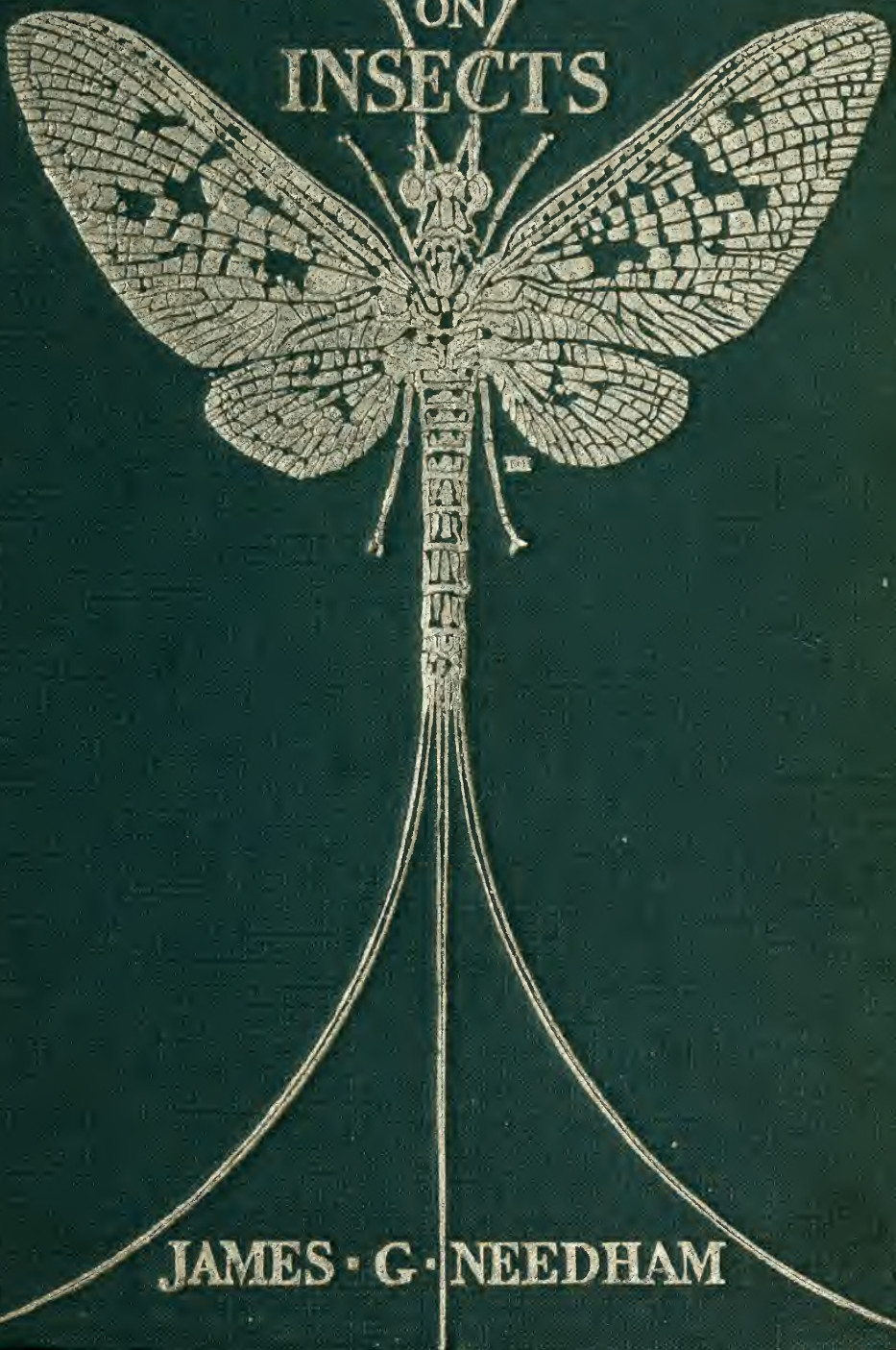
ELEMENTARY LESSONS ON INSECTS



JAMES · G · NEEDHAM

ELEMENTARY LESSONS ON INSECTS

BY JAMES G. NEEDHAM

ELEMENTARY LESSONS ON INSECTS

A HANDBOOK OF THE DRAGONFLIES OF NORTH AMERICA

LEAF-MINING INSECTS
(NEEDHAM, FROST AND TOTHILL)

NATURAL HISTORY OF THE FARM

LIFE OF INLAND WATERS
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ELEMENTARY LESSONS IN ZOOLOGY

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GUIDE TO THE STUDY OF FRESH WATER BIOLOGY

ELEMENTARY LESSONS ON INSECTS

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PREFACE

This book presents an outline for a brief introductory course in entomology. It embodies a new selection of materials for elementary instruction, and some new plans for their use; but its aim is the same as that of its worthy predecessors by other authors—sound knowledge of the essentials of insect structure and development and habits. These are things worth knowing. These are the things that must underlie all intelligent efforts at insect control.

In making a small book for beginning scientific study of this vast group of animals much desirable material has had to be omitted. A serious effort has been made to retain and include the things most essential to sound knowledge, most necessary to the public welfare, and most fit to be a part of the common intelligence.

It is recommended that the teacher suit the order of these lessons to the materials available, keeping them always full of practical contacts with things, avoiding abstractions and rote. The bane of our schools is bookishness. Pupils learn to memorize and to imitate, rather than to see and think for themselves. Let us have a practical course on insects and let us make it worth while. Real knowledge in any subject is based on first-hand contact with the sources of its materials.

Ithaca, September 1, 1928.

James G. Needham

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PART I

INTRODUCTORY

I

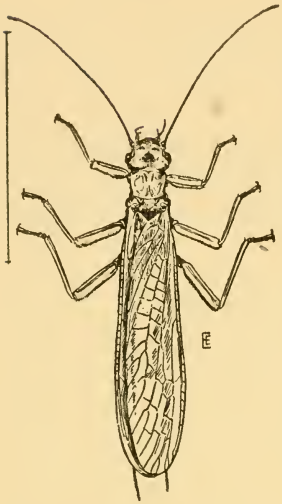
WHAT AN INSECT IS LIKE

Outside

Let us begin our study by inquiring how an insect is built. How it lives will be better understood when we know something of how it is organized. What is its plan of structure?

A stonefly is a primitive sort of insect that will show us this plan very plainly. Let us get one of the larger stoneflies from a stream and examine it. Taking a fresh specimen in hand we first note that the body has some conspicuous appendages. There are two long antennae in front and two tails behind and six legs at the sides. We see that the body is divided into segments encased in rings of armor with flexible membranous joinings, and that the appendages are similarly encased. There are no bones as in us. There are big horny rings about the body, and little ones about the appendages. These rings, together with some internal processes from them, constitute the skeleton of the insect, which is worn on the outside, and has the muscles attached to its inner surface.

If we bend the body and appendages at their joinings and note how the parts move on one another, we will see that some of them move freely in any direction on the infolded membrane, while others, like the knee joint in the legs for example, bend freely in one plane only, two pivotal points being developed in the membrane on opposite sides.



The hardening of the skin is due to the formation in it of a horny substance called *chitin*. This chitinous hard layer, forming an outer skeleton, segmented on body and appendages, is characteristic also of crustaceans, spiders and myriapods. These together with insects comprise that great division of the animal kingdom known as the Arthropoda.*

When we look at the stonefly more closely we observe that its body is divided into three principal parts, *head*, *thorax* and *abdomen*.

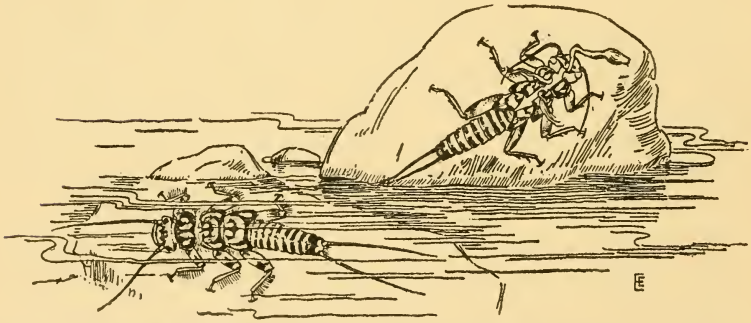


FIG. 1.—Stoneflies: an immature specimen (a nymph) in the water and a cast skin on the large stone, from which the adult stonefly shown above it has issued.

* From (arthros joint, podos=foot; joint-footed animals).

The *head* bears the eyes, the antennae and the mouth-parts. The eyes are of two sorts:

Compound eyes: a single large pair at the sides of the head. If the surface of one of these be examined with a lens it will be seen to be composed of a multitude of shining, transparent hexagonal *facets*. Each facet bears a little lens through which the light enters, to reach the sensitive nervous apparatus inside. Each unit of the compound eye contributes its own spot light, giving inside what is called a mosaic pattern. This type of eye, so different from our own, is believed to be especially good for detecting moving objects.

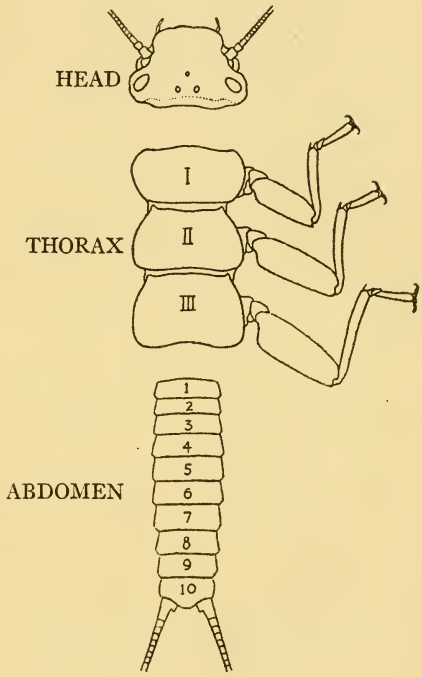


FIG. 2.—A diagram of the structure of an insect.

Simple eyes, or *ocelli*: there are three of these on the top of the head between the compound eyes, minute shining convex spots, each with a single lenticular cornea; one ocellus

on the middle line of the head and a pair beside and behind it.

The *antennae* are attached in front. Their function is fairly expressed by the name of "feelers" that is often given them.

The *mouthparts* are built on a plan of four: an upper lip hanging down from above, a lower lip rising up from below, the two together covering two pairs of jaws that swing laterally between.

The upper lip or *labrum* is of simple structure. It is a broad chitinous flap-like covering plate hanging free below.

The upper pair of jaws, called *mandibles* are the heavy chewing organs. Each is a single piece, incurved to the toothed tip, heavily chitinized and strongly joined to the head on a stout basal hinge.

The lower jaws, called *maxillae* (singular *maxilla*) are chewing organs of a lighter build, and of a much more complicated structure. They are composed of a number of segments as follows: there are two basal segments (*cardo* and *stipes*) that together uphold three appendages, the tips of which may be seen without dissection. The innermost of these appendages (the *lacinia*) is most like the mandibles, being rather heavily chitinized and toothed at its tip and used for chewing. The outermost appendage, the palp or *palpus* (plural *palpi*), is a free, five-jointed appendage, somewhat like a small antenna. It is a food "feeler."

Between lacinia and palpus is a middle appendage (the *galea*) that is a curved and more or less spoon-shaped plate, whose function seems to be that of closing the mouth laterally for the retention of food.

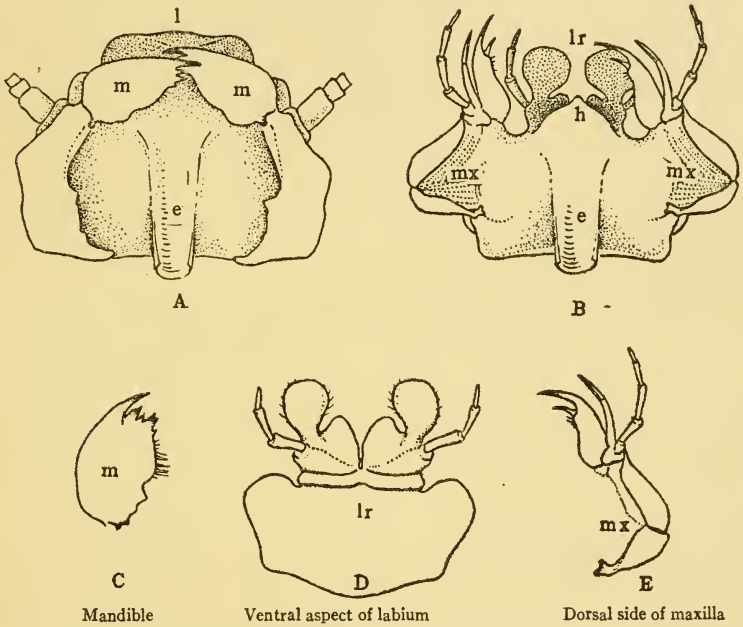


FIG. 3.—The mouthparts of stonefly nymph. Figures A and B represent the head divided horizontally through the esophagus *e*, and both halves exposed from within: *l*, labrum or upper lip; *m*, mandibles; *mx*, maxillae; *lr*, labium or lower lip; *h*, hypopharynx, or tongue. Figures C, D, and E represent these parts, detached.

The *thorax* is composed of three segments, each of which bears a pair of legs. Insects proper are called *Hexapods*

(*hex*, six and *pous*, *podos*, foot). Their six feet readily distinguish them from other Arthropods. Why we, ourselves, have two feet, and vertebrates generally have four, and insects six and spiders eight, and crustaceans and millipedes still more, is not explained, but three pairs are the allotment of this group we are now studying.

The first segment is called the *prothorax* (*pro*, before) and the other two together, being more alike and more closely conjoined, are called the *synthorax* (*syn*, together).

For futher convenience, each segment bears its own name, the second or middle segment being appropriately called the *mesothorax* (*mesos*, middle), and third, the *metathorax* (*meta*, beyond).

The prothorax bears only a single pair of legs, but mesothorax and metathorax bear each a pair of wings (in addition to a pair of legs). In the young of some stoneflies on the under side of the thorax will be found tufts or gills, arising from the thin membranes at the joinings of the segments.

The leg of an insect is built on the following plan: there are two short basal segments, *coxa* and *trochanter*, that make attachment to the body and provide for the upward turn; then there are two long segments, *femur* and *tibia*, meeting at the knee; then there are three short segments (the number varying from one to five in other insects), composing the foot or *tarsus* (plural, *tarsi*). All these names, being borrowed directly from human anatomy, ought to be easy to remember, if we know the names of the bones

in our own body. Then, there is a pair of spurs at the tip of the tibia, and there is a pair of claws on the last segment of the tarsus. There are often sole pads (*pulvilli*,) underneath the tarsal segments and between the claws.

The chitinous armor that encases the thoracic segments is itself subdivided into plates, two of which may be seen at the sides, and two more below on each segment, all separated by thinner sutures that meet at the base of the legs.

The wings of insects are two pairs, borne always on the synthorax, one pair on each segment. In the young of the stonefly we may see how they arise as outgrowths from the hind angles on the back. At the time of transformation to the adult the wings suddenly expand to full size, and acquire proper basal attachment and muscles and become capable of flight. The wing when fully developed is a thin sheet of membrane supported on a framework of *veins* or *nervures*. It is moved by stout muscles within the thorax, attached close beside its basal hinge. In flight the wing is swung up and down in rapid vibration. Its front border is stiffened by closely placed veins and its hind border is thin and pliant. Its action, therefore, is that of sculling and gliding.

The venation of an insect wing is very complicated in the details of the branching and conjoining of the veins: but its general plan is simple enough, as shown in the accompanying diagram. There are three veins close together and parallel near the front border, named *costa*, *subcosta*,

and *radius*, followed by two, *media* and *cubitus*, that spread out across the middle of the wing and then several *anal veins* that radiate to the hind border. Of these veins only radius, media and cubitus are conspicuously branched. These veins are joined together by cross-veins in a very light and strong supporting framework; and the joinings and branchings in the outer half of the wing confuse their identity; but they may be easily recognized in their basal unbranched stems. Our diagram, Fig. 4, omits the cross-veins for the sake of clearness; but the next figure, Fig. 5, shows the venation as it actually appears in the adult stonefly.

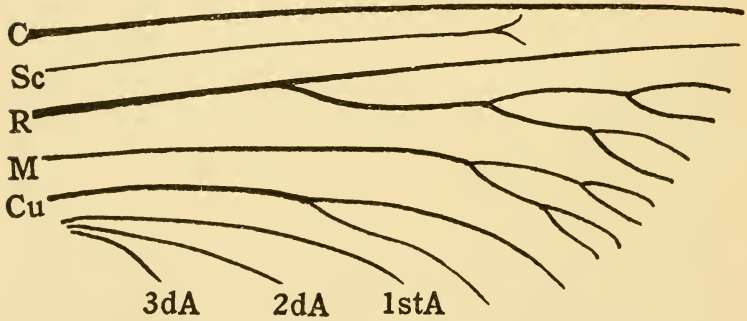


FIG. 4.—Diagram of the principal veins of an insect wing, showing their types of branching, cross-veins omitted.

The abdomen of the stonefly consists of ten similar rings or segments, and a terminal cluster of three minute plates, one median and dorsal, and two lateral, the latter bearing the long tails. The segments are less rigid than in

the thorax. They are more or less "telescoped" from front to rear, with infolded joining membranes and overlapping edges. Each segment, moreover, is capable of a somewhat bellows-like expansion at its infolded lateral margins.

The tails (or *cerci*) are long, tapering, close-ringed, many-jointed appendages that function as "feelers" to rearward.

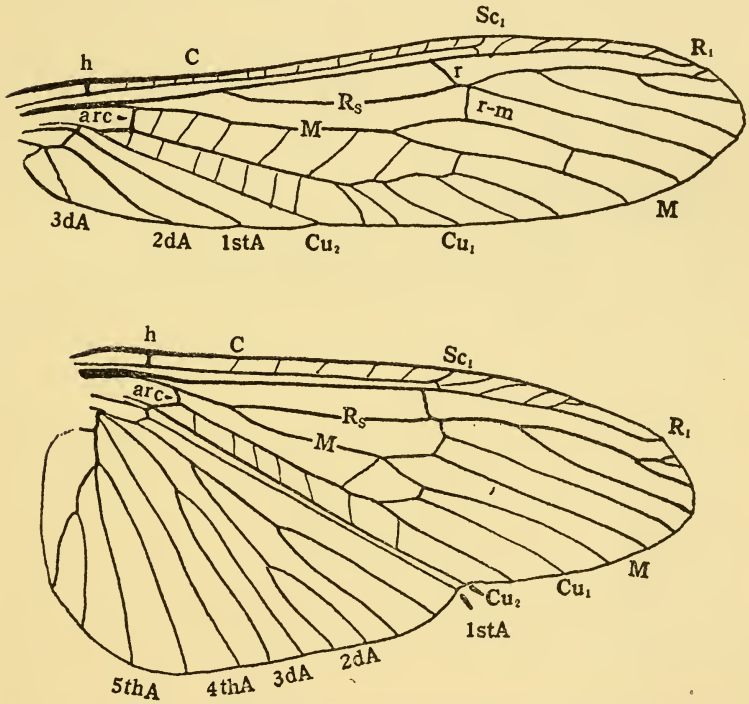


FIG. 5.—The venation of the wings of the stonefly, *Perla capitata*. Principal veins are marked by capitals; cross-veins, by small letters.

Development.

The young of stoneflies are called *nymphs*. They live in streams, where they cling by means of their strong claws to the surface of stones and drift wood (see Fig. 1). When fully grown they climb out of the water upon some exposed surface and shed their old skins and appear as winged aerial adult insects.

If we compare a stonefly nymph with an adult, we will see that the change in form of body is a slight one, that legs, antennae and tails remain much as before, but that the wings have been enormously expanded and newly articulated at their bases, and now lie folded close upon the back. There has been a development of reproductive apparatus on the hindmost abdominal segments, and the gills of the nymph have disappeared, being no longer needed.

LESSON I*

External Structure

WORK PROGRAM

1. Collect stonefly nymphs from streams (see p. 183).
2. Collect stonefly adults at lights.
3. Collect grasshoppers from the corn field.
4. Cage and feed grasshoppers for use in Lesson 3.
5. Collect dragonflies by the waterside (see p. 182).
6. Collect beetles from under stones (see p. 181).

* *Suggestion to the teacher.*—This course involves the use of a good bit of apparatus, but it is all comparatively simple and inexpensive; and, given stock materials and a few hand tools, the pupils can make much of it on the job to their own educational profit. The school should provide this equipment in advance of need, so that the pupils may get their insects while the getting is good. Considerable foresight must be exercised for a course that runs far into the winter season.

Much collecting of insects also is proposed, but the teacher should not do it all. Why should the pupils be deprived of such stimulating exercise? They will do it gladly if given the same school credit that they receive for other comparable effort. It is not necessary to organize many excursions for the purpose. They will do it individually, and will do it better so. Incidentally they will learn in the field something of the work that insects do in the world; something that the laboratory can never teach. And afterward in the laboratory they will work over the specimens that their own hands have gathered, with a zest and personal interest that is quite unknown to the study of "pickles" and slides obtained from the laboratory shelves.

Much material is needed. Team work will provide it easily. It is all common stuff, that can be found in any locality. It will have to be

7. Collect wasps from flowers (see p. 181); or, if these, or any of these are already collected, and in papers in storage, then

8. Relax specimens for study (see p. 186).

9. Make slide mounts of stonefly nymph mouthparts (see p. 190).

10. Make slide mounts of adult stonefly wing.

11. Make slide mounts of antennae of various forms, such as ant, mosquito, dragonfly and housefly.

12. Make slide mounts of the feet of the same insects.

13. Assemble for the laboratory exercises the tools (forceps, needles, lenses) and the specimens needed.

14. Put these away again at its close.

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collected in advance of need and brought to the laboratory, and some of it will have to be prepared for study. There are indoor tasks that will appeal to some tastes: tasks of rearing and caring for living insects, and tasks of preparing and labelling specimens. A statement of the things to be done and the conditions for doing them, and a promise of proper credit for the work performed, and then a call for volunteers, should do much toward finding the tastes suited to the tasks, and toward securing good team work.

A list of the things to be done in preparation for each lesson will be placed first under the heading "Work Program." Division of labor among the members of a class will make the work light for everybody. Each one in doing his bit will acquire useful knowledge for himself and provide help for others.

LABORATORY PROGRAM

1. With a specimen of a stonefly nymph in hand read the preceding pages, 3 to 12, and verify all the statements therein.

2. Do the same with adult stonefly. Note especially the wings. Expand and refold them, and note their basal articulation.

3. Examine a grasshopper, nymph and adult, following the same outline; identify every part. Note differences in the shape of the body, in the larger development of the hind legs. Note the backward slant of the side pieces of the synthorax toward the leg bases. Observe that the wing pads of the nymph are in position upside down, hind wings overlying the fore. Note that the heavy, parchment-like fore wings of the adult have become protective in function and useless in flight, and that the broadly expanded hind wings have a fan-like folding.

4. Examine in like manner an adult dragonfly, noting especially (1) the freedom of movement of the head; (2) the enormous development of the compound eyes; (3) the slenderness of the bristle-like antennae; (4) the smallness of the prothorax; (5) the great size and consolidation of the synthorax, with the *forward* slant of its side pieces toward the bases of the slender and spiny legs; (6) the rigidity of the long, veiny wings; and (7) the freedom of the slender abdomen. (To be continued later, p. 51.)

5. Examine in like manner an adult beetle, noting especially the freedom of the prothorax, and the consolida-

tion of the synthorax with the abdomen, under the protection and covering of hardened fore wings. Note that these meet in a straight line down the middle of the back. Lift a fore wing and find the hind wing underneath, and note that it is folded both crosswise and lengthwise. (To be continued later, page 94.)

6. Examine an adult wasp, noting expecially (1) the elbowed antennae; (2) the small hind wings, hitched on to the rear margin of the fore wings by a row of minute hooklets, so that the two pairs function as a single unit; (3) the consolidation of the basal segment of the abdomen with the metathorax, and (4) the sting at the tip of the abdomen. (To be continued later, page 124.)

7. Examine prepared slides showing special forms of antennae and feet in a number of common insects.

This brief survey of external parts will show the plan on which an insect skeleton is built, with certain modifications in its details, and will give some idea of what may be expected in other insects.

II

WHAT AN INSECT IS LIKE

Inside

The parts we have been considering are but the outer skeleton of an insect. They are the dead parts, produced and ever renewed by the living substance within. They are the mold, so to speak, in which the living being is cast. They are the parts with which in this course we will have most to do; but they are non-living parts, and if we would understand how the insect lives, we must look inside. Inside are all the parts for using its food, disposing of its waste, distributing its air, circulating its blood and maintaining its nervous connections.

The stonefly nymph as it appears in a median longitudinal section is shown in the accompanying figure. The main features of its plan are three. There is a food tube, or *alimentary canal* running lengthwise through the middle of the body, connecting at the ends with the body wall, which forms an outer tube, and there is a body cavity between, which contains the colorless blood, the white fat and air tubes and other organs. Thus the plan of the body is that of a tube within a tube, and an enclosed space between the tubes.

There is a central organ of circulation—a sort of tubular heart, lying lengthwise above the food tube and nearer the back, and there is a double nerve cord, and a chain of nerve ganglia, one ganglion for each segment (excepting a

few at the rear end), extended lengthwise beneath the food tube on the ventral side. In the top of the head there is a brain from which two nerve bundles descend, surrounding the front end of the food tube, to join the foremost of the ventral ganglia. So much of structure insects have in common with other Arthropods.

The food tube or *alimentary canal* begins at the mouth. Here there are minute paired *salivary glands* opening into it. It soon narrows down to a slender tubular *esophagus* or

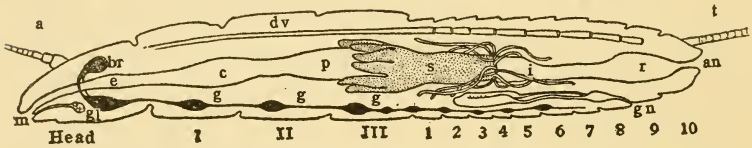


FIG. 6.—Diagram of the internal plan of structure of a stonefly. Body wall marked as before Head, thorax (I, II, III) and abdomen (1 to 10), with antennae (*a*) at the front and tails or cerci—(*t*) at the rear—the inner food tube or alimentary canal begins at the mouth (*m*) and extends to rearward in esophagus (*e*), crop (*c*), proventriculus or gizzard (*p*), stomach (*s*) with a whorl of renal or Malpighian tubules at its rear end), intestine, (*i*) and rectum (*r*) to end at the anus (*an*). Underneath the intestine lie the paired reproductive organs (ovaries or spermaries, according to sex) opening to rearward at *gn*. Opening into the mouth are paired salivary glands (*gl*). Above the food tube lies the dorsal vessel or heart (*d.v.*). The central parts of the nervous system are shown in solid black; brain or cerebral ganglion (*br*) above the esophagus, and chain of ventral ganglia (*g.g.g.*) on the floor of the body cavity.

gullet. It widens again sometimes into a thin-walled food receptacle called a *crop*, or into a thick-walled chewing stomach called a *gizzard*, or both. So far it is lined with chitin, mostly thin, but in the gizzard the chitin often forms teeth or ridges that are useful for grinding and mixing the food.

Then comes the *stomach* proper, whose naked walls are

thick and glandular. It is in this relatively short portion of the tube that the food is both digested and absorbed.

At the hind end of the stomach is a circle of slender urinary or *Malpighian tubules*, whose function corresponds to the kidneys in us, since they remove nitrogenous wastes from the blood. These tubes discharge into the food tube at the beginning of the intestine. The remainder of the food tube consists of *intestine* and *rectum*.

Malpighian tubules are peculiar to insects. So also are the air tubes, or *tracheae*, that extend everywhere throughout the body, sending fine branches into every living tissue. The tracheae are lined with thin chitin and are connected with breathing pores on the outside of the body (or else, with tracheal gills), and their function is that of supplying oxygen to the tissues. The insect has no lungs, and no capillary blood vessels: for moving the blood about in the body it has only the single, simple tube called a *dorsal vessel*. This receives the blood through slit-like valves on its sides, and by pulsating, pushes a current forward out of its open front end toward the brain. There are no capillary blood vessels to carry the oxygen, as in us; but the open tracheae carry it directly to the tissue; hence, the completeness of their distribution, and the fineness of their ultimate branching. In our cross-section diagram on page 25 a few of the larger tracheal trunks are shown.

The cast skin of a stonefly, left behind by the adult at transformation (see the lower righthand figure on page 4) will furnish the evidence that the front part of the food tube

and the larger tracheae are chitin lined: for the lining pulls out from the body at the final moulting, and hangs as a white thread attached to the old abandoned skin.

For the upkeep of the body the insect is equipped with the following internal organs:

1. For preparing and mixing the food: jaws and salivary glands and gizzard.
2. For both digesting and absorbing the food: a stomach.
3. For circulating food to all the tissues: an open body cavity, surrounding the food tube, containing the blood, into which the food passes, and a dorsal vessel, whose pulsations keep the blood moving.
4. For removal of wastes: Malpighian tubules, intestine and rectum.
5. For respiration (i.e., for intake of oxygen and removal of carbon dioxide): a system of air tubes, large and small, called tracheae and tracheoles, respectively. The former are the passage ways; the latter, the laboratories. The external openings of the tracheae in the body wall are called *spiracles*.

For the continuance of the species there are also paired reproductive organs lying in the abdomen. Their ducts open near its apex on the ventral side.

LESSON 2

Internal Structure

WORK PROGRAM

1. Collect minute, transparent nymphs of damselflies* and mayflies from a pond (see p. 182).

2. Care for this living material indoors until it is needed.

3. Carefully dissect out the food tube of some large stonefly or grasshopper, and place it in a vial of formalin to be used for demonstration.

4. Do the same with the ovaries of a large female stonefly or grasshopper.

5. Carefully dissect away all of one side of the body of a large stonefly or grasshopper, exposing alimentary canal and brain and ventral nerve ganglia but leaving them all in place so as to show their relations to each other, and put the specimen in a vial of formalin to be used for demonstration.

6. Assemble materials in the laboratory, including a few permanent slides of cross-section of a stonefly or a damselfly.

* Small stoneflies are not recommended for this because they are so much harder to keep alive when brought out of the well aerated water of streams into the still water of the laboratory (see page 200).

LABORATORY PROGRAM

A. *Living Specimens.*

I. See the living insects in the dishes of stuff from the pond, especially three small kinds that will be useful as transparent objects for the microscope. Chase them around the edges of the dish, and observe their manner of swimming:

1. Damselfly nymphs, that swim by sculling with the

FIG. 7.—A dish of water with floating algae, weeds, etc., dipped from the pond, *a*, a mayfly nymph; *b*, a damselfly nymph; *c*, a midge larva; *d*, the flocculent dwelling tube of a smaller midge larva; *e*, a young water strider (runs on the surface); *f*, a very small dragonfly nymph; *g*, a young tadpole.

three flat, vertically placed gill plates at the end of the body, slowly swinging these from side to side.

2. Mayfly nymphs, that swim with up and down undulations of the abdomen and of the three fringed tails at its tip, aided by backward strokes of the paired gills on the first seven abdominal segments.
3. The worm-like, pale cylindric larvae of midges, that swim by figure-of-8 loopings of the body.

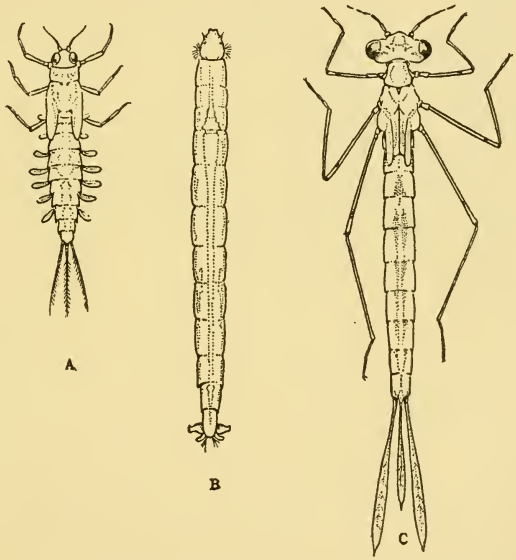


FIG. 8.—The young of three insects that are suitable for microscopic examination as transparent objects. *A*, a mayfly nymph; *B*, a midge larva; *C*, a damselfly nymph.

A. *Internal structure, externally visible.**—Select the most transparent specimen available, half an inch or less in length. Mount it on a slide in water. Add a coverglass, and see that the space beneath the cover is filled with water. Study with low power of the microscope. You will at once see that it has the same general external organization of body and appendages as has the stonefly: internally the two are sufficiently alike for our present needs.

The most striking feature of internal structure will be the thing that is most distinctive of the insect group—the air tubes or *tracheae*, which run through the body everywhere. These reflect the air strongly and appear black or silvery. There are main trunks extending lengthwise, and principal branches extending to the legs and other organs, and innumerable branchlets ramifying through every organ. In insects air is not carried to the tissues by the blood as in us, but is distributed through these tracheae directly to every part.

The relation between the other principal internal organs may be seen also by looking more closely: (1) an *alimentary canal* running straight through the center of the body from end to end; it is dark colored where filled with food. (2) A very delicate and transparent *dorsal vessel* extended longitudinally above the alimentary canal and just beneath the skin; (3) *ganglia* of the central nervous system, lying beneath

* May be shown to a whole class at one time by means of a projection microscope.

the alimentary canal upon the floor of the body cavity. Let us now examine these structures.

I. Study with a microscope the respiratory system of a small living damselfly or mayfly nymph, mounted on a glass slide under a coverglass that is properly supported to prevent crushing. Use the smallest and most transparent specimens for this. The air-filled tracheae stand out sharply as black lines, and are clearly visible even to their finest ultimate divisions (tracheoles).* Observe:

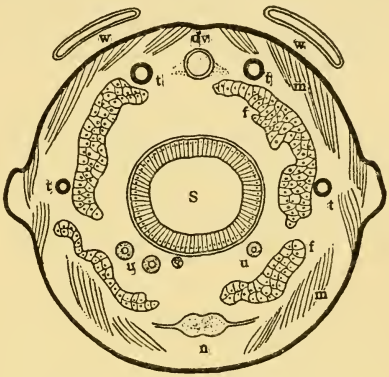


Fig. 9.—A diagram of a cross section through the abdomen of a damselfly nymph. The chitin of the body wall and of the linings of principal tracheal trunks (*t.t.t.t.*) is shown in solid black. *S*, stomach; *d.v.*, dorsal vessel or heart; *n*, nerve ganglion with outgoing nerves; *m.m.*, muscles; *f.f.*, fat; *u*, urinary (or renal, or Malpighian) tubules; *w.w.*, sections of hind wings.

1. The number and arrangement of the principal longitudinal tracheal trunks.
2. Their principal connections with each other.
3. Their principal connections with the (dark colored, centrally located) alimentary canal.
4. Their connections with the legs and with the antennae.
5. Their connections with the gills.
6. Focus just beneath the surface of the head and note

* Preserved specimens will not do for this because the preservatives replace the air and fill the tracheae, rendering them invisible.

the tree-like distribution of tracheal branches into the substance of the brain.

II. Study the circulatory apparatus. This will call for careful focusing of your microscope on parts that lie at different levels. With the living specimen back uppermost on the slide:

1. Focus just beneath the skin of the rear part of the abdomen, and watch for the movements of the pulsating walls of the very transparent dorsal vessel. When found, move along its edge to find one of the valves thru which a stream of minute, pale, white blood corpuscles may be seen passing into it. Find the valves at its rear end.
2. Trace the blood current forward to the head.
3. Observe the flow of the blood corpuscles out into the bases of the legs and back again; out into the gills and back again.

Some of these things are difficult to make out and may have to be shown in demonstration, using the most favorable specimens.

III. See what you can of the divisions of the alimentary canal: it will be partly dark in color, because of contained food. The slender Malpighian tubules will mark the posterior end of the stomach and the beginning of the intestine.

B. *Internal Structure Seen In Preparations.*

I. In dissections of the food tube, note the three principal divisions:

1. The foregut, extending from the mouth to the stomach. This is the chitin-lined front portion. Its lining layer is shed at every moult and hangs attached to the head, as already noted. It is usually differentiated into mouth, esophagus, crop and gizzard, as described on page 8.
2. The thick-walled stomach, ventriculus, or mid gut.
3. The hind gut, consisting of intestine and rectum. This portion, also, is lined with thin chitin and is moulted with the skeleton. At its front end arise the Malpighian or renal tubules.

II. In dissections of one side, showing food tube and nervous system in place, study the latter, noting:

1. The large brain, occupying the top of the head with some fine white nerves extending forward from it into antennae and mouthparts. This lies above the esophagus.
2. The smaller, subesophageal ganglion, placed ventrally in the head and connected to the brain by a pair of nerve trunks that surround the esophagus.
3. The chain of ganglia, lying on the floor of the body cavity, one ganglion for each segment (excepting the rearmost ones), all connected by a double nerve cord, and all giving off nerve fibers to adjacent parts of the body.

III. In dissections of the ovaries note:

1. The single oviduct, leading to the outside, in which the ducts from the two ovaries are conjoined.
2. The cluster of egg strings composing each ovary.
3. The tapering form of each egg string (or tubule), with bead-like enlargements where eggs are developing in it. A nearly mature, oblong egg will lie nearest its outlet, and a series of smaller less mature eggs, gradually diminishing in size will run out to its tapering tip. The eggs of each size mature and are deposited at successive layings. By counting the egg tubes you will obtain the number of eggs that may be laid at one time; and multiplying this by the number of eggs in a tube, will give the possible egg production of one female.

IV. In cross sections prepared for microscopic study of the tissues, observe the parts indicated in figure 9 and make your own diagram, showing their relations within the body.

III

HOW AN INSECT GROWS UP

All insects come from eggs. The ancient notions that they may generate spontaneously—midges from mud, blowflies from carcasses, moths from dust, etc.—have all proved erroneous.

The eggs are laid by the mother with wonderful instinct and precision in the places where the young on hatching will find food. It may be in earth or in water or on some particular kind of plant or of animal; and often it is in a place where the mother herself could not live. The eggs are laid by different insects in a great many ways—singly or in clusters; naked or under a covering; on the surface on stalks or in deep holes drilled to receive them.

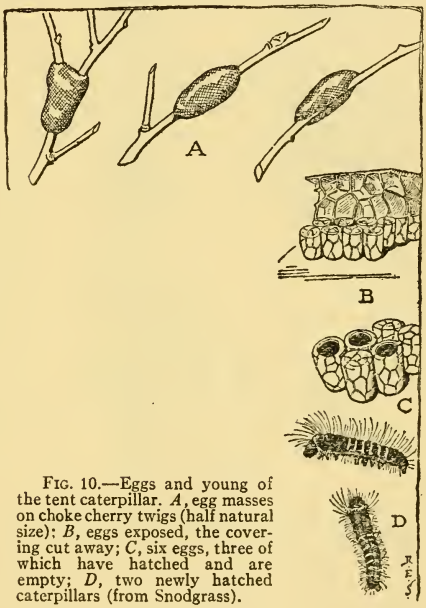


Fig. 10.—Eggs and young of the tent caterpillar. *A*, egg masses on choke cherry twigs (half natural size); *B*, eggs exposed, the covering cut away; *C*, six eggs, three of which have hatched and are empty; *D*, two newly hatched caterpillars (from Snodgrass).

On hatching, the young insect, released from the cramped

quarters of the egg shell, stretches itself, and expands. Its skin hardens. Chitin is formed and it becomes, as we have seen (page 4) like a coat of mail; for it will not stretch very much. Therefore, with growth, it becomes too small and has to be cast off. The process is called molting. The chitinous outer layer of armor loosens from the underlying new skin. Then it splits down the back, and the soft, limp, pale, but lusty and growing insect creeps out of it. Head and thorax first come up through the rent then the legs and abdomen are withdrawn. After each molt a sudden expansion and increase of size occurs, while the skin is new and stretchable. Then it hardens again.

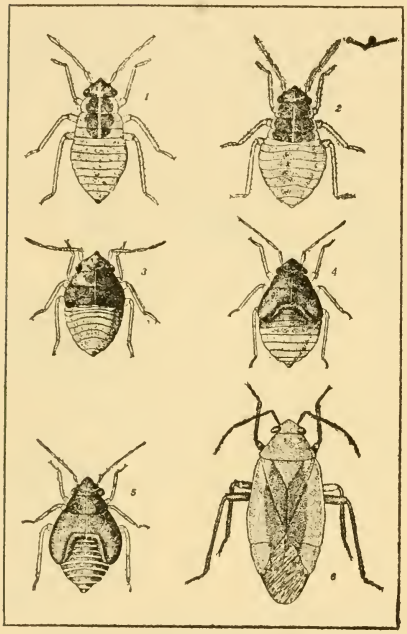


FIG. 11.—The developmental stages of a plant bug, *Tropidosteptes cardinalis* (after Leonard). Figures 1 to 5 are the successive nymphal instars; 6 is the adult.

The number of molts undergone by different kinds of insects in their growing up varies, but is rather constant for each kind. One common stonefly, (Nemoura) moults

22 times, but most insects molt from three to six times. The intervals between molts are technically called *instars*; and the larger divisions of the life history that are marked by great changes of form are called *stages*. The egg is the first stage.

The second stage comprises a number of instars—five of them in the plant bug shown in the accompanying figure. Differences in size are not shown in this figure (but see figure 19 on page 53) for the smaller are magnified to the size of the larger for easy comparison. The changes of form are slight. Most marked is the development of wings. These appear on the back in the 3d instar, and increase progressively in the 4th and 5th. During all this growth period the bug is known as a *nymph*.

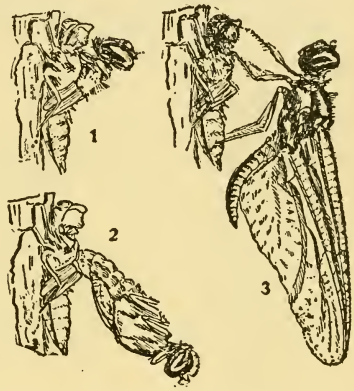


FIG. 12.—The emergence of a dragonfly from its nymphal skin.

Then comes the final molting, ushering in the *adult* stage (6 in the figure). The wings are now fully expanded, covering the body, and capable of flight. The antennae are enlarged. Sex organs are developed. Growth is ended, and the period of reproduction is at hand.

The change of form from nymph to adult is often greater than that shown in the plant bug. The nymph of a dragonfly,

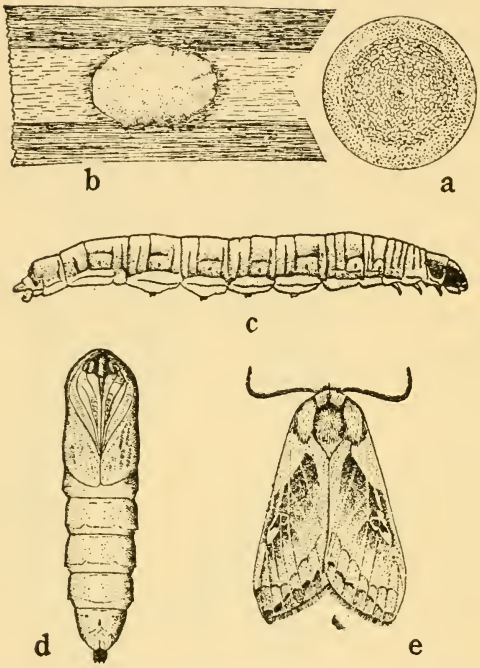


FIG. 13.—The developmental stages of an owlet moth, *Arzama obliqua* (after Claassen). **a**, a single egg taken from the covered egg cluster, **b**, and highly magnified; **c**, the grown larva; **d**, pupa; **e**, adult moth.

for example, is very different from the adult (compare figures 16 and 18). The accompanying figures (see figure 12) show the change in progress. In 1—the nymph has climbed from the water up a post attached its claws firmly, and the adult has lifted its head out through a rent in the back of the old nymphal skin. In 2—head, thorax, wings and legs are all out, and the creature is hanging by its still enclosed tail, momentarily resting. In 3—the adult has righted itself and is standing on the now empty skin, but its wings are not yet fully expanded. This is, indeed, a *transformation*. It may require half an hour for completion. During this time the callow insect is peculiarly helpless.

When greater changes of form than this occur in insects they seem to require an additional stage devoted to the making-over process. This is the *pupal stage* or *chrysalis*. It is interpolated between the growth period and the adult life. It is a period of relative inactivity that is spent in retirement. The owlet moth shown in figure 13 will serve for illustration. From the egg (*a*), there hatches a worm-like caterpillar (*c*), which eats and grows, undergoing five molts, with very little change of form (only the last instar is shown in the figure). No wings appear externally, and the legs and other appendages remain very minute indeed. This is called a larva.* The grown larva goes into retirement and sheds its skin, disclosing a pupa (*d*), in which the parts of the adult insect plainly appear. Later, after the making-over is completed, out of the pupal skin the adult (*e*) emerges.

These changes collectively we call *metamorphosis*. Of metamorphosis there are many degrees and variants; but for our purpose we may regard them all as falling into two principal categories, as follows:

Metamorphosis	*Stages*
1. Incomplete	—egg, nymph and adult.
2. Complete	—egg, larva, pupa and adult.

* The name *larva* is often used in a more general sense to cover all immature stages, including nymphs.

PART II

THE PRINCIPAL GROUPS OF INSECTS

IV

ORTHOPTERA

Grasshoppers, Crickets, etc.

This is an important group of mostly herbivorous insects of rather large size. The wings when present are straight, as the name* of the order implies, and usually lie flat upon the back with the hind wings folded lengthwise like a fan and covered by the front ones. The mouthparts are formed for chewing. The tarsi are 1- to 5-jointed.

This order includes:

I. The true, or jumping Orthoptera.
   1. Short-horned and pygmy grasshoppers.
   2. Long-horned grasshoppers and katydids.
   3. Crickets.

II. The Orthoptera allies.
   1. Running Orthoptera—cockroaches.
   2. Grasping Orthoptera—mantids.
   3. Walking Orthoptera—walking sticks.

The *jumping Orthoptera* have these common features:

1. Long, strong, hind legs, with enlarged muscular femora, spiny tibia and stout claws.
2. Strong biting jaws of the type already studied, but

* *Orthos*, straight, and *pteron*, wing. Named by "the immortal Swede" Linnaeus, on the basis of wing characters, as are many of the other orders of insects.

heavier, more bluntly toothed and better adapted for eating coarse vegetable foods.

3. A large prothorax shieldshaped above, that more or less overlaps the head in front, and the synthorax behind.
4. The males are equipped with a sort of musical or chirping apparatus.
5. The end of the abdomen in the female is armed with an ovipositor for making the holes in which the eggs are laid.
6. The nymphs as already noted (page 15), have the wing pads inverted in position on the back.

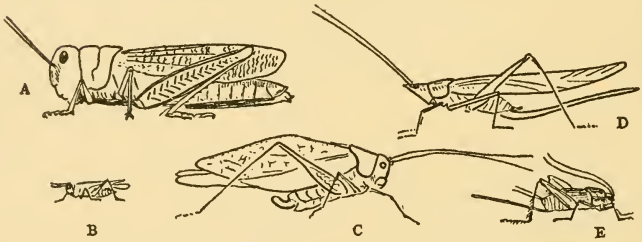


FIG. 14.—Jumping Orthoptera. *A*, a short-horned grasshopper; *B*, a pygmy grasshopper; *C*, a Katy-did; *D*, a cone-head grasshopper; *E*, a field cricket.

Let us begin our study of the group with one of the short-horned grasshoppers. There are many kinds of these and several kinds may be found in any corn field or meadow where they eat notches in the edges of the leaves of the corn and the grasses. One familiar gray species rises from the dusty roadside on our approach, and flies away on rustling wings, which show a conspicuous yellow border behind.

Young grasshoppers will be found in the same situations as the adults. They resemble the adults quite closely in form, but are smaller, and lack fully developed wings.

There are three very common groups of short-horns that we should know:

1. The common grasshoppers of the fields, mostly dark colored, often ornately striped, recognizable by the possession of a "bumper" or tubercle underneath the prothorax between the bases of the fore legs.
2. The band-wing grasshoppers of the more open spaces, mostly mottled in color like the ground they rest upon, recognizable by the brightly colored border of their hind wings.
3. The pygmy grasshoppers, found by the waterside, half the size of ordinary grasshoppers or less, recognizable by the long point on the rear of the prothorax that projects backward over the whole length of the body.

The long-horned grasshoppers and katydids are mostly greenish, and live amid the green herbage, protected by their color. They are less often seen, and more often heard than the preceding. The wings are somewhat elevated, rooflike above the back, especially in the katydids. The tarsi are 4-jointed. The ovipositor of the female is flattened laterally and more or less sword-shaped.

There are three very common groups of crickets that we should know:

1. Greenish or whitish tree crickets that live in the foliage

2. Black field crickets that live on the ground.
3. Mole crickets that live in the ground in burrows.

The tree crickets are most like the long-horns just discussed, but are smaller and more delicately built insects, having in the females an ovipositor that is spear-like rather then sword-like (not laterally flattened), and 3-jointed tarsi. The wings lie flat on the back. The males are prone to incessant chirping during late summer and autumn.

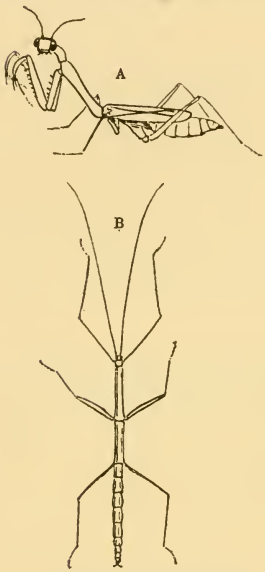


FIG 15.—Two Orthopteran allies *A*, a praying mantis; *B*, a walking-stick.

The Orthoptera allies, cockroaches, mantids and walking-sticks are all few in kinds. One, the cockroach, is only too well known. The others are so unique in form that they are all instantly recognizable by a reference to figure 15. A brief outline for the study of representatives of these groups is provided in the following lesson:

LESSON 3

The Grasshoppers and their Allies

WORK PROGRAM

1. Collect short-horned grasshoppers from the fields and roadsides.
2. Collect pygmy grasshoppers from the waterside.
3. Collect long-horned grasshoppers from the meadows and fence corners.
4. Collect field crickets by overturning boards, etc.
5. Collect tree crickets from berry patches.
6. Collect mole crickets at lights.
7. Collect cockroaches with traps.
8. Collect walking-sticks from the bushes.
9. Collect mantids from the meadow.
10. Feed and care for caged grasshoppers.
11. Prepare slide mounts of an ovipositor, showing blades.
12. Prepare slide mounts of wings of males to show musical apparatus.
13. Home problems on crop pests (see p. 174).
14. Routine (see p. 204).

LABORATORY PROGRAM

A. *Study of the Living Grasshopper.*

I. *Locomotion.*

1. Liberate a specimen from the rearing cage in a warm

room, and measure its longest leap: how many times the length of its body?

2. Place it on a large horizontal pane of glass, and observe its difficulties when the spines on its tibia cannot be used effectively.
3. Place it under a glass tumbler or bell jar and note the size and arrangement of its legs: which are most used in walking? in leaping?

II. *Respiration.* Place a live specimen in a cyanide bottle and *as soon as it is stupefied* observe:

1. The opening and closing of the two lips that guard the entrance to the large spiracle just above the base of a middle leg.
2. The bellows-like expanding and contracting of the abdominal segments. Could a grasshopper be drowned by holding its head under water?

III. *Feeding.* Place a grasshopper that has been kept without food for half a day under a tumbler with some fresh leaves of clover or corn, and watch it eat. Observe the action of the antennae, the feet, the jaws, the lips and the palpi.

IV. *Molting.* If chance offers, if a grasshopper nymph in the rearing cage happens to be undergoing a molt while the class is in session, let it be used as demonstration, so that all may see the remarkable sloughing off of the old skeleton that permits free growth of the body.* The young

* In absence of this opportunity, preserved specimens that have been fixed in the act of molting may be shown.

grasshopper molts its skin five times before reaching maturity, and grows each time a new skin of larger size. At first it is soft and pale, but soon the new chitin hardens and takes on color.

B. *The Study of Preserved Specimens.*

I. *Short-horned grasshoppers.* With a specimen in hand note again the division of the body and appendages into regions and segments, as outlined in the first lesson (pp. 4 to 11). Then proceed to examine more in detail some of the structures peculiar to this group.

In the head note:

1. The long, many-jointed antennae.
2. The large compound eyes, and the three small, shining, beadlike ocelli on the top of the head between them.
3. The mouthparts; a broad, two-lobed labrum, and beneath it, mandibles, maxillae and labium somewhat of the form shown in figure 3.

In the thorax note:

1. The shield-like prothorax.
2. The bulky synthorax, its last segment (the metathorax) expanded, especially on the ventral side, to accommodate the muscles involved in both flying and jumping.
3. The legs. Note especially in the huge hind legs:
   (a) The club-shaped femur, its outer face having a braided appearance from impressed lines that

correspond in position to the ends of bands of muscles within.

(b) The slender tibiae, each with a double row of spines down the rear (which is, of course, the lower side when these are set flat on the ground ready for a leap), and with two pairs of clawlike spurs across its tip. These claws take hold on the ground at the final get-away.

4. The wings. Seize the fore wing by its front margin, draw it forward, and hold it extended. Then in the same manner draw the hind wing forward. Note how it is folded. Compare the two wings in form, color, size, and texture. The dry, horny fore wings of grasshoppers are called *tegmina*.

In the abdomen observe:

1. A longitudinal groove on either side. Just above this groove, in each segment, is the opening of a breathing pore (or *spiracle*).
2. In the female on the ventral surface of the abdomen there are eight visible segments. The abdomen terminates in an *ovipositor*, having four stout points, which are used for making holes in the ground for the reception of eggs. The four points are repeatedly pressed together, pushed into the ground, and there separated, thus pressing the earth aside, until a hole is made of sufficient depth, when the eggs are deposited in the bottom.

3. In the male grasshopper there are nine segments visible on the ventral side, and an elongated, bilobed *subgenital plate* terminates the abdomen beneath.
4. The hearing organs. If the wings be raised, so as to uncover the side of the abdomen, on the middle of each side of the basal segment will be seen a small oval depression, across the bottom of which is stretched a thin vibrating membrane; this being remotely comparable to the drum of the ear is called a *tympanum*. A nerve connects the inner side of it with the central nervous system.
5. The sound-producing organs. These belong to the males only, and consist of a file and a scraper. The microscopic file is on the inner side of the hind femur, and it rasps across the edge of the partly extended wing, throwing that into vibration, and thus producing the "music." By searching the inner surface of the femur with a lens the minute pegs may be found in a row at the lower margin of the braided central area. This scraper is best developed in some of the band-wing grasshoppers. These sing only in flight.

Developmental stages. If grasshopper nymphs of all sizes have been collected, compare those of one species together, and see if they cannot be arranged in a series to show five nymphal instars. The size of the horny head capsule will remain rather constant between molts. Study also some preserved specimens that have been fixed in the act of

molting. From all these determine the answer to the following questions:

1. Has the young grasshopper, when first hatched from the egg, any wings? (Use lens in determining.)
2. Where does the skin split open when molting occurs?
3. What part of the insect comes out first? Last?
4. What organs are relatively best developed and what least developed in early stages? For what organs has the newly hatched grasshopper most use?

If then we examine one of the pygmy hoppers we shall find the prothorax remarkably developed, the head being set deeply into its front end and the entire body to rearward is over-reached by a long process from the dorsal shield. The forewings, also, are reduced to a pair of little scales, that peep from underneath the edges of this process.

II. *Long-horned grasshoppers.* With a specimen of a conehead, or a katydid or any other true meadow grasshopper in hand the following characteristic structures should be noted:

1. The length and slenderness of the antennae.
2. The thin-bladed, sword-like ovipositor of the female (short and curving in the katydids, long and straightish in the others). Prepared slide mounts may be used to study its composition. This type of ovipositor is well adapted for thrusting eggs into deep crevices, such as those within sheathing leaves and scales.
3. The organ of hearing, located in the swollen base of the front tibia, in an oval depression.

4. The sound-producing apparatus of the male: again it is a file and scraper; but in this group both are on each fore wing. The file is on the under side of one of the thickened basal veins, and the scraper is on the hind margin near the base. In "singing" the fore wings are lifted and rubbed together, the file of either one being drawn like a violin bow across the scraper of the other. Adjacent to the file the wing veins take a circuitous course to inclose a wide, disclike vibrating ("sounding board") area. Thus the venation of the male fore wing has come to differ from that of the female.

III. *Crickets.*

1. With a common black field cricket in hand compare part by part with the preceding, noting in addition especially:
   (a) The polished and shining surfaces of the body that facilitate escaping through tangles of rubbish and weeds. Crickets are "slippery."
   (b) The shorter, more cylindric, prothorax.
   (c) The two long tails.
   (d) The long, slender, cylindric ovipositor of the female, by means of which the eggs are laid singly, deep in the soil.
   (e) The sound-producing apparatus of the male, similar in type to that of the long-horn grasshopper but more highly developed.

2. With a snowy-tree cricket in hand, compare again, noting especially:
   (a) The pale color and delicate structure of the insect.
   (b) The greater breadth of the fore wings in the male than in the female (due to development of the "sounding board" area of the wing in this, the most persistent performer among all Orthopterous choristers).
3. With a mole cricket in hand, compare again, noting especially those adaptations that fit this cricket for life as a burrower in the soil:
   (a) The narrow and more pointed head.
   (b) The shorter, reversible antennae.
   (c) The enormously enlarged digging fore legs, with stout femora; toothed and flattened, scraperlike tibiae; and dangling, almost rudimentary tarsi.
   (d) The appressed, pushing hind legs.
   (e) The reduced wings.

For information concerning other crickets, of which there are many sorts, consult the larger textbooks.

IV. *Orthoptera Allies.*

1. With a cockroach in hand note a very different type of structure, viz.:
   (a) A flat body with the head tucked underneath the front of the prothorax.
   (b) Legs all fitted for running, close together at their bases, tibiae loosely spined.

(c) Forewings broadly oval, with broad areas traversed by numerous closely parallel veins (many cockroaches are wingless).

(d) Short tails.

(e) Absence of ovipositor in the females: the eggs are laid in big cross-ribbed egg cases, that are left in crevices and in runways and other dwelling places of the adult roaches.

2. With a mantis in hand, note another distinct, and rather grotesque type of structure, viz.:

(a) A body angulate at the middle joint, cylindric in front and flattened behind.

(b) Legs correspondingly differentiated into one pair for grasping in front and two pairs for standing behind.

(c) Head narrowed behind the rounded and prominent eyes into a long necklike portion.

(d) Antennae short, slenderer, threadlike.

(e) Rapacious jaws; sharp toothed at their tips.

(f) Prothorax very long, cylindric, bearing the legs far forward.

(g) Fore legs with extremely long and strong coxae; femora and tibiae, all toothed for grasping and holding prey.

(h) Slender middle and hind legs, and 5-jointed tarsi.

(i) Broad fore wings, that in color and veining often resemble leaves.

(j) A stout abdomen, ending in a pair of short tails.

(k) The absence of ovipositor in the female: the eggs are laid in broad patches (often an inch long) on vertical stems, in a double row, alternately placed and overlapping, so that the surface of the egg mass has a braided appearance.

3. With a "walking-stick" in hand, note:

(a) The slenderness of the long cylindric body, which in color and surface markings often resembles a twig.

(b) The short head, with long antennae and blunt, plant-eating jaws.

(c) The long, slender legs, with 5-jointed tarsi.

(d) The entire absence of wings.

(e) The pair of forceps-like appendages at the end of the long abdomen in the male.

(f) The absence of ovipositor in the female: the eggs are scattered on the ground beneath the woody plants on which the adults feed.

V

ODONATA

Dragonflies and Damselflies

This is a very peculiar group of strong-flying carnivorous insects. Some of them are of large size and many are brilliantly colored. They capture their prey in flight. During hot summer weather they haunt every pond and stream in considerable numbers, and a few of them linger on until late autumn. The name of the order *Odonata* is supposed to have been suggested by the very sharply toothed rapacious jaws.*

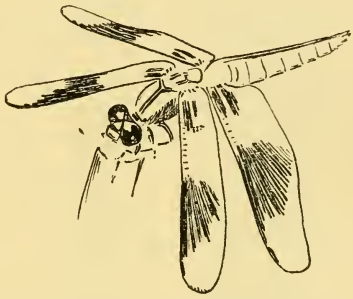


Fig. 16.—The "White-tail" dragonfly (*Plathemis lydia*), perching.

The head is very freely movable on a slender neck, and the immense compound eyes overspread its sides. The synthorax is very large and strongly aslant with the wings shoved far backward above, and the legs far forward below: the wings are flat and veiny with a somewhat hingelike notch near the middle of the front margin. The spiny legs are adapted for standing but not for walking, and their forward position favors perching on vertical stems. The long abdomen of ten segments is loosely attached at its base.

* *Odons*, tooth.

With these characters noted it will be quite impossible to confuse a member of this order with any other group. All are aquatic in their immature stages; and hence, however widely the adult females may wander over the land, they return to the water to lay their eggs. Their food is largely other insects that have aquatic larvae, such as midges and mosquitoes.

FIG. 17.—A damselfly (*Ischnura verticalis*).

Dragonflies proper are mostly large, stout-bodied insects, having broad wings, the hind wings broader than the fore, and which at rest are held horizontally outspread.

Damselflies are smaller and slenderer with fore and hind wings narrow and alike in form. At rest they are closed together above the back, or are held obliquely aslant.

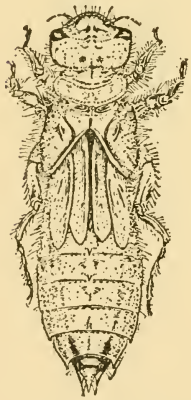


FIG. 18.—The nymph of the "white tail" (*Plathemis lydia*).

The nymphs of Odonata are very different sort of creatures from the adults. They live in the water, are rather inactive and lie in wait for their prey. They are all carnivorous. They feed upon almost any aquatic animals that are small enough for them to capture. Some are cannibals, and eat each other. All are equipped with a long, hinged and jointed grasping labium that is a remarkable organ

for capturing prey, and that is altogether unique and peculiar to this order. All are aquatic and breathe by means of gills.

The nymphs of dragonflies are stout-bodied, rather unattractive, stiff-legged creatures, that usually lie among the water weeds or in the bottom silt. The abdomen is wide and includes a large gill chamber in which the alimentary canal terminates. There are no external gills. These nymphs can swim rather jerkily by successive expulsions of water to rearward out of the gill chamber.

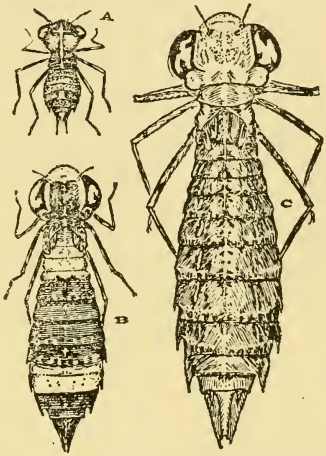


Fig. 19.—Three selected instars in the nymphal life of the "Big Green Darner" dragonfly, *Anax junius*; *A*, new hatched; *B*, one-fourth grown; *C*, half grown. Such color changes are uncommon in this order.

The nymphs of damselflies are slender, long-bodied, lank-legged creatures that cling to water weeds. The abdomen is narrow and bears on its tip three flat gill plates placed side by side with edges vertical. They swim by sculling with these gill plates, swinging the tip of the abdomen slowly from side to side.

LESSON 4

Dragonflies

WORK PROGRAM

1. Collect adult dragonflies and damselflies by the waterside: hot sunshiny days will be best for this.

2. Collect cast nymphal skins of the same. Most of them will be found within a foot of the edge of the water, sticking to plant stems, posts, etc.

3. Collect dragonfly and damselfly nymphs from still water: a sieve net will get them best;—the climbing nymphs by sweeping the submerged water weeds; the bottom sprawlers by scraping them up with the bottom sediment; the burrowers, by sifting them out of the mud and sand.

4. Arrange water jars or aquaria for keeping alive a stock of the nymphs for class use. Keep the largest apart, where they cannot eat the little ones.

5. If full grown nymphs are found, ready for transformation (as shown by the length and darkening color of the wing pads on the back), put them in a wire cloth rearing cage (see p. 199), half immerse it in a pail or tank of water and leave them to transform.

6. Gather mosquito "wrigglers" or other small insects for food for the dragonfly nymphs.

7. If dried specimens are to be used in the laboratory, give them over-night treatment in a relaxing jar (see p. 186).

8. Mount a few showy specimens for exhibition, using a spreading-board (see p. 188).

9. Make slide mounts of the mouthparts, especially the extraordinary labium. Use the smaller nymphs for this, and see that the grasping apparatus at the tip of the labium is well opened out.

10. Routine (see page 204).

LABORATORY PROGRAM

A. *Study the Living Specimens.*

Adult dragonflies are not very manageable indoors. There is little they will do besides hanging to the wall of a cage. But their nymphs are excellent subjects for indoor observation. Observe:

I. *Their locomotion.* They climb, they sprawl or they burrow, according to the equipment of their bodies; but whether endowed with parts suited to one purpose or to the other, they mainly sit (or stand) and wait for prey.

1. Chase them about the dish. Turn them over and see them right themselves.
2. Observe their swimming by outpush, at the end of the abdomen, of water from the gill chamber. Sediment in the dish will be disturbed and will swirl about with every expulsion that drives the nymph forward.
3. Hold a copying or indelible pencil close to the tip of the abdomen of a quiet nymph until the color dissolves a little: the color will enable you to watch the slow inflow of water into the gill chamber, and its sudden expulsion in a colorful cloud.
4. Feed a nymph that has been kept for a day or more

without food. While it is resting quietly, liberate a mosquito "wriggler" (or any other suitably small living and active aquatic animal) close in front of it, and see what happens. The stroke of the labium is so swift the eye cannot follow it; but a flashlike movement is seen, and then there is a struggling captive held close to the terrible jaws.*

B. *Study Preserved Material.*

a. *The Adult*

A few of the more striking characters of a dragonfly were noted in the first lesson (see p. 15). With one of the larger dragonflies in hand, note further:

I. *In the head.*

1. The typically carnivorous mouth parts: everything fitted for capturing prey: mandibles, maxillae, and even the lobes of the labium sharply toothed.
2. The shelf-like prominence above the mouth—a sort of "cubist" nose, with three shining beadlike ocelli above it and the bristle-like antennae arising farther out at the sides.
3. The very great number of facets (try counting them) making up the compound eye, and the difference in size between those of the upper surface and those below.
4. The concavity of the rear of the head.

* Dragonfly nymphs will take only living and actively moving prey; but in absence of suitable food, they may be induced to grab a bit of earthworm or even of beefsteak, if the bit is held with a forceps or on a needle point and wriggled in front of the nymph within reach of its labium.

II. *In the thorax.*

1. The small prothorax, tapering forward into a small stalk, that loosely supports the head.
2. The large side pieces of the synthorax, expanded to meet in front of the wings above, and behind the legs below. This is the "housing" of the immense wing muscles of these strong flying insects.
3. The two pairs of spiracles of the synthorax; one above the base of the middle leg and the other at the front partially concealed by the overlapping margin of the prothorax.
4. The position of the legs and the direction of the spines on them: in flight these are so carried as to form a big basket, that is thought to be useful in capturing prey—bagging it, so to speak, as in a net.

III. *In the abdomen.*

1. The pair of infolded longitudinal furrows along the sides. The abdominal spiracles are in these furrows, which expand, bellows-like, with the respiratory movements.
2. The swollen region about the 2nd and 3rd segments. In the male there is a special development of copulatory apparatus underneath these segments that is another peculiarity of this order of insects.
3. The short appendages at the end of the abdomen, longer and clasperlike in the male. Beneath the tip of the abdomen of the female there is a flat ovipositor

in the big blue and green darner dragonflies, but it is wanting in the skimmers.

With a damselfly in hand, note:

1. The differently shaped head and wider spacing of the compound eyes.
2. The slenderness of the body and the greater obliquity of the thorax.

Fig. 20.—The nymph of the damselfly, (*Enallagma signatum verticalis*).

3. The similarity of fore and hind wings.
4. In the male the four appendages (two pairs) instead of three at the tip of the abdomen.
5. In the female the sharp-bladed ovipositor that is used for cutting holes for eggs in the stems and leaves of green plants.

b. *The Nymph*

With a dragonfly nymph in hand note:

I. *In the head.*

1. Short antennae, less slender than in the adult.
2. Compound eyes, less expanded than in the adult.
3. Sharply toothed jaws of the same carnivorous type.
4. A very remarkable grasping lower lip that is hinged in the middle and folded backward beneath the head. When closed its tip rests against the lower part of the face, but it can be thrust far forward like an arm for grasping prey, and its tip is armed with hooks and

spines. Its palpi are modified into a pair of grasping lateral lobes. These are flat and naked in the nymphs of the darners but in the skimmers they are broad and concave, and when closed together the tip of the labium is spoonshaped and covers the face almost up to the eyes. No other creature has a lip like this. It is quite distinctive of this order of insects.

II. *In the thorax.*

1. The relatively greater size of the prothorax.
2. The backward extension of the hind legs.
3. The inverted position of the wing cases, the hind wing on top, as in grasshoppers.

III. *In the abdomen.*

1. The ten free segments.
2. The wide expansion at the rear, providing space for the gill chamber in which the alimentary canal terminates.
3. The five sharp spines at its tip: between these are three minute valves that guard the opening into the respiratory chamber. Through their fringed edges the water is strained as it enters.

In the damselfly nymph, the most noteworthy differences are in the slenderness of the body and in the respiratory apparatus. There is no internal gill chamber, but instead there are three large, oval, platelike gills attached to the tip of the abdomen. The air tubes entering these have already been noted (p. 25).

VI

EPHEMERIDA

Mayflies

This is a small group of aquatic insects, very unique in form and habits. The nymphs live in the water—in all fresh waters—and are everywhere available. Adults are on the wing for a brief season,* and are seen in flight only on certain hours of the day. They are, therefore, little noticed by most persons. Certain large species that emerge from the water all at one time and swarm for a few days by the lake or riverside are well enough known; for they fly to lights in city streets and cover the lamp posts and sidewalks. The cast skins they leave behind on emergence from the water float on the surface and drift in windrows upon the shores.

Being weak flyers and easy to catch, there is no difficulty about obtaining specimens in any number at swarming time. They are best preserved in alcohol.

The most remarkable thing about this group is perhaps the brevity of the life of the aerial adult† as compared with the long life of the aquatic nymph. The longest lived adult mayflies live several days, but their nymphs live several years. The shortest lived among them live as adults but a few hours. Mouthparts are lost at transformation, and hence there is no more feeding after that, but only swarming and

* Whence the name of the order: *ephemeros*, living but a day.

† Read in this connection Benjamin Franklin's *Soliloquy of a Venerable Mayfly, that had lived 420 minutes.*

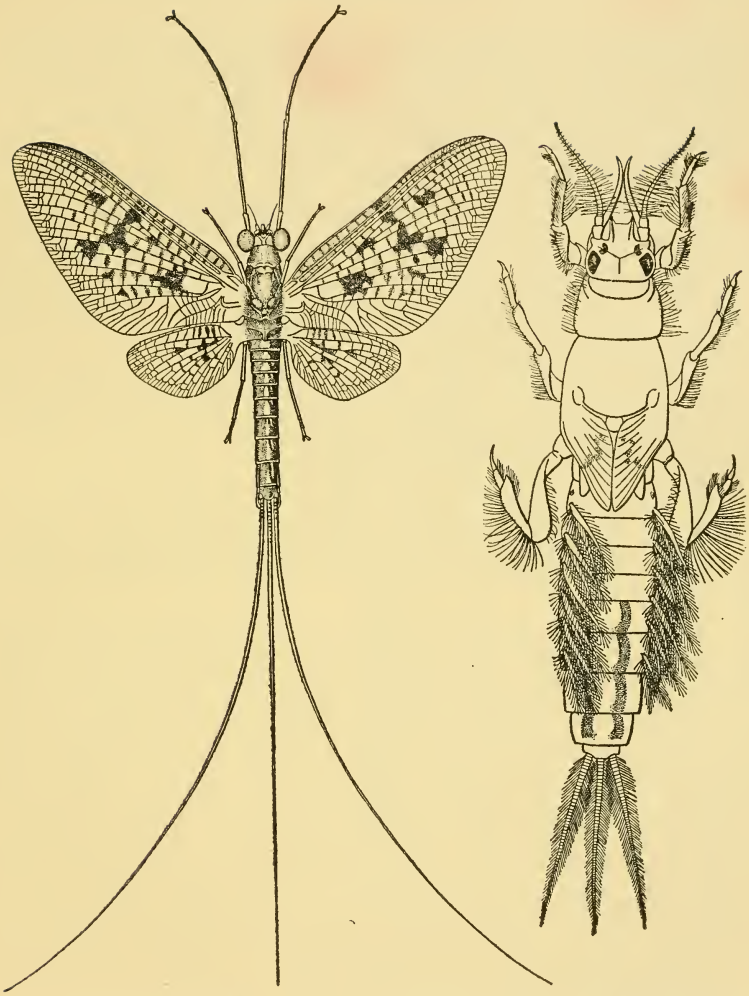


FIG. 21.—The mayfly, *Ephemera simulans*, adult and nymph (Drawing by C. H. Kennedy).

mating and egg-laying. Feeding and growth are the business of the nymphs: provision for posterity is that of the adults; and these two major functions of all living things are in mayflies sharply separated.

The living material, available during the school year, will be mainly aquatic *nymphs*. These abound in all fresh waters and are easily collected. They may be at once distinguished from all other animals by the presence of paired leaflike gills upon the back of the abdominal segments. There are three principal forms of mayfly nymphs:

1. *Climbing forms*, such as shown in figure 8A. These are mainly pond species, found climbing among water weeds. They are easily taken with a dip net.

2. *Burrowing forms*, that live in the bottom mud, especially where it is somewhat sandy (see fig. 21). These may be scraped up and sifted out from the mud with a sieve net.

3. *Close-clinging forms*, that live in moving waters, in rapids of streams, or on lake shores. They are very flat and lie with legs outspread upon the surface of submerged rocks or logs. When a stone is quickly lifted from the rapids and turned over they appear almost as if engraved upon its surface; they may then be picked from the stones by hand. They soon die for lack of air if kept in still water; and are best carried to the laboratory in so very small amount of it that they are partly exposed to the air in transit. They may be kept alive only in running water. A cage of the form

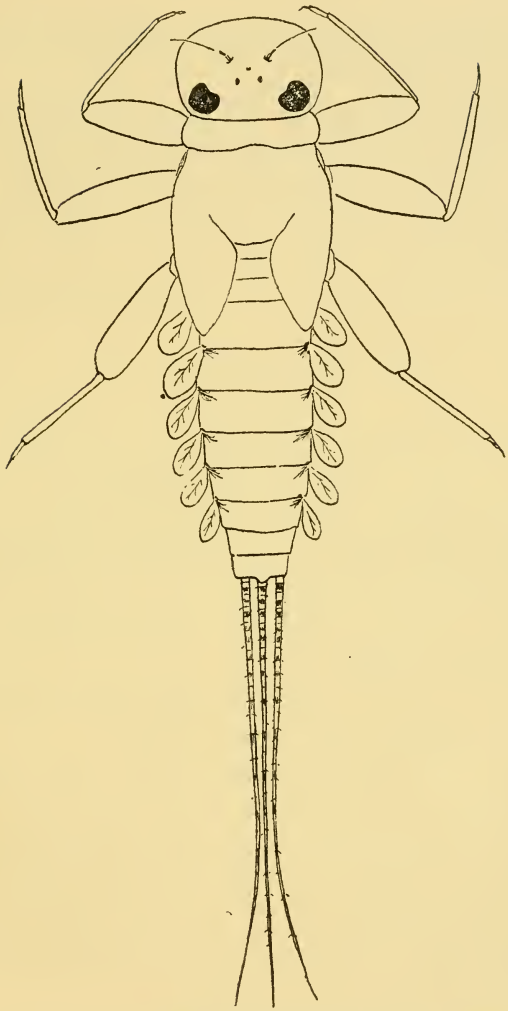


FIG. 22.—The flat nymph of the mayfly *Heptagenia elegantula*. Drawing by Elsie Broughton.

shown in figure 70 placed under a water faucet, partly immersed, will keep them.

Though life after leaving the water is brief, yet there is an additional molt that is not found in other insects—another casting of skin after the adult form is assumed. The first form (*subimago*) has dull surfaces and the wings bear a fringe of pale pubescence. The ultimate form (*imago*) has shining surfaces and naked wing borders; also, longer legs and tails.

LESSON 5

Mayflies

WORK PROGRAM

1. Collect adult mayflies, if in season; if not,
2. Prepare dry specimens for study by an overnight stay in a relaxing jar (see p. 186).
3. Collect nymphs of the flat type from stones or logs in streams (hand picking).
4. Collect nymphs of the burrowing type from the sandy beds of streams or ponds (use sieve net).
5. Collect the ordinary nymphs from weedy pools and trash in ponds. (Use any sort of water net.)
6. Place the flat nymphs in a screen cage (see p. 199) half immersed in a jar of water placed under a water-tap and keep the water flowing.
7. Keep the live burrowers in a jar having the bottom covered with clean-washed fine sand.

8. Keep the others in an aquarium with water weed and exclude all carnivorous animals.

9. Pin and mount a few specimens on a spreading board.

10. Prepare slide mounts of the wings of the adult.

11. Prepare slide mounts of the legs and tails of the adult.

12. Prepare slide mounts of mouthparts of any of the nymphs.

13. Routine (see p. 204).

LABORATORY PROGRAM

A. *The Study of Living Specimens.*

Adult mayflies must be studied in the field, where, only, they behave normally; but the living nymphs are quite available for study in the laboratory. In all of them first note the presence of paired more or less leaflike gills on the back of the abdominal segments—this is the best distinctive mark of a mayfly nymph. Then note:

1. The shuttle-like shifting of the gills for contact with fresh water and better aeration.
2. The use of the legs in climbing and clinging.
3. Their rather indifferent swimming by undulations of the body and backward lashings of gills and tail.
4. Throw a burrowing nymph out of the sand and watch it dig in again. Observe how it lifts with its tusks, scrapes the sand aside with its front feet and pushes with its hind feet.

5. Chase a flat nymph about the surface of a stone and see how it runs sidewise, with legs extended and claws gripping the surface.

B. *Study of Preserved Materials*

a. *Adult*

With specimens outspread for examination first observe whether both imagos and subimagos are present (the latter dull-surfaced, as stated on p. 64, and sometimes more deeply colored). Then, with either, note the following peculiarities of the order:

The softness of the body and the slenderness of its fragile appendages. The long front legs extended forward, balancing the long tails extended backward. Both serve as "outriggers" in flight. The mayfly does not walk. It stands on middle and hind legs, holding the front ones extended forward. Then note further:

I. *In the head.*

1. The absence of mouth parts, except for mere functionless rudiments of jaws.
2. The minute bristle-like antennae.
3. The huge compound eyes, larger in the male, each more or less separated into two divisions, upper and lower, having facets of different size.
4. The nose-like ridge on the face and the three ocelli above it.

II. *In the thorax.*

1. The great size of the mesothorax; it contains the muscles that move the large fore wings. Note its form and finish.
2. The excessive length of the fore legs, especially in the male.
3. The five segments of the tarsus, consolidated basally with the tibiae in middle and hind legs.
4. The form of the tarsal claws. Are those on each tarsus alike in form?
5. The small size of the hind wing and the lengthwise furrowing and dense venation of both wings.

III. *In the abdomen, note.*

1. The ten free segments.
2. The two or three long tails.
3. In the males, a pair of jointed *forceps* beneath the terminal segments.

b. *Nymphs*

In any of the three types observe:

1. The biting mouthparts.
2. The slender antennae.
3. The large compound eyes.
4. The one-jointed tarsi, each with a single claw.
5. The wing cases right side up (not inverted, as in dragonfly nymphs).

6. Paired gills on the back of the abdomen on some or all of the first seven segments.
7. The long tails.

In a nymph of the climbing type note:

1. The more or less grasshopper-like form of the head.
2. The large laterally directed eyes.
3. Smoothly tapering body.
4. The densely fringed tails.

In a nymph of the burrowing type note:

1. The more tapering front.
2. The huge tusks projecting forward on the mandibles.
3. The smaller eyes.
4. The flattened front tibia, shovel-like, adapted for digging.
5. The oblique-tipped hind tibiae, adapted for pushing.
6. The feathery gills, close laid on the back.
7. The paler color.

In a nymph of the close clinging, flat type note:

1. The thin flaring margin of the head.
2. The dorsal position of the eyes and antennae.
3. The ventrally placed mouth.
4. The prothorax, broad and evenly contoured.
5. The flattened legs with fringed hind margins.
6. The down bent claws.
7. The wide spreading, thinly fringed tails.

VII

HEMIPTERA

The True Bugs, and Their Allies

This is a very large and a very important order of insects, readily distinguished from others by the form of the mouth-parts. These are combined into a jointed beak that is adapted for puncturing and sucking (see figure 26). Palpi have disappeared, and the prolonged labium enwraps the other parts in its up-folded edges. Two pairs of slender, chitinous, bristlelike stylets inside the sheath thus formed represent the two pairs of jaws. These stylets are channelled internally, so that when placed together they form a sucking tube. Their tips puncture: a muscular pharynx at the base of the stylets sucks through this tube. This group is thus equipped for obtaining either the sap of plants as in the squash bug, or the blood of animals, as in the bedbug.

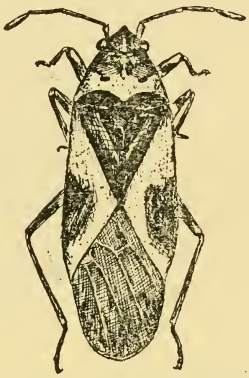


Fig. 23.—The red milkweed bug, *Oncopeltus fasciatus*. (From the author's *General Biology*.)

The nymphs in this group so closely resemble the adults, there is seldom any difficulty in recognizing their identity. They are mostly of similar habits.

There are four great groups of Hemiptera that everyone should know, two of larger and two of smaller size.

I. The horny-winged bugs (*Hemiptera* proper) in which the fore wings are half horny (the basal half) and half membranous.*

II. The membranous winged bugs (*Hemiptera-Homoptera*†) in which the fore wings have a more uniform texture.

III. The aphids, or plant lice, minute and gregarious and mostly wingless.

IV. The scale insects, or bark lice.

LESSON 6

Bugs

WORK PROGRAM

1. Collect some bugs from any weedy pool of permanent water.

2. Collect some squash bugs or any similar broadbacked plant bugs in the garden. Adults and young and eggs of the squash bug may all be found together on the same vine of squash or cucumber or pumpkin.

3. Collect some of the membranous winged Homoptera, such as cicadas or tree hoppers.

4. Collect some of the minuter members of this same group, leaf-hoppers or lace bugs, together with their cast nymphal skins (the latter to mount for study of mouth-

* *Hemi*, half and *pteron*, wing.

† *homos*, alike.

parts)*; these may often be found sticking to the underside of leaves of small fruit bushes in the garden.

5. If dried specimens of any of these, or of any other Hemiptera are to be used, give them a stay over night in a relaxing jar. Some carnivorous forms, like bedbugs and assassin bugs, may be included.

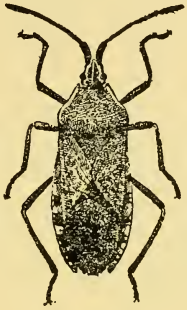


FIG. 24.—The squash bug. (From Chittenden).

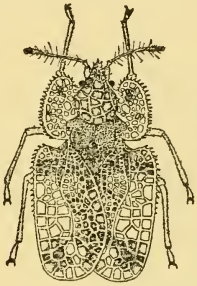


FIG. 25.—A lace-bug (from Wellhouse).

6. Collect aphids and scales by bringing in stems bearing colonies.

7. Set up jars or aquaria for the water bugs, and live cages for the others.

8. Make slide mounts of the heads taken from cast skins of

* Many nymphs of leaf hoppers, previous to molting anchor themselves by their beaks deeply sunk into the vein of a leaf on the under side. It is easy to find the cast skins that are left hanging by their beaks; and there is no better material for showing how they puncture the plant tissue, and why they do not get the poison when that is sprayed on the plant. Just cut out a bit of the leaf with the nymph skin hanging to it, and mount it for the microscope by the simple method outlined on page 190.

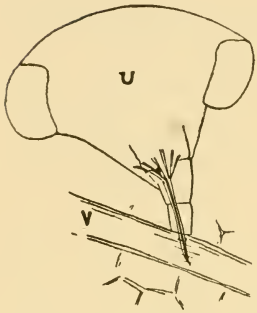


FIG. 26.—Diagram of a bug's puncturing apparatus. *U*, head of a leaf lopper with its beak inserted into *V* the vein of a leaf.

some of the small Homoptera for use in study ing the mouthparts. Mount a number of heads on each slide, and with needles separate the stylets, and different views of the mouthparts will then be obtainable.

9. Make slide mounts of fully expanded wings of both horny and half-horny wings.

10. Make slide mounts of both wingless and winged aphids, whole specimens.

11. Pin, mount and label for exhibition a variety of the odd bugs obtained by sweeping vegetation.

12. Home problems on crop pests (see p. 174).

13. Routine (see p. 204).

LABORATORY PROGRAM

A. *Study of the Living Specimens.*

1. Observe in the rearing cage how the bug feeds. Find the punctures made by its beak in the plant tissue. Try to find one with its beak deeply immersed, sucking the sap from beneath the surface. This one will explain why arsenicals and other food poisons applied to the surface are ineffective against true bugs. They escape the poisons by feeding from beneath them.
2. With a colony of aphids on a stem in hand, look them over for:

(a) Winged and wingless individuals.
(b) Big and little individuals. Those of all ages live together gregariously.
(c) Old ones in the act of giving birth to young.
(d) Feeding individuals: poke one and make it withdraw its beak from the plant.
(e) Restless individuals, that in walking about get kicked at by the others in passing.

FIG. 27.—Aphids; winged and wingless forms of the same species.

3. Try out a contact insecticide, like nicotine sulfate, with a colony of greenhouse aphids (see p. 146). Potted plants in the window garden will often furnish aphids enough for this. The "dope" may be sprayed on with an atomizer, or a colony on a slender shoot may be dipped in a dilute solution. Note the result next day.

B. *The Study of Preserved Materials.*

a. *The Adult*

With a specimen of a squash bug or any similar bug in

hand compare part by part with the insects of the other orders studied, noting especially:

1. The broad, stout body, closely overlaid behind by the overlapping wings.
2. The head tapering forward to the beak.

In the head note:

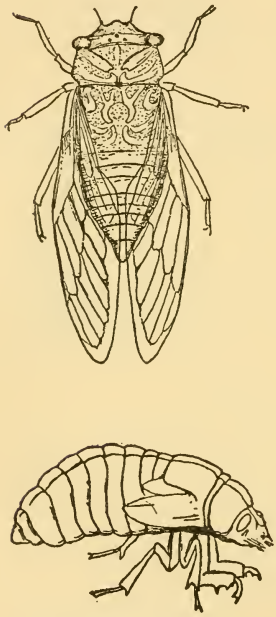


Fig. 28.—The cicada and its nymph.

1. The jointed beak, directed backward between the fore legs when not in use. Its composition may best be studied in microscopic mounts of heads of some of the small Homoptera. The usual mouthparts are present but in greatly altered form. The jointed sheath enclosing the other parts is the modified labium. Two pairs of channelled stylets, laid close together to form the sucking tube, represent the maxillae and mandibles, and a small lancet-like pointed labrum overlies their bases in front.
2. The prominent few-jointed antennae.

In the thorax note:

1. The angular form of the prothorax.
2. The openings of the stink glands, a pair of minute pores on the sides of the mesothorax beneath, close to

the basal segment of the legs. The odoriferous secretion that issues from these pores is highly protective.

3. The peculiar form and texture of the close-fitting fore wings. Note that the membranous tip is obscurely veined, and that the horny basal portion is subdivided into definite areas by thin membranous sutural lines of joinings. Compare with a homopterous fore wing.
4. The thinner hind wings. Open and close them and note the manner of their folding.

b. *The Nymph*

With a nymph of the same species in hand, note that it differs from the adult chiefly in size and in lacking wings. Observe that the sheaths of the developing wings are right side up (not inverted as in the jumping Orthoptera). Greater differences in form will be found in those membranous winged bugs in which nymph and adult differ greatly in habits. The homely burrowing nymph of the cicada,* for example, with its pointed head and great flat, scraper-like fore legs, is very different from the ornate arboreal adult insect.

Compare other available bugs. There are so many diverse forms in the vast order, it will not be practical to offer here any further specific outline. Consult the larger text books for further information. Read in these books about the remarkable life histories and habits of the aphids and the scale insects.

* Cast nymphal skins of the 17-year cicada ("locust") are at times available in vast quantities. They are easily gathered and stored in a box, and will serve excellently for showing how completely the external skeleton with all its internal processes, is shed at transformation.

VIII

TRICHOPTERA

Caddisflies

This is the largest group of aquatic insects. The adults are abundant enough at the waterside, but they are mostly of rather small size and obscure coloration and nocturnal habits, and they are by most people little noticed. The wings and body are covered with hair.* The antennae are long, often very long, and are extended forward when at rest. Both maxillary and labial palpi are well developed, though the biting parts of these organs are not. The wings are extended to rearward, and meet roof-like above the abdomen. The legs are slender. The tarsi are 5-jointed and the tibiae are armed with large spurs—often more than one pair of spurs on each.

They are quite inoffensive. Their jaws are little developed and they cannot bite. Only by fluttering in people's faces when extremely abundant, do they cause any inconvenience.† They are oftenest seen when gathered about waterside lights at night, or resting motionless on boats and docks by day.

The young of the caddisflies, called caddisworms, are better known. Their interesting habit of constructing cases in which to dwell, and carrying these cases about on their

* Hence the name of the order: *trix* hair, and *pteron*, wing.

† It was a small caddisfly of the Niagara River (*Hydropsyche chlorotica*) that caused the site of the Pan American Exposition in 1892 to be relocated inland, far away from the river site first selected. It was thought that visitors would not like them, even though harmless.

backs has been noted by everyone who looks into a brook.

The net-making caddisworms (Hydropsyche) live among the stems and stones in the rapids of streams. Their young are *larvae* and not nymphs. They differ most markedly from the nymphs of the groups we have been considering in being more wormlike in form, in having a greater development of the abdominal region of the body, less development of the eyes, antennae, palpi and legs, and no externally visible development of wings at all. This last character at once distinguishes all true larvae of insects from nymphs.

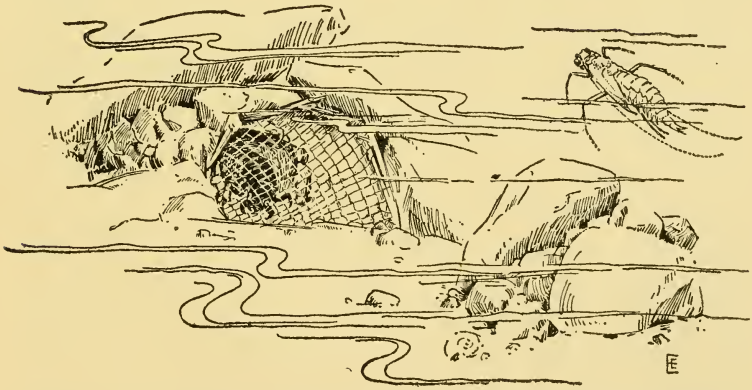


FIG. 29.—The net-making caddis fly Hydropsyche. At the left below is a larva in its shelter, its head behind its catching net. At the right is a pupa that has left its pupal chamber under the barricade of stones below, and is swimming to the surface to transform. Above is the adult caddisfly. The line at the right shows actual length.

They differ correspondingly in their transformations. When the larva is grown and the last larval skin is cast, out of it comes the pupa. Then appear the organs of the adult, long legs and antennae and wings, etc., but not at once in condition for use. They are folded closely about the body and so remain during a long resting period.

All feeding is done for life in the larval stage—the stage of growth and fat accumulation. The pupa is the stage of making over. The adult is the stage of reproduction, mating and egg-laying.

Let us now follow the life history of a caddisfly. The net-maker, Hydropsyche, is one that can be found about any clean brook, where their larvae dwell in the riffles. The oblong brownish eggs are laid on the underside of sticks or stones, the female creeping down under water to deposit them. She lays them on their sides in dense patches one layer deep, in part in regular rows, and covers them over with a thin transparent gelatinous secretion. The patches, often as large in area as a penny, and chocolate tinted, are easily found in their season by lifting and overturning stones.

The larvae that hatch from these eggs construct for themselves fixed shelters at the edge of the current. They spin silk and use it to attach bits of sand and rubbish all over the outside in making these shelters. Then they spin delicate nets of silk at the head end, next the current. These are beautiful fine-meshed nets, attached at their edges below and by stay lines above, that swing, baglike, down stream.

They serve for catching food which the current sweeps into them. The larva lies protected within its shelter with its head conveniently near to the bottom inside of the catching net. Here at the bottom is a catching surface of much finer mesh—a sort of woven dinner plate.

In any riffle of a clear brook one may find these nets. They are usually dirty from accumulated silt. They are often somewhat funnel-like as seen from above. When made by full grown larva they are about big enough to hold the tip of one's thumb. They hang on the face of the stones or stems, where the water may fall or glide into them. They are to be found only in flowing water.

Larvae may be easily obtained by taking them from their shelters with a forceps or with a knife blade.

When we examine a larva we find it has a rather soft, thin-skinned, cylindric body with a hard horny head (this part being often exposed from under the shelter) and with a pair of large draghooks at its rear end.

It has typical biting mouthparts, but with reduced palpi. It has gills in dense tufts of clustered filaments underneath the abdomen. Its rather strong legs are directed forward for easy extension beyond the tubular shelter, and the front tibia bears a rather distinctive spine. The paired draghooks on the last segment of the body serve as an anchor to rearward, holding firmly in the walls of the shelter tube. When the larva has completed its growth, it builds a more substantial shelter of pebbles or bits of wood and transforms within it to a pupa of the form shown in figure 29. One may

find these shelters commonly on the underside of submerged stones and may get the living pupae from them by picking away the pebbles and carefully opening the cocoon with a forceps. When the outer part of the cover is removed one may see through the transparent silken lining of the shelter that the pupa is not wholly inactive. Its body undulates regularly, in such a way as to drive a current of water backward through its case. The pupa also breathes by means of gills. Its middle legs are provided with marginal fringes of hairs, adapting them for swimming. It possesses big mandibles, with which at the last it cuts a hole in the end of its case. Then it comes out, and swims to the surface of the water, and molts the pupal skin, and steps out into the air as an adult caddisfly.

LESSON 7

Caddisflies

WORK PROGRAM

1. Collect adult caddisflies at lights at night.
2. If dried specimens are to be used, give them a stay over night in a relaxing jar.
3. Collect larvae and pupae of the net-maker (Hydropsyche) from the riffles in streams (see p. 183).
4. Collect different kinds of caddisworms in portable cases from ponds (see p. 182).
5. Set up a net trough (Fig. 70) with running water; put in

some living larvae, and get some new, clean nets "made to order" in the laboratory (see p. 197).

6. Set up some jars or aquaria with pond caddisworms in them and water plants.

7. Mount for exhibition a few adult caddisflies. Use a spreading board and extend the wings fully.

8. Make slide mounts of the head and legs and draghooks of the larva.*

9. Make slide mounts of the head of the pupa to show its big mandibles.

10. Make slide mounts of the wings of the adult caddisfly.

11. Routine (see p. 204).

LABORATORY PROGRAM

A. *The Study of Living Specimens.*

1. At the net-maker's trough, if the larvae have established themselves in it, observe:

   (a) The nets, opening upstream, distended by the current, attached directly below and with stay-lines above, tapering to the finer meshed feeding surface at the bottom where the head of the larva enters.

* Inside the pupal case, at the rear end of the pupa will be found the crumpled-up, cast-off skin of the larva, with these hard parts perfectly preserved and freed from muscles and other tissues, furnishing the best of material for making these slide mounts.

(b) The shelter tube, built in a crevice lined with silk, to the surface of which sand grains and bits of tissue may be attached, its front end opening into the bottom of the net.

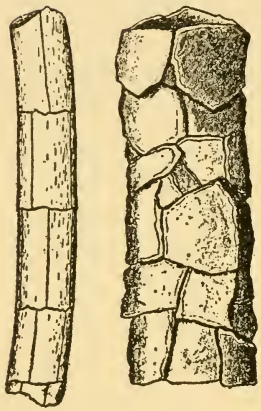


FIG. 30.—The portable cases of two species of caddis worms (from Lloyd).

(c) The larva, with brown head sometimes visible in the bottom of the net, retreating well inside when disturbed by means of a pull on its draghooks.

2. In aquaria watch the caddis-worms in portable cases drag their lumbering houses about. See them retreat inside when disturbed, and see them come out again. Some may be seen feeding on the plants present.
3. Pick up one of the larger cases containing an active larva, and drive the larva forward out of its case by poking a match stick into the case at the rear. Put the larva, naked, into the water and observe what a helpless creature it is when deprived of its proper shelter.
4. If you have at hand the living larvae in cases of the form shown in figure 30, or any other similar large form, drive the larvae out of one case, and put it and another larva in a dish of water with a single case, and watch them strive for the possession of that case.

5. Remove a living pupa from its case, and watch its respiratory movements.

B. *The Study of Preserved Specimens.*

I. *With adult specimens in hand, note.*

1. The general hairiness of wings and body.
2. The long slender antennae.
3. The rather small eyes.
4. The reduced mouthparts bearing two pairs of well developed palpi.
5. The slender legs with large spurs on the tibiae, usually a different number of these on front and middle legs.
6. The broad wings, fore and hind of nearly equal size, and of rather similar venation.
7. The cylindric, thin-skinned hairy abdomen, quite distinct from thorax, and with short appendages at its tip.

II. *With a caddisfly pupa in hand, note.*

1. The appendages, close folded against the body.
2. The large mandibles.
3. The gills upon the abdomen—this is the only group of insects that is truly aquatic in its mode of respiration in the pupal stage.
4. The lateral fringes of the abdomen; these aid in driving water through the tube when the body is waved up and down.
5. The spines at the tip, and the teeth on the back of the abdomen.

III. *In the caddisfly larva, note.*

1. The wormlike form.
2. The heavily chitinized exposed parts and the soft mid-body.
3. The biting mouthparts.
4. The short antennae and the small eyes.
5. The strong legs directed well forward for protrusion from the shelter-tube.
6. The short tarsi.
7. The spine-bearing front tibia.
8. The absence of wings externally.
9. The horny, rubbing surface underneath the last abdominal segment.
10. The gills in clusters underneath the body.
11. The pair of false legs (prolegs) at the rear end of the body and the paired draghooks with which they are armed.

IV. *With a variety of cases at hand observe.*

1. Their diversity in form.
2. Their materials.
3. Their manner of construction.

Note that they all have a lining of silk.

IX

NEUROPTERA

Lace-wings, Dobsons, etc.

This is a small order of carnivorous insects of peculiar and interesting form. The wings are broad and nearly equal and full of veins or nervures, as the name signifies,* and these veins have more than lace-like delicacy and beauty of design. The antennae are long. The mouthparts are of the biting type already described. The tarsi are 5-jointed, and there are no tails.

These insects are often more or less local in range, and not all of them are everywhere available, but they are common enough in proper situations. Dobson flies and their larvae "hellgrammites," are among the insects best known to the fishermen who catch them for bait in the riffles of rapid streams.

One of the commonest Neuroptera is the lace-wing fly. This we will have encountered already in our sweeping of the vegetation; a slender green insect with shining golden eyes and exquisite gauzy wings with green veins. It is distinguished also by its bad odor. We may have seen the eggs attached to some green leaf—oblong, chalky-white eggs, each on a white, threadlike stalk half an inch long. The mother lace-wing with wonderful instinct puts out with each egg a drop of fluid silk and then lifts the egg, drawing the silk out into a stalk beneath it, holds it an instant while

* *Neuron*, nerve and *pteron*, wing.

the silk hardens and then leaves it there, high up out of the way of creeping predatory enemies.

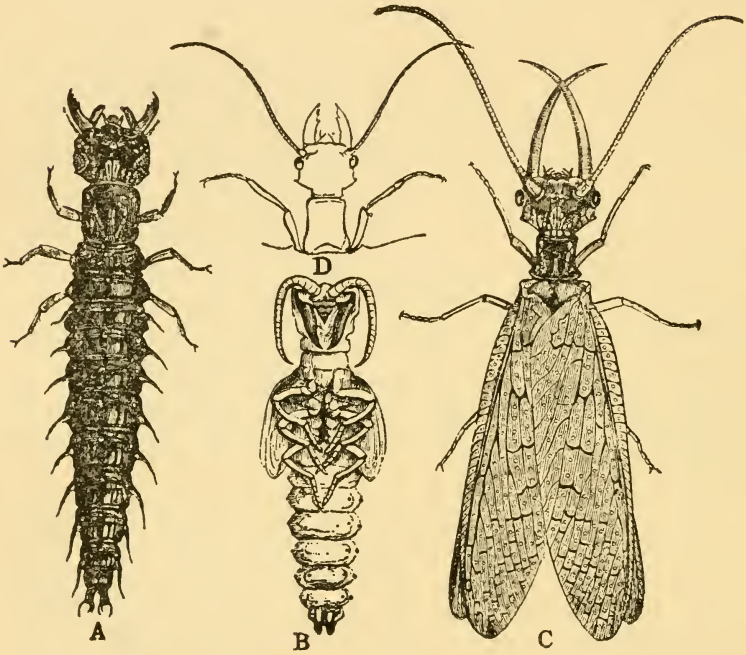


FIG. 31.—The dobson, *Corydalis cornuta* (after Lintner); *A*, its larva (known to fishermen as the "hell-grammite"); *B*, the pupa; *C*, the adult male; *D*, the head of the female (note the shorter mandibles).

The larva that hatches from the egg creeps down the stalk, and at once starts foraging. It is a very useful insect for it eats aphids (whence the name "aphis lion" by which it is sometimes known), and has a big appetite. It is one of

the most important of nature's agencies for keeping these plant pests in check.

Its mouth parts are very peculiar. On first glance it seems to have one pair of big pincher-like sharp-pointed jaws, but each half of the pincher is a sucking tube. It sucks the blood of an aphid through two straws, so to speak. The mandible and the lacinia of the maxilla of each side are prolonged

FIG. 32.—The lace-wing fly, Chrysopa. Two adults, a larva below on the stem and a cocoon containing a pupa under the leaf (from Kellogg.)

together, channelled and closely united and pointed at the tip to make this grasping, puncturing and sucking pair. If living larvae, swept from the vegetation, be placed with a colony of aphids, the use of these jaws will be quickly demonstrated.

When the larva is fully grown, it spins a spherical, tight-fitting cocoon of white silk about itself on the underside of some leaf and transforms therein to a pupa. This pupa also has big horny, free mandibles. When matured it lifts a circular lid in one side of the cocoon, pushes out, clambers to a favorable position on a leaf and casts its pupal skin, and becomes the beautiful aerial lace-wing.

There is great diversity of form and size and appearance among the different members of this remarkable order, as may be learned by consulting any of the larger textbooks of entomology. We shall content ourselves here with a brief outline for a study of three outstanding types represented by the green lace-wing, the ant-lion and the orl fly.

LESSON 8

Lace-wing, Ant-lion and Orl Fly

WORK PROGRAM

1. Collect adult lace-wings at lights, or
2. Collect adults and larvae by sweeping vegetation.
3. Collect cocoons and eggs with the leaves on which they are found.
4. Cage an aphid colony for demonstration with living aphis lions.
5. Collect adult ant-lions when they fly to lights at night.
6. Collect living ant-lion larvae from their pitfalls in the sand by sifting.

7. Arrange sand boxes in which these living larvae may construct new pitfalls.

8. Collect, cage and keep ants for food for these living larvae.

9. Collect orl flies when they swarm by the waterside.

10. Collect orl fly larvae from sandy shores by sifting with a sieve net.

11. Arrange dishes of sand in water for keeping them alive indoors.

12. Pin, mount and label a representative lot of Neuroptera for the collection.

13. Make slide mounts of an aphis lion's head and feet.

14. Routine (see p. 204).

LABORATORY PROGRAM

A. *The Study of Living Specimens.*

1. Place lace-wing larva that has been kept without food for several hours in the midst of a colony of living aphids and watch its procedure with them.

FIG. 33.—An ant-lion pitfall in the sand, and an ant near it.

2. If cocoons containing living pupae are at hand, and if chance offers, watch a pupa emerge and clamber upon a leaf and select a place to attach itself firmly and transform.

3. Drop a live ant into a pitfall containing a living ant-lion and watch the result. See the ant-lion try to seize the

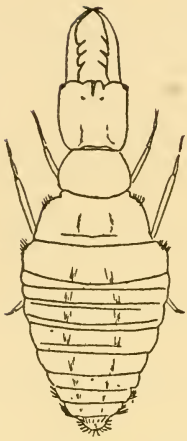


FIG. 34.—An ant-lion (larva) removed from the sand.

ant and drag it down under the sand. If at first it fails, it may toss sand into the air to fall on the ant and drive it downward within reach.

4. Toss a living ant-lion out on the surface and see it run backward and dig into the sand again.

5. Note how the sand grains are held about the body by the curved and appressed hairs that cover it.

6. Destroy the pitfalls and see them renewed over night.

7. Throw a living orl fly larva into a dish of water whose bottom is covered with fine, clean-washed sand and see it "dig in."

B. *The Study of Preserved Specimens.*

I. *The lace-wing*

a. *The Adult:*

With an adult in hand, note:

1. The general green color of the body.
2. The distinctness of the three regions of the body, head, thorax and abdomen.
3. The long, slender antennae.
4. The hemispherical, shining eyes.
5. The biting mouthparts with rapacious jaws.

6. The broad, transparent wings, of similar form and size folded together and resting rooflike above the abdomen.
7. The absence of tails.

b. *The Pupa*

With a pupa in hand, note:

1. The free appendages.
2. The large eyes.
3. The large, sharp mandibles.
4. The large palpi.

Fig. 35.—An adult ant-lion fly.

c. *The Larva*

With a larva ("ant-lion") in hand, note:

1. The spindle-shaped body beset on the back and sides with warty tubercles that bear stiff hairs.
2. The slender and very sharp-pointed antennae.
3. The small eyes, compounded of a few large facets.
4. The pincher-like jaws, each half of which is a hollow tube made of a mandible and maxillary stylet, placed with channelled sides in apposition. The outer opening is just before the tip. The inner opening communicates with the mouth. There is a pumping apparatus developed in the pharynx. Through these tubes the blood of an aphid, impaled on these tips, is sucked into the mouth.
5. The shorter and blunter labial palpi underneath.
6. The short legs with one-jointed tarsi, each bearing

two claws and a remarkably developed sucking pulvillus.

7. The absence of wings.

II. *The Ant-lion.*

With an adult ant-lion fly in hand, note:

1. The club-shaped antennae.
2. The sharp-toothed, rapacious jaws.
3. The long, elegant, gauzy wings.
4. The spiny legs.

With a larva in hand, note:

1. The humpbacked body, narrowed forward to the neck.
2. The pointed rear end, clad with stiff hairs that point forward.
3. The forward slant of the spiny legs. All these things facilitate moving backward in the sand.
4. The huge forceps-like jaws, similar to those of the aphis lion, but larger and toothed inside for holding larger, struggling captives.

III. *The Orl Fly.*

With an adult in hand, note:

1. The broad, smoky wings and dusky body.
2. The long antennae.
3. The biting mouthparts.
4. The depressed thorax.
5. The slender legs with 5-jointed tarsi.

With an orl fly larva in hand, note:

1. The wide, smooth head.
2. The slender antennae and small eyes.
3. The big, biting jaws.
4. The digging fore legs.
5. The lateral filaments projecting like "outriggers" at the sides of the first seven abdominal segments, one pair on each segment.
6. The long, tapering tail.

FIG. 36.—The larva of the orl fly.

X

COLEOPTERA

Beetles

This is the largest order of insects on earth. There are more than 20,000 species of beetles in North America. They are adapted to almost every situation and every kind of food. They "possess the earth" more fully than does any other similar group of animals.

Fig. 37.—Beetles on goldenrod flowers; a locust borer (center), two soldier beetles (at right) and three black blister-beetles (from the author's *Outdoor Studies*).

Beetles form a very natural and easily recognizable group. They are mostly hard shelled. The fore wings are horny and close fitting over the body, and meet in a straight line down the middle of the back. These form a highly protective sheath.* The mouthparts are formed for biting, and are similar to those of the stonefly described in our opening chapter. The antennae are generally prominent, but vary endlessly in details of form. The prothorax is unusually free, and the synthorax is consolidated with the abdomen. The coxae of the hind legs are closely applied to the metathorax.

* Whence the name of the order (*coleon*, sheath, and *pteron* wing).

The larvae of beetles show considerable variety of form and are known by a variety of names, such as grubs, borers, wire-worms, glow worms, meal worms, and weevils. All are true larvae, lacking wings externally until the pupal stage is reached.

Let us use the locust borer to illustrate the life history of a beetle. This handsome longhorn is blackish in color with yellowish crossbars on the wings. It is found rather commonly on goldenrod flowers in autumn feeding on the pollen. The female beetle lays her eggs on the bark of locust trees. The larvae bore into the trunk of the tree and feed there for nearly a year, and then transform within their burrow, becoming pupae. A few weeks later the handsome adult beetles emerge.

LESSON 9

Beetles

WORK PROGRAM

1. Collect water beetles and their larvae from a pond.
2. Collect ground beetles and their larvae from under stones, boards, etc.
3. Collect flower-visiting beetles on goldenrods, asters, etc.
4. Collect leaf beetles and their larvae from the garden.
5. Collect maybeetles, elaters, darkling beetles, etc., at lights.

6. Collect white grubs and wire-worms from the soil (easiest done while sod is being overturned with the plow).

7. Collect wood borers where seasoned firewood is being split.

8. Collect meal worms from the floor crevices of grain bins.

9. Collect weevils from infested stores of rice or wheat.*

10. Keep larvae of these until they transform, and obtain the pupae.

11. Pin, mount and label representative beetles for the collection.

12. Care for the living material in rearing cages.

13. Home problems on crop pests (see p. 174).

14. Routine (see p. 204).

* If such are not available, here are two sources of weevil larvae that are generally unfailing:

1. Acorns: gather them in quantities as soon as they fall: place them in glass jars; the weevils will come out in a few days and be found in the bottom of the jars; place these on the surface of a box of soil and they will burrow in and (if kept in the laboratory where warm) will transform to pupa by midwinter.
2. Stems of the common weed known as lamb's quarters. The weevils in these transform where they have fed; hence, keep the collected material in a rearing cage (see p. 200), dip it in water every week to prevent death by evaporation if kept indoors, and cut open a stem now and then to note changes going on.

LABORATORY PROGRAM

A. *The Study of Living Specimens.*

Of most beetles it may be said that neither adults nor larvae lend themselves well to observation of habits indoors; but here are a few exceptions:

1. Ladybird beetles and their larvae will demonstrate their usefulness to us if placed in the midst of a colony of living aphids in an observation cage.
2. Leaf beetles and their larvae (such as the potato beetles) will feed normally in captivity if supplied with fresh leaves of their food plants.
3. Adults and larvae of water beetles make interesting specimens for small aquaria, where their swimming, feeding, and air-taking may be easily observed. If the large larvae known as "water tigers" are kept together they will cheerfully eat one another.
4. With such active forms as these it will be well to compare a series of living larvae from soil, stems and seeds to note the progressive helplessness of the latter as they become adapted to a restricted environment. Note the plight of the grubs when out of the soil and of the woodborers when removed from their tunnels.

B. *The Study of Preserved Specimens.*

This group is so abundant we may have much choice of forms for study. More than 100 families of beetles are now

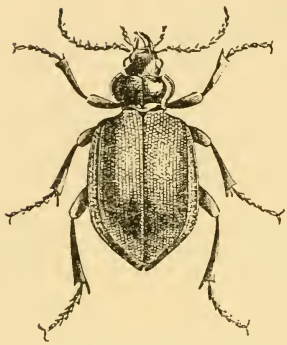


FIG. 38.—A ground beetle, *Calosoma sycophanta*. This species was imported from Europe to prey upon the Gipsy moth in New England.

recognized as occurring in North America. Many of these are small and obscure families, that need not concern us here: but the following fifteen are large and important groups; and representatives of them should be available for this study. We have already (page 15) glanced at the characters that are common to all beetles. Let us now note the family characters in a few of these.

1. *Tiger beetles:* Large, very active, strong flying, diurnal, graceful, beautifully colored, predacious beetles found on sandy beaches. Note the metallic luster, the long legs, the sharp-toothed carnivorous jaws.

2. The *ground beetles:* Mostly flat-bodied, long-legged, blackish, nocturnal beetles found under stones and logs. They run rapidly to cover when disturbed. Note the fine sculpturing of the body, the predacious jaws, the slender antennae, the long legs and the long five-jointed hind tarsi. Many members of this family secrete an ill-smelling fluid that serves for their defense. The Bombardiers secrete a fluid that explodes like a little pop gun, producing a cloud of smoke to alarm and confuse a pursuer. The Bombardiers are yellow with dark blue wing covers.

3. The *water beetles* (Fig. 39): There are several families of these, all similar form, having boat-shaped bodies and flattened oar-like hind legs. These are adaptations for swimming. Note in any of the forms:

(a) The compactness and rigidity of the body.

(b) The predacious jaws.

(c) The naked, slender, reversible antennae.

(b) The difference between the hind (swimming) feet and the other feet.

(e) The difference in some of these between male and female in the form of the fore feet. The ones with sucking discs underneath the front tarsi are the males.

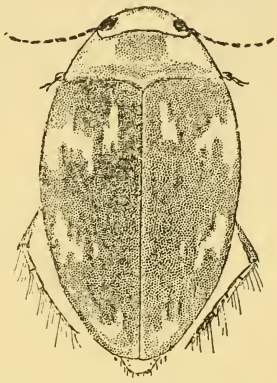


FIG. 39.—A diving beetle *Hydroporous undulatus.*

The most peculiar of water beetles is the group of the whirligigs (Gyrinidae) which have the eyes divided, so that there seem to be two pairs, one for looking up into the air and one for looking down into the water as they gyrate in the surface film. These have an unique form of hind feet.

4. The *rove beetles:* Mostly small, elongate, actively running beetles, secretive in habits, having a very characteristic appearance that is due to the shortness of the wing covers. These cover only the basal segments of the abdomen, and are cut off squarely behind, like a sackcoat.

5. The "*fireflies*": These are not flies at all, but true beetles, rather soft-bodied, with loose-fitting wing covers. They are obscure beetles that would hardly be noticed but for their remarkable powers of illuminating the black summer night with little flashes of light.

Note:

(a) The stout antennae, toothed on one edge like a saw.

(b) The wide prothorax, with margins flaring at the sides and also in front where it more or less completely covers the head.

(c) The yellowish spots underneath one or more of the abdominal segments where the light organs are situated.

6. The *blister beetles* (Fig. 37): Long-legged, nearly cylindric in form, diurnal in habits, commonly found in autumn feeding on the leaves of potatoes and other plants and on the pollen of goldenrods. The defensive secretion that is produced by the living insects has the property of blistering the human skin; and in former times an old world species, known as the "Spanish fly," was dried and powdered to make blister plasters.

Note especially:

(a) The long antennae.

(b) The slender form.

(c) The four-jointed hind tarsi.

7. The *click beetles:* Smoothly contoured, elongate-oval, often very handsome beetles, having a shield-shaped prothorax with projecting hind angles and a remarkable joint

connecting it with the synthorax. By means of the mechanism of this joint one of these beetles when placed on its back can spring bodily into the air. The gray "owl beetle" is one of the largest members of the group. The larvae of the group are known as "wire worms."

Note especially:

(a) The small head and blunt herbivorous mouth parts.

(b) The fine coloring and sculpturing of the body.

(c) The form of the rear of the prothorax.

(d) The grooved hind coxae, into which the hind femora fit.

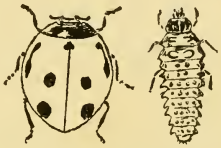


Fig. 40.—The nine-spotted lady-bird beetle and its larva.

8. The *metallic woodborers* or *Buprestids:* These are among the hardest of the hard shelled, often appearing as if cast in bronze. Though somewhat similar in form to the click beetles, they lack the springing joint in the thorax, and they are further distinguished by having the two basal segments of the abdomen fused together on the underside. The larvae are known as flat-headed borers.

Note especially:

(a) The fine sculpturing and coloring of the body.

(b) The short, saw-toothed antennae.

(c) The grooves for close infolding of the legs.

9. The *ladybird beetles* or "*lady bugs*": Little nearly hemispherical beetles, brightly marked with black, white, red, or yellow spots, diurnal in habits and mainly carnivorous,

feeding both as adults and as larvae on aphids and scale insects: hence, beneficial.

Note especially the:

(a) The small head, overshadowed by the prothorax.

(b) The polished surface of the body.

(c) The color pattern.

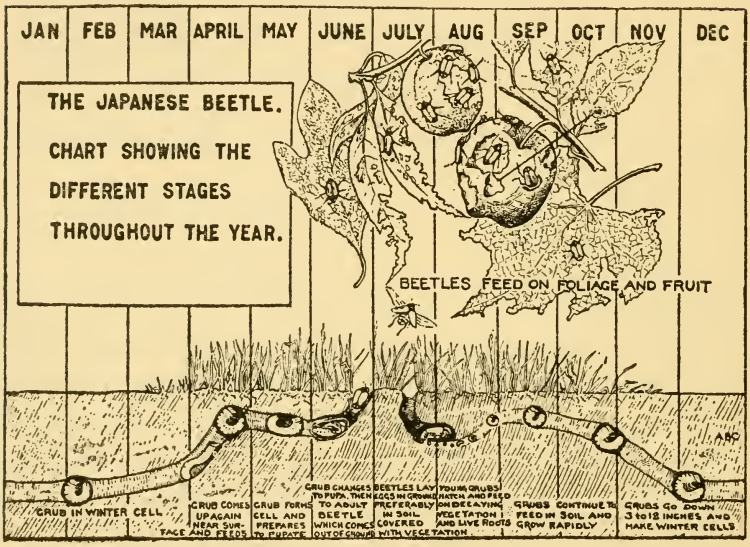


FIG. 41.—Diagram illustrating the seasonal habits of the imported Japanese beetle (From U. S. Dept. Agr.).

10. The *darkling beetles:* Mostly blackish, somewha flattened nocturnal beetles, very numerous in kinds and varied in details of bodily form. Somewhat resembling the ground beetles, but less active, and readily distinguished

therefrom by having the hind tarsi only four-jointed. The one perhaps best known is the meal worm of our granaries.

Note:

(a) The form of the antennae.

(b) The sculpturing of the body.

(c) The joints of the fore and hind tarsi.

11. The *scarabs* or *lamellicorn beetles* (Fig. 41): Stout bodied, convex, herbivorous beetles (the most common ones known as "June bugs"), having spiny legs, and tarsi armed with big claws, and their antennae of very peculiar form, the club at its tip being composed of closely apposed plates. The larvae of the group are known as white grubs.

Note:

(a) The form of the head.

(b) The form of the antennae, especially its club.

(c) The spiny legs.

12. The *stag beetles:* A small group of large beetles, one of which, at least, a big brown fellow with huge pincher-like mandibles on its wide head, is very well known because it flies to lights at night. The antennae are similar to those of the scarabs, but the plates of the club are not closely appressed. Larva, a big white grub.

Note especially:

(a) The wide head.

(b) The long antennae.

(c) The flattened tibia, widened toward the tip and toothed on the outer margin.

(d) The smooth shining, brown body.

(e) The huge mandibles.

13. The *long-horn beetles* or *Cerambycids:* The locust borer just discussed is a member of this family, which includes a large number of the handsomest of insects. Many beautiful species may be found visiting flowers. Their larvae are round-headed borers.

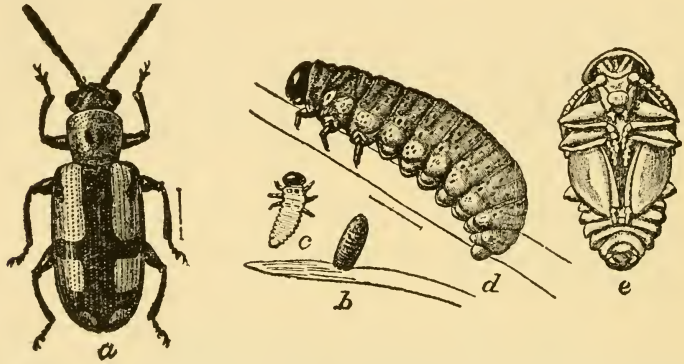


FIG. 42.—The asparagus beetle: *a*, adult; *b*, egg (enlarged); *c*, larva (new hatched); *d*, larva grown; *e*, pupa (after Chittenden).

Note in the adult beetle:

(a) The long nodose antennae.

(b) The waist-like constriction at the rear of the prothorax.

(c) The form of tarsi, with reduced fourth segment, two-lobed third segment, and elongate fifth segment.

14. The *leaf beetles* or *Chrysomelids:* Oval convex beetles, having antennae and legs of moderate length, and a very

great variety of coloration. A large and most important family of leaf-eating beetles, containing some of the worst crop pests (Fig. 42). The Colorado potato beetle belongs here.

Note especially:

(a) The form, sculpturing and coloring of the body.

(b) The blunt herbivorous mouthparts.

(c) The form of tarsi, similar to that of the preceding family.

FIG. 43.—A pine-bark weevil, *Pissodes terminalis* (after Smith).

15. The *snout beetles* or *weevils:* This is a group of several families of small herbivorous beetles, nearly all of which have the front of the head prolonged into a beak, with the mouth parts carried out to its tip and the antennae part way down its sides. They are mostly hard shelled and convex; and there are numberless kinds of them.

Note especially:

(a) The form of the head and position of its appendages.

(b) The antennae elbowed in middle and clubbed at the tip.

(c) The feet, formed as in the two preceding groups.

Compare together beetle larvae of the following types:

(a) Active, free ranging, carnivorous larvae of ground beetles or of water beetles.

(b) Free living but sedentary larvae of leaf beetles.

(c) Soil inhabiting; white grubs and wire worms.

(d) Seed inhabiting weevils.

Compare as to loss of legs, antennae and other appendages, and chitinous covering; compare as to gain of fat. Compare them as to powers of locomotion and defense.

XI

LEPIDOPTERA

Butterflies and Moths

This is a large group of very interesting insects. They number perhaps 10,000 species in North America. The group is recognized by the flat scales that densely cover body and wings, and that rub off on the fingers like dust.* The mouthparts of the adults are of a type that is peculiar to the order. They are formed for sucking. That which appears on a superficial examination is a long slender horny tube, that is coiled up when at rest like a watch spring, lying between a pair of hairy or scaly palpi. A very careful examination is needed to discover the presence of the same parts that we have been noting in other insects; for some of these parts are vestigial, and those that are preserved are very much altered in form. When the scales have been completely removed from the face, the vestiges of labrum (*l*) and mandibles (*md*) appear as shown in our figure; the palpi are seen to arise below the mouth and to belong to the closely applied labium. The intermediate position of the coiled "tongue" naturally suggests that it is a development from the maxillae. It is, in fact, double—a tube formed by a pair of channelled processes placed together, each maxilla developing half of it.

Fig. 44.—Head of a butterfly, with scales removed to show the mouth parts.

* Giving the order its name: *lepis*, *lepidis*, scale, and *pteron*, wing.

The antennae are generally large and prominent. They are knobbed or clubbed on the end in butterflies, and variously formed in moths. The eyes are large and the ocelli are small and often (the median one always) absent. The wings are usually flat and broad, unfolded, but held when at rest in a great variety of positions. In most butterflies they are closed together and held vertically above the back. A venational characteristic of the order is seen in the fading out of the base of the median vein within the confines of an area known as the *discal cell*. Wings are wanting sometimes, as in the female moths of the cankerworm.

The legs are generally slender; the tibiae often bear spurs, as in the caddisflies. In one large family of butterflies (Nymphalidae, the family of the common fritillaries) the fore legs are vestigial and these butterflies, therefore, are quadrupeds.

The young, or larvae, of Lepidoptera are called caterpillars. They are more or less cylindric and wormlike and have biting mouthparts. They spin silken thread. That is one of their most characteristic habits. They are mostly herbivorous and consume every sort of vegetable substance. Collectively they are the greatest consumers of herbage on the earth. Among them are very many of our most important economic insects.

The head of the larva is small and is encased in a horny capsule, with small eyes and antennae at its sides. The mouthparts are not like those of the adult, but are of the ordinary biting type, only with reduced palpi. Labrum and labium above and below, with two pairs of jaws swing-

ing laterally between them, may readily be seen with a lens. A careful search of the labium with a lens will reveal the pointed tip of the spinning tube at its apex. Out from this the silk secretion is poured in a liquid state, to harden on contact with the air when drawn out into a silken thread. One pair of large glands inside the body secretes the silk and pours it out through the opening. By this means all the suspension lines of the cankerworm, and all the webbings of the tent caterpillars and webworms, and all the cocoons of all the order and all our silk of commerce is spun. Silk is spun only in the larval stage; and most of the spinning is done at the end of larval activity in the making of cocoons and other shelters for transformation.

The thorax is clearly marked by the possession of jointed legs. The prothorax often bears a horny brown shield above. Spiracles open at the sides of the synthorax. The legs are very short—almost clawlike, but are composed of the usual parts, greatly reduced in length.

The abdomen is very large, composing in the caterpillar by far the greater part of the body. To support and propel it, fleshy, unjointed *prolegs* are developed, underneath some of the segments. There are from two to five pairs of these, each bears at its tip a circlet of minute crotchets, that are well adapted for hooking onto the roughnesses of a leaf or into the mesh of a web.

With the shedding of the last larval skin, the pupa is disclosed. Sometimes it is formed openly, as in most butterflies, then it may take on the bright tints of green and gold

that have given us the name of *chrysalis* for it. Oftener the pupa is formed in the seclusion of a protective cocoon and is plain and brown in color. Always it is much less active than the pupa of a caddisfly. Generally the appendages that enwrap the body are all sealed down tightly to it, only the tip of the abdomen remaining freely movable. The same parts already discussed for the caddisfly pupa—the parts of the adult that is to be—are readily recognizable in it.

LESSON 10

Butterflies and Moths

WORK PROGRAM

1. In some cabbage patch collect all stages of the cabbage butterfly: adults from the air, eggs and larvae from the cabbage leaves, and pupae from neighboring posts and walls.

2. Bring in some well grown larvae alive and rear them in closed jelly tumblers, cleaning the glass and adding fresh cabbage leaves daily until they transform to pupae. This they will usually do on the underside of the tin lid. Then keep the pupae until the butterflies emerge. Sometimes a lot of small winged parasites will issue instead; but this will equally well illustrate another great natural phenomenon: Nature's method of control.

3. Collect miscellaneous adult butterflies from the flowers by day.

4. Collect miscellaneous moths at lights by night.

5. If dried specimens are to be used keep them over night in a relaxing jar.

6. Collect moths and caterpillars of some of the abundant sorts, such as spanworms or loopers, hornworms or sphinxes, and garden cutworms. Many of the economic species listed on pages 152 and 153 will be prevalent in any locality. Get some of these.

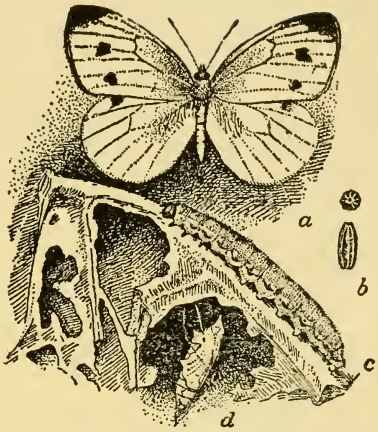


FIG. 45.—The cabbage butterfly: *a*, the adult; *b*, end and side views of two eggs, enlarged; *c*, larva; *d*, pupa. From U. S. Dept. of Agriculture.

7. Collect native silkworm and other cocoons from the twigs and bark of trees and keep them until the moths emerge. If these are hung on the wall in plain sight, you will be more likely to see the emergence of the adults.

8. Carefully prepare some of the finest specimens of both moths and butterflies for exhibition, by mounting them on a spreading board.

9. Prepare slide mounts of caterpillars' antennae, mouthparts and legs.

10. Carefully scrape off the scales from the face of a large moth or butterfly to show the mouthparts uncovered.

11. Home problems on crop pests (see p. 174).
12. Routine (see p. 204).

LABORATORY PROGRAM

A. *The Study of Living Material.*

Little can be done with adult moths and butterflies indoors, but living larvae are excellent subjects for observation.

1. Note their locomotion, and the use of legs and prolegs. This will be different in loopers and in ordinary caterpillars.
2. Note in some leaf-eating moth larva the spinning of a thread by it wherever it goes; and if chance offers, then watch the spinning of a cocoon when it is full grown.
3. Note the feeding upon a leaf, and the use of the jaws and feet.
4. Take a living pupa in hand and by examining it carefully determine how much of its body is freely movable, and how much close-sealed.

B. *The Study of Preserved Material.*

I. *With an adult moth or butterfly in hand rub some scales off from it with your finger, dab them on a glass slide and examine them with a microscope.*

Compare this specimen in form and arrangement of parts with the insects previously studied; and then note further:

1. The length and form of the antennae and the position in which they are carried.
2. The mouthparts: compare with Fig. 44. Examine a microscopic slide mount of the proboscis, if one is available.
3. The form and size and relations of fore and hind wings.

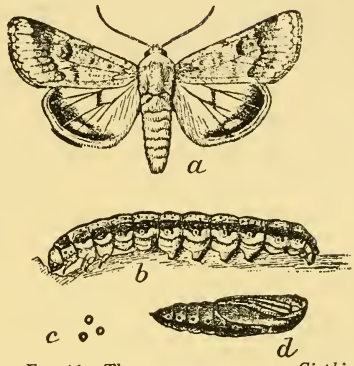


FIG. 46.—The corn ear-worm, *Cirphis unipunctata*: *a*, the moth; *b*, the larva that eats into the corn ear; *c*, the eggs; *d*, the pupa (from Severin, after Howard).

II. *With a pupa in hand note that all the appendages not only enwrap the body, but they are solidly sealed down to it, only the tip of the abdomen being free.*

III. *With a larva in hand, note.*

1. The horny head capsule, with its armor plates meeting in a V-shaped suture on top.
2. The small pigmented eyes.
3. The minute bristly antennae.
4. The biting mouthparts: a horny upper lip, a pair of stout toothed mandibles, thinner maxillae and labium with palpi of both much reduced in size.
5. The minute spinneret near the middle of the tip of the labium.
6. The jointed legs on each segment of the thorax. Find in them the usual leg parts. Use slide mounts for this.

7. Spiracles at the front margin of each segment of the synthorax and of the first seven segments of the abdomen.
8. The absence of wings externally.
9. The prolegs underneath the abdomen, their number and position, and the circlet of crochets on the end of each.
10. The vestiture of bristles on the body.

XII

DIPTERA

Flies, Mosquitoes, etc.

This is another very large order of insects. There are perhaps 10,000 species in North America. The adults are two-winged, as the name signifies.* These two are the fore wings, and pertain to the mesothorax, while the hind wings are never developed for flight, but are represented by a pair of minute knobbed threadlike organs, called *halteres* or balancers. The metathorax is small and the mesothorax is correspondingly large, since it contains the flight muscles. The head is generally freely poised on a conic prothorax. The eyes are large, covering most of the surface of the head. The antennae are variously formed. The mouthparts are combined into a sucking beak, very different from that of the bugs and the butterflies. As in the bugs, the labium forms a sheath inclosing the modified jaws and these may be developed as sharp puncturing stylets. They are so in the mosquitoes and biting flies; but in the commoner flies, the tube is soft and pliant, and bears a pair of flaplike lobes (*labellae*) at its tip. The beak is more or less retractile. The tarsi are 5-jointed.

This group includes many of the worst pests of man and beast and many parasitic insects.

The group is one in which there are remarkable differences in life history and habits. Let us illustrate the more special-

* *dis*, two and *pteron*, wing.

ized and distinctive characteristics with the life history of the fly, *Muscina stabulans.* This fly is common about dwellings and barns, preferring basements and other half-lighted places. It seeks out soft pulpy fermenting vegetable substances, fruit parings, melon rinds, etc., on which to lay its eggs. The eggs hatch within a few hours, and the larvae bore into and feed upon the vegetable pulp. They grow with extraordinary rapidity, attaining full size in ten days or less.

FIG. 47.—Muscina fly, *Muscina stabulans* (from Howard).

These larvae are of the soft, white, thin-skinned legless and headless type commonly known as "maggots." This name may suggest stenches, for the reason that the best known maggots live in carrion: but Muscina fly maggots are vegetable feeders and their environment holds nothing more offensive than odors of fermentation.

A maggot is perhaps the most remarkable form that any insect takes on. Though fully grown it shows externally none of the parts of the fly that is to be: no wings, no legs, no antennae, no eyes; and what remains of mouthparts (two minute mouth hooks) may not be readily identified with the mouthparts we have been examining or with the parts of the proboscis of the fly.

The rudiments from which these parts of the fly will all later develop are present within its body, and along with them there is a great store of soft white fat that will furnish the materials out of which, during the pupal period, all these parts will be formed.

FIG. 48.—An adult yellow fever mosquito (from Howard).

When the larva is fully fed it leaves the pulp, and burrows into the soil. There its skin shrinks and hardens into a brown capsule-like case, called a *puparium*, (plural *puparia*) within which the pupa is formed. The pupa is soft and white, and carries the legs, wings, antennae, etc., that have suddenly appeared at the last molting. The pupal stage lasts several weeks. Then the adult flies emerge and scatter, and feed and mate and lay eggs. They may live several months.

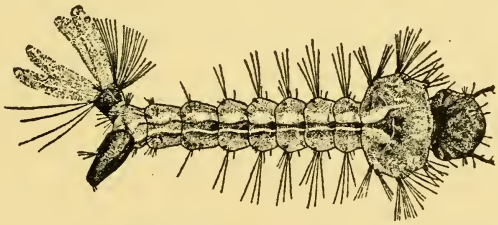


FIG. 49.—The larva of this mosquito (from Howard).

The most abundant and most familiar flies are of this type: the house-fly, for example, whose larvae live in stable manure; also, these pests of our fields and gardens, whose larvae are known as "root

maggots;" also tachina-flies, whose larvae live as parasites within the bodies of other insects. Very many such flies will be obtained in collecting from flowers, for nectar and pollen are attractive food for them.

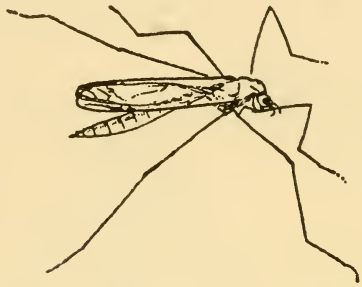


FIG. 50.—An adult crane fly, *Tipula abdominalis*.

Another sort of fly may be found about the live stock in our pastures—biting flies, whose carnivorous larvae live in wet soil.

There are also long-horned flies (*Nematocera*), and these are very different. They are mostly long-legged and long-winged, and of a slender build. Most familiar among them are the mosquitoes, midges and craneflies. The antennae are made up of a considerable number of similar segments; sometimes, as in the males of mosquitoes and midges, they are formed like bottle-brushes, being densely ringed with long hairs.

All dipterous larvae lack true legs, but they do not all lack a visible head. The larvae of the long-horns last mentioned have a well chitinized head capsule, with eyes, antennae and jaws that are enough like those of more primitive biting insects to be readily identified: upper and lower lip, with two pairs of jaws moving laterally between. The head is quite free in the larvae of mosquitoes and midges and is retracted into the front of the prothorax in cranefly larvae. Many of these more primitive Diptera are aquatic.

A number of annoying and dangerous pests are members of this order: house-flies which carry the germs of typhoid fever; mosquitoes, which carry the germs of malaria and yellow fever; tse-tse flies which carry the germs of sleeping sickness; black flies and horse-flies, which bite painfully. From the standpoint of public health, this is the most important order of insects.

LESSON 11

Two-winged Flies

WORK PROGRAM

1. Raise some banana flies (Drosophila)* and get all stages for observation.

2. Collect house-flies in all stages. Trap, or poison, or gather with a net some of the adult flies. Get the larvae and pupae by raking over the stuff about the edges of a manure pile at some ill-kept horse stable.

3. Collect some horse-flies when they are pestering the live stock in the pasture.

4. Collect some robber flies with a net along the pasture paths, where they will be found swiftly darting from one resting place to another.

* To raise Drosophila, crush an over-ripe banana, and leave it exposed in a dish in warm weather. The little brown flies will find it and will lay their eggs on it. Sprinkle a little earth dust over it to prevent growth of molds. In about a week look for larvae and puparia.

5. Collect some mosquitoes—no trouble to find them on a warm evening.

6. Collect mosquito larvae with a dip net from temporary pools.

7. Collect midges from some of the cloudlike swarms that appear above the marshes at nightfall. Larvae (Fig. 8B) of some of them (easily recognizable when alive by their figure-of-8 swimming) will usually be collected along with mosquito larvae.

8. Collect some craneflies with a net as, on approach, they rise from the vegetation of the low meadow.

9. Collect some big cranefly larvae from leaf-drifts in a wood-land stream. Hold a screen in the water below the obstruction. Disturb the accumulated leaves, dislodge the larvae driven down by the current, and they will lodge on the screen. Lift it and pick them off.

10. Prepare slide mounts of the wings and antennae of the flies studied.

11. Prepare slide mounts of the mouthparts and spiracles of a maggot.

12. Prepare slide mounts of some of the smaller larvae of mosquitoes and midges.

13. If dried specimens are to be used for study, give them an overnight stay in the relaxing jar.

14. Pin and mount and label for the collection a variety of representative Diptera.

15. Home problems on crop pests (see p. 174).

16. Routine (see p. 204).

LABORATORY PROGRAM

A. *The Study of the Living Specimens.*

1. Compare the flight of a house-fly and a cranefly as to speed, directness and courses.

2. Study the action of the proboscis of a fly in feeding on sugar. To do this put a hungry fly and a lump of sugar under a glass tumbler and sit by watching.

3. Study the creeping locomotion of a maggot and of a big cranefly larva.

4. Study the swimming of a mosquito larva and of a midge larva. Note rate, direction of movement, and how effected.

5. The same, for the pupae.

B. *The Study of Preserved Material.*

I. *With a Muscina fly or a banana fly, or a house-fly in hand, note.*

1. The compact body, and consolidation of all thoracic segments.
2. The large, wing-bearing mesothorax.
3. The freely movable head.

On the head note:

1. The huge eyes, overspreading the sides and top.
2. The minute ocelli.
3. The short, thick 3-jointed antennae, with a long bristle arising from near the base of the third joint.
4. The hinged, retractile sucking proboscis, bearing a pair of palpi on its base, and a pair of opposable flaps (*labellae*, singular *labella*) at its tip.

On the thorax note:

1. The few veined, transparent and highly efficient wings.
2. The knobbed *halteres* that replace the hind wings on the metathorax.
3. The slender tarsi whose end segments bear sucking pulvilli, that adhere to very smooth surfaces.

II. *With a maggot in hand, note.*

1. The soft-skinned body, wide in the rear and tapering forward to a pointed front end.
2. The absence of head and of all external head appendages of the usual sort.
3. The mouth hooks, a single pair laid parallel, brownish or blackish in color, strongly chitinized and hooked downward at the tips, retractile, adapted for tearing up tissues to liberate their juices.
4. A pair of small spiracles at the rear of the prothorax—one each side.
5. A pair of larger spiracles on the blunt rear end of the body, opening to rearward.
6. Longitudinal air trunks inside the body (more or less visible through the transparent skin) connecting with the spiracles, and sending branches in to all the tissues.
7. A dark colored alimentary canal extending lengthwise through the body. By looking inside the body of the larva great masses of white fat may be found filling the greater part of the body cavity.

III. *With a puparium in hand, note.*

1. The cylindric, capsule-like form. It is produced by the contracting and hardening of the old larval skin.
2. The larval mouth hooks solidly, held in the hardened skin at the more pointed front end.
3. The mesothoracic spiracles similarly sealed in, a little farther back. (These are hard to see.)
4. The more evident posterior spiracles at the rear.

If the puparium be carefully opened, there may be found within a soft, white pupa, bearing the partly fashioned wings, legs, antennae, etc., of the adult.

XIII

HYMENOPTERA

Bees, Wasps, etc.

This is another very large group of insects. The wings are membranous, as the name implies,* but that alone does not distinguish the group. The hind wings are small, and are often attached by a row of hooks on their front margin to the rear of the front wings, so that the two together function as one. The veins of the fore wing are bunched at the front margin to stiffen it, and strongly conjoined toward the wing apex in a chitinous thickening (*stigma*).

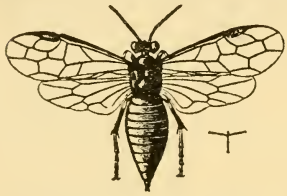


Fig. 51.—A saw fly, (from Ritsema Bos).

The mouthparts are of the biting type, and functional mandibles are present throughout the group; but in the bees labium and maxilla are prolonged and combined into a sucking tube that is suited to gathering the nectar of flowers. The antennae are long and often elbowed and reversible. The tarsi are 5-jointed. The end of the abdomen in the female is armed with an ovipositor or a sting.

The order is remarkable for an extraordinary diversity of habits. The sawflies are herbivorous. A very large portion of the group is of parasitic habits. The wasps are mainly predatory; the ants, omnivorous and social; the bees, mainly social and with a domestic economy that is based on flower

* *hymen*, membrane, and *pteron*, wing.

products, nectar and pollen, which they are wonderfully fitted for gathering.

Out of the vast array of forms included in the order we will select for examination four representatives: a bee, an ant, an ichneumon fly and a sawfly.

LESSON 12

Hymenoptera

WORK PROGRAM

1. Collect some honeybees.
2. Get a beekeeper to furnish some larvae and pupae for class study.
3. Collect some ichneumon flies by sweeping the vegetation of the meadow.
4. Collect some sawflies in the same way.
5. Collect and preserve in vials some sawfly larvae.
6. Collect some ants.
7. Make slide mounts of a bee's tongue and antenna.
8. Make slide mounts of a fore and hind leg.
9. Make slide mounts of head and legs of a sawfly larva.
10. Mount and label a representative lot of Hymenoptera for the collection.
11. Watch the cages in which pupae of other orders are being reared for the emergence in them of Ichneumons and other Hymenopterous parasites.
12. Home problems on crop pests (see p. 174).
13. Routine (see p. 204).

LABORATORY PROGRAM

With a honeybee in hand, note:

I. *In general.*

1. The well-knit, compact body.
2. The massive thorax with small, closely applied metathorax, and marginal attachment of fore and hind wings.
3. Its covering of brushes of stiff hairs above and below and on the legs. If these hairs be examined with a microscope they will be seen to be plumose, with grains of pollen lodged in the angle of some of the branches: they are pollen brushes.
4. The closeness with which the reversible antennae and the curving thighs can be applied to the body. This facilitates entering the corollas of flowers.

II. *In the head, note.*

1. The wedge-shaped front—another adaptation to flower probing.
2. The prominent eyes and ocelli.
3. The elbowed antennae.
4. The mouthparts divided on the mid-horizontal plane as to functions:
   (a) Labrum and mandibles of a somewhat simple type: the mandibles are rather broad and spatulate at their tips, adapted by their form to molding wax.
   (b) Maxilla and labium are together modified to form a composite nectar-gathering organ—a sucking

tube very different from the three types already noted in bug and fly and butterfly.

III. In the thorax, note:

1. The tapered neck that flexibly supports the head.
2. The few-veined, sturdy wings and the manner in which front and hind wings are hooked together.
3. The long and adaptable legs, composed of the usual parts, besides, on the front ones an antenna cleaner at the tip of the tibia, and on the hind ones a pollen basket upon the outside of the greatly enlarged basal tarsal segment, and pollen combs on the inner side of the same.

IV. In the abdomen, note:

1. The basal segment separated from the others by a waistlike constriction, and more closely applied to the rear of the synthorax.
2. The overlap of the plates, and the infoldings at the spiracles along the sides.
3. The wax glands underneath segments 4 to 7.
4. The sting at the tip.

Drone, Queen and Larva

Compare a drone, noting:

(a) The generally clumsier form.
(b) The bluntness of rear end of the body.
(c) The lack of sting and of pollen baskets.

Compare a queen, noting:

(a) The larger size and more elongate abdomen.

(b) The more graceful form.

(c) The lack of pollen baskets.

With a bee larva in hand, note:

1. The soft pale translucent skin.

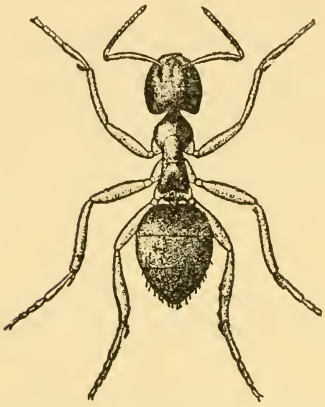


FIG. 52.—A corn-field ant, *Lasius niger* (from Forbes).

2. The reduced front end and enlarged abdomen.
3. The absence of legs.
4. The reduced condition of all head appendages.
5. The curved position of body.

With a piece of empty honey comb in hand, note:

1. The double cell layer.
2. The shape of the cells and their fitting together.
3. The overlap of the cell bases.

Ant, Ichneumon-fly and Saw-fly

With a worker ant in hand, note:

1. The entire absence of wings.
2. The simpler hind legs.
3. The elbowed and clubbed antennae.
4. The subdivision of the abdomen, one or two basal segments being separated from the others by constriction.

With an ichneumonid in hand, note these differences:

1. The long legs, with three short basal segments instead

of the usual two, the trochanter being itself divided and appearing as two segments.

2. The flatly compressed abdomen with a longitudinal fold in its walls.
3. The ovipositor of the female by means of which she deposits her eggs on or in or near the larva of some other insect.

With a sawfly in hand, note:

1. The stocky body with abdomen broadly joined to the thorax—not "wasp-waisted."
2. The long, simple antennae and the ordinary biting mouth-parts.
3. The wings, more nearly equal and with more numerous veins than in the others.
4. The saw (ovipositor) of the female.

With a sawfly larva in hand, note:

1. The caterpillar-like form.
2. The biting jaws and reduced eyes and antennae.
3. The jointed thoracic legs.
4. Prolegs underneath the abdominal segments (absent from segment 9).
5. The spiral curvature of the abdomen.

XIV

INSECTS OF OTHER ORDERS

We have now had before us the insects of eleven orders. There are other orders*—just how many orders entomologists are not agreed. The others are all small groups, and some of them are rarely collected. On land there are four big orders that make up the bulk of the insect population—Coleoptera, Lepidoptera, Diptera and Hymenoptera; and in the water there is one that exceeds all other aquatics—the Trichoptera. All these have complete metamorphosis, with wormlike larvae, that are very different from the adults, and that for the most part have different feeding habits. The two most important groups having incomplete metamorphosis are the Orthoptera and the Hemiptera. Nearly all the economic species of insects are members of these six terrestrial groups.

* A List of the Orders of Insects

Scientific names	*Common names*		
Thysanura	Bristle-tails	Dermaptera	Earwigs
Collembola	Springtails	Anopleura	Lice
Plecoptera	Stoneflies	Hemiptera	Bugs
Orthoptera	Grasshoppers, etc.	Trichoptera	Caddisflies
		Neuroptera	Lace-wings, etc.
		Mecoptera	Scorpionflies
Odonata	Dragonflies	Strepsiptera	Stylopids
Ephemerida	Mayflies	Coleoptera	Beetles
Isoptera	Termites	Lepidoptera	Moths, etc.
Mallophaga	Bird Lice	Siphonaptera	Fleas
Corrodentia	Psocids	Diptera	Flies
Thysanoptera	Thrips	Hymenoptera	Bees, etc.

For lack of space we shall have to dismiss the other orders with a mere mention. There are two orders that have no metamorphosis:

THYSANURA or bristle-tails, and

COLLEMBOLA, or springtails.

These hatch from the egg in the form they will retain through life, and bear no signs of wing development.

There are four orders that are small, wingless, parasites:

MALLOPHAGA, or bird lice.

ANOPLEURA, or true lice, three species of which infest man.

SIPHONAPTERA, or fleas.

STREPSIPTERA, or stylopids, that infest other insects.

FIG. 53.—The fire brat, one of the Thysanura that lives around furnaces and kilns.

There are two orders that are minute winged insects, scarcely reaching a fourth of an inch in length:

THYSANOPTERA, or thrips, very slender insects that are common in the heads of flowers, and that may be found by pulling apart such flowers as daisies and clover. The narrowly linear, nearly veinless wings, bearing long fringes of hairs, are laid flat upon the back. A few of these are important garden pests.

CORRODENTIA, or psocids, bark and crevice inhabiting insects having two pairs of rather broad wings, that are traversed by zig-zag veins, held when closed rooflike over the body and not folded. The antennae are long and slender.

These are common on lichen-covered bark of trees and on boards of fences. A minute pale, wingless species, commonly found between the leaves of old books, is known as the "book louse."

For further information concerning all of these, consult the larger works on entomology.

There remain three orders containing a few insects of larger size and more importance.

ISOPTERA, termites or "white ants"; soft-bodied, mostly pale insects with biting mouthparts and incomplete metamorphosis. The wings when present are two pairs that are alike, as the name implies,* with a few stiff veins at the front and a broad irregular meshwork of faded-out venation behind. Termites are social in habits are differentiated into castes.

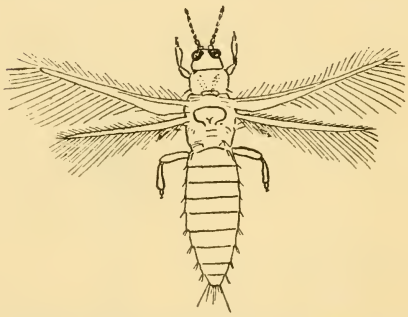


FIG. 54.—The onion thrips, *Thrips tabaci*, a minute sucking insect of much economic importance.

These are wood-eating insects of great importance in the warmer parts of the earth, where they destroy books, furniture and even houses. They live in colonies like ants, but are quite unlike ants in every other way.

* *Isos*, equal and *pteron*, wing.

DERMAPTERA, earwigs; small, elongate insects with short leathery* forewing, having the appearance of rove beetles, but distinguished by the possession of a pair of long forcepslike appendages at the rear end of the body. The hind wings when present are very peculiar, being folded both lengthwise and crosswise; the lengthwise fold opening like a lady's fan. Metamorphosis is incomplete. In feeding habits they are chiefly herbivorous.

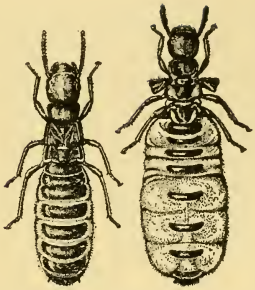


FIG. 55.—Termites male and female (from Snyder).

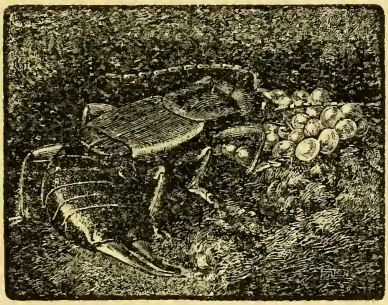


FIG. 56.—Female earwig with her nest of eggs (from Fulton).

MECOPTERA, scorpion-flies, etc.; a small group of beaked insects, having long wings,† the two pairs of similar size and form. Metamorphosis is complete.

There are beaks and beaks among insects. As already noted, the beak of the bug is composed wholly of the elongated mouthparts; and the beak of the weevil is composed wholly of the elongated front of the head, which carries all

* *Derma*, skin, and *pteron*, wing.
† *Mekos*, length and *pteron*, wing.

the mouthparts out at its tip. This Mecopterous beak is a half-and-half combination of the two plans of beak formation: above, the front of the head is prolonged, carrying labrum and mandibles out to the tip; below, the basal parts of maxillae and labium are prolonged, themselves forming the lower half of the beak.

It is the curving, upturned, pincherlike tail of the male of Panorpa that has given the group its common name.

LESSON 13

Other Orders of Insects

WORK PROGRAM

1. Collect insects of any of the above mentioned smaller orders, wherever they may be available.
2. If dried specimens are to be used in the laboratory, give them an overnight stay in a relaxing jar.
3. Make slide mounts wherever these are needed to clearly expose the structure of mouthparts, legs or wings.
4. Pin, mount and label specimens for the collection.
5. Home problems on crop pests (see p. 174).
6. Routine (see p. 204).

LABORATORY PROGRAM

The study of living and of preserved specimens will have to be adapted by the teacher to the materials available.

XV

Clues* for Recognition of the Commoner Orders of Winged Insects

Order	Fore Wings	Hind Wings		Mouth parts	Tarsal joints
		Size†	Folding		
Plecoptera....	membranous	broader	lengthwise	biting	3
Orthoptera...	leathery	broader	fan-like	biting	1 to 5
Odonata.....	membranous	broad	not folded	biting	3
Ephemerida..	membranous	small	fluted	wanting	5
Isoptera.....	membranous	equal	not folded	biting	3
Thysanoptera.	linear fringed	narrower	not folded	sucking	2
Corrodentia...	membranous	smaller	not folded	biting	2 to 3
Hemiptera....	various	various	lengthwise	sucking	1 to 3
Dermaptera..	leathery	broader	doubly‡	sucking	3
Trichoptera...	membranous	broader	lengthwise	reduced	5
Neuroptera...	membranous	various	various	biting	5
Mecoptera....	membranous	equal	not folded	biting	5
Coleoptera....	horny	broader	doubly‡	biting	3 to 5
Lepidoptera..	membranous	smaller	not folded	sucking	5
Diptera.....	membranous	wanting		sucking	5
Hymenoptera.	membranous	smaller	lengthwise	various	5

* Admitting of exceptions; therefore, when in doubt. compare with the fuller statements of the text. Winged adults only considered.

† In relation to fore wing.

‡ Both crosswise and lengthwise.

Some of the orders of insects may be recognized by

Single Distinctive Characters:

Hemiptera, by the jointed beak (see p. 72).

Coleoptera, by the horny fore wings that meet in a straight line down the middle of the back.

Lepidoptera, by the scaly wings, and by the coiled sucking proboscis.

Diptera, by the possession of one pair of wings and a pair of halteres.

Odonata, by the forward position of the legs, and by the forward slant of the side pieces of the synthorax to their bases.

Ephemerida, by the fluting of the wings, the smallness of the hind wings, and by the long tails.

Dermaptera, by the short fore wings, the narrow, the fan-like hind wings and the forceps-like appendages at the end of the body.

Isoptera, by the form and color of the body and the faded-out venation of the wings.

Mecoptera, by the form of the beak (see p. 133).

PART III

INJURIOUS INSECTS AND THEIR CONTROL

WHY STUDY INSECTS

Insects affect our interests in numberless ways. A few of them we cultivate for their products; honey bees, and silk worms, and some others. Many of them are competitors with us for foods, eating it green in the fields and gardens or eating it dry in storage. A few attack our persons, and give us great annoyance.

By far the largest number of injurious species are those attacking our growing crops. Competent observers estimate that these cause a loss of at least ten per cent of all field crops each year. In the United States, this means a tax on agriculture of more than $100,000,000 a year. In addition to this, there are the losses caused by insects that destroy stored food products and woolens, and by those that infest live stock, and that convey infectious diseases to man and beast. The causative agents of such losses surely merit careful consideration.

XVI

PLANT PESTS

There is no part of a plant exempt from insect attack: leaf, stem and root; bark, wood and pith; bud, flower and fruit; all are eaten.

There is no part of the growing season free from danger of their depredations. Some come early, like the bud moth; some come late, like the fall webworm; some compass the whole season by repeated broods, like the codling moth; some persist through several seasons, like wireworms and white grubs.

They have all specialized more or less for feeding on particular kinds of plants. Some are general feeders but most of them eat only of one kind of plant, such as the strawberry, or of a few closely related plant species, such as cabbage and kale, beets and spinach, tomato and tobacco, melon and cucumber, peach and plum; timothy and other grasses.

1. *Destroyers of herbage.*—This is the most numerous class of injurious insects. Green herbage is the most abundant sort of food on earth, and insects are its greatest consumers. As compared with the grazing beasts, they make up in numbers what they lack in size. Grasshoppers and army worms and the gipsy moth larvae browse like the beasts rather generally on every green part above ground; but most herbivorous insects confine themselves to one part, and feed in one particular way. There are all these classes of leaf-eating insects that may be found side by side on a single tree:

(a) Consumers of entire leaves.

(b) Leaf skeletonizers, that eat out the soft parts, leaving the large veins.

(c) Sap feeders, bugs and thrips, whose puncturing mouthparts penetrate to the sap and suck it out, leaving the leaf shrivelled and empty.

(d) Leaf miners, that eat out a residence chamber in the inner leaf tissues, leaving the skin (epidermis) intact.

(e) Gall insects, that feed within excrescences whose growth upon the leaf they stimulate.

The two last mentioned live within the leaves; and some of the others make for themselves shelters by fastening leaves together that cause them to be known as leaf-rollers, leaf-crumplers, leaf-folders, and leaf-tyers; or they make portable shelters of such sort that they are called casebearers and bagworms.

All these habits intergrade; and leaf-eating in general intergrades with feeding on green stuffs elsewhere, in stems and buds and young fruits.

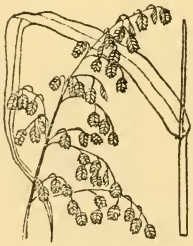
2. *Destroyers of roots and tubers.*—These work beneath ground, some of them boring also into the stems. They consume both growing and stored root crops, but only a few go with the root crops into storage. Most important among them are the root maggots, the wire-worms, the root borers, the root worms and the tuber worms.

3. *Destroyers of fruits and nuts.*—These, like ourselves, take advantage of the food stores that plants accumulate.

Most important among them are the fruit flies, the fruit worms, the codling moth and its allies, and the nut weevils.

4. *Destroyers of seeds and grains.*—These feed on the most concentrated foods that plants produce, but most of them, like the cotton boll weevil eat the seeds while they are soft and newly forming. Some of the more specialized, however, like the bean, rice and grain weevils, feed on dry seeds. These are our most direct competitors for food.

5. *Destroyers of wood.*—These are mostly termites (see fig. on p. 132) and beetle larvae. The latter are known as borers of various sorts. They destroy timber, lumber, furniture, implement-stock, etc.



XVII

ANIMAL PESTS

1. *Destroyers of woolens and furs.*—These are to us serious pests; but they do not much bother the animals, because they feed only on dead and dry stuffs, like hair and wool and skins. The most important ones are the clothes moths and the carpet beetles. Some of the latter also eat dried insects, and are the eternal pests of our collections.

2. *Other household pests.*—These are insects that variously take advantage of the artificial shelter our houses afford, and that come in and live with us in various ways. Cockroaches like the shelter and the food in our kitchens so well they gladly come in and stay and raise their families with us. So also do fish moths and book lice. Mealworms and flour moths and cheese skippers live and grow up in certain of our prepared foods. Ants and flies dwell elsewhere but come in and eat with us: and sometimes they bring on their feet contamination to our food.

3. *Pests of man.*—Fleas and bedbugs, mosquitoes, punkies, and lice—ancient, abominable scourges of our race, all of them capable of transmitting the germs of communicable diseases—we may be rid of, by diligently applying modern means, and by taking thought.

4. *Pests of live stock.*—These are of the same groups (and some, of the same species) as human pests; but the animals

have some additional, such as the horn fly of cattle, the bot fly of horses and the nose-maggot of sheep.

5. *Miscellaneous.*—These principal classes of insect injuries are intergrading and overlapping, and they do not cover all the cases. The damage done to the combs by the wax moth of our bee hives, or to the stored milk flakes of our milk drying factories, will hardly fit any of them. Nature is no respector of categories. She is infinite in resources.

XVIII

CONTROL MEASURES

The thing most needed in the control of insect pests is knowledge of their habits. Without this the means available cannot be intelligently applied. We will discuss the control measures as we have done the injuries. Under separate classes, beginning with the most modern, and now the most used, means:

Insecticides. These are poisons. They take effect either through the digestive system of the insect or through the respiratory system or through the skin. If through the first, they are *food poisons.* Otherwise, they are *contact insecticides* and *fumigants.* Food poisons are cheapest and easiest to apply and would be preferred, but for a limitation that will be at once understood, if we recall the difference between biting and sucking mouthparts. Biting mouthparts chew the food and take in the poison with it. Sucking mouthparts penetrate to the sap beneath, and so avoid the poison that is sprayed or dusted upon the surface. It is, therefore, the sucking insects and those others to whose food the poison cannot be applied that have to be reached through their respiratory system or through their skin.

1. *Food poisons.*—These are chiefly arsenicals. Paris green was the first to be used extensively. Nowadays lead arsenate and calcium arsenate are preferred, for they are less liable to "burn" tender foliage. These may be applied either as a spray or as a dust.

2. *Contact insecticides.*—The most important of these are lime-sulfur and nicotine sulfate. Lime-sulfur kills by its corrosive action upon the tissues. It is used chiefly to kill scale insects on the bark of deciduous fruits during the dormant season, when there are no green leaves to be injured by it. Nicotine sulfate is preferable for summer use.

3. *Fumigants.*—These are substances that give off poisonous gases that, in general, are effective for killing insects only when placed in some sort of inclosure. Carbon bisulphide, carbon tetrachloride, fumes of burning sulphur or tobacco, hydrocyanic acid gas, calcium cyanide and calcium fluo-silicate are among them, and the list is still growing. These are all poisonous to man, and must be used with great care. *They must not be inhaled.*

Carbon-bisulphide and calcium cyanide are two that are well adapted to many small fumigating operations in closed containers, such as the treatment of unseen pests that get into collections. The former is a heavy ill-smelling liquid, obtainable at any drug or insecticide store. On exposure to the air it gives off a heavy poisonous and explosive gas. The dosage is one pound to 100 cubic feet of space in the box or bin containing the materials to be treated. Expose over night. No light or fire or burning cigar may be allowed near, until the fumes have disappeared.

Calcium cyanide is available as a dry powder that may be thrown into the container with the infested material.

All these insecticides, together with ingenious machinery for applying them, are advertised in farm and garden

periodicals, and the makers are anxious to furnish all needed information as to their proper use. A few simple and inexpensive things will serve the needs of the ordinary householder. He probably can do not better than to buy standard commercial preparations, and then follow the directions that are printed on the packages.

4. *Repellants.*—These are as varied as are the means whereby they are applied. "Tangle-foot" is applied as a band around the trunks of trees to keep the wingless females of the spring canker worm from crawling up the trunks to lay their eggs. Finely powdered borax is shot from a powder gun into the retreats of cockroaches. Naphthalene and moth balls are put into the chest where woolen goods find summer storage, or tar or cedar oil are used to saturate the walls of the containers for such goods, etc.

5. *Traps.*—The inventor has come forward with various devices for capturing, dead or alive, such household insects as flies and fleas and cockroaches; and these when used with due regard to the habits of the insects are more or less successful. Trap lanterns will capture such as are attracted to lights at night, but they have not proved of much economic value. Other famous inventions for insect catching are the "hopper-dozers" and "curculio-catchers," illustrations of which may be found in books on economic entomology.

6. *Cultural control.*—Prevention is better than cure; and prevention on a large scale is practiced by all good farmers when they rotate their crops. When, for example, the soil of a piece of land growing meadow grass becomes heavily

infested with wireworms, by planting it to some other crop that they will not eat, such as clover or alfalfa, the wireworms are starved out. It is fortunate for the farmer that most of his crop pests will eat of but one or of a few closely related plants. Proper rotation temporarily clears the fields of some of them. He may clear the field of clover-seed insects by mowing the hay early, before the larvae have matured. He may further practice prevention by plowing and planting at seasons unfavorable to his crop pests; avoiding the cotton boll weevil, for example, by planting early; the pea weevil and the Hessian fly by planting late. So, he must know their times and seasons, their food and broods, and their requirements as to temperature and shelter.

7. *Removal of breeding places.*—Removal of the breeding places is the most effective sort of prevention. It cuts off the supply of pests at its source. It is practiced with house-flies when the manure piles, that are their hatcheries, are drawn to the fields and plowed under. It is practiced with mosquitoes when the temporary pools, in which their larvae flourish, are drained.

8. *Destruction by other artificial means.*—Hand picking as for tomato worms; burning of infested stalks, as for the European corn borer; plowing of the ground under plum trees to break up the pupal cells of the plum curculio; oiling of the rain water barrels to kill mosquito larvae: in these, and in many other ways, countless insects may be destroyed.

9. *The use of natural enemies.*—Chicken raising and small fruit raising go well together because the chickens help to

keep the plantings freed from insect pests. Hogs, if allowed tor oot, will clear a field of white grubs. Hop growers protect the skunk because it so diligently searches out the hop borers for food. A big ground beetle has been successfully imported from Europe to help keep down the numbers of the gipsy moth in New England. The importation of a ladybird beetle into California once saved the citrus orchards from the ravages of the cottony cushion scale. All these are predatory enemies. There are parasitic ones as well; and these very small ones are even more important in reducing the numbers of injurious species. How to best utilize the aid of these parasites is one of the live subjects of entomological investigation at the present time.

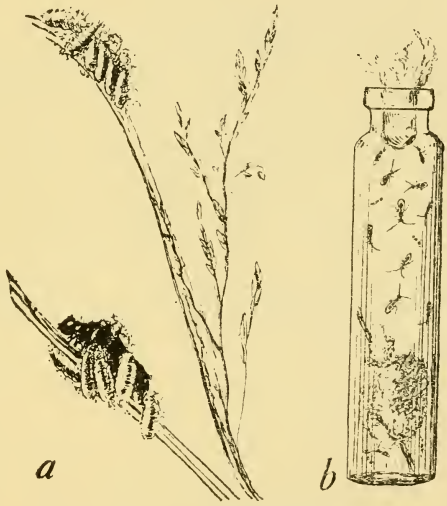


FIG. 57.—The work of Hymenopterus parasites. At *a* is shown a dead caterpillar, killed by parasites, some of which have spun their cocoons beside it, others, on the grass blade above. At *b* is shown an easy way to get the adult parasites: put the cocoons in a vial and stop its mouth with a plug of cotton, and wait for them to appear.

10. *Trap crops and miscellaneous.*—*Trap crops* are sometimes effective. For example, early kale is sometimes grown in the South to attract all the early harle-

quin cabbage bugs. Then the kale and the bugs are destroyed together and the cabbage, coming on later, has fewer enemies. There are other methods of control. One of these that is now extensively practiced is that of keeping furs in cold storage at so low a temperature that the destructive insects will not develop. There is no virtue in any method unless it be applied with knowledge of habits and life histories. There is now available in government publications* a vast store of such knowledge, and it is furnished freely to all who apply for it.

First, find out what your pest is. If you cannot learn this from your books or from some local person who knows, then send specimens for naming as directed on page 207. Then for specific information as to how to control this pest, apply to the Bureau of Entomology, U. S. Department of Agriculture, Washington, D. C., or to Entomologist's Office of the Department of Agriculture of your own State.

* Bureau of Entomology, U. S. Department of Agriculture, Washington, D. C., or to Entomologist's Office of the Department of Agriculture of your own State.

XIX

A CONDENSED LIST OF INJURIOUS INSECTS

with brief general indications of the type of injury and of the means of control. The letters and figures after the names are those of the following key tables:

CLASSES OF INJURIOUS INSECTS

A. Destroyers of wood
B. Of roots and tubers
C. Of fruits and nuts
D. Of seeds and grains
E. Of herbage
F. Of woolens and furs
G. Other household pests
H. Pests of man
I. Pests of live stock
J. Miscellaneous

MEANS OF CONTROL

1. Food poisons
2. Contact poisons
3. Fumigants
4. Repellants
5. Traps
6. Cultural control
7. Removal of breeding places
8. Destructive acts
9. Natural enemies
10. Trap crops—Miscellaneous

THYSANURA

1. The fish moth. G;1

PLECOPTERA

2. The bud-eating stonefly. E;1

ORTHOPTERA

3. Cockroaches. G;5,8
4. Crickets, ground. E;J;1
5. Crickets, mole. B;5,6,10
6. Crickets, tree. A,E;1,8
7. Grasshoppers. E;1,8
8. Walking-sticks. E;1

ISOPTERA

9. Termites. A;3

MALLOPHAGA

10. Bird lice. I;4

CORRODENTIA

11. Book lice. G;1,4

THYSANOPTERA

12. Thrips. E;2,3,6

DERMAPTERA

13. Earwigs. B,C,E;1,5

ANOPLURA

14. True lice (human). H;4,8
15. Stock lice. I;4

HEMIPTERA

16. Aphids (above ground). E;2,3,9

17. Aphids (on roots). **B;3,6,9**
18. Bedbug. **H;2,7**
19. Boxelder bug. **E;2**
20. Chinchbugs. **E;2,4,8**
21. Cicadas. **A,E;6,8**
22. Cotton stainer. **E;2**
23. Harlequin bug. **E;10**
24. Lace bugs. **E;2**
25. Leaf-footed bug. **E;2**
26. Leafhoppers. **E;2**
27. Mealy bugs. **E;2,3**
28. Negro bug. **E;2**
29. Plant bugs. **E;2**
30. Scale insects. **E;2,3**
31. Psyllas. **E;2**
32. Spittle bug. **E;2**
33. Stinkbugs. **E;2**
34. Tree hoppers. **E;2**
35. White flies. **E;2,3**

COLEOPTERA

36. Asparagus beetles. **E;1,5**
37. Billbugs. **B;6**
38. Blister beetles. **E;1**
39. Boll weevils. **D,E;1,6,8**
40. Cadelle. **G;3**
41. Carpet beetles. **F;3,8,10**
42. Colorado potato beetle. **E;1**
43. Crown borers. **E;6**
44. Cucumber beetles. **E;1,4,10**
45. Curculios (fruit). **C;1,8**
46. Curculios (vegetable). **E;6,8**
47. Drugstore beetle. **G;3**
48. Flea beetles. **E;1,2,10**
49. Lady beetle. **E;1**
50. Leaf beetles. **E;1**
51. Meal worms. **G;3,7**
52. Japanese beetle. **B,E;1,6,10**
53. Green June beetle. **B;6**
54. Larder beetles. **G;8,10**
55. Mexican bean beetle. **E;1**
56. Root borers. **B;6**
57. Raspberry-cane borer. **A;8**
58. Saw-toothed grain-beetle. **G;3**
59. Shot-hole borer. **A;3,8**
60. Stem borers. **E;6,8**
61. Weevils (in seeds). **D;3**
62. Weevils (herbage). **E;6,8**
63. White grubs. **B;6**
64. Wire worms. **B;6**

LEPIDOPTERA

65. Army worms. **E;1,4,8**
66. Bagworms. **E;1**
67. Bollworms. **E;1,10**
68. Borers. **B;6,8**
69. Brown-tail moth. **E;1,8**
70. Bud moths. **E;1**
71. Case-bearers. **E;1**
72. Cankerworms. **E;1**
73. Clothes moths. **F;3,4,7,8**
74. Codling moth. **C;1**
75. Corn ear-worm. **D;6,8**
76. Crown borers. **E;6**
77. Cutworms. **E;6,8,10**
78. European corn-borer. **E;6,8**
79. Fire worms. **E;1,8,10**
80. Fruit worms. **C;6,9**
81. Gipsy moth. **E;1,8**
82. Hornworms. **E;1,8**
83. Loopers. **E;1**
84. Leaf crumplers. **E;1**
85. Leaf folders. **E;1**
86. Leaf miners. **E;8**

87. Leaf rollers. **E;1,8**
88. Leaf skeletonizers. **E;1**
89. Leaf tyers. **E;1**
90. Meal moth. **G;3,7**
91. Other free-living caterpillars. **E;1**
92. Palmerworms. **E;1**
93. Plume moths. **E;1**
94. Tent caterpillars. **E;1**
95. Tuber worms. **B;3,6**
96. Wax moth. **J;7**
97. Webworms. **E;1,8**
98. Yucca moth. **D;8**
99. Zebra caterpillar. **E;1**

SIPHONAPTERA

100. Fleas. **H,I;4,7,10**

DIPTERA

101. Cheese skipper. **G;7**
102. Cluster fly. **I;4**
103. Deerflies. **I;4**
104. Fruit flies. **C;1,10**
105. Gall midges. **E;6,8**
106. Hessian fly. **E;6**
107. Hornfly. **G;4,7**
108. Housefly. **G;5,7**
109. Leaf miners. **E;8**
110. Leather jackets. **B;6**
111. Mosquitoes. **H;7,8**
112. Turkey gnats. **I;4**
113. Vegetable maggots. **B;6,10**

HYMENOPTERA

114. Ants. **G;3,7**
115. Gall wasps. **E;8**
116. Pigeon tremex. **A;8**
117. Sawflies (slugs). **E;1,6**
118. Seed chalcids. **D;8,9,10**
119. Wheat straw-worm. **E;6,8**

CLASSES OF INJURIOUS INSECTS

A. Destroyers of wood.
B. Of roots and tubers
C. Of fruits and nuts
D. Of seeds and grains
E. Of herbage
F. Of woolens and furs
G. Other household pests
H. Pests of man
I. Pests of live stock
J. Miscellaneous

MEANS OF CONTROL

1. Food poisons
2. Contact poisons
3. Fumigants
4. Repellants
5. Traps
6. Cultural control
7. Removal of breeding places
8. Destructive acts
9. Natural enemies
10. Trap crops—Miscellaneous

In the preceding list we have disposed of considerable groups of species under the following collective names:

In Lepidoptera; cutworms, webworms, loopers, borers, case-bearers and hornworms.

In Coleoptera; leaf beetles, flea beetles, blister beetles, borers, curculios and weevils.

In Diptera; fruit flies, root maggots and gall midges.

In Hymenoptera; ants and sawflies.

In Orthoptera; grasshoppers.

A recent name list* of our economic species includes 524 species of insects, of which 162 are Lepidoptera, 151 are Coleoptera, 110 are Hemiptera,†, 41 are Diptera, 23 are Hymenoptera, 23 are Orthoptera, 9 are Thysanoptera, and 3 are scattering.

The preceding list will show both prevalent types of pests, and prevalent modes of treatment; but for specific instructions as to treatment, consult the bulletins‡ and other literature dealing with particular species.

In the following list of principal crops the crop-destroying species (and groups of species) of the foregoing list are listed again (by numbers only) under the plants and plant groups that they infest. Use the two lists together. For example, the number 26 after the word "Grape" in the following crop list will tell you that there is a leaf-hopper affecting the

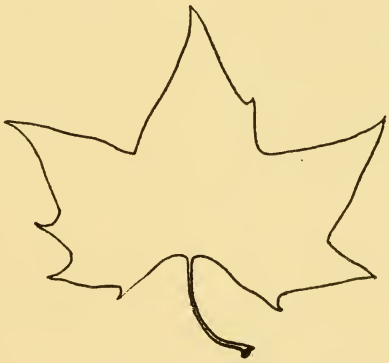
* Official name list of the American Association of Economic Entomologists of 1925.

† This includes the true (sucking) lice, Anoplura.

‡ Obtainable on request from the sources mentioned on page 150.

grape. Then turning to number 26 in that list, the symbols E;2 after the name Leafhopper will tell you that it feeds on herbage, and that it is normally treated with a contact insecticide.

Now, supposing you are raising potatoes and find that a hornworm is eating their leaves: in the tomato-potato group of the following list you will find sixteen leaf-eating insects, belonging to several orders. Referring to the insect list on page 152 you will find that five of them belong to the order Lepidoptera, and that one of them is a hornworm and that a food poison may be used to control it.



XX

INSECT ENEMIES OF PRINCIPAL CROPS

The plants are arranged in related plant groups, having considerable infestation in common. Their enemies are designated by the numbers of the preceding list. The part of the plant attacked is indicated by the full-faced letters **A** to **E**, as per key table, on p. 151, in which **A** means destroyer of wood; **B**, of roots; **C**, of fruits; **D**, of seeds; **E**, of herbage, this last term including all green parts.

Alfalfa and clovers (legumes)	**B.** 56 **D.** 61, 118 **E.** 7, 26, 46, 50, 60, 62, 65, 77, 83, 91, 92, 99, 105
Apple, pear, quince and crab (pome fruits)	**A.** 21, 59, 60, 116 **B.** 5, 17, 53, 63, 64, 68 **C.** 45, 74, 80, 104 **D.** 118 **E.** 6, 16, 26, 29, 30, 31, 34, 62, 66, 70, 71, 72, 77, 80, 81, 83, 84, 85, 86, 87, 88, 89, 91, 94, 97
Asparagus	**B.** 113 **D.** 36 **E.** 7, 16, 23, 33, 36, 44, 77, 83, 91
Beans and peas (lentils)	**B.** 64, 68, 113 **D.** 61 **E.** 7, 12, 16, 23, 29, 38, 48, 49, 50, 65, 77, 83, 88, 91, 97
Beets, spinach and rhubarb	**B.** 17, 113 **E.** 7, 12, 16, 38, 44, 46, 48, 66, 77, 89, 91, 99, 109

Orange, lemon and grapefruit (citrus fruits)	**B.** 56 **E.** 27, 30, 35
Peach, plum, cherry, and prune (stone fruits)	**A.** 59 **B.** 53, 68 **C.** 45, 80, 104 **E.** 16, 21, 29, 30, 48, 50, 60, 70, 71, 83, 87, 91
Raspberry and blackberry	**A.** 6 **B.** 68, 113 **E.** 6, 28, 30, 43, 50, 60, 77, 83, 84, 86, 87, 88, 97, 117
Strawberry	**B.** 17 **E.** 12, 16, 28, 29, 34, 43, 48, 50, 62, 76, 77, 84, 87, 91, 117
Sugar-cane	**B.** 16, 68 **E.** 26, 27, 60, 91
Sweet potato	**B.** 64 **E.** 16, 29, 38, 48, 50, 62, 77, 87, 91, 93, 97
Timothy and other grasses	**B.** 37, 63, 64, 110, 113 **E.** 7, 12, 16, 20, 65, 91, 92, 97
Tomato, potato, tobacco and peppers (solanums)	**B.** 63, 64, 68, 95, 113 **C.** 80 **E.** 12, 16, 23, 26, 29, 38, 42, 44, 48, 50, 60, 77, 82, 86, 91, 97
Wheat, rye, oats and barley (grains)	**B.** 64, 110, 113 **E.** 4, 7, 12, 16, 65, 91, 92, 106, 119

Three lessons follow that are of a strictly economic character. Each may be divided or expanded or repeated with new materials if desired. They are:

14. Insect injuries and their control.
15. Wormy apples.
16. The seasonal history of a plant pest.

LESSON 14

Insect Injuries and Their Control

I. *Crop Pests*

Select some common crop such as apple or potato. Go out where it grows and find as many as you can of the kinds of injuries to it outlined in pages 157–59.

During the growing season both biting and sucking insects will be readily found in almost any garden. Leaves wholly or partly consumed will mark the work of the insects with biting jaws; leaves badly curled or wrinkled, the work of the sucking insects. Select insects of both sorts for experiment. Food plants with their depredators on them may be kept fresh for a few days under bell-jars in the laboratory, if the work cannot be done in the garden.

Experiments with Insecticides

Food poison experiment.—For the *biting insects*, dissolve a teaspoonful of arsenate of lead in a quart of water and spray it on the leaves to be eaten by the insects.

Experiment with a contact insecticide.—For the sucking insects (preferably plant lice or aphids) add 25 drops of "Black-leaf-40" or other equivalent nicotine preparation to a quart of water (with a little soap added to make it adhere better), and immerse the aphids in it bodily, either by dipping them if they be on twigs, or by applying the liquid to them in a spray.

Experiment with a fumigant.—Place the insects with their food in a tight box; throw in some calcium cyanide dust and close the lid tightly. Do not open for twenty-four hours.

Watch the results of these experiments for a few days, and then write up a brief account of them, and their results.

Observations on Predatory Enemies

Natural enemies.—Nature's method of keeping these plant destroyers in check is to set some of their predatory enemies upon them. Thus aphids are consumed by the larvae of the lace-wing fly (fig. 32). If one of these larvae (easy to obtain by sweeping low vegetation with an insect net) be placed among a colony of aphids, it will usually begin feeding at once, picking up one aphid at a time on the tips of its long hollow jaw-tubes, and holding it aloft while sucking out the blood and other fluids from its body; then, casting away the empty skin. Other predatory enemies of aphids are syrphus fly larvae and ladybird beetles and their larvae.

Observations on the habits of any of these may be made by placing them in the midst of an aphid colony, and watching for their attack upon the aphids. An aphid colony on a

potted geranium will be convenient for the purpose; or an infested apple twig may be kept in a vase of water under a bell-jar. A written report of things seen should name the plant used, and the group to which the predatory insect belongs—whether aphis lion, syrphus fly larva, or ladybird—and should describe the method of attack upon the aphids.

II. *Household Pests*

1. *Injuries to woolens*, etc.—Search such a place as attics, closets and unswept corners in garages for scraps of discarded woolens and fur, and you will be likely to find pieces that are heavily infested with larvae of clothes moths (small, nearly naked-skinned caterpillars) or of carpet beetles (small hairy-skinned grubs), or of both. Observe that the feeding is all upon wool, cotton being entirely avoided.

Treatment.—Put the infested scraps in a tight box, and pour in a little carbon bisulphide (see page 146) and close the box over night. Observe next day what has been the effect on the larvae.

2. *Injuries to stored food products*, cereals, beans, etc., by meal worms, flour moth larvae, bean weevils, etc., may be treated in the same way.

III. *Body pests*

A little diplomatic searching might possibly find some fleas or bedbugs for treatment.

For specific directions as to treatment, dosage, times, and

conditions always consult the economic literature dealing with particular species.*

For record of your observations, write up for each experiment an account of the nature of the injury, the habits of the pest, and the method of its control.

LESSON 15

Wormy Apples

If it is autumn, and if near by there is an old apple tree carrying a load of fruit (whether good or bad fruit does not matter), let us examine the scars† on the apples for thus we may learn what are the principal enemies of the apple fruit and how different are the ways in which they do their work.

First, we will gather the apples—all of them; good, bad and indifferent. Or, if there be too many, then all that are on some natural division of the tree. Then we will arrange

* See page 150.

† Since it is not always easy to identify the insect by the scars it has left, we must be careful in gathering the apples not to throw away certain bits of evidence, especially these two sorts:

1. Clusters of numerous dwarfed apples having skins puckered toward the blossom end, and borne on very tough stems; these clusters should be kept together, for they are the sure signs of the work of aphids.

2. Apples with leaves fastened against them by means of silken threads; each apple should be kept with its leaf attached until we are ready to study it; for this is the sign of the bud moth. With these precautions observed, this study may be kept in reserve for a rainy day, and all the apples gathered and brought indoors for study.

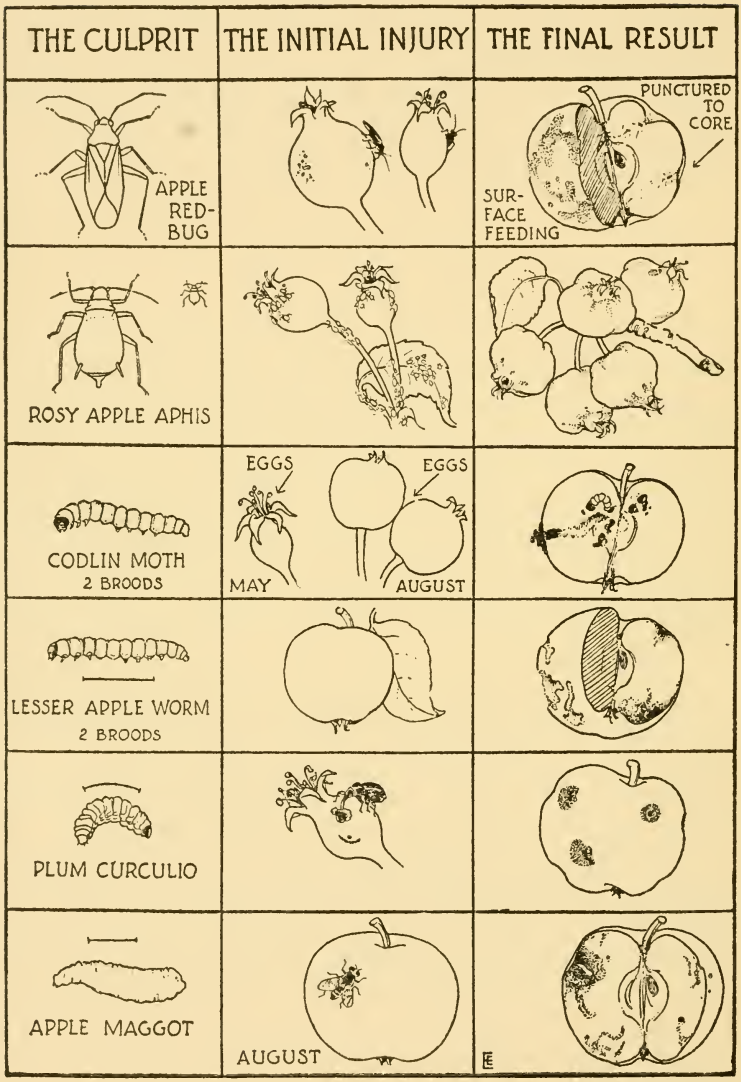


FIG. 58.—Apple blem

THE CULPRIT	THE INITIAL INJURY	THE FINAL RESULT
FRUIT TREE LEAF-ROLLER	JUNE	AUGUST
GREEN FRUIT WORM	JUNE	AUGUST
WHITE-MARKED TUSSOCK MOTH	JUNE JULY	SEPT.
BUD MOTH	SEPT.	SEPT.
PISTOL CASE-BEARER	JUNE JULY	AUGUST SEPT.
THE APPLE MINER	SEPT.	SEPT.

ishes, and their causes.

them in piles, each pile containing apples that show one kind of injury, with all sound and uninjured ones in a separate pile. Then the extent of the damage done by each kind of insect will be at once apparent.

The scars and other blemishes upon the apples are the signs that the enemies of the apple leave behind them. We will first examine the scars as to their size, shape, depth, color, and surface markings. We must remember that these apples have been upon the tree since blossoming time in May. During most of this time they have been small and green and fuzzy, and much like the new shoots of the apple in their sap content. Many of the scars are due to insects that feed mainly upon the leaves and that bite into the apples only incidentally, with no apparent preference for the fruit.

Then we will look inside the apples for further evidence. Few of the insects will be present in the apples in the autumn; most of them will have done their damage earlier in the season, and departed. There will be far more blemished than wormy apples but there are at least two kinds of "worms" that may still be found in the fruit:

1. Small pinkish caterpillars, boring deeply into the core, and depositing brown stuff along the sides of the burrow; these are the larvae of the codling moth.

2. Soft whitish headless apple maggots, that bore irregularly through the flesh of the apple, mostly near the skin; these are the larvae of a fruit fly.

We should remember also that an apple tree tends to

"set" more fruit than it can possibly mature, and corrects this by a "June drop," during which most of the weaker and the injured apples fall to the ground. During the rapid growth that follows the drop, all wounds in apples that remain on the tree tend to heal over quickly. A new skin is formed beneath the old dead tissue, and scabs off more or less completely, leaving a russet surface.* The scars will tell us what insects caused them if we will study their form and appearance carefully.†

There are perhaps a dozen kinds of apple insects whose work may often be identified in the fruit of a single tree. These are shown diagrammatically in the accompanying figures, and brief notes concerning them are set down in the following 12 paragraphs.

1. *The apple red bug:* Sucking insect; half grown when the apples bloom; punctures the apple with its beak; punctures made in very small apples reach the core and make shallow irregular russet scars; scars often confluent, forming "valleys" over the surface of the apple.

2. *The rosy apple aphid:* A sucking insect; gregarious, feeding in flocks on the new shoots; increases rapidly and spreads over leaves and young fruit; punctures cause the

* This new skin being thinner than the old sometimes yields to internal pressure, rising up on wart-like protuberances. These warts have no significance for us here.

† The scars vary with the size of the apple when injured, with the number and position of the wounds made, and with the growth-habits of the variety of the apple, but still they have constant features by which the work of each kind of insect can be known.

fruit to pucker at the blossom end; stems toughen, and no drop occurs; hence, too many apples on a twig, competing, and they remain small; aphids leave the apple trees in June.

3. *The codling moth:* Damage done by the larva, which eats its way deeply into the apple; two broods a season; first brood generally enters at blossom end, second brood generally at the side where a leaf or a twig or another apple touches; larva bores down into the core; brown pellets in the burrow; larva leaves apple and transforms under loose bark or other shelter; the hole is plugged while the larva remains inside. This is the worst pest of the apple grower.

4. *The lesser apple worm:* Damage done by larva, similar to the preceding, but smaller; burrows less deeply, mostly just underneath the skin of the apple, leaving the skin uneaten, except for the entrance hole, and remains longer in the apple in autumn.

5. *The plum curculio:* Damage done by both adult and larva; adults feed on young fruit, eating small round holes in the skin, and then eating under the skin as far as the beak can reach; adult female also makes other punctures in which to deposit her eggs; half way around each egg puncture she cuts a crescentic slit in the skin of the apple; scars, therefore, are of two shapes; circular, around feeding punctures, and semicircular (one side is at least straightish) around egg punctures.

6. *The apple maggot:* The larva of a pretty fly; attacks nearly mature apples. The adult fly inserts her eggs through minute punctures in the skin; the soft white legless and

headless larvae burrow through the pulp very irregularly, sucking up its juices, causing it to soften and turn brown with decay; little superficial scarring (often unnoticed until the apple is cut open) but sad results inside. A widely distributed and very injurious pest.

7. *The fruit tree leaf-roller:* Damage is done by the larva of a small moth; larva lives in a shelter of uprolled leaves that are fastened together with threads of silk; it eats the leaves; it also reaches out from its retreat to eat holes in nearby apples; eats deeply; scars bronzy in color, some part usually showing a narrow deep excavation.

8. *The green fruit-worm:* Damage by larva, a naked caterpillar; feeds restlessly about eating many small apples, and biting into many more; makes broad shallow scars, that often show tooth-marks at their margin.

9. *The white-marked tussock-moth:* Damage by moth larva, a caterpillar with tufted hairs; feeds shallowly while roaming about, often feeds in several places on the same apple; scars shallow, irregular, but showing narrow lobes that mark feeding tracts.

10. *The bud moth:* Damage by little caterpillars (of later broods than those that infest the buds in earliest spring). The larva feeds beneath a web of silk spun against a leaf; normally it eats leaves; but when its sheltering leaf lies against an apple, it attaches the leaf to the apple by means of threads of silk, and eats minute holes in the skin of the apple; the leaf still adheres to the skin of the apple at picking

time; when removed, the holes appear on a paler area that has been bleached by the leaf's shadow.

11. *The pistol-case bearer:* Damage is done by the larva of a small moth; larva makes a portable case out of bits of leaf fragments and carries it about on its back; feeds mainly on the leaves, but now and then on young fruit; eats a small hole through the apple skin; sticks its head in through the hole and feeds under the skin in all directions as far as it can reach without letting go its case. Scars circular, often several on one fruit, differing in size because they stretch with the growth of the fruit, and the smaller ones are those made later in the season.

12. *The apple miner:* Damage by the larva of a very minute moth; the flat yellowish larva eats a narrow passage way, or "mine," close to the surface; mine shows through the transparent skin, cylindric, winding, with a dark line down the center. Not common, but easily recognized when present; little damage—mainly disfigurement.

It is to be borne in mind while we are studying this motley apple crop that not all the scars that appear on apples are caused by insects. There are frost cracks; there are mechanical injuries, such as rents in the skin made by hailstones; there are surfaces that are roughened by continual rubbing against boughs; there are chemical injuries to the skin, due to lime or strong arsenicals applied as sprays; and there are fungous injuries in great variety caused by apple scab. Among all these, the scars caused by insects will generally be recognizable by the constant recurrence of the

characters stated, and illustrated in the figures of the last column.

Control.—These pests are so abundant that every apple grower must fight them or suffer the loss of the best of his crop. Poisons applied to the trees as sprays or as dust are his chief reliance. Quite as important as knowing what poison will kill an insect is knowing when and how to apply it. State Agricultural Experiment stations issue "spray calendars" giving this information. Everyone who raises apples should follow the spray calendar applicable to his own locality, even though he has but a single apple tree; for the neglected tree is a nursery of pests, and may become a center of infestation of a whole neighborhood. The person who maintains such a nursery is not a desirable neighbor.

LESSON 16

The Seasonal History of an Injurious Insect Plant Pest

Select one of the worst crop pests of your home locality. Get bulletins* or books that will give its life history in full detail, and study them. Study the diagram on page 102 (figure 41) of the Japanese beetle, and make a similar diagram of your own, showing the same things for the pest you have chosen.

On the opposite page is an other example of the excellent way in which the U. S. Bureau of Entomology is telling the story of the life history of a common pest, and recommending control measures.

* See page 150 as to sources of this literature.

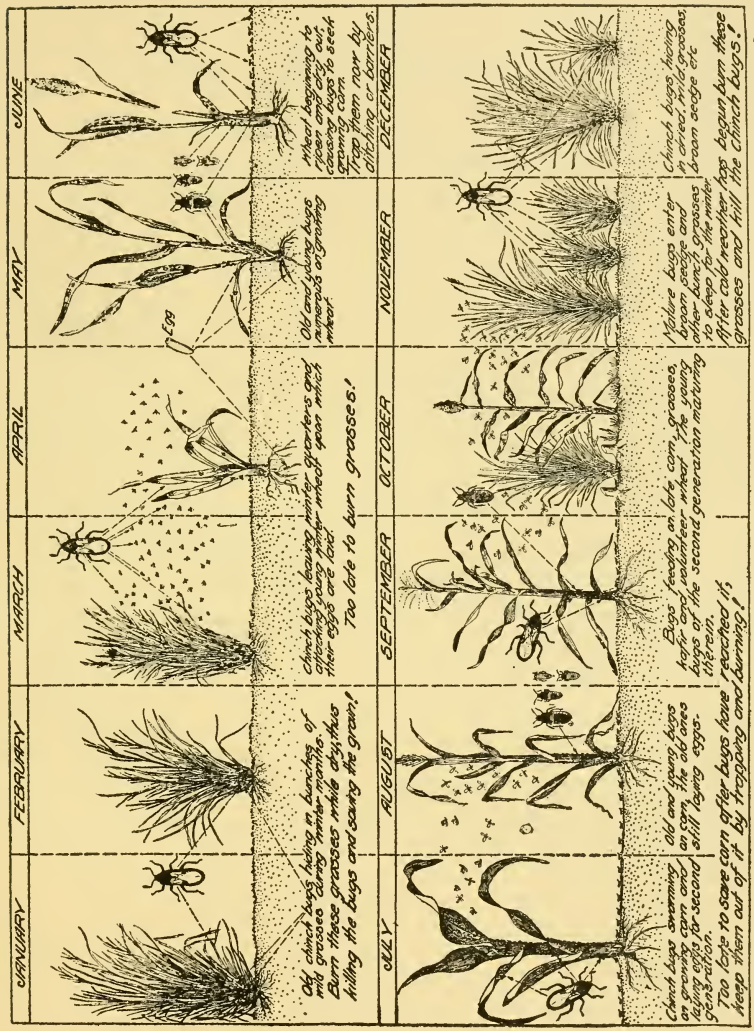


Fig. 59.—The seasonal history of the chinch bug.

XXI

HOME PROBLEMS ON CROP PESTS

Here is a way to make your study of the preceding insect groups very practical: Examine the crop list on page 157 and pick out the crops in it that are of most importance in your home locality. The insect enemies of those crops are told by numbers in that list. Then turn to the pest list on page 152 and get their names (the insect names corresponding to these numbers). Write them down; and then go to some intelligent grower and ask him which of the insects that you have written down are the important ones in your locality. Then get these insects and use them for study as representatives of the several orders.

For example, if you are studying the true bugs (Hemiptera, Lesson 6 on page 70), and if the grape is an important crop in your locality, the crop list on page 158 will tell you that among the enemies of this vine there is an aphid that attacks the roots (B,17), and that there are also leaf aphids (E,16), leaf hoppers (E,26), plant bugs (E,29), and scale insects (E,30). Now, if the leaf hopper is the worst pest of this vine in your locality, be sure to use grape-vine leaf hoppers as part of the illustrative material for this lesson, and learn all you can about them, their habits, their life history, and the best means for their control.

PART IV

COLLECTING, PRESERVING AND REARING INSECTS

XXII

COLLECTING

Tools

The one most indispensable tool of the insect collector is a killing bottle. This is a wide-mouth bottle of any sort containing cyanide of potassium or some other quick-acting poison. The cyanide, if mixed with a little boracic acid, will give off its poisonous fumes more readily. It is usually fastened either in the bottom of the bottle, under retaining discs, or in the hollow stopper. Insects are very susceptible to the fumes, and when placed inside they are quickly killed, and so, are obtained undamaged. Many insects may be collected with a cyanide bottle alone, by handpicking.

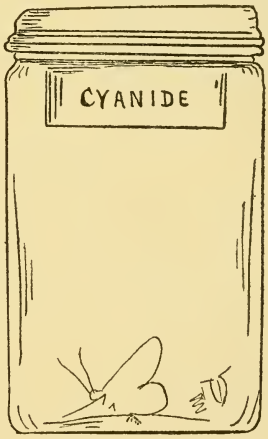


Fig. 60.—A cyanide bottle.

Next in importance is an insect net of some sort. The standard net is twelve inches in diameter of rim and a handle $2\frac{1}{2}$ to 3 feet long. The bag should be rounded or tapered to the bottom and, for convenience in using, its depth should not exceed the length of the collector's arm. A net is quite necessary for capturing swift-flying insects. For taking dragonflies and butterflies it should be light and strong, and of rather open mesh.

A heavy net with a shorter handle and a bag of stout muslin (called a beating net) may be used with advantage for sweeping vegetation. This will obtain many kinds of insects in all stages where few are ordinarily seen—protectively colored insects that hide in the grass and weeds.

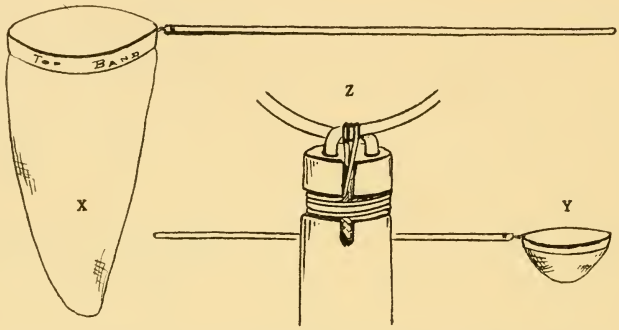


Fig. 61.—Nets for insect collecting. *X*, an air net; *Y*, a water dip net; *Z*, a simple method of attaching home-made rim and handle.

With either net, when the insects have been swept inside, a quick turn of the wrist closes its mouth and keeps them there until a cyanide bottle can be introduced to receive them. A little practice will enable any one to use these tools effectively.

A dip net for individual collecting should be shallow and flat bottomed (so that the catch can be seen in it before removal). It should have a rim stiff enough to stand pushing in and out among water weeds. For use in common by members of a class the most generally useful sort is a sieve net,

preferably one with a long detachable handle. This may be used both for sweeping submerged weed beds for insects, and for scraping up the bottom sand and mud and sifting them out of it.

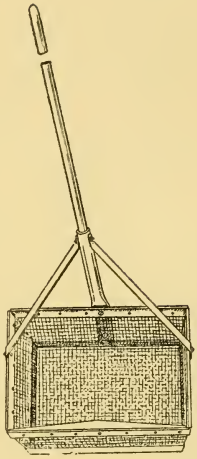


Fig. 62.—A sieve net.

It will be found advantageous in collecting aquatic insects to dump the sifted stuff from the net into a white-lined dish of water, where the insects will at once show themselves by swimming about. They may then be taken from the water on a lifter made from a small piece of wire cloth, having infolded edges.

Fig. 63.—A lifter.

Adult insects from the water (beetles and water bugs) may be killed in a cyanide bottle and pinned like other insects; but the immature stages are better preserved in vials of alcohol.

Specimens from the cyanide bottle when dead and beyond resuscitation, may be kept in paper envelopes. These are "made on the job" from rectangles of paper (say, post-card size) by first folding the sheet diagonally across the middle and then folding the ends over the sides beyond which they project, and then cross folding the two acute angles. Large, free-winged specimens, like butterflies and dragonflies, should be placed singly in these

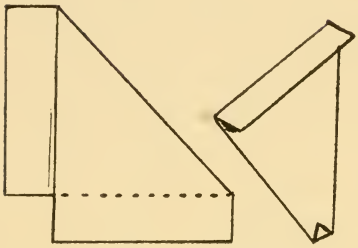


FIG. 64.—A storage envelope.

envelopes with the wings closed together above the back. The name of the insect, locality and date of collecting should be written on the outside of the envelope.

Specimens so "papered" may then be preserved indefinitely in any pest-proof box. This is a very economical method for keeping duplicate specimens, and it is used by the best entomologists everywhere. These specimens may be "relaxed" (see p. 186) and mounted at any time later.

For quick handling of small insects in large numbers (as often obtained by sweeping, or from swarms) there is a quicker and easier method. Get a small tin box and cut rectangles of glazed sheet cotton to fit it inside. Place a sheet of cotton in the bottom, then a thin layer of the insects, as they come from the cyanide bottle, then other sheets of cotton and layers of insects until the box is full. Then put on the lid and keep it away from pests. Do not use loose cotton, for claws will hook in it and legs will be broken off; or, place layers of tissue paper next the insects. The insects will need to be relaxed before removal from the box.

Where to collect.—Insects are everywhere; but particular kinds, such as this course demands—even the commonest kinds—must be sought in particular places. Here are a few suggestions as to the sources.

1. *Freshly blooming fields* of goldenrods, asters, thistles, etc., will furnish butterflies, long-horn beetles, soldier beetles, ambush bugs and numberless kinds of bees and flies, and *the way to get them* is by means of a net and cyanide bottle. Sunshiny weather is required for best results.

2. The *meadow herbage* will furnish meadow grasshoppers and katydids, tree crickets and plant bugs, leafhoppers and aphids, moths and butterflies and their larvae, sawflies and craneflies and numberless other little flies and bees and beetles, and *the way to get them* is by sweeping the vegetation with a net and picking them out of the net.

3. The *beds of vegetables* in any garden will furnish squash bugs and cucumber beetles, and grasshoppers and numberless other pests, together with their young, and *the way to get them* is with net and cyanide bottle and vials of alcohol, and considerable hand-picking. Specimens, always available.

4. The *shelters* under logs, old boards, stones, etc., that have long lain on the ground undisturbed, will furnish cockroaches, ground beetles, field crickets, moth larvae and pupae, and other terrestrial animals, not insects (such as pill bugs, slugs and millipedes), and *the way to get them* is by overturning these things and by hand-picking. If the collector will turn the shelters back again, later others may collect from the same source.

5. The *sand bank* or barren shore will furnish tiger beetles, ant lions, digger wasps, robber flies, and many kinds of bees and flies and beetles, and *the way to get them* is by energetic

use of net and cyanide bottle. Dry weather is best for this.

6. The *electric lights* at the street corners will furnish adult stoneflies and mayflies, lace-wings, caddisflies, and numberless kinds of moths and beetles, and *the way to get them* is by net and hand-picking at night. Atmospheric conditions control this sort of collecting. There is no better collecting on favorable nights; but such may be few and far between. Humid, cloudy nights just before a rain are best. Watch the lights nearest home, and when insects are seen to be about them, then go out. Streamside lights should be visited for aquatic insects.

7. The *edge of a pond* that is rich in shore vegetation will furnish dragonflies and damselflies, midges and swaleflies, pygmy grasshoppers and leafhoppers, and many kinds of small flies and ichneumon flies, and the *way to get them* is by energetic use of the net.

8. The *weed beds of a pond*, or of a stream embayment ("backwater"), will furnish water bugs and their nymphs, diving beetles and their larvae, dragonfly and damselfly and mayfly nymphs, midge and mosquito and swalefly larvae, caddisworms in portable cases and other animals not insects (such as snails, scuds, tadpoles and minnows) and *the way to get them* is by sweeping the submerged water weeds with any kind of water net. Dump the contents of the net into a white dish of clean water for examination. Take specimens with a lifter.

9. The *muddy* or *sandy bottom of the pond* will furnish dragonfly and mayfly nymphs and orl fly and cranefly and

midge larvae and other animals, not insects (such as craw-fishes and little white mussels) and *the way to get them* is by scraping up the bottom stuff in a sieve net, sifting it and picking them out. Where loose bottom trash occurs, they may be gotten with a common garden rake by raking the trash ashore and then picking it over.

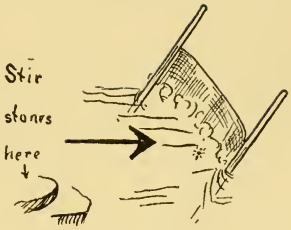


FIG. 65.—A screen with handles, for use in riffle. A piece of window screen wire cloth 1 x 2 feet, with edges "hemmed," ends inserted in saw groove cut in handles and nailed fast there.

10. The *rapids of the brook* will furnish stonefly and mayfly nymphs, hellgrammites and fish fly larvae, flat "water pennies" and other larvae of riffle beetles, midge and cranefly larvae, etc., and *the way to get them* is to hold a screen in the current, stir the stuff on the bottom, upstream side, to dislodge them, and as soon as they are gathered on the screen, lift it and pick them off.

Some general suggestions.—Aquatic insects are best gathered at times of low water when they are more concentrated in the contracted water areas. This is of less consequence in steep banked ponds and in small spring-fed streams; but larger open streams after a flood will often seem to be entirely "washed out"; and in very shallow newly filled ponds many of the shore animals will be for a time out in deeper water.

Collect in quantities when the collecting is good. Collect when you find the insects swarming, as do mayflies, midges

and caddisflies in their mating flights; when you find hosts of nymphs emerging and transforming together, as do cicadas, coming from the ground, or dragonflies, from the pond; when you find them accumulated after a storm at the drift line on sandy lake beaches as often are many beetles; or, when the picking is good, on flowers, at lights, etc.

For purposes of study of skeletal parts, no material is better than cast skins, and these can often be found abundantly where transformations have occurred. Preserve these dry in small boxes or vials and use them for slide mounts. Exercise foresight, and provide against future needs.

XXIII

PRESERVING

In alcohol.—The quickest way of disposing of insect specimens, and one that gives good preservation as well, is to put them at once in vials of alcohol (4-dram homeo vials are perhaps the most generally useful). "Proof spirit" (95%) diluted with one-fourth water will be about the right strength: if undiluted, it hardens too much, making the specimens brittle. This is perhaps the best way to preserve larvae and soft-bodied insects. It is not suited to preserving scaly insects, like butterflies; or hairy ones, like caddisflies; or bristly two-winged flies; and all adult insects having sufficient rigidity of body to keep a proper shape on drying are ordinarily mounted on pins. Unfortunately alcohol spoils the natural colors.

Only the best quality of corks should be used in the vials, for poor corks permit evaporation, and alcoholic specimens allowed to become dry are well nigh worthless. Good corks if not directly in contact with the alcohol will last for many years. Racks that will keep the vials in proper erect position may be quickly made in the shop.* Labels should be written on strips of white paper with a soft lead pencil (writing ink fades in alcohol) and placed inside the vials, with the writing outward against the glass. They should read from the bottom

* The specifications are: dimensions: 1″ x 2″ x 15″; the bottom, a 1″ wooden strip 15″ long and ¼″ thick and the ends two 1¾″ pieces of the same. When these are nailed together a piece of strawboard or binder's board 2″ x 15″ is nailed to them for a back and a piece of celluloid 2″ x 15″ for a front.

of the vial to the top. Outside gummed labels are not permanent. The celluloid front permits reading without removal of the vials from the rack.

Preservation on pins.—This is the regular way of making an insect collection. The horny outside skeleton allows insects to be dried with less alteration of appearance than any other animals.

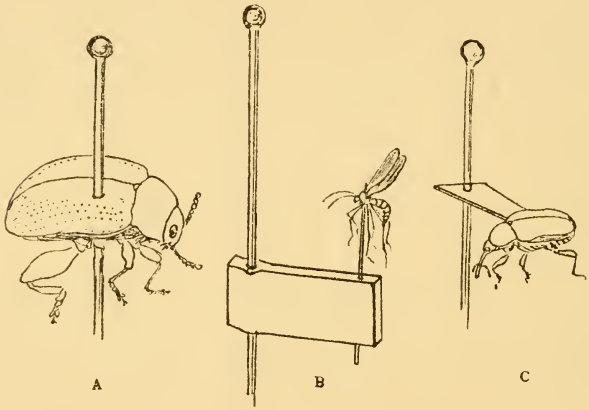


FIG. 66.—Odd ways of pinning insects: *A*, a fleabeetle pinned (as is the rule for beetles) through the right wing cover; *B*, a gall midge mounted on a pin point; *C*, a snout beetle glued to a paper point.

When removed from the cyanide bottle they may be pinned at once; and best so, if time permits. When once they have become dry and brittle, they have to be relaxed before they can be pinned. The *relaxing jar* commonly used for this purpose is a two-gallon jar of glazed earthenware containing damp sand over which clean papers are spread.

The specimens are placed within it over night (or longer if necessary), and the jar is closed with a lid. When again flexible, the insects are pinned as when freshly killed.

The best insect pins are $1\frac{1}{4}''$ long, black, stiff, sharp-pointed, with small round heads. They are thrust vertically through the mesothorax in most insects, through the right wing cover in beetles, leaving one-fourth of the pin exposed above the back. Uniformity in position of specimen on the pins, adds to the appearance of the collection, and depth-gauges of various sorts may be used to secure it; but if, in pinning, the pin head be grasped uniformly between thumb and forefinger, and pushed through the insect into a cushion, until the back of the insect touches the finger tip, a degree of uniformity will be secured, and time will be saved.

There are other ways of pinning insects when so minute that the pins would split the bodies. Very small beetles are glued to the points of elongate paper triangles, and the triangles are then pinned. Minute Diptera are usually mounted on pin points (slender pins cut to half length), thrust upward through small pith or paper blocks, with another larger pin through each block.

Preservation in papers.—Dried specimens must not be allowed to lie around over night exposed, else some of the little beetles that are museum pests may find them and lay their eggs on them. Larvae, hatching from these eggs, will quickly reduce the specimens to dust. Mice have destroyed many a day's patient collection when left exposed. Specimens put up in paper envelopes, or in layers between glazed

cotton, as above directed, may be kept indefinitely in any kind of boxes if sealed and made pest proof and kept in a dry place.

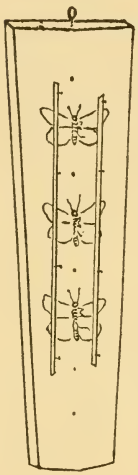


Fig. 67.—A very simple spreading board, on which insects are placed upside down, expanded and dried in that position.

Spreading.—For purposes of display of beautiful butterflies, moths, dragonflies and other showy-winged insects, nothing adds so much to the appearance of a collection as the proper spreading of their wings. This requires a spreading board, on which the wings may be arranged and held until dry in proper position. They must be symmetrically placed on the two sides of the body. The hind margins of the fore wings should be on a line at right angles to the axis of the body, with the hind wings drawn forward to meet them properly.

There are two standard forms of spreading board. The simpler one has a row of holes down its face half an inch deep. On this board the insect, with the pin inserted, is placed upside down, with the head of the pin at the bottom of of one of the holes. The wings are drawn forward to proper position for display, and are held there under strips of paper pinned across them. The legs and antennae are arranged in position easily on this type of board. The other sort of board is grooved, and the body of the insect is placed in the groove, right side up, its wing bases on a level with the edges of the groove. The wings are spread and held in

position, as in the other. This board is best for insects having on the back tufts of scales or of hairs that should not be depressed.

Proper spreading of the wings of little moths is something of an art; the wings must be symmetrically placed. A hooked pin point is often useful in drawing them into position. The fine colors of the wings of butterflies and moths are in the scales, and these must not be rubbed off.

A drying box with shelves on which spreading boards may be placed, and with ventilating windows covered with fine meshed wire cloth to keep out museum pests, is a convenience that any manual training department can provide. Spread specimens must be left on the boards until thoroughly dry (a week, perhaps); for if removed too soon, the wings will droop.

Cases for pinned specimens are made with soft bottoms to receive the pins; and if the specimens are to be seen without being handled, they should also have glass tops. They should be made tight, and pest-proof.*

Preservation on slides. Some insects are so minute and so fragile that they are best preserved by being mounted in balsam on microscopic slides. The mouthparts and other small appendages of most insects are so small that when prepared for critical scientific study they are best mounted in this way. The method is so simple that any one can learn to

* If pests get in, the sign of their presence will be a brown dust falling on the bottom of the box beneath the specimens. They may be killed with carbon bisulphide. Stick a bit of sponge on a pin; saturate it with carbon bisulphide; stick the pin in the box and close it up tight.

do it at the first trial. The specimens, whether whole minute insects, or minute parts of larger insects, are first soaked in strong alcohol until the water is extracted from them. Two changes of 95% alcohol may be required for this, with a stay of some 5 to 10 minutes (longer if impervious) in each.

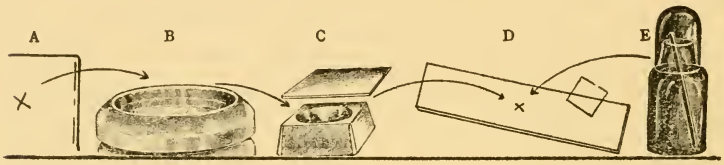


Fig. 68.—Diagram illustrating a method of making slide mounts. Specimens are prepared on the stage of a dissecting microscope, *A*; then soaked in strong alcohol in the watch glass, *B*; then cleared in carbol-turpentine in the second glass, *C*; then placed at *x* on the glass slide, *D*, on which there has been placed a drop of canada balsam from the bottle *E*. Then the coverglass is added and a gummed label attached.

Then they are transferred to carbol-turpentine or carbol-xylol.* This is a clearing agent. It replaces the alcohol and prepares for balsam. Then they are transferred from the clearer with a forceps to a drop of Canada balsam that is first placed on a slide. In the balsam they are then arranged in proper position, and a thin cover glass is lowered over them. When the balsam has spread out evenly to the margins of the cover glass, filling the space underneath completely, the mount is finished.† It should then be

* A mixture of 1 part of carbolic acid (pure phenol crystals) to 3 parts of either turpentine or xylol.

† Small air bubbles, if accidentally included, will escape of themselves slowly. More balsam, if needed to fill the space, may be added at the edge of the cover; The specimens should be placed well within the margin of

labelled. It should stand horizontally until the balsam has hardened.

Preservation in Life History Boxes.—A most useful preparation illustrating the life history (all stages) of a single species, together with its work, may be made by mounting the specimens in a pasteboard box on cotton under glass (a "Riker mount"). The adult, if wings should show, is spread and dried without pinning. Eggs, larvae (or nymphs) and pupae if hard shelled, are dried; if soft, they are put in small vials of alcohol, and the corks are cut close and covered with sealing wax. Then, with a layer of soft, clean cotton filling the box, all these specimens are arranged on top of the cotton* and then the glass-topped lid is put on. The lid presses the specimens down into the cotton, where they remain fixed in place. The box is then sealed with adhesive tape and made pest-proof and safe for handling. Such life history exhibits of economic insects are often a good means of conveying very useful information where it is most needed.

A school collection.—The best kind of a school collection is one that is made out of local materials by the members of

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the cover: if at the edges, they may be pushed inward by means of a fine wire or a No. 0 insect pin. All the slide mounts called for in the preceding lessons (excepting only the one cross-section of an insect's body) are to be made in this simple way. The ordinary cheap wooden boxes, grooved for holding 25 slides each, are quite satisfactory containers for such preparations.

* If the specimens are small and the box is not filled by them, enlarged photographs or other pictures may occupy some of the space under the glass.

the school itself. It should be begun by one class and continued by succeeding classes. It should grow; it should not be bought. The only things purchased for it should be the equipment and supplies necessary for the making of it.

It should be in part an exhibition collection of local insects, neatly mounted and labelled with both common and scientific names, and kept in glass-topped boxes on accessible shelves. Every collecting trip will yield materials for it. To be of use to the community it should be made as complete as possible in local economic species.

The school collection should be in part a study collection, containing:

1. Reserves of specimens, gathered when abundant and stored either in papers, or in alcohol. There are important groups of insects, like cicadas and mayflies and caddisflies, adults of which are easily obtained from summer swarms, but not so easily during the school year.

2. Slide mounts for showing structural details. These should be prepared in sets, in numbers sufficient for class use, and stored in slide boxes, plainly labelled. Some slides should be prepared by each pupil, and the best from each year should be saved and added to the collection.

3. Reserves of living materials, gathered each autumn for use during the following winter. These are best kept outdoors; the simple wire cloth cages described on page 200 will keep most of them, whether terrestrial or aquatic. In a dry, heated school building most of it will die of evaporation. But transformation may be hastened by a stay indoors, and

evaporation may be prevented by a momentary immersion of the whole cage in a tank of water now and then. This wetting will take the place of normal rains.

4. Miscellaneous preparations showing habits.
5. Cages and traps for living insects.
6. Samples of insecticides, fumigants and repellants.

Equipment for slide mounting and for cage-making.

There should be a table set apart for making slide mounts, and permanently equipped with one or more dissecting microscopes, needles, forceps, alcohol, clearer, balsam, cover glass, slides, covers, slide labels and slide boxes.

There should be a bench available for cage making (perhaps in the manual training department), equipped with window-screen wire cloth, tin shears, tinner's folding tongs, hammer and nails.

LESSON 17

Preparing Specimens of Insects

This lesson consists entirely of a:

WORK PROGRAM

1. Pin up some freshly collected (or freshly relaxed) bugs or other insects that do not require spreading of the wings, carefully inserting the pins through the middle of the thorax, vertically, and adjusting all to uniform height on the pins.

2. Pin a dragonfly and a butterfly or moth, and fix the wings in proper position on a spreading board (see page 188).

3. Pin a few beetles (vertically, through middle of the right wing cover).

4. Mount a few weevils or other minute beetles on paper points (see figure on page 186).

5. Mount a few mosquitoes on pin points (see figure on page 186).

6. Make a slide mount in balsam of several of the smallest midges obtainable.

7. Dissect and mount the mouthparts of a stonefly nymph or a cockroach.

LESSON 18

Getting the Equipment Ready

This lesson consists entirely of a:

WORK PROGRAM

I. *Making things for personal use.*

1. Prepare several dozen triangular envelopes to receive insects when collected (see page 180).

2. Prepare several dozen mounting points (see page 186). Cut these from strips of thick white paper 3/8″ wide; each snip of the shears cuts one point off the end of the strip.

3. Prepare a few pin-points mounted erect in pith blocks ready to receive mosquito specimens (see page 186).

4. Prepare several dozen slide labels (if printed ones are not furnished) by cutting 15/16″ squares of white gummed paper.

5. Prepare record sheets on paper to fit your note book by copying on it the outlines on pages 203 and 204.

II. *Making things for common use.*

1. A number of beating nets (see figures on page 178 and 196 as to plan).

(a) Prepare the wooden handles, first boring the holes in the ends; then cutting the grooves in the sides; then sandpapering them.

(b) Prepare the wire rims by cutting heavy wire into lengths of 39″, and bending each into a circle and smoothing the cut ends.

(c) Cut out bags of strong muslin, using a heavy wrapping-paper pattern of the dimensions shown in the accompanying diagram.

(d) Sew the bags, making a wide ($1\frac{1}{2}''$) hem for a top-band twice doubled to increase its strength. Close the side below the top-band with a French seam.

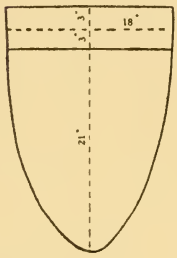

FIG. 69.—Diagram of a pattern for a (half) beating net (the same as for an air net). Double the cloth, lay this on it, and cut.

(e) Put the parts together, as follows:

Insert the rim into the top-band.

Bend the projecting ends so that they will be parallel when crossed.

Wrap ends twice around at crossing with a piece of soft wire.

Insert ends of rim into holes in handle.

Draw down wrapping wires tightly into the longitudinal grooves of the handle, and wrap them around the cross grooves and then twist them together and tie them firmly in place.

Heavy water nets, having shallow bags of netting and top-bands of duck, may be made after the same plan.

2. Prepare screen cages (see figure 70 on page 197) by cutting squares of wire cloth, hemming two edges together and opening out to form cylinder, and then cross-folding one end.

3. Cut and fit sods in flower pots for a few of the live cages shown on page 200.

4. A single caddisworm net-spinning trough will be needed. The making of it is a small job for the manual training shop.*

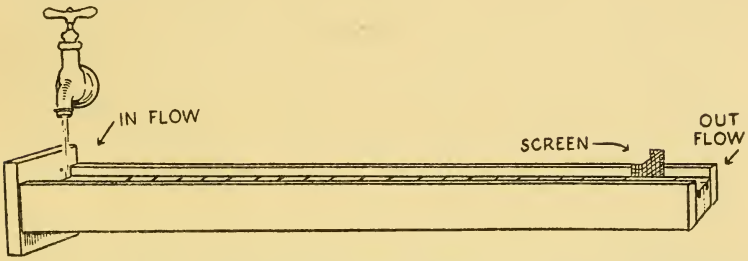

FIG. 70.—A trough for net spinning caddis worms, in which "made to order" food-catching nets are easily obtained.

* The materials needed are: (*a*) a piece of wire cloth 2″ x 3″; (*b*) two pieces of flooring or other stuff, grooved on one edge and two feet long; (*c*) two strips of equal length for the sides; and (*d*) a short cross strip for the intake end.

Make it as follows: Nail the two grooved strips together to form the bottom. Saw a cross-groove near one end to receive the screen. Place the screen in this groove, bending the ends flat against the sides of the bottom pieces. Nail on the two side pieces so that they will stand an inch higher than the bottom. Nail the short strip across the intake end (the end opposite the screen), in position, projecting both above and below the trough; below, far enough to give a slant to the trough of about an inch per running foot. If the bottom be painted black inside and dried before use, the nets made in this trough will show up better.

XXIV

REARING AND RECORD-KEEPING

The care of living specimens.—The way to learn most about the development of insects is to keep them alive under observation in cages. This is, also, the best way to get good specimens of the adults. Old specimens taken at large are apt to be tattered of wing and worn and rubbed, while those reared in cages issue usually in perfect condition. Furthermore some, like the larger dragonflies, are very difficult to capture in flight, but are easily reared. After transformation they must be kept alive until colors mature.

The best way to rear insects is to let them rear themselves. If they are near at hand and abundant, keep an eye on their progress; let them feed naturally where found until nearly ready to transform; then cage them, and there will be little further provision needed.

Small caterpillars, like those of the cabbage butterfly, may be reared in jelly tumblers, with close fitting lids. These should be cleaned and supplied with fresh food every day, until they transform. The larvae of this butterfly will pupate under the lid. Many moth caterpillars will require soil in which to bury themselves. If they can be obtained after the feeding is ended, rearing them will be a very simple matter of keeping them caged so that the winged adults will not escape.

The most generally useful of all insect cages is the very simple one shown in figure 71. It is made from a square piece

of wire cloth* by doubling and twice folding ("hemming") two edges together, then opening it out, forming first a cylinder; then in like manner the ends are cross folded and closed. Two tools only are needed: tin shears to cut the cloth and a tinner's small (4″) folding tongs to make the "hem." All kinds of materials containing fully fed larvae or pupae may be shut inside to await their transformation. The nymphs of dragonflies and other aquatic insects may be reared in it, if it be only partly immersed in the water, leaving room in the part above for their emergence as adults.

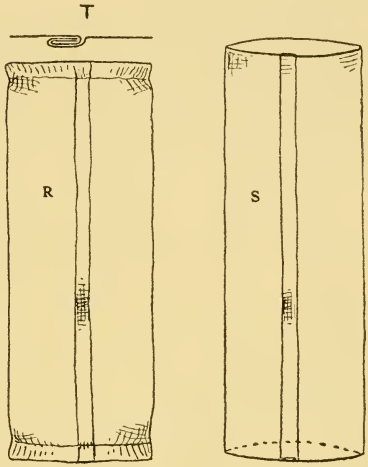

FIG. 71.—A cage for rearing insects. A square of wire cloth is doubled and the edges opposite the fold are "hemmed" (that is, twice folded over) by means of a tinner's folding tongs. It is then opened out into a cylinder as at S; then the ends are cross folded as at *R* to complete the cage. *T* is a section of the side seam of the completed cage. Bug tight. Easily opened and closed with the fingers.

For observing the feeding habits of such terrestrial insects as grasshoppers and crickets there is probably nothing better than the old reliable lantern-globe cage shown in figure 72, consisting of a flower pot containing a growing sod, the

* Ordinary window screen wire cloth 36″ wide cut into four per yard makes cages of convenient size for most common insects. To avoid pricked fingers, the woven edge should form the top.

glass having its lower edge sunk in the soil of the pot, and a cheese-cloth cover.

Small transparent insects, for examination with the microscope.—These may be obtained from any weedy, permanent pond, by lifting some of the floating "pond scums" and trash with a small dip net and placing it in shallow white dishes in clean water. Damselfly and mayfly nymphs will quickly appear (along with water fleas and other minute aquatic animals) swimming around the edges of the dish. The damselfly nymphs will be recognized by the three flat, vertically placed platelike tracheal gills in which the body terminates; the mayfly nymph, by the paired gills on the back of the abdomen, one pair on each of the first seven segments. Midge larvae will also probably appear: minute worm-like creatures that swim jerkily, by means of figure-of-8 loopings of the body. Either will show what is wanted for this study.

Fig. 72.—A lantern-globe live cage.

Choose the smallest and most transparent specimens to place under the microscope. Put them in hollow ground slides, or support the coverglass over them to avoid crushing. Use only living specimens.

Record Blanks

Records of individual observations.—Rearing work yields practical knowledge of insects. A good means of making it specific and permanent is the making of records of observations on particular species. For this purpose two outlines for the use of students are offered on the next two pages. One of these calls for observations on the feeding, locomotion, resting, shelter-making, defensive and other activities of the insect selected for study. The task is one of quietly watching the insect and of recording what is seen.

The second outline is for the use of any one who may have the industry and "stickability" to rear some insects through their entire life cycle from the egg to the adult. If such be selected as are easily supplied with common food and have a brief life period, this is not a difficult task. Certain common garden insects, like the cabbage butterfly, or noxious household insects, like the mosquito, are most favorable.

Here are five rules applying to all rearing work with insects:

1. *Maintain natural conditions.*
2. *Supply natural food.*
3. *Keep out enemies.*
4. *Keep close to your stuff.*
5. *Be watchful, and anticipate needs.*

I

An outline for:

OBSERVATIONS ON THE ACTIVITIES OF

Name of insect.....

Date..... Measurements
Length.....
Expanse.....

1. Stages found where found number found together
   adult..... .....
   pupa..... .....
   larva or nymph..... .....
   eggs..... .....
2. *Feeding* where.....
   on what.....
   in what manner.....
3. *Moving about* how (walking, swimming, flying, etc.).....
   using what parts (legs, wings, tail, etc.).....
   speed.....
   directness.....
4. *Resting* where.....
   in what position.....
5. *Shelter making* (describe or sketch nest, burrow, web, cocoon, etc.).....
6. *Enemies* and means of defense.....
7. Other activities.....
8. Beneficial or injurious to man and why.....

.....

II. An outline for a:

LIFE HISTORY RECORD

Name of insect.....

I. *Eggs*

1. Where laid.....
2. How clustered (sketch).....
3. How protected.....
4. Shape of egg (sketch).....color.....size.....
5. Hatching; describe how young comes out.....

.....

.....

Time required.....date.....

II. *Larva* or nymph

1. Molting (describe how skin is shed, time required, etc.)

.....

2. Length of larval life (give dates).....
3. Number of molts (give dates).....

III. *Pupa*

1. Size.....Color.....
2. Where found.....
3. Nature of cocoon or other shelter.....
4. Length of pupal life (give dates).....

IV. *Adult insects*

1. Emergence, date observed.....Time required.....
2. Form changes.....
3. Color changes.....

Summary: Dates of egg laying.....of hatching.....

of transformation to pupa.....to adult.....

Number reared.....

Cooperation is the way to success in this course. Let every member of the class do his bit, and the work will go well, and all will benefit by it. Here is a list of the tasks that are common to most of the laboratory exercises:

1. Collecting of fresh specimens as needed.
2. Papering or bottling and labelling reserve specimens.
3. Relaxing of dried, reserve specimens.
4. Pinning and labelling insects for the collection.
5. Making slide mounts.
6. Care of living materials; providing food for nymphs or larvae; providing quarters for pupation; making cages, stocking cages, cleaning cages.
7. Home problems on crop pests (see p. 173).
8. Routine. Assembling materials for the laboratory exercise, and putting the stuff away again at its close.

XXV

AIDS

How to Get the Names of Unknown Insects.—Specimens will have to be sent to some one for determination, and they must be in fit condition for study. If papered they may be sent in any sort of stout box (never in a letter). If alcoholic, the vials containing them may be sent in ordinary pasteboard, screw-cap mailing cases or in other boxes, packed in cotton. There are usually three available sources of this information.

1. The entomologists of the U. S. Department of Agriculture, Washington, D. C., will secure identifications of all kinds of insects, and will on request send bulletins concerning the habits and methods of control of the economic species.

2. The state entomologist, who is usually located either at the State Capitol or at the State Agricultural College, will do the same. These two officials are our servants in such matters. But they have other things to do; so get your insects named at home if you can, and when necessary to call upon these officials, pool your requests for information and let one person do the sending for the school.

3. Often there is a local entomologist who may be consulted in person, and who will gladly name specimens for young collectors, insofar as he is able.

When a local collection has been built up, and correctly named specimens are in the boxes, fewer specimens will have to be sent away for identification, for most can then be named

by comparison. Every pupil should do what he can to make such a collection more complete, by furnishing from his own catch whatever species are not already contained in it.

4. Many species, especially the more important species, may be recognized from the figures in well illustrated books, among which the following, if available in the school library, will prove useful:

Reference Books

Blatchley, W. S., The Coleoptera of Indiana
" " The Hemiptera of Indiana
Comstock, J. H. Introduction to Entomology
" " A Manual for the Study of Insects
" " How to Know the Butterflies
Comstock, Mrs. J. H. A Handbook of Nature Study
Crosby and Leonard. A Manual of Garden Insects
Essig, E. O. Insects of Western North America
Folsom, J. W. Entomology
Hancock, J. L. Nature Sketches in Temperate America
Herrick, G. W. Household Insects
" " Manual of Injurious Insects
Holland, W. J. The Moth Book
Howard, L. O. The Insect Book
Kellogg, V. L. American Insects
Lutz, E. F. A Field Book of Insects
Needham, J. G. The Natural History of the Farm
Needham and Lloyd. The Life of Inland Waters
Needham and Heywood. A Handbook of North American Dragonflies
O'Kane, W. C. Injurious Insects
Sanderson, E. D. Insect Pests of Farm, Garden and Orchard
Slingerland and Crosby. A Manual of Fruit Insects

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