color film *Youth Can Teach—A demonstration in 4-H Entomology* shows how to grow moths and preserve a life-cycle display. This may be borrowed from the Film Library, 31 Roberts Hall, Cornell University, Ithaca, N.Y. 14853, for a small charge.

Blacklighting or sugaring (pages 7-10) in the school yard or during a class or club camp out can be very exciting. One 4-H club that I know of holds regular blacklight parties each summer, having a lot of fun combining Entomology and Outdoor Cookery project sessions.

These are very brief and basic suggestions. Put your own imagination and creativity to work from here.

Finally, one of the greatest things any teacher can do is instill a love of Nature in the young people with whom he or she has contact. Help your group appreciate the beauty of moths and their life pattern. Share with them the thrill of holding a big, colorful beauty on one's fingertips. Try to overcome common prejudices about

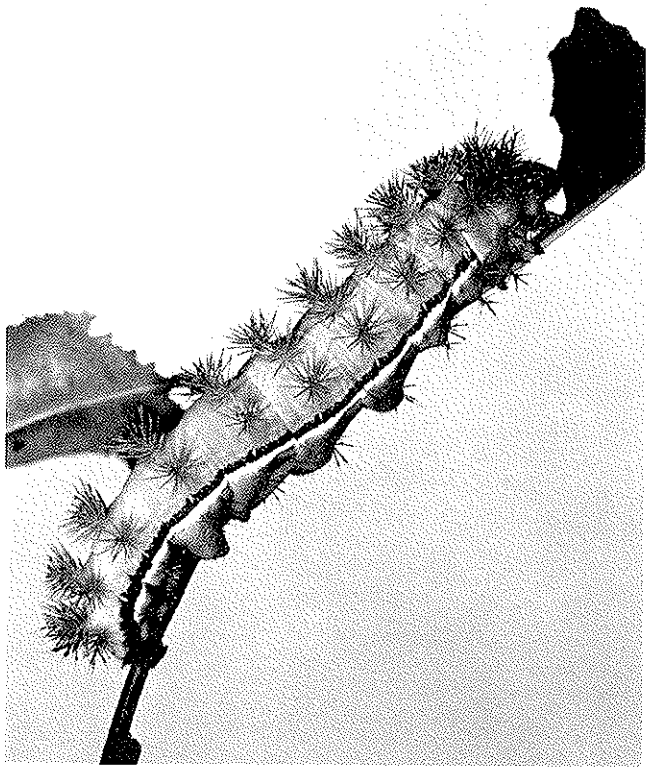


Figure 48. Io larva (urticating spines).

"worms" by stressing the useful function of caterpillars as natural pruners and foods for other animals, and their beauty. Allow the killing of only *perfect* (fresh and unblemished) wild or reared specimens. Saving a *few* specimens for a collection or display is permissible, but mass slaughters should be discouraged.

Stress the study and observation of *living* moths. Tell your group that they won't just happen upon a moth life cycle. It will take a deliberate setting out to see and learn; and it will take work, patience, and perseverance. But the challenge, excitement, and ultimate rewards and satisfaction that come with personal discovery will be far beyond any estimation.

Metric system equivalents for common English system units used in this booklet:

1 inch (in.) = 2.54 centimeters (cm)
1 foot (ft.) = 0.3 meters (m)
1 mile (mi.) = 1.6 kilometers (km)
1 liquid ounce (oz.) = 29.6 milliliters (ml)
1 cup (cu.) = 0.24 liter (l)
32 degrees F. = 0 degrees C.
122 degrees F. = 50 degrees C.
212 degrees F. = 100 degrees C.

The quarter (a metal coin) mentioned on page 24 weighs approximately 5.7 grams (g).

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