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# AGRICULTURAL ENTOMOLOGY

## FOR STUDENTS, FARMERS, FRUIT-GROWERS AND GARDENERS

BY

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# PREFACE.

This book is designed to meet the needs of students and others who wish to learn something of insect life especially in relation to farm crops and livestock. The author assumes that the students who read it will have had some training in general biology and will have the guidance of teachers familiar with the subject in connection with adequate laboratory facilities and opportunities for field studies. The details of laboratory and field studies have not been included since these are easily supplied by the teacher. For those making individual studies there are many available books covering the technic of entomological work. A glossary has been included which covers the subject as presented in these pages and in most of the reports and bulletins that are likely to be consulted by the average student.

In order to make the scope of the book adequate it has been necessary to condense the matter to the most essential details, and to omit much that has value but which is not absolutely indispensable to the presentation of the important principles that concern the practice of economic entomology.

The author acknowledges his indebtedness to many sources of information which are too numerous to mention individually, but he is especially indebted to Dr. Howard, of the Bureau of Entomology, for the privilege of using the illustrations secured from his office and for suggestions; to

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# CONTENTS.


CHAPTER I.

Introduction . . . . . 17

CHAPTER II.

Class Arachnida . . . . . 22

CHAPTER III.

The Six-footed Insects . . . . . 38

CHAPTER IV.

Lower Pterygota . . . . . 51

CHAPTER V.

Order Hemiptera . . . . . 93

CHAPTER VI.

Neuroptera and Allies . . . . . 165

CHAPTER VII.

Coleoptera. Beetles . . . . . 172

CHAPTER VIII.

Lepidoptera . . . . . 206

CHAPTER IX.

Order Diptera . . . . . 248

CHAPTER X.

Bees and Wasps . . . . . 291

CHAPTER XI.

Principles of Economic Entomology . . . . . 312

Glossary . . . . . 329

Index . . . . . 339

# AGRICULTURAL ENTOMOLOGY.

## CHAPTER I.

## INTRODUCTION.

The recent rapid growth in the subject of Agricultural Entomology makes it a difficult matter to bring together a comprehensive statement that will cover all of its different phases in a thorough manner. Some idea of its growth may be indicated by the fact that instead of a single entomologist employed in the United States Department of Agriculture, as was the case forty years ago, there are now several hundred who are devoting their entire time to the investigation of entomological problems, practically all of which are related to agriculture.

A similar development of this work has taken place in the State Experiment Stations, and there are also State Entomological departments working in almost every State, and in many of them two or three different organizations, each with a large quota of workers.

Economic entomology in its wider sense covers all those phases of the subject which have to do with insects of importance in relation to mankind. The forms which have distinctly agricultural relation are so numerous and represent so completely all the different groups of insects that we are compelled to include a very general survey of the subject.

Some idea of the size of the group of insects and of its place in biological study may be secured from the statement

that there are now known and have been scientifically recognized and described something over three hundred thousand species of insects, a number which far surpasses that of all other groups of animals together. Furthermore, the immense numbers of individuals in each species and the great facility which they possess for migration and rapidity of increase make them a very dominant group of animals.

Not all insects, to be sure, have a direct importance to mankind, but there is so large a number that are very directly related to human interests in the way of destruction of property or menace to health that it is unnecessary to emphasize their importance. Many estimates have been attempted of the extent of loss of crops, livestock, forests, agricultural products, etc., and while none of these can be considered exact, it is increasingly evident that such estimates are conservative and in many cases the loss is greater than is recognized. One of the current estimates is that about 10 per cent. of the aggregate of farm crops in the United States is lost by insect attack, and if this be taken as an approximate proportion there is something like one billion dollars to be counted an economic loss from this source each year.

It must be admitted that the entomologist has not been able as yet to solve all of the problems of insect control. There will doubtless be many cases where a practical control of insects may not be reached for many years, but for a considerable number of the most common and serious pests it has been possible to discover methods by which a very large proportion of the loss can be prevented. One phase of entomological work, therefore, is the demonstration of these possibilities in order to secure a general adoption of control measures that have been proved successful.

While it is manifestly impossible to include in a small book any full discussion of the many phases of entomology, it is the purpose of this work to present a basis for the understanding of field observations, and especially for the understanding of the many articles relating to economic insects which are now appearing in Government and State pub-

lications. Many of these publications are available and will be found to contain an immense store of information, much of it of very practical value, but its greatest utility will be found to rest upon some acquaintance with the general facts of insect life and insect habits. These are so dependent upon certain conditions of structure and development that acquaintance with some of the fundamental biological features of insect life are essential to the most effective utilization.

Formerly all of the arthropods, that is, all animals with jointed bodies and jointed appendages, were grouped under the head of insects, and even yet this term has a pretty wide application in popular usage, although it is seldom used now to cover as wide a range as formerly. The Arthropods, as a whole, include crustaceans, myriapods, arachnids, hexapods, or six-footed insects, and of these the air-breathing forms, all except the crustaceans, are still quite commonly treated as insects.

The *Onychophora* is a tropical group including peripatus, the most primitive of tracheate animals, and would on this basis be considered as falling next to the crustacea.

The most generalized next to these, the myriapods, might be counted as possessing the greater number of insect-like characters. This group, however, does not include any forms that possess wings, but in the matter of antennæ and the tracheal respiration they are closely associated with insects. The members of this group are, for the most part, of comparatively little economic importance. A few of the species included in the group of centipedes (*Chilopoda*) are poisonous, and in tropical countries are of some importance on this account. The few species that occur in temperate regions have little importance except as they may feed upon other insects which occur under the litter at the surface of the ground.

One species, the house centipede, a peculiar long-legged creature, which is occasionally found in cellars or around houses, usually where there is some dampness, is, however, of a certain amount of importance because of its feeding

upon insects, and is looked upon as rather serviceable in the destruction of flies. It is a quite ungainly looking creature,

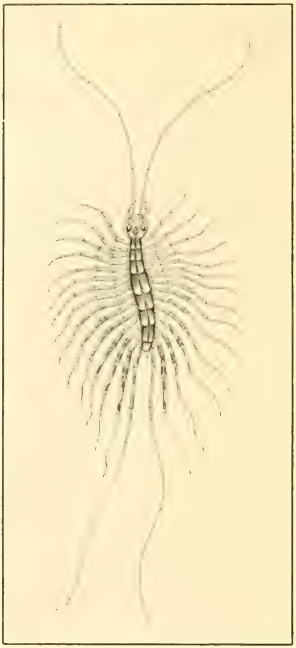

FIG. 1.—*Scutigera forceps:* Adult—natural size. (From Marlatt, Div. Ent., U. S. Dept. Ag.)

with slender, flattened body, extremely long legs, and an apparent duplication of anterior and posterior ends.

The millipedes (*Diplopoda*) are nearly cylindrical in

shape, are recognized as having two pairs of legs to each apparent segment and there is usually a large number of segments, 40 to 100 or more, so that the name thousand-

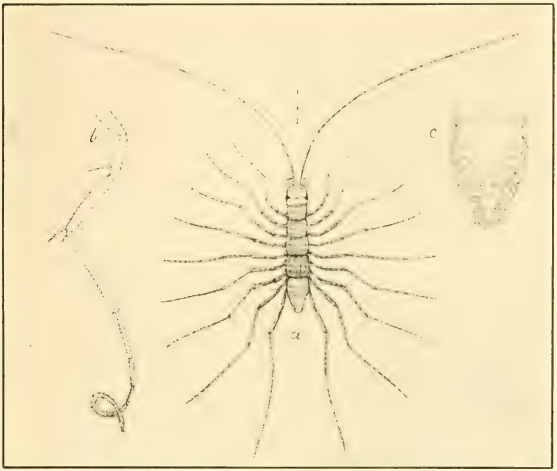


FIG. 2.—*Scutigera forceps: a*, newly hatched individual; *b*, one of the legs of same; *c*, terminal segment of body showing undeveloped legs coiled up within—all enlarged. (After Marlatt, Div. Ent., U. S. Dept. Ag.)

legged worm is fairly descriptive. Most of these species are found in moist places and feed upon vegetable debris, but a few have been recorded as attacking vegetation, and one species has been credited with injuring seed corn.

## CHAPTER II.

## CLASS ARACHNIDA.

In the strict technical sense the group Arachnida may be excluded from the Insecta, but in general usage, and to a large extent in entomological practice, these divisions are put together, and it seems desirable that the group should be given a place in any work dealing with the insects in general.

The group *Arachnida* includes spiders, scorpions, harvestmen, mites, ticks, etc., and is characterized by the presence of four pairs of legs, the absence of antennæ and compound eyes, and the lack of distinct metamorphosis, although in certain groups there is a considerable change from the newly hatched or six-legged form to the mature eight-legged stage.

In general structure the Arachnida agree with other Arthropoda, but the head and thorax are usually merged into a cephalothorax separated from the abdomen by a more or less distinct stalk; in the Acarina, however, this separation is not marked and the body is without distinct separation of head, thorax, and abdomen.

The economic importance of the group depends upon their attacks upon certain crops, from the fact that many of the species, such as spiders and harvestmen, are uniformly predaceous and serve as important checks upon injurious species; while other forms, such as the mites and ticks, are parasitic upon domestic animals and man, and some of the species occupy a most important relationship as carriers of infectious diseases.

The subdivisions of the group are, for the most part, very well marked and represent ancient groups which have diverged quite widely from each other.

The scorpions (*Scorpionida*), mostly tropical in distribu-

tion, are represented by fossils in early geological times, and are noted as possessing poison glands. They are recognized by the broad cephalothorax, a division of the abdomen into two portions, an anterior preabdomen of seven segments, and a slender hinder postabdomen of six segments, on the last one of which there is a large poison gland and sting. The sting is distinctly venomous and fatal to insects or smaller animals, but seldom serious in its effect on the human species.

The *Pseudoscorpionida* are minute forms resembling scorpions in the width of the body and the long pedipalps, but have no postabdomen or sting. They occur somewhat commonly under bark or decaying logs or occasionally in old papers or books, where they may secure book lice as food.

The *Pedipalpi*, or whip scorpions, have a tropical or subtropical distribution and differ from the preceding groups in the presence of a long, slender bristle or whip extending from the hinder abdominal segment.

In the group *Solpugida* there is an exceptional separation of head and thorax and the abdomen is distinctly segmented, while the chelicerae are greatly enlarged and strongly chelate. These are not only largely tropical, but are particularly characteristic of arid regions. One species occurs in the Rocky Mountain region as far north as Colorado. They are carnivorous in habit, but not of particular economic importance, as they occur usually in small numbers and in locations which do not offer opportunity to capture especially injurious insects.

The *Phalangida*, or harvestmen, often called "daddy-longlegs," are somewhat large and resemble spiders in appearance, but the abdomen is not distinctly separated from the thorax and the legs are in most species extremely long. They feed on insects, especially on flies and other small forms, and are to be counted as distinctly beneficial. On account of a strong pungent odor they are disagreeable to handle, but their presence in gardens and other places where insects abound may be considered as distinctly desirable.

## Order ARANEIDA.

This group includes the familiar spiders which are very generally distributed over the world, and occupy a rather conspicuous place among other animals. Their body is sharply divided into cephalothorax and abdomen, and the four pairs of legs are usually nearly equal in length. The

FIG. 3.—*Epeira scolopetaria*, showing normal position of spider in web head downward. A vibrator at *x* agitating the web will cause the spider to rush at once to point of contact. (Photo by Prof. W. M. Barrows.)

eyes are simple and usually eight in number, and the large mandibles are attached at right angles to the axis of the body. In some species these are provided with a poison duct. The bite is venomous to smaller organisms, and in some of the larger, like the tarantula, the bite is a serious matter for man. Spiders offer a great many attractive

features, particularly in their web-making habit and in their adaptation for the capture of prey. They are distinctly carnivorous in habit and may be considered useful, since the majority of them capture insects, and the kinds of insects captured are quite generally such as are detrimental to man. In general, therefore, spiders should be left unmolested and their insect-feeding habits utilized in the reduction of injurious insects.

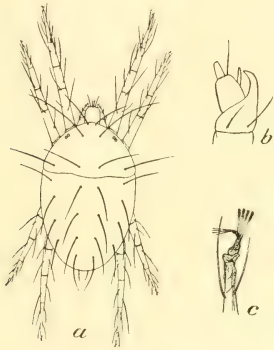


FIG. 4.—The common red spider (*Tetranychus bimaculatus*): *a*, adult; *b*, palpus; *c*, claws; *a*, greatly enlarged; *b*, *c*, still more enlarged. (After Banks. From Bur. Ent., U. S. Dept. Ag.)

## Order ACARINA.

These are commonly known as mites, ticks, scab insects, mange insects, etc., and are in general distinguished by having no prominent separation between the different regions of the body, the head, thorax, and abdomen, forming one closely connected structure. They have eight legs, except in the early stages, when there are but six; the eyes are often small or obsolete, the spiracles reduced to one pair, sometimes apparently wanting; the mouth parts

are fitted for piercing, biting, or in some cases for combined biting and suction, there being usually a pair of slender, sharp mandibles capable of penetrating the skin of the host animals. Much variation of habit exists, and ranges from free forms to strictly parasitic forms.

FIG. 5.—*Tetranychus gloveri:* Adult—much enlarged. (Titus, Div. Ent., U. S. Dept. Ag.)

### Harvest Mites; Chiggers.

In the family *Trombidiidæ*, which includes normally plant-feeding species, we find a few species which have adopted a phase of parasitism which, though apparently abnormal, results in extreme annoyance to the animals affected.

Apparently the most abundant species in this country is the Leptus irritans of Riley, which is illustrated herewith. This occurs in a large portion of the United States, and occasions during the summer months an enormous amount of suffering. It ranges north in the Mississippi Valley into

central Iowa, at least, and in Ohio to Lake Erie, appearing by the latter part of June or fore part of July, but becoming especially annoying during August. In the latitude of Washington it is very abundant early in June, and farther south its season extends until, in southern Mexico, what is apparently the same species is abundant and equally annoying in January.

The form in which this pest is observed usually is the larval or six-legged form. It is nearly circular in outline, the legs extending well beyond the margins of the body, of a bright red color, and so minute that it is only with the closest scrutiny that it can be detected.

FIG. 6.—*Leptus irritans* to the right and *americana* to the left. (From Riley.)

It is brushed from the leaves of various plants on to the hands or clothing of people and to the bodies of other animals, and the mite then proceeds to burrow into the skin, notwithstanding the fact that, so far as all evidence shows, this proceeding is absolutely fatal to it and prevents any possibility of its maturing or producing eggs.

There is great difference in the susceptibility shown by different persons to the attacks of this mite, some not seeming to be affected seriously by them, while others must submit to extreme torture every time they happen to become attacked by them, even if but few in number.

As the mites are invariably secured by working among raspberries, currants, or other shrubbery which harbors them, or by walking in grass or low herbage where they occur, sometimes even by sitting or lying for a short time upon grass or clover, it is evident that the best precaution for susceptible persons is to avoid all such exposure. When such avoidance is impracticable, the clothing may be made to fit closely at the wrists and ankles, and then as soon as possible after having been exposed to the mites make an entire change of clothing, bathe in hot, soapy water, and if any indications of mites are present, wash the affected parts with diluted carbolic acid, 1 part to 50 or 100 parts water.

In the tropics rum or whisky is recommended as a wash, and diluted alcohol can be used with good results.

With a little pains it is possible to locate the mites, as they may be found before they have completely buried themselves in the skin in the centre of the little red swelling that has been raised by their preliminary irritation, and if they are removed at this stage, instead of being allowed to bury themselves in the skin the subsequent inflammation and itching will be largely prevented.

**Family Gamasidæ.**—The family *Gamasidæ* contains a large number of small mites, most of them being free or semiparasitic in habit.

A large number occur as parasites on various species of insects, but the two species to be mentioned here occur on birds, and are sometimes very troublesome.

**The Bird Tick** (*Dermanyssus avium*).—The bird tick is a very familiar form to keepers of cage birds, and is known in many places as the red mite. It occurs on a great variety of birds, and has sometimes been considered to embrace the chicken tick, mention of which follows, but that is now generally conceded to represent a distinct form. The mites are easily seen with the naked eye and appear as animated red specks running over the bodies of birds, or on the perches, bars of cages, etc. The eggs are laid in cracks or corners of the cage, where may be found also the molted skins and often numerous young and old mites.

The attacks on the birds are made probably for the most part at night, but the mites are usually well filled with blood, which gives them their red color.

The use of perches that are solid, smooth, and free from cracks, and the frequent dipping of these in hot water, and the thorough cleansing of the entire cage, using boiling water if there are inaccessible cracks, will serve to destroy the pests.

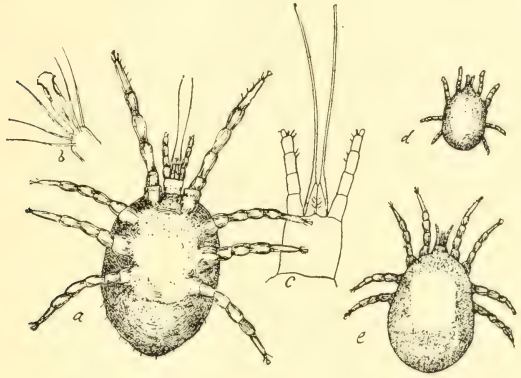


FIG. 7.—Poultry tick (*Dermanyssus gallinæ*): *a*, adult; *b*, tarsus; *c*, mouth parts; *d* and *e*, young—all enlarged. (After Osborn, Bur. Ent., U. S. Dept. Ag.)

**The Poultry Tick** (*Dermanyssus gallinæ*).—One of the most persistent and injurious of the pests of the hennery is the little chicken mite, which gathers on the fowls, especially at night, and sucks their blood. It is a well-known form, and has been described for many years, though in many works it is confused with the preceding species or considered simply a variety of that form. Its distribution seems to extend pretty generally over the world where domestic fowls are kept.

The full-grown mites are about 1 mm. long, of a light gray or whitish color, with dark patches showing through the skin, but when full fed have a distinct red color. They swarm in cracks and corners of the henhouse, and often when numerous, over all surrounding objects, and at such time are liable to become a great pest to man and such other animals as they may get access to.

The dust bath is considered of use in checking this pest, but when there is a general infestation, the best plan will be found to clear the house, then spray well with kerosene or kerosene emulsion, taking pains to reach the cracks; thoroughly drench the roosts with hot water or kerosene, benzine, or gasoline, whitewash the house, or dust with carbolated lime, and then daub the ends of the roosts, where they come in contact with supports, with coal tar, so the mites would have to cross it to reach the fowls.

**Family Ixodidæ.**—This family includes forms known commonly as ticks, and familiar examples are the dog tick or wood tick, frequently found upon domestic animals, and other examples are the cattle tick of the Southern States and spotted fever tick of the Rocky Mountain region. In this group the body is robust and becomes much distended in the female when the eggs are developed. The mouth parts are adapted for puncturing the skin of host animals, and the species generally attach themselves to warm-blooded animals as a part of the life-cycle, and in some cases this attachment is permanent, while in others it is temporary and the individual tick may occupy several different hosts in the course of its life-cycle.

The family is of particular importance because of the fact that some of the species are carriers of important diseases, most notable of which is Texas fever, transmitted by the cattle tick. The spotted fever tick is the carrier of spotted fever.

**The Pigeon Tick** (*Argas reflexus*).—The pigeon tick is a common species on pigeons found mainly in pigeon houses, and sucks the blood of pigeons for its nutriment. It is, however, able to survive for long periods without food,

some recorded instances are of individuals kept in confinement for two years without food, but which moulted at frequent intervals.

The related *Argas persicus* occurs both in the old world and America. It is a troublesome pest for chickens and is credited also with attacks on human beings.

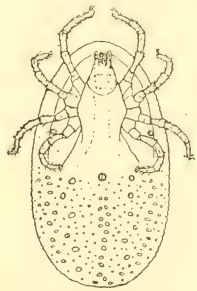

FIG. 8.—*Argas miniatus*, a tick which infests poultry. Greatly enlarged. (Banks, Div. Ent., U. S. Dept. Ag.)

**The Cattle Tick** (*Margaropus annulatus*).—The cattle tick, as already mentioned, has received probably more attention than any other species, as it has been known for many years as the carrier of Texas fever in cattle, and its great importance to the cattle industry has been the occasion for elaborate studies regarding its habits. In this species the newly hatched tick locates as soon as possible upon a warm-blooded animal, preferably upon cattle, as these seem to be by all means the preferred host. Once located they retain their attachment until mature. The females when mature and gorged with eggs loosen their hold, drop to the ground and eggs may be distributed wherever the adults fall. The period of incubation differs greatly with regard to temperature, so that the rate of development and number of generations differ much at different seasons of

the year. An important fact concerning the transfer of disease is that the protozoa in the diseased animal are taken into the body of the tick, and within the body of this host may enter the eggs, so that young ticks that have never fed upon an animal may serve to introduce the parasite in an individual that has not previously had the disease.

Elimination of ticks from the cattle and prevention of their attacks therefore become essential factors in the eradication of Texas fever. To accomplish the eradication of the ticks in any given locality it is necessary to rotate animals from one field to another, allowing time for hatching of eggs and dying of the ticks before the field again is used as a pasture for cattle. Working upon this basis, considerable areas in the Southern States are now considered tick-free and the hope is that the quarantine line will be pushed farther and farther south until ultimately the ticks and associated disease may be completely eradicated. Certain districts in Tennessee and North Carolina are now considered tick-free and released from quarantine restrictions.

**The Spotted Fever Tick** (*Dermacentor venusta*).—The spotted fever tick has come into great prominence in recent years because of the determination that it serves as the carrier of the much-dreaded spotted fever. This disease has caused many deaths in Montana and adjacent States, and the rate of mortality for individuals attacked is very high, so that its appearance is very much dreaded.

It has been shown that this disease is carried by this particular species of tick, and in no other way. It differs in habit from the cattle tick in that a number of different hosts may be fed upon at different periods in its development. Usually the young larvæ attach themselves to ground squirrels or smaller mammals and remain upon these from three to five days, after which they drop to the ground. After a resting period of from one to three weeks the skin is moulted and an eight-legged form appears, which in turn attaches itself to some host and feeds for several days, dropping to the ground and developing into the adult

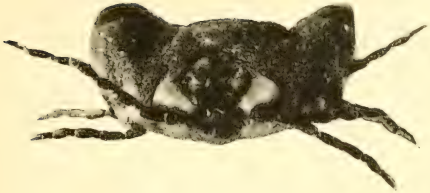

FIG. 9

FIG. 10

FIG. 11

FIG. 12

FIG. 13

FIG. 14

FIGS. 9 to 14.—The spotted fever tick (*Dermacentor venustus* and *Dermacentor albipictus*). (Hunter and Bishopp.)

Fig. 9, adult spotted fever tick which has deposited eggs. Fig. 10, larva of spotted fever tick. Fig. 11, engorged nymph of spotted fever tick. Fig. 12, the same, ventral view. Fig. 13, adult male of *Dermacentor albipictus*. Fig. 14, adult female of *Dermacentor albipictus*, unengorged.

stage. In the adult stage still another host is sought, this time usually some of the larger animals, such as domestic cattle or sheep, and probably in the wild condition such

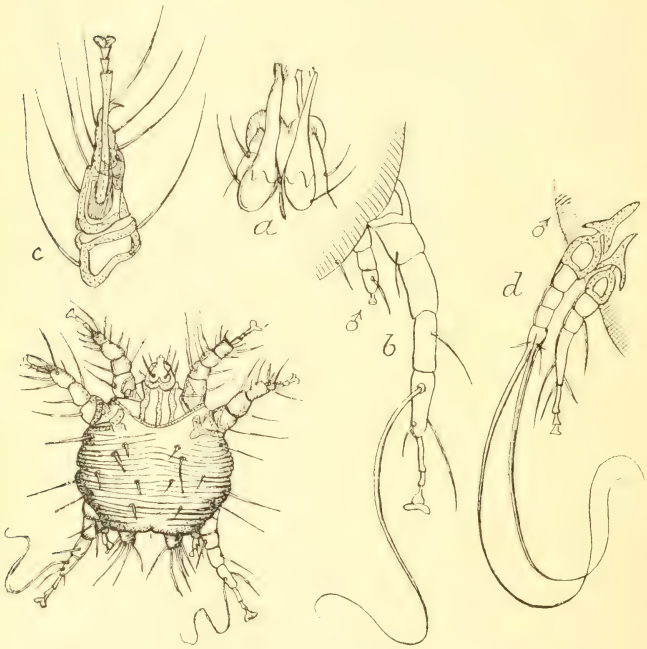


FIG. 15.—*Psoroptes communis*, var. *equi*. (Reduced from Furstenberg, after Murray.)

animals as the antelope or Rocky Mountain sheep or other ruminants of the Rocky Mountain region. On these hosts fertilization occurs and the females then drop to the ground

where the eggs are laid and a new cycle begun. The disease has some remarkable limitations in its distribution which are probably associated with the distribution of the ticks or the animals which serve as a reserve for the disease germs.

**Family Sarcoptidæ.**—This family includes parasitic mites, affecting particularly birds and mammals.

**The Sheep Scab Mite** (*Psoroptes communis*, var. *ovis*).—The sheep scab mite produces a very serious condition among sheep, evidenced by matting and tagging of wool and the formation of thick, encrusting scabs. The eggs of this mite are minute, glistening white specks, longer than broad and nearly uniform in thickness. They may be found under the scabs by careful inspection, and their detection, even when mites are not seen, may be taken as evidence of the disease.

The larvæ have nearly the same shape as the adults, but are to be distinguished by the fact that only six legs are apparent.

The full-grown mites are nearly as broad as long, and are characterized by their piercing mouth parts and the structure of the two posterior pairs of legs (see Fig. 15). In the male the fourth is much reduced, and the third bears a long thread-like appendage passing the sucker, while in the female this leg carries two long, thread-like organs and no sucker.

The only treatment for this species worthy of recognition is that of dipping, and this, if properly done, will secure the extermination of the pest. A flock once freed will not become again infested except by exposure to infected animals or by the introduction of scabby individuals.

So important is this parasite deemed that many of the States have adopted stringent laws for the quarantine of infected animals and for prescribing dips that must be used.

The particular kind of dip is of less importance than the thorough use of the one selected. The tobacco dips, sulphur and lime dips, and also several of the patent dips prepared by reputable firms can be recommended. The main objection to the latter, perhaps, is the fact that the user must

pay a rather exorbitant price for a few simple chemicals, and further, in case of the arsenical dips, that he may not know the ingredients or their proportions and thereby endanger the animals treated.

**The Itch Mite.** The itch mite, or "itch insect," affecting man is perhaps becoming a rather rare pest in civilized communities, but since it occurs at times on domestic animals, and in certain varieties becomes at times a serious pest to such animals, it deserves mention here. Authors

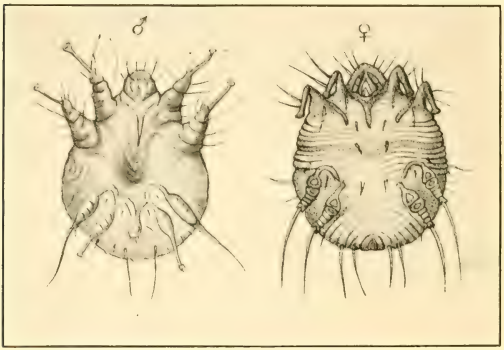


FIG. 16.—*Sarcoptes scabiei:* male and female. (Reduced from Furstenberg, after Murray.)

have differed greatly in their treatment of the species, some making a different species for each host animal, believing that they could find distinctive characters in the size, arrangement of spines, etc.; but recent authors have combined most of these under the one species, scabiei, though in some cases retaining the varietal distinction for various hosts.

All stages of the parasite occur on the host upon which

it is absolutely dependent for existence. Generation after generation may occur on the same animal. The mite burrows under the skin, in this respect differing from scab mites.

The adult mites are flattened, rather circular in outline, and may be separated from related forms by the character of the feet and by the presence of six short spines or thorns on the thoracic portion and fourteen on the abdominal portion of the body.

Eggs are deposited along the burrow as the mite extends its channel into the deeper portions of the skin, and as they hatch the young feed upon the surrounding tissues, and it is said moult four times before maturity. When fully grown they wander around and mate on the surface of the skin, after which the females begin a fresh burrow.

Infection with this parasite is accompanied by intense itching during the formation of pustules and inflamed areas, and while in man it is usually confined to the base of the fingers and between the knuckles, in aggravated cases the whole hand and arm may become invaded.

The "seven-year itch," "army itch," and "Jackson itch" are simply aggravated cases, where from lack of good sanitation the mites are able to thrive better than usual.

In the human subject the application of sulphur ointment, in addition to frequent washing with soap and hot water, and for domestic animals the use of washes and dips, as for scab mites, are to be adopted.

## CHAPTER III.

## THE SIX-FOOTED INSECTS.

The *Hexapoda*, or the true insects, include those forms with three pairs of legs, and the group is further distinguished from the other tracheate forms by large compound eyes and for a considerable portion of the group the presence of one or two pairs of wings.

Of the various arthropods this division includes by far the greater number of species and to a large extent those forms which have the greatest agricultural importance.

### STRUCTURE OF INSECTS.

There are some details in the structure of insects that have a special importance in connection with the use of remedies and some that from their frequent use in the description of injurious species require explanation as a basis for proper understanding of these principles. These will be treated here as briefly as may be, bearing in mind constantly this main issue in their presentation.

The insect body is divided into three regions, head, thorax, and abdomen. The first appears to be one solid segment, though believed fundamentally to consist of six or seven segments closely fused together. The thorax has three segments usually pretty closely joined, while the abdomen possesses from three to nine visible segments, and these articulate so as to be free to move on each other.

The head bears appendages, a number of definite structures connected with sensation or nutrition, and which are of special service in separating the different groups of insects. The antennæ are jointed appendages usually situated on the upper and front part of the head, composed of a varying

number of segments and modified in a great variety of ways in different groups of insects. Some of these modifications may be mentioned briefly.

The joints may be widened so as to appear toothed along one margin, in which case they are called serrate. If constricted at each end so as to appear like a string of beads they are called moniliform; if expanded widely toward the apex on one side they form a series of comb-like teeth and are then said to be pectinate; if swollen toward the apex, or club-shaped, they are called clavate; and if this swollen portion is confined to a few of the terminal segments and expanded so as to form a ball they are capitate. In moths

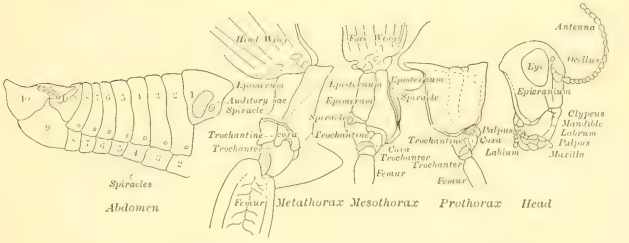


FIG. 17.—Anatomy of grasshopper. (Reduced from Packard.)

they may be provided with a series of plume-like expansions on either side and are then bipectinate, or if extremely wide and feathery are called plumose.

The compound eyes are usually large and conspicuous, and composed of an immense number of facets, these numbering in some insects many thousands, being especially numerous in dragon flies, horse flies, and some butterflies. The *ocelli* are the more simple eyes, composed of a single lens, and are often so minute as to be seen with difficulty except by the aid of a lens. They may be three in number, sometimes two and in some cases wanting. Usually they are located between the compound eyes, and on either

side a short distance from the margin of the compound eye, and the third, if present, lower down on the face and on the middle line.

The lower portion of the face is divided into *clypeus*, which forms the basis for attachment of the *labrum* or upper lip, the movable flap-like part which covers the front part of the mouth. Beneath this are the strong *mandibles* capable of cutting and tearing the leaves of plants, and in some cases of inflicting a severe bite if handled.

Next to these is a pair of more slender appendages, the auxiliary jaws or the *maxillæ*. These have a jointed structure and bear each a slender, jointed appendage called the *maxillary palpus*.

Beneath the maxillæ is the *labium*, which is in reality a structure formed by the fusion of a pair of organs similar to the maxillæ and sometimes termed the second maxillæ. The first part of this organ is called the *mentum*, and is attached by the *submentum* to the *gula* or basal part of the head. Attached to the mentum are the *glossa* and *paraglossæ*, at the sides of which are the *labial palpi*.

The structure of the mouth is of special interest on account of the relation to the food habits. It becomes possible to determine from this structure what the food habits of any particular insect may be. Where the mandibles and maxillæ are well developed and capable of biting and tearing the foliage of plants, we may assume that the diet is herbivorous. However, if the insect captures and devours other insects while the mandibles appear wanting or they seem to have developed a suctorial tube fitted for puncturing the tissue of plants and animals, a liquid diet may be assumed, and it will follow that insects of this kind would not be affected by poisons applied to the surface of the plants. We have here then a basis for the application of poisonous solutions such as the arsenites, which are effective for those insects which consume the surface of the leaf, or, on the other hand, for the application of oily substances for those of suctorial habits which enables them to secure the juices of plants without consuming any of the surface. For insects of this

latter type we must apply substances which penetrate the body and close up the breathing pores, and for this, oily substances, particularly kerosene, tobacco extract, and various other substances, are especially useful. The breathing pores, as will be seen later, are minute openings along the sides of the body, these being closed by minute quantities of an oily substance, so it is easy to see how these substances operate to kill the insect.

The central region of the body, the thorax, consists of three distinct segments called the pro-, meso- and metathorax. The first of these next to the head bears the front pair of legs; the middle segment, or mesothorax, the second pair of legs and the first pair of wings; and the hinder or metathorax, the third pair of legs and the second pair of wings. The legs are jointed appendages adapted for walking, running and jumping, sometimes for clinging, and consist of a basal segment, the coxa; a large, strong segment, the femur; a more slender segment, usually of the same length as the femur, the tibia, and the terminal portion, composed of from one to five small segments, called the tarsus. The last segment of the tarsus usually bears a pair of strong claws, and sometimes between these is located a disk-like pad or brush called the pulvillus.

The wings, ordinarily four in number, are membranous expansions of the body wall and are supported by stout, thickened, and rod-like portions termed nerves or veins, and the arrangement of these throughout the wings is spoken of as neuration or venation. Wings are greatly modified in different groups of insects. In some cases they are thin and transparent in both pairs, as in the dragon fly. The front pair may be thickened or leathery, as in the grasshoppers, or still more thickened, forming a hard, horny case (elytra), as in beetles, or partially leathery and partly membranous, as in Hemiptera. They are broad and covered with minute scales in butterflies and moths (Lepidoptera), and the number is reduced to two in flies and mosquitoes, the hinder pair being aborted or modified into special organs called balancers or halteres.

The abdomen or third region of the body is composed of about nine or ten visible segments that do not bear any segmented appendages, but the terminal segments are modified to form the external reproductive organs. The first seven or eight segments have on either side small openings into the respiratory system, the spiracles, and there are also usually two spiracles located on the thorax. They are so small as to be scarcely visible without magnification. They are connected internally with the delicate respiratory tubes, the trachea, which extend throughout the body, so that the air is distributed to all of the tissues and the respiratory process is consequently carried on in all parts of the body. The minuteness of the pores, as has been already mentioned, makes it possible for the insect to be suffocated by a very small amount of oily material spread over the pores, closing them.

Some further details of structure will be given in connection with the general characters for each order.

The internal structure of insects may seem at first sight to be of little relation to economic problems, but if it is recognized that their modes of feeding and the character of food depends upon the digestive organs, and their mode of respiration is very directly connected with certain important modes of treatment, and that all of their special senses associated with the attraction to certain kinds of plants, the attraction or repulsion to light or to odors, and in fact that the activities of the insect, as a whole, are dependent upon the organization, it can be realized that these structures have a very direct relation to their injuries and to methods of control.

The digestive system of the insects is in general like that of all arthropods, the mouth opening being connected with a pharynx, the esophagus merging with the crop, commonly the first part of the stomach (proventriculus), in which the food is received and undergoes some digestive changes; following this the true stomach around which are a number of gastric ceca that secrete the gastric fluids. Following the stomach is the intestine, divided into the ileum, colon,

and rectum, and connected with this is the Malpighian tubules which are excretory in function.

The circulatory system is simple; it consists of a delicate tube near the dorsal wall, and in this the blood current is carried forward and blood circulated freely through the various tissues.

The respiratory system of insects is very different from that of the vertebrates and in fact is of a type that occurs only in part of the arthropods. It consists of a great number of minute tubes, tracheæ, which are distributed throughout the tissues, so that the air contained in the tubes may be brought in contact with tissues in all parts of the body. Externally these tracheæ open through the spiracles which have been noted as located on the thorax and abdomen. The tracheæ arising from the abdominal spiracles in most insects unite each side with a longitudinal tube running through the abdomen into the thorax, and from this longitudinal one numerous smaller tracheæ are given out, and these in turn divide into smaller branches until they terminate in minute parts called tracheoles, which are so delicate that the air contained in the tubes is readily absorbed into the surrounding tissues. The movements of respiration are fairly rhythmetical in expansions and contractions of the body, expecially of the abdomen, serving to force the air in and out of the spiracles. Minute valves in the spiracular openings permit air to enter and closely hold the contained air, so that further contraction of the muscles serves to force the new supply of air out into the minute tracheoles. It is very evident from the structure of the respiratory system that contact insecticides which serve to close the spiracles or which may penetrate along the trachea and be absorbed into the tissues must serve very effectively for the destruction of the insect. It is for this reason that contact poisons, and especially oily substances, such as kerosene emulsion, are so efficient in the control of suctorial insects.

The nervous system of the insect consists of a ladder-like arrangement of ganglia and fibers along the ventral wall

of the body, separating at the anterior end, so as to pass around the œsophagus, after which there is a large mass, frequently termed the cerebrum, as it occupies the upper part of the head. This ganglionic mass contains three pairs of ganglia, while the subœsophageal is composed of three or four, and the primitive distribution of thorax and abdomen is one pair of ganglia to each segment. This condition is modified, especially in the higher insects, so that the ganglia may be fused, causing a single ganglion in the thorax, and five, three, or one in the abdomen.

The various ganglia of this system act with considerable independence and even dismembered parts of an insect may maintain their movements if the ganglia are not destroyed.

The special senses present many diverse features as compared with higher animals, but insects give good evidence of possessing sight, hearing, smell, taste, and touch, although the exact range of these functions may differ considerably from the same senses of vertebrates.

The reproduction in insects agrees for the most part with that of other arthropods, and except for certain remarkable deviations, such as are found on the aphids and bees, a general statement will suffice. Insects have separate sexes, and in a great majority of cases the males and females are distinct and usually may easily be distinguished by external characters. The reproductive organs are located in the abdomen, the ovaries in the central anterior part, and are composed of a number of ovarioles or tubular structures, within which the ova are developed and from which they pass into the oviducts. These oviducts combine near the end of the abdomen into a common duct leading to the external opening. Frequently connected with this common duct is a sac-like structure, the spermatheca, which serves for the retention of the spermatozoa. In the males the testes are located about as the ovaries, and lead by rather slender, more or less curved vasa deferentia to a common duct which leads to the external opening at the posterior end of the abdomen. The external organs are modified widely in different groups of insects, and in many cases furnish most

important characters for classification. In general they consist, for the female, of the ovipositor, and in the male, of external claspers and a central intromittent organ.

Mating, in many insects, is accomplished during flight, but this is by no means general.

The eggs are fertilized in the oviduct, in most cases doubtless in the common duct, or in the vicinity of the spermatheca, and the spermatozoa enter the egg by way of a minute pore termed the micropyle, located usually at one end of the egg.

## THE TRANSFORMATION OF INSECTS.

Insects, like all other animals, begin their development from an egg, not unlike any other forms. They pass through a series of more or less distinct stages in development from the egg to the mature or adult form. These stages are designated for the insects in general as egg, larva, pupa, and imago. While differing greatly in the definiteness of separation between the different stages, it is convenient to use these terms in tracing the life history of any insect and in describing the character of each of the stages somewhat more in detail and considering the bearing in the connection with economic treatment.

The egg is generally a comparatively small object, containing a considerable portion of yolk material and providing for some degree of development before hatching. The shapes differ greatly in the different forms, perhaps the most common, and consequently the most fundamental, being an elongate, oval shape. Spherical forms are by no means scarce, and flattened spherical, elongated spherical, or even linear or cylindrical forms are very common. The greater difference may be noted in the character of the surface of the eggshell, which may be minutely reticulated, striated, punctured, beset with fine spines, and frequently having a distinct lid through which the larvæ are to escape. They may be placed loosely in suitable locations, attached simply by a glutinous secretion, forced into the tissue by the ovipositor, etc. For aquatic species they may

be arranged in clusters on the surface, attached to objects above the surface, to leaves overhanging the water, to stems of aquatic plants, either above or below the water line, and for some of the distinctly aquatic forms placed upon the bodies of the insects themselves. The period of incubation varies enormously, some hatching immediately upon deposition, or, in some cases, preceding deposition, in which case the insect appears to be viviparous and for the other extreme remaining in the egg stage for many months, many species passing the winter in this stage. Ordinarily the eggs of any particular egg mass, or of any species, hatch with great uniformity, so that larvæ will appear at the same time. This results at times in the very sudden appearance of larvæ in startling numbers and to the uninitiated suggests the occurrence of some very remarkable invasion. Usually no nutritive material, other than contents of the egg, can be used during this period, but some species in which the eggs are forced into plant tissues and in which the egg covering must be very delicate, there is an absorption of fluids indicated by the distinct increase of the size of the egg prior to hatching The hatching of the egg is usually accomplished simply by pushing off of the egg-cap or rupture of the egg membrane, but in some species it depends upon external factors associated with the future history of the larva. For instance, the eggs of the horse bot fly are hatched only upon the application of friction or moisture and warmth, conditions which are brought about when the horse licks the hair bearing the eggs and thus provides ready means of transfer from the eggshell to its mouth, thus providing the necessary conditions for future development of the insect. The particular method of hatching may therefore have very important relation to preventive or remedial measures.

The larval stage is the active feeding stage during which the growth of the insect occurs, and during this period there are a varying number of moults, most frequently from four to five, at which there is a rapid increase in size, the larva accommodating itself to the tough, chitinous body wall, which as soon as hardened is incapable of any expansion.

The larvæ present the most diverse characteristics for the different groups of insects, and vary extremely even for closely related species. There has been a distinct adaptation to conditions during this stage, and larvæ with slightly varying habits have doubtless been affected by natural selection in the same manner as adults have been affected by their particular environment.

## THE LENGTH OF THE LARVAL PERIOD.

The length of the larval period is also in a wide degree an adaptation of this kind, which is frequently of the utmost importance in economic treatment of the species.

The pupa stage is the connecting stage between the larva and the adult, and may be similar to larval form or differ markedly from it, according as the insect has incomplete or complete metamorphosis. While in some forms it may feed to some extent, the more common condition is that of a quiescent non-feeding period. During this stage, however, important internal changes occur which lead to the maturing of the insect. For those forms which have a perfectly quiescent pupa stage, various forms of cells are made within which the pupation occurs, others secrete themselves in rubbish, folds of leaves, crevices or cracks in bark, while some construct a tough, silken cocoon as a permanent protecting case.

The adult stage or imago differs usually from the preceding stage in the acquisition of well-developed wings, excepting, of course, in the wingless forms, and especially in the maturity of the organs of reproduction. The period of life varies in the adult also in quite a degree for species living over winter and others for varying periods, although more commonly the adult perishes soon after the completion of the reproductory process. To indicate the various forms of adults would be to review all the different groups of insects, and hence need not be attempted even in brief.

A very distinct grouping of insects may be made with reference to the definiteness of transformation. Those which develop without marked changes between the different

stages are said to have incomplete metamorphosis (heterometabolic). Those which have very striking or marked differences between these stages, including the distinctly quiescent, non-feeding pupa stage, are said to have complete metamorphosis (holometabolic). A third group is sometimes noted for the primitive forms in which no change whatever occurs, and in which no wings have developed, they being said to be without metamorphosis (ametabolic).

A reference to some of the common injurious species, in which the different stages are shown, will illustrate these different phases of development.

## CLASSIFICATION OF INSECTS.

At this point it is well to discuss in a brief way what is termed the classification of insects. When we speak of the different members of the animal kingdom or describe some particular insect it is quite important that we have and use a name which would be distinctive for that one form. The general practice is to use two names for each insect, namely, the genus name and the species name. A species includes those which are similar in habits and characteristics and that may interbreed as a species or a kind. A genus includes a number of species and a group of genera with more general similarities form a family, and families are grouped into orders. The order then is the more general group and the class insecta includes about twenty orders.

**Apterygota** (Primitive Wingless Insects).

Order 1. *Thysanura*, Bristle tails; Campodea, Lepisma.
Order 2. *Collembola*, Spring tails; Podura, Smynthurus.

**Pterygota** (Winged Insects).

*With Incomplete Metamorphosis.*

Order 3. *Orthoptera*; Cockroach, locust, cricket, mole cricket, "walking stick," "walking leaf." Biting mouth

parts. Anterior wings usually shorter and firmer than those behind, or modified into wing covers. Both pairs are sometimes absent.

Order 4. *Dermaptera;* Earwigs. Biting mouth parts. Anterior wings small; hind wings large, but folded both longitudinally and crosswise. Posterior forceps.

Order 5. *Plecoptera;* Perla. Biting mouth parts. Two pairs of wings or none. Larvæ aquatic.

Order 6. *Ephemerida;* May flies. Adult mouth parts degenerate and rarely used. Fore wings large, hind wings small or absent. Larvæ aquatic, with biting mouth parts.

Order 7. *Odonata;* Dragon flies. Biting mouth parts. Two pairs of large unfolded wings. Larvæ aquatic.

Order 8. *Isoptera;* Termites. Biting mouth parts. Wings often wanting. Social in habit.

Order 9. *Corrodentia;* Book lice. Psocids. Biting mouth parts, wings often wanting.

Order 10. *Mallophaga;* Bird lice. Parasitic, wingless, with biting mouth parts.

Order 11. *Thysanoptera;* Thrips. Suctorial mouth parts. Wings very narrow, often rudimentary or absent. Only three or four pairs of stigmata. Concentrated nervous system.

Order 12. *Hemiptera;* Phylloxera, aphides, scale insects, cicadas, bugs, water scorpions, lice. (Male scale insects (coccidæ) have complete metamorphosis.) Mouth parts adapted for sucking and piercing. Two pairs of wings or none. No compound eyes in parasitic forms which are degenerate in several respects.

*With Complete Metamorphosis.*

(Holometabola.)

*Biting Mouth Parts* (Mandibulate).

Order 13. *Neuroptera;* Ant lions, lace-winged flies. Two pairs of glassy wings with many nervures. Larvæ sometimes aquatic.

Order 14. *Mecoptera;* Scorpion flies. Two pairs of narrow, membranous wings or none. Larvæ caterpillar-like.

Order 15. *Trichoptera;* Caddis flies. Hind wings usually larger than fore wings, both folded like fans. The body is hairy, rarely scaly. The larvæ are somewhat caterpillar-like, usually live in the water in special cases, and are apneustic.

Order 16. *Coleoptera;* Beetles. Fore wings modified into wing covers, hind wings folded when not in use. Larvæ very diverse, generally with feet. The little bee parasites Strepsiptera are probably allied.

*Suctorial Mouth Parts* (Haustellate).

Order 17. *Diptera;* Two-winged flies. Mosquito, midge, gnat, gad fly, house fly. Sucking mouth parts, but sometimes with power of biting. Two anterior transparent, unfolded wings and posterior "balancers" or "halteres." Larva usually a footless maggot, without a distinct head.

Order 18. *Siphonaptera* or *Aphaniptera;* Fleas. Wingless. No compound eyes. Ectoparasitic. Larva a footless maggot.

Order 19. *Lepidoptera;* Butterflies, moths. Two pairs of uniform, scaly wings. Larva, caterpillar.

*Mouth Parts Developed for Biting and Sucking.*

Order 20. *Hymenoptera;* Ants, bees, wasps, gall flies, saw flies, etc. Usually with four transparent wings. Larvæ are footless grubs, except in saw flies.

## CHAPTER IV.

## LOWER PTERYGOTA.

*(Wingless Insects—Bristle Tails and Spring Tails.)*

THIS group of insects includes those forms which are primitively wingless, there being no trace of wing structure,

FIG. 18.—*Lepisma domestica:* Adult female—enlarged. (After Marlatt, Div. Ent., U. S. Dept. Ag.)

and the evidence showing conclusively that unlike certain wingless forms, which are related to winged species, these have not had any winged ancestry. These species are minute, scaly, mouth parts fitted for biting. The development is direct, the young hatching in the form of the adults and developing by simple growth to the adult stage.

FIG. 19.—*Lepisma saccharina:* Adult—enlarged. (After Marlatt, Div. Ent., U. S. Dept. Ag.)

## Order THYSANURA.

This group, the "bristle tails," includes the forms which are provided with three bristles or bristle-like appendages at the posterior end of the body. The antennæ are long,

slender, bristle-like, the body usually densely covered with overlapping scales.

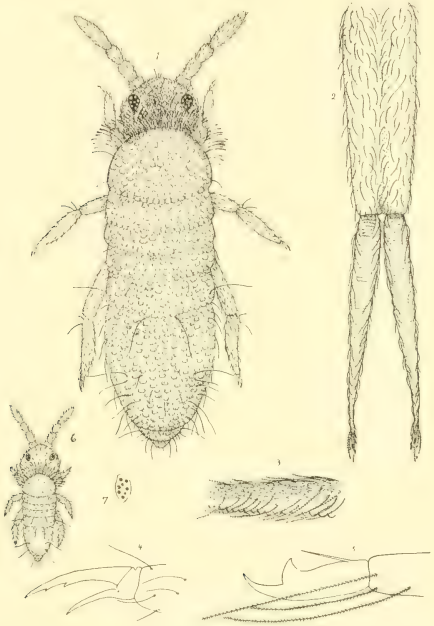

FIG. 20.—*Lepidocyrtus purpureus* (Lubbock): *1*, dorsal view of insect; *2*, spring; *3*, side view of dens showing serrations and barbed hairs; *4*, foot; *5*, side view of mucro; *6*, larval form; *7*, eyespot of larval form (From *Ohio Naturalist*. After Mrs. Alma D. Jackson.)

The common bristle tail of dwellings, *Lepisma domestica*, is about one-half inch long, of a light silvery color, with some darker bands on the back. They run with great rapidity and are very smooth and flexible, so that they are

caught with difficulty. If caught the scaly covering brushes off readily as a fine, whitish dust.

A related species, *Lepisma saccharina*, is found, especially in pantries, bakeries, or in places where they can secure starchy materials for food. In some cases they attack the bindings of books or the starchy covering of labels, and may cause a good deal of annoyance and injury in libraries.

### Order COLLEMBOLA.

This order, including the spring tails, is characterized at once by the strong spring which is folded under the abdomen and which catches into a loop on the thorax. The release of the spring from this throws the insect into the air with a sudden spring, which doubtless serves it as a protection against certain kinds of enemies. The species are generally found in moist places in cellars, under loose boards, chips, or stones, and some of them are found floating on the surface of water in quiet pools or along the margins of streams or ponds. They feed mainly on decaying organic matter and are of little economic concern, but a few species are credited with feeding on vegetation, especially in greenhouses.

## THE LOWER WINGED INSECTS (PTERYGOTA).

The remaining groups are primarily winged, and a number of the lower orders may be grouped together in this chapter.

### Order ORTHOPTERA.

This order, including cockroaches, crickets, grasshoppers, etc., is distinguished by the biting mouth parts being rather simple and primitive in structure, the wings of rather simple pattern, the front wings narrow and the hind wings broad and folded in a fan-like manner, so as to be covered by the fore wings when at rest.

They differ in their mode of locomotion, some having rapid running movement, using all of the legs equally well, others walking slowly, and others, more specialized, having

the hind legs much enlarged and adapted for leaping. The group is conveniently divided on the basis of their movements into the running or walking and the jumping divisions.

**Cockroaches.**—Of these groups the cockroaches, family *Blattidæ*, may be considered as about the most primitive representatives for the winged insects, the Ephemeridæ, often placed as the lowest order, having been specialized in the direction of aquatic life. This position is supported by the primitive structure of the mouth, by the venation of the wings, and also by the fact that they are to be found in strata of the early Paleozoic era, the earliest to appear of the winged insects whose structure agrees quite closely with that of present-day cockroaches. No other winged insects

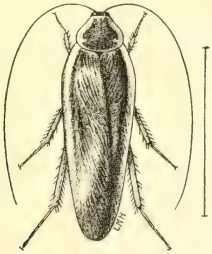

FIG. 21.—*Ischnoptera pennsylvanica*. After Lugger.

have been found in any numbers in as early geologic formations. Cockroaches of the present time seem to be persistent forms that have preserved ancestral characters. Their life history is interesting on this account.

One species of cockroach (*Ischnoptera pennsylvanica*) is fairly common in woods under bark of dead timber and sometimes in houses. The females are often found with the egg-capsules protruding from the body. It is abundant all over the United States and is really an outdoor native species. They have well-developed wings, and often fly into houses and are found in stumps, under logs, etc., during daytime, and make migrations during the night, or in the

evening and early morning. They are seldom active during the bright part of the day. The egg-capsules are bean-shaped and contain 50 to 60 or more eggs packed closely together, and after being carried some time are probably slowly extruded, finally left in some crevice. The young hatch from the egg-capsules and for a time are somewhat gregarious and are inclined to cluster together in company with the adult. This may be simply an incident of location, though

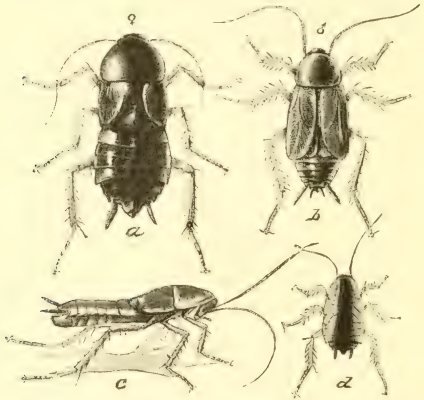


FIG. 22.—The oriental roach (*Periplaneta orientalis*): *a*, female; *b*, male; *c*, side view of female; *d*, half-grown specimen—all natural size. (From Marlatt, Div. Ent., U. S. Dept. Ag.)

it appears like maternal care. The young are similar to the adults in shape, much flattened, and much lighter in color, and the wing pads are scarcely visible. They grow by successive moults, and with each moult the wing pads increase in size, until in the final moult they acquire the full-sized wings of adults. The development of the nymphs goes on somewhat irregularly during the summer months.

An introduced species, the Oriental cockroach (*Periplaneta*

*orientalis*), is a common species in houses and is responsible for much annoyance in kitchens and pantries. Another introduced species, the German cockroach (*Ectobia germanica*), is much smaller, but a persistent pest in houses and common in eating houses, bakeries, and other places where starchy food is available.

The second family in the group, *Mantidæ*, *Praying Mantides*, have the front legs much modified for capturing insects. These legs have a peculiar structure. Instead of having short coxæ with elongated tibia, the coxæ are very much elongated. This is evidently correlated with the grasping

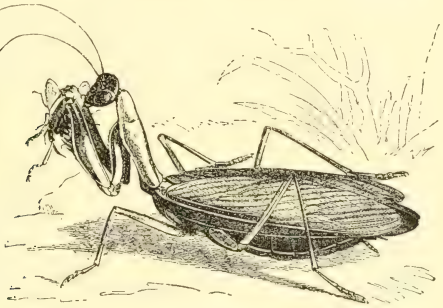

FIG. 23.—Praying mantis. (After Lugger.)

habit, and is paralleled in Emesidæ and Nepidæ. They are rather tropical in distribution, occurring in the Southern States.

One species, *Phasmomantis carolina*, is found to some extent in southern Ohio and north to Washington, D. C., but is rarely taken in the northern part of the United States, or, in general, north of 40 degrees of latitude. The pairing habits of the adults are rather interesting. The females often capture and devour the males during the process of courtship. The eggs are laid in large masses attached to a twig or some part of a plant, grouped together, lying one

over the other in a dense mass and exposed freely and rather commonly attacked by parasites.

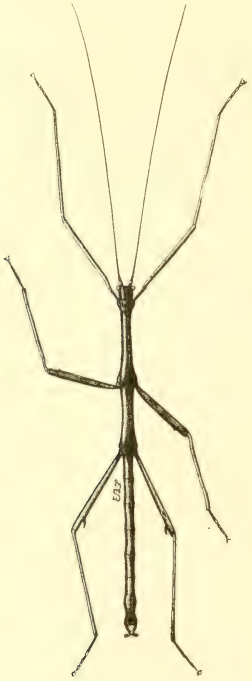

FIG. 24.—*Diapheromera femorata.* (After Lugger.)

**Family Phasmidæ.** — **The Walking-stick** (*Diapheromera femorata*).—The walking-stick is a common representative of this family throughout this part of the country. It has a

slender body and reduction of wings. The female is green and the body is thicker than that of the male. In autumn the bodies of the males become brown and resemble in color the twigs on which they are found. This species has one generation each year, hatching about the first of June, and the adults maturing in the latter part of the summer. The adults are found as early as the first of September. They are most commonly found in trees and shrubbery, at some little distance from the ground. Eggs are simply dropped from the trees or shrubs on which the adults are resting, and instances are cited where they are so abundant that the dropping of their eggs makes a sound like the falling of rain. The eggs rest on the ground and are protected more or less completely by leaves. They retain their vitality through winter and early spring and hatch in early summer. This represents a rather simple life-cycle with an annual generation and one in which the winter is passed in the egg stage. When these insects are so abundant as to be injurious, it would be of service to rake up and burn leaves, but they are not usually abundant enough to do any great damage. Another way would be to spray the trees with arsenical poison at the time the young are feeding. They are leaf-feeding forms and would secure the poison with their food. A grass-feeding species, *Monomera blatchley*, occurs in the Mississippi Valley.

Some of the tropical forms are more striking than this native variety and show more forms of mimicry. One form has wings in form and venation like the leaves of certain plants, so that the insect is remarkably well protected. Other forms simulate growths of lichens, etc. The whole family seems built on the plan of representing protective resemblances. Several species have the same form as the walking-stick, but possess short wings. There is a wide divergence in wing development.

**The Locusts** (*Acrididæ*).—The locusts include some of the most important economic species. They are great pests in some parts of the country. The group includes the old-world migratory locusts, which still appear as an occasional plague

over some parts of northern Africa. The old-world species is represented in this country most nearly by the western migratory locust or the grasshopper of the western plains, *Melanoplus spretus*. This western species, the devastating locust, is far less destructive in the aggregate than one or two other species, but has attracted more attention because of complete devastation which follows its appearance. There is one species in Argentina that has attracted a great deal of attention and has been a great menace to the crops of that country.

**The Devastating Locust.**—The devastating or Rocky Mountain locust, is limited in its normal distribution to the plateau region of the Rockies, the normal conditions for its survival being the high altitude, dry atmosphere, and a supply of grassy vegetation. They are most dependent on the buffalo grass or other native grasses. The species became important during the days of early settlement of that portion of country just east of the mountains, because at times, when vegetation ran short in its native breeding ground, it migrated sometimes 300, 400 or 500 miles, reaching places that were settled and proving extremely destructive to growing crops. During the late 70's they were such a serious source of injury that a very decisive effort was made to work out their habits, life history, and means of suppression. It is now generally assumed that it is only under conditions when it becomes extremely abundant and must migrate that it causes serious devastation outside of its regular breeding ground.

The adults may fly long distances and after finding suitble places for depositing eggs, bore into the ground with the ovipositor and abdomen for one and a half or two inches. The process consists of merely pressing the earth away by the ovipositor, and denotes a great degree of power because the eggs are preferably deposited in hard ground where the soil is packed. The eggs are coated with a glutinous secretion which protects them from the weather and they remain in these little burrows through autumn and winter and hatch early in spring. Sometimes they hatch before

there is much vegetation and sometimes the young are killed off in large numbers by late frosts. The young develop pretty rapidly and are able to travel quite considerable distances, especially if vegetation is scarce. They acquire

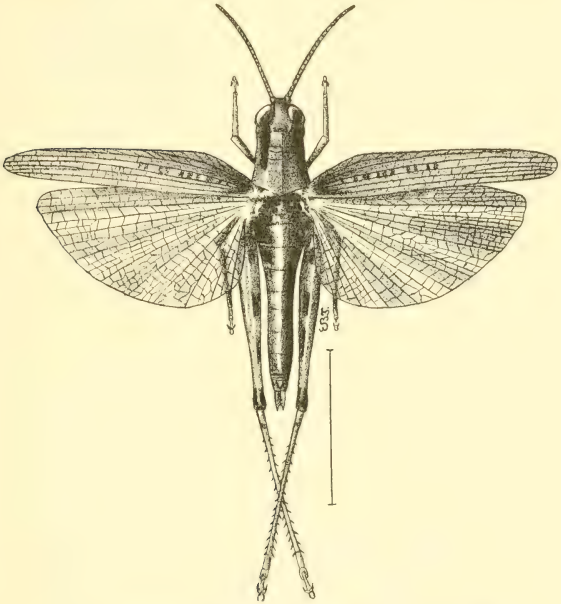

FIG. 25.—*Melanoplus femur-rubrum*, female. (After Lugger.)

wings often as early as the latter part of June. Flights may occur as early as July and often in August and September. Migration probably occurs rather sparingly unless food supply is scanty.

We have several species in the eastern United States closely related to the Rocky Mountain species. The most common

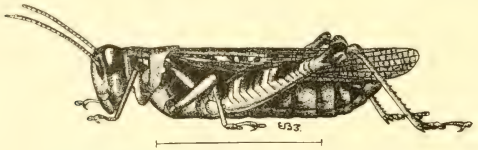

FIG. 26.—*Melanoplus atlanis*, male. (After Lugger.)

FIG. 27.—*Melanoplus atlanis*, female. (After Lugger.)

is the red-legged grasshopper (*Melanoplus femur-rubrum*). It is similar to the Rocky Mountain species, but is not cap-

able of any sustained flight. There is seldom anything like a general migration. They will travel out of dry pastures into corn, wheat and oat fields, and sometimes injure apple trees. Their ordinary habitat is in pasture or meadow and grass is their most common food. This species is abundant all over the eastern United States; is an economic factor

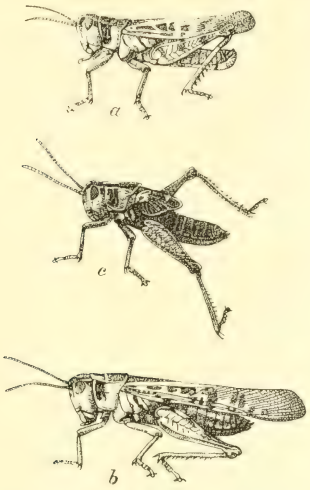


FIG. 28.—The yellow-winged locust (*Camnula pellucida*): *a*, adult male; *b*, female; *c*, nymph—somewhat enlarged. (After Simpson, Div. Ent., U. S. Dept. Ag.)

year after year, and undoubtedly causes more damage than the Rocky Mountain species. They do not usually destroy the grass completely, but take a large share of the crop. If they were eliminated the same acreage would supply more hay, or support more cattle or other stock in pasture.

Plowing the ground where eggs have been deposited, rota-

tion of crops, and the catching of the newly hatched hoppers in early summer before the damage has been done are measures that will assist in keeping them in check. They are preyed upon by several parasitic and predaceous insects

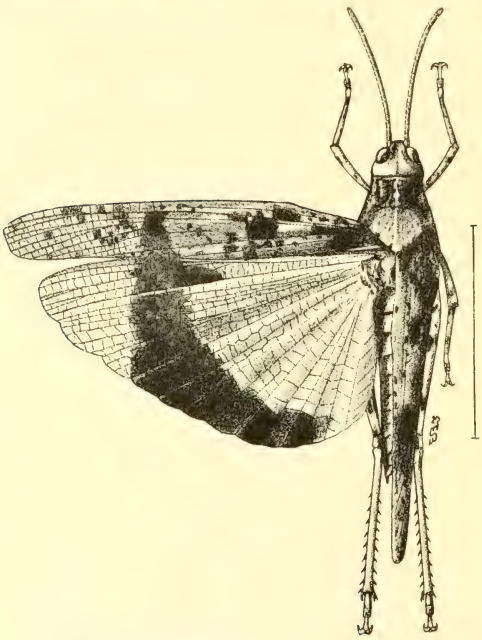

FIG. 29.—*Trimerotropis maritima*, female. (After Lugger.)

and by spiders and birds as well as fungous diseases, which together serve to hold their numbers down.

Another very similar species, but with longer wings, and which occasionally has a migration, but probably not so

uniformly destructive, is *Melanoplus atlanis*. The wings are long and the capacity for flight more like *Melanoplus spretus*, but flight seldom reaches more than a few miles.

**The Beach Locust** (*Trimerotropis maritima*).—The beach locust is an interesting species that occurs along the coast of the ocean as well as fresh-water lakes or where sand dunes are common. The coloration and markings are very distinctly adapted for protection and the nymphs are really about as well protected as the adults. They are conspicuous on the wing, part of the wing being bright yellow in color, but when they alight on the sand they immediately disappear on account of the color and markings. They must feed on grasses in such locations and are often found around clumps of Juncus and Arenaria, but rarely seen feeding.

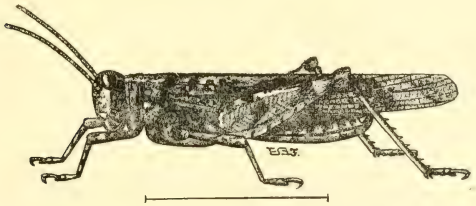

FIG. 30.—*Trimerotropis maritima*, male. (After Lugger.)

This species is found in June and July in the larval and nymphal stages, and in different sizes, some comparatively small, representing the second and third moult. Their moults occur fairly rapidly during this particular time. There is some difference in the time of hatching from eggs, and adults are to be found by the early part of July. The time varies in different seasons. Later in summer there will be very few larvæ and a large number of adults, and still later only adults. The adults remain active and travel over the sand for several weeks. They make characteristic tracks on the sand, easily detected. They probably do not

mate until somewhat late in the season, seldom during midsummer, but probably by the latter part of August.

In regard to the deposition of eggs, it would seem that they must select rather solid parts of the sand, but egg masses have not been found. There is no way for the nymphs to travel any great distance. The eggs must be deposited during the autumn months, probably in September and October. They survive the winter protected in the

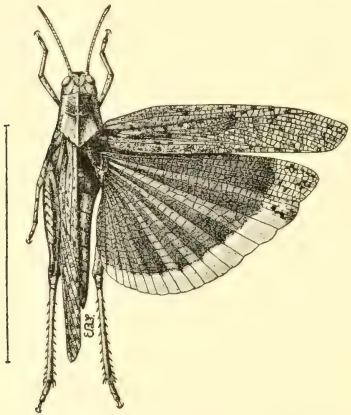

FIG. 31.—*Dissosteira carolina*, female. (After Lugger.)

sand or in places where there is more solidity in the soil. The eggs hatch in the spring, probably in June, some perhaps in May. It does not seem necessary for them to adjust themselves particularly at this stage to any conditions, for the life-cycle can be carried through easily in summer. There is one generation a year.

The more common form is a rather light gray, with the spots of a rusty color, and some spots of darker color, a granite combination, resembling the surface of the sand. Another

fairly common form has a brownish band or stripe on the upper part of the thorax or wing covers, and making a prominent line when the wings are closed. It occurs about as commonly on the sand, but may have a preference for places where there are little sticks. A less common form is lighter colored, almost ochre yellow, and more common among grass, leaves, and clumps. The color is close enough to the general color of the sand to afford some protection on the bare sand.

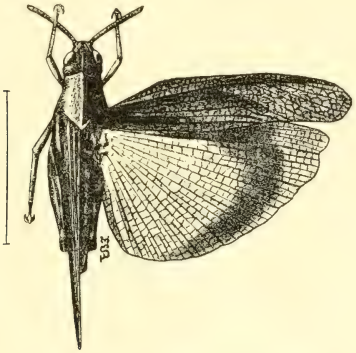

FIG. 32.—*Arphia sulphurea.* (After Lugger.)

**Family Locustidæ.**—The family Locustidæ includes insects which are usually green in color and called green grasshoppers or meadow grasshoppers, katydids, and stone crickets. They are characterized by great length of antennæ, the width of wings, and generally a green color. They are common among the coarse grasses along the roadsides and in meadows. A rather striking group includes the sword-bearers, *Conocephalus*, the striking feature being the form of the head, which is extended in a prominent horn, varying somewhat in size and shape in different species and with long, slender antennæ. The wing covers are somewhat

sword-shaped and the ovipositors also have a sword-like shape. They are found during the latter part of the summer as adults, occurring on grasses and low vegetation, but seldom on shrubby plants or trees. The females use the long, sword-shaped ovipositor for thrusting eggs into the tissues of plants, and thus they are protected during the winter time. The eggs hatch in the spring and larval development occurs during the early summer, the adults appearing in the middle or latter part of summer.

**Katydids.**—The katydids include several species, but the one most properly called katydid has broad, concave wings with rather prominent veins, quite strongly concave.

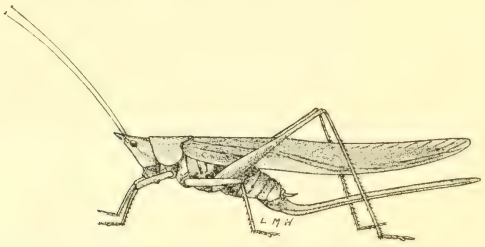

FIG. 33.—*Conocephalus ensiger*, female—natural size. (After Lugger.)

The name of the species is *Cyrtophyllum concavum*. They are noted for their song, and sing particularly during the twilight and early part of the night. This species is the best singer of the katydids. Their life history is practically the same as that of *Conocephalus*.

A species nearly related to this is the angular-winged katydid, which deposits eggs on the surface of twigs, the eggs overlapping each other like tiles on a roof.

**Stone Crickets.**—In this family also have been placed the stone crickets. Most of them are included in the genus *Ceuthophilus*. Quite a large number of species is included in this genus. They have changed from the food habit of

the other members of the group, and instead of feeding upon ordinary vegetation they secrete themselves in dark places and feed upon debris or decaying organic matter occurring in such places. The character of the ovipositor is like that of the crickets, but the head, antennæ, and other parts look like those of field locusts. The details of their life history are not fully worked out, but it is probable that there is one generation a year.

**Family Gryllidæ.**—This family includes the crickets and may be separated into herbivorous, carnivorous, and omnivorous forms.

*Oecanthus*, tree crickets. *Oecanthus niveus*, snowy tree cricket, is most commonly referred to, but *O. fasciatus* and other species are more common. The larvæ feed upon plant lice and are distinctively carnivorous, and therefore are serviceable during that stage. The adults may feed on flies, but were formerly thought to be herbivorous. The adults are found in autumn, and then they gather on various kinds of trees, fruit trees, etc. The eggs are forced into the twigs, forming a series of punctures. The eggs are deposited in two rows. They are elongated in form, and the masses of eggs include forty or fifty eggs deposited by each individual. The eggs remain in the twigs during the winter and are well protected in that way. They are sometimes deposited in galls on willows; if not by this species by one closely related. Some eggs are forced into the stems of annual plants, Helianthus, Solidago, etc. The eggs hatch during the spring season and the larvæ depend upon plant lice for food supply. They grow to reach adult stage, when they probably feed upon other insects. They are probably not destructive, and the attacks upon plant lice make them valuable. They are rather desirable on fruit trees, only in some cases the punctures of the twigs result in rather severe pruning.

A quite common species on Helianthus is *Oecanthus fasciatus*. There are four or five species that look a great deal like the common forms. In the males the wings are broader and very transparent. One form lays eggs in separate punctures at different points.

The mole crickets are extremely specialized as subterranean forms. They burrow in the earth and have become adapted to this habit. They have a dense velvety covering, which is doubtless serviceable as a protection against moisture, etc. In one species the wings are considerably reduced, but in another species they are longer. In all the species the legs are well developed, and are excellent for digging and burrowing, with toothed arrangements for pushing into the soil, much as in the mole and other digging animals. These teeth are mostly on the tibia. The tarsi are rather slender. Almost the same kind of structures occur in certain beetles

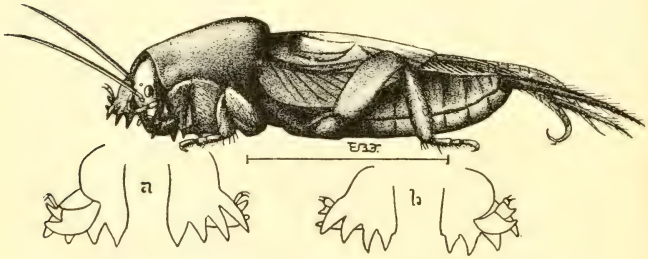


FIG. 34.—*Gryllotalpa columbia: a*, side view of anterior claw; *b*, the same of *G. borealis*. (After Lugger.)

and in burrowing Hemiptera. The mole crickets feed on vegetation, especially tuberous roots of plants; sometimes they dig into potatoes. Ordinarily they are not abundant enough to attract much attention. The long-winged form flies at night and sometimes flies into houses. They are completely covered with a fine pile, as velvety as that of a mole, and are also as well fitted for burrowing.

## EUPLEXOPTERA (DERMAPTERA).

**Earwigs.**—The earwigs, or *Euplexoptera*, are characterized by the presence of four wings, the first pair of which are very

short, veinless, and meeting in a straight line when at rest, the second pair of which fold both lengthwise and crosswise; biting mouth parts; forceps-like caudal appendages; incomplete metamorphosis.

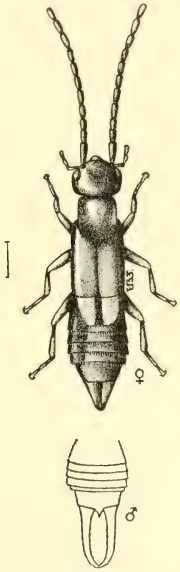


FIG. 35.—*Labia minor.* (After Lugger.)

These forms resemble rove beetles in appearance, being very long and slender, but differ in having the caudal appendages. They are found in the southern part of the United States and on the Pacific Coast, and are very common in parts of Europe, where they are troublesome, because of their habit of feeding on flowers and fruits.

A common species in the northern states is *Labia minor*, which occasionally may be seen flying in large numbers around barnyards. It has not occasioned noticeable injury, however, and is not counted of special economic importance.

### Order PLECOPTERA.

This group includes the stone flies, and the species are all aquatic, but in general characters they are pretty closely related to the Orthoptera. The mouth parts are mandibulate, the front wings are narrower than the hind wings, which fold together and are covered by the front wings when at rest. The transformations are incomplete, the larvæ distinctly aquatic and provided with tracheal gills along the side of the body, which permit them to absorb oxygen from the water. The species have an importance as a source of food supply for aquatic animals, and in some localities they probably furnish a considerable support for certain kinds of fishes.

The adults are usually found in the vicinity of water, on tree trunks or rocks, but except as they may attract attention they have no particular importance. Unlike the May flies, they are not strongly attracted to light, and are seldom noticed except in their native habitat.

### Order EPHEMERIDA.

May flies form an order frequently placed as the lowest of the winged insects. While showing some simple structure, we may consider their simplicity due to reduction or specialization. The mouth parts of adults are reduced, fore wings large, hind wings small. They are specialized in the aquatic habit of the larval stage. The genera and species are not particularly numerous. The name Ephemera was applied on account of their very short apparent life. They are developed from aquatic forms that have a period of development of from one to three years, but have a very short life in the adult stage. There are many species that come out

toward evening and fly for an hour or two, deposit their eggs, and then disappear. Other species live for several days, some perhaps for a week or two. Their first flight is in what is called the pseudimago stage. When coming to rest they attach themselves to some convenient object, and there the skin of this stage splits and the insect escapes, leaving the skin still clinging to the object. After this moult they are mature adults with full-sized wings, but with a difference in texture, and in genital organs, which are not fully developed in the pseudimago stage. For many of the species it is probably safe to say that they mate the same day that they come out of the pseudimago stage. The normal method of mating is on the wing. Eggs are probably deposited within a day or two, being laid either on the surface of the water or else underneath the surface. This is done by the adult folding the wings and descending beneath the surface. In one species the eggs are extruded in long packets and then the insect descends close to the water and deposits them on the surface.

The eggs after deposition in one way or another—in or on the water—hatch in a short time and the larvæ grow and probably migrate more or less in the water. They do not have to come to the top of the water for respiration, as they are fitted with organs which provide for aquatic respiration, and probably live two or three years in the water. The adults appear every year, and if the larvæ require two or three years to grow, there must be different broods, and if there are two or three different generations in the lake, there must be an enormous shifting of its population. They constitute an enormous body of animal life, furnishing the basis of food supply for other forms of animal life, fishes, etc., which in a few days shifts its position and disappears, thereby lessening the food supply materially. The larvæ of these nymphs come to the surface and the skin splits and the pseudimago form issues and flies. The exuviæ or skins which are left on the surface drift in on shore and pile up in windrows on the beach.

## Order ODONATA.

This group includes the dragon flies and damsel flies, insects with incomplete metamorphosis, biting mouth parts, and large, net-veined wings without folds.

The larvæ of these dragon flies and damsel flies are aquatic and distinctly predaceous, feeding on aquatic animals. The adults are also predaceous and catch insects in flight very readily. The former, particularly, have very swift, rapid flight, and may be seen darting here and there, especially in the vicinity of water, while the latter fly somewhat more slowly. Both groups catch insects and feed upon them, and so they are thought of as being beneficial, since many of the insects that they feed upon are destructive.

The eggs in all cases are laid close to the water's edge, either at or just above the surface, or in some cases attached to stems of water plants beneath the surface. When the larvæ hatch they are already under water and can begin their active life, preying upon the aquatic animals. In both adult and larval stages the mouth parts are provided with strong mandibles fitted especially for biting. In the larval or nymphal stage there is a very peculiar enlargement and elongation of the labium, so that it becomes a large mask for the front part of the head, covering the outer mouth parts and lower part of the face. These are provided with a pair of very strong, clasping, or pincer-like organs, which are used in capturing the aquatic animals on which they prey. The elongated and jointed structure of the labium permits the insects to thrust this forward a distance of about half an inch from the head, so that they can reach out and capture animals that seem to be out of their reach. These are snatched up very quickly and ground up with their mandibles.

After passing the larval stage they crawl out of the water on the bank of the stream or pond or sometimes on the stem of a plant, then the nymphal case splits along the centre line of the back, the adults draw themselves out of this

case, their wings expanding rather slowly or gradually. In about a half-hour they are ready for flight.

Their very rapid movements and habits have given rise to a number of common names. Aside from the dragon fly they are called mosquito-hawks, which is quite appropriate on account of their feeding on mosquitoes. Sometimes they are called snake feeders or snake doctors. In the past the name devil's darning needle was quite popular, although not used much at present. It was said that they sewed up the ears of untruthful children.

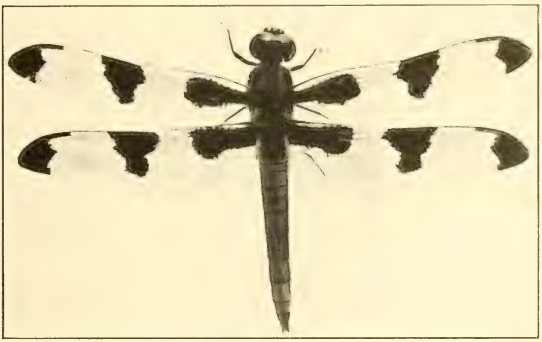

FIG. 36.—Dragon fly *Libellula pulchella*. (Photo by author.)

These different common names illustrate different popular interest in the group and forms of superstition. These insects seemed to inspire a great deal of dread before their life history and habits were known definitely.

The group Odonata can be looked upon as being very useful and serviceable to mankind, as they feed on destructive insects, mainly mosquitoes and many aquatic organisms. Of course they feed on useful insects as well as detrimental ones, but it is generally believed that the majority are detrimental ones.

Throughout a large part of the country is found the handsome *Libellula pulchella*, shown in Fig. 36. It is a large species with pruinose body, and the wings are each conspicuously marked with three black patches. This species is seen very frequently flying over low meadows and in the vicinity of ponds and rivers. Judging by the abundance of the adults it must be one of the quite important species as affecting the aquatic life, and the adults must dispose of many troublesome pests.

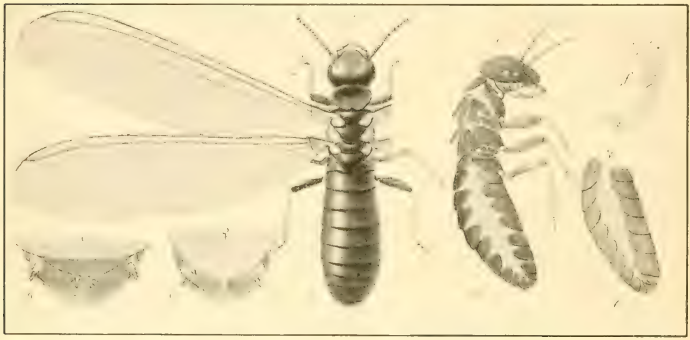

FIG. 37.—*Leucotermes flavipes:* *a*, adult male; *b*, terminal abdominal segments of same from below; *c*, same of female; *d*, male, side view, somewhat inflated by treatment with ammonia; *e*, abdomen of female, side view; *f*, tarsus, showing joints and claw; *a*, *d*, *e*, enlarged; *b*, *c*, *f*, greatly enlarged. (After Marlatt, Div. Ent., U. S. Dept. Ag.)

## Order ISOPTERA.

This order is characterized particularly by the thickly net-veined wings which fold flat upon the back and by the biting mouth parts and incomplete metamorphosis.

The order includes one family, the Termitidæ, in which there is a remarkable separation of habits, the species living in communities and showing much the same kind of adap-

tation for community life as is shown in the ants. The colonies usually include a large number of individuals, but may vary from a few dozen to many thousands. Each colony also includes several kinds of individuals, some of

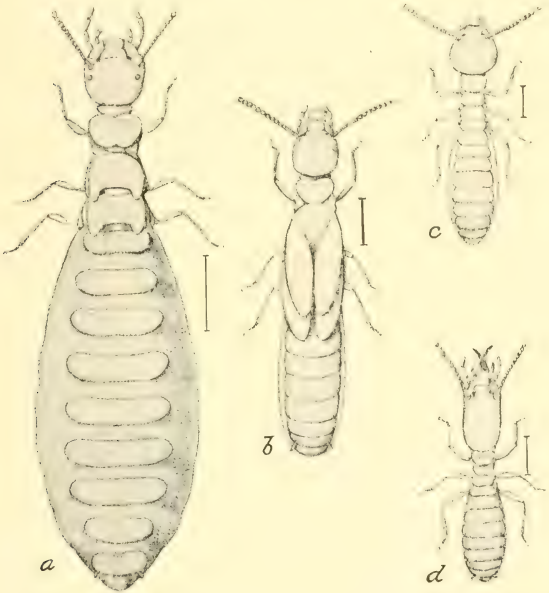


FIG. 38.—*Leucotermes flavipes: a*, queen; *b*, nymph of winged female; *c*, worker; *d*, soldier. All enlarged. (From Marlatt, Div. Ent., U. S. Dept. Ag.)

which are neuters, while others represent the males and females of normal species. The males and females are winged at time of maturity, but the wings are broken off after flight, and thereafter these individuals, like the neuters,

appear to be wingless, although the stubs of the broken-off wings may be noted. At the time of flight the different individuals come to rest at different places, so that they are pretty generally distributed. They then set to work to form a new colony. This, however, is impossible unless some of the workers are also located at the same place. It often occurs that many die off, without establishing a new colony, for lack of workers.

The colonies are located in the earth, or for some species upon the trunks of trees, or in some of the tropical forms

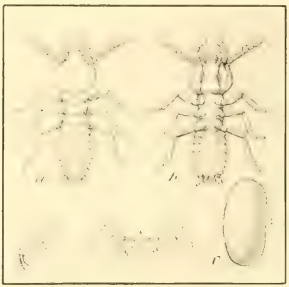

FIG. 39.—*Leucotermes flavipes:* *a*, newly hatched larva; *b*, same from below; *c*, egg. All enlarged. (From Marlatt, Div. Ent., U. S. Dept. Ag.)

large ant hills are built above ground which accommodate immense numbers of individuals.

The white ants feed upon wooden fiber and make attacks upon trees or upon dead timber and are especially destructive to wooden structures, so that in regions where they are abundant they constitute a very serious menace to wooden structures. They also feed very extensively upon wooden furniture, books or papers in places accessible to them, and the damage occasioned by such attacks is often very extensive.

The colonies include as neuters two forms: one, the workers, having moderately large heads, strong jaws, and adapted for carrying on the labor of the colony, such as col-

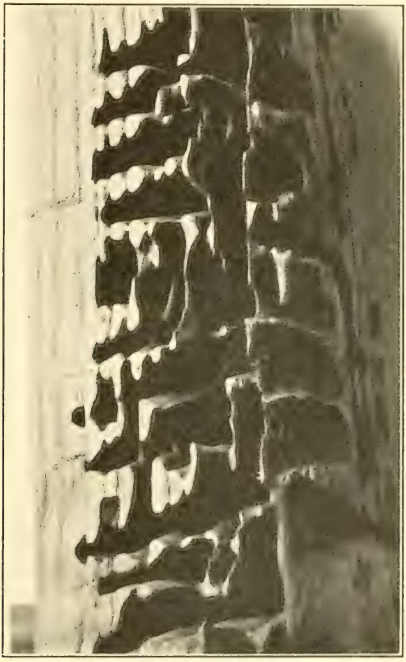

FIG. 40.—Work of white ant (*Leucotermes flavipes*) in chestnut.

lecting food, caring for the young, and in fact, all of the ordinary work of the colony. The other form, called soldiers, has as its special function the protection of the colonies.

They have enormous heads, strong jaws, and are especially fitted for attacking enemies that may enter the colony. They are, of course, helpless against larger kinds of animals,

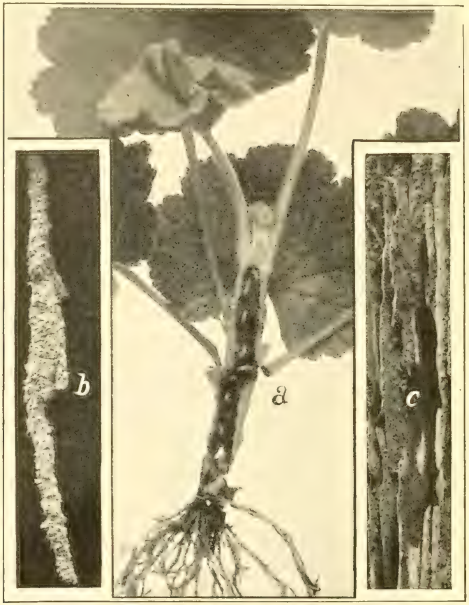


FIG. 41.—Termites and their work: *a*, adults working in the stem of geranium (photograph by Wm. P. Beeching, Jr., Ohio Agric. Exp. Sta.); *b*, enclosed gallery suspended from the underside of greenhouse bench (photograph by J. L. King, Ohio Agric. Exp. Sta.).

but their bite is very severe and they doubtless in this way serve as very effective guards against a numerous host of smaller-sized animals.

The most abundant individuals are the workers and then the soldiers. Both of these forms never acquire wings.

For this region and for the eastern and southern United States there is one common species, *Leucotermes flavipes* which is distributed as far north as the Great Lakes, to Boston on the Atlantic coast, and into central Illinois in the Mississippi Valley. The colonies of this species are formed, usually under old logs or stumps, and from these nests the termites construct tunnels, sometimes for long distances, to reach dead wood, buildings or other structures in which they can secure a food supply. Porches, fences, and all sorts of wooden structures suffer from their attack, but the greatest menace, perhaps, is to wooden trestles and bridges which are likely to have sudden weight thrust upon them. In feeding, the ants eat out the inner part of the timbers, leaving an exterior shell, thus it happens the timbers are greatly weakened before any indication is seen upon the surface.

The most effective treatment is to locate the nest, give it a thorough treatment of bisulphide of carbon to kill out especially the reproductive individuals, so that the colony will not be able to multiply.

Particularly the use of stone, brick or concrete foundations in bridges or trestles and the separation of the wooden part of structures from the earth in localities where white ants are present will serve as a prevention from their attacks. In tropical regions the practice is to use stone or metal, not only for bridges, trestles, etc., but in many places for railway ties, in order to avoid loss from the termite's attacks.

## Order CORRODENTIA.

**Family Psocidæ.—Book Lice.**—These are small insects, a considerable number of them are entirely wingless, but there are many species in which the wings are fully developed. The wings are held in a sloping position, a somewhat roof-like arrangement over the abdomen, but not folded flat, and have a rather small number of veins. Their appear-

ance is considerably like that of the plant lice, but they have distinct biting mouth parts. They are totally different,

FIG. 42.—Clothilla.

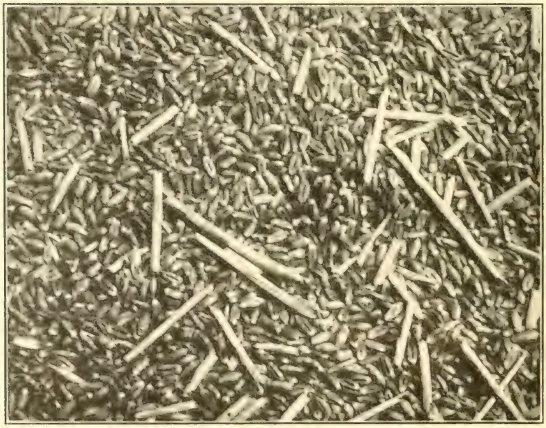

FIG. 43.—Work of *Atropos* on grain. (Photo from Ohio Exp. Sta.)

though, in their method of reproduction. The more interesting members of the group are those which are wingless

and occur in houses, commonly found among books, old papers, insect collections or herbaria, and which do a great deal of damage in such places.

The common book louse, *Atropos divinatoria*, is most abundant in houses among old books. They are too small to be pinned, but they can be mounted on micro slides to good advantage, for study with the microscope. They are about one-sixteenth of an inch in length, rather flat, nearly white, antennæ slender, and eyes quite small. Their mandibles are strong and they feed on the mucilage and glue or paste of book bindings, on the tissues of preserved insects,

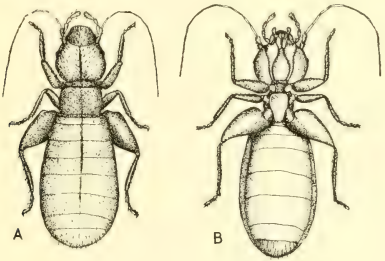


FIG. 44.—*Atropos divinatoria.*

and they are quite detrimental to collections of plants in herbaria.

They may be destroyed by fumigating with bisulphide of carbon for half an hour or so. They are so very small that it is almost an impossibility to exclude them entirely from any place.

## Order MALLOPHAGA (Bird Lice).

This order includes the biting lice infesting birds and mammals. They are usually hard and horny and much flattened. They possess mandibulate mouth parts adapted

to cutting and biting the hairs, feathers, epidermal scales, or excretions on the bodies of their hosts. The mandibles are situated in most forms underneath the head and near the centre, the clypeus projecting and forming the most anterior portion of the head. The labrum is present and the maxillary palpi are prominent in a part of the group. The eyes when visible are located back of the antennæ. The antennæ are five-jointed except in *Trichodectes*, where they are three-jointed. The thorax is generally narrow and

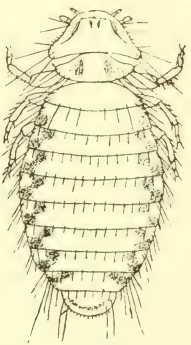

FIG. 45.—The common hen louse (*Menopon pallidum*). Greatly enlarged. (Banks, Div. Ent., U. S. Dept. Ag.)

frequently but two divisions are apparent. The legs are adapted to clasping (Philopteridæ) or to running (Liotheidæ), the tarsi in the first case being short and in the latter case being long, well adapted to running, and provided with two claws. The members of the first division occur on both mammals and birds, those of the second, except *Gyropus*, are limited to birds. Wings are entirely wanting, and the abdomen contains nine or ten segments and is usually oval in shape.

The eggs are glued to the hairs or feathers of the host

animal and open with a circular cap or lid at the free end. The larvæ are less flattened, shorter in proportion, and without the hardened parts common to the adults, covering a part or all of the surface. The length of life and rapidity of multiplication has not been determined accurately for

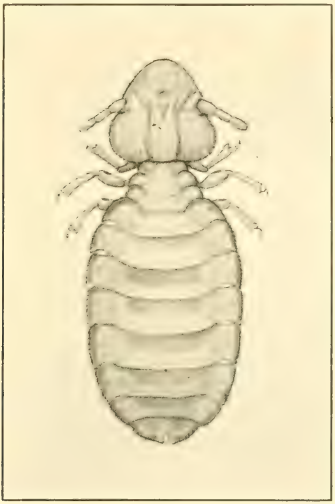

FIG. 46.—*Trichodectes scalaris* (biting cattle louse). (Bull. 5, Fig. 134.)

these insects and the habits of the insects make any such determination a matter of considerable difficulty.

While it is, of course, very desirable that a more complete knowledge of the life history of the species be secured, it may be considered as already established that all the species, with no known exception, pass their transformations on the body of the fowl, and that, unlike the mites, they may be

attacked with the assurance that eggs and newly hatched young are not developing in some out-of-the-way corner.

Moreover, the observations made on the length of time required for the hatching of the eggs indicate that they require a number of days at least, so that in repetition of treatments intended to kill individuals hatched since a former treatment a period of ten days to two weeks may be counted on as probably short enough.

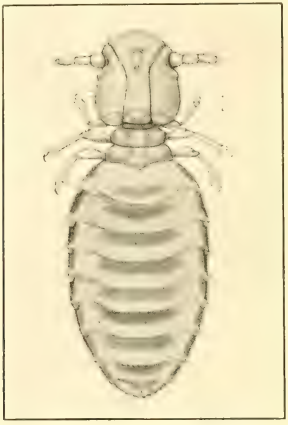

FIG. 47.—*Trichodectes parumpilasus* (biting horse louse). (Bull. 5, Fig. 133.)

It should always be borne in mind that lice must grow from eggs laid by the adult louse, and can never originate from filth or other matter. Chickens hatched in an incubator should be absolutely free from lice and remain so until brought in contact with a lousy hen or put in a lousy chicken house.

The effect of these lice may be less important than the

suctorial lice, or the sucking ticks or mites; but judging from the serious results following the efforts of the animals to rid themselves, and from the known irritation due to anything crawling among the hairs or feathers, it cannot be doubted that they cause much annoyance and inconvenience to the creatures that become their involuntary supporters.

The biting lice of cattle and horses are annoying pests and demand the attention of the stockman.

## Order THYSANOPTERA.

The species of this order are all very small and have mouth parts intermediate between the biting mouth parts of the Orthoptera and the suctorial mouth parts of the Hemiptera. In some respects they may be considered as an intermediate group between the Orthoptera and the Hemiptera, but not as a distinct connecting link between the two, because in the matter of wings they have a specialization of their own. They are minute, all very small, the largest not over one-eighth to one-fourth of an inch in length. Many are not over one-sixteenth of an inch long. They have very slender bodies and slip around readily between the parts of the blossoms of many different kinds of plants. The different stages may occur in the bloom, and they feed, at least in large part, upon the soft tissues of the parts of the blossoms, puncturing and corroding them so as to secure the juicy contents.

The mouth parts are drawn out in style-like form. Their structure is partially like that of Hemiptera, but the styles are not produced beyond the length of the head. They are not capable of cutting and biting as the mouth parts of the grasshoppers, nor are they strictly suctorial organs. The wings are characteristic. In one division the wings are narrow, with few veins and provided with quite long marginal setæ which furnish a large part of the area of the wings. The hind wings of this form also have setæ but no veins. Another division has wings very simple, without any venation, and provided with enormously long setæ. They are

fringe-winged forms, a characteristic structure. Another character almost equally distinctive is found in an aborted tarsal joint modified into a bladder-like expansion of the tarsus. This joint is evidently a modification from the ordinary form with claws. Bladder-foot is one term applied to this group and Physopoda is the name given in some text-books, based on this particular structure.

The life history of the group in general is rather simple. The adults deposit eggs at different periods through the summer, the generations being somewhat irregular, often three or four in a summer. The eggs are rather large for the size of the insect and somewhat ovoidal or oblong in shape, almost transparent. They are deposited on the foliage or bloom of plants, and hatch quite promptly. The larvæ develop gradually by successive moults, without any striking metamorphosis, until they reach the adult stage when wings are developed. Between the larval and adult stages is a stage of quiescence; parts, including the antennæ and legs, are almost immovable. This may be looked upon as a development along the line of the more striking metamorphosis in other cases. The eggs are deposited by means of an ovipositor that differs in the two subgroups of the family. In one case there is a saw-like ovipositor with blades that glide on each other and enable them to push eggs into soft tissues. In the other division the ovipositor consists of the elongated tubular abdominal segments. The latter is a more simple condition, but the former is more primitive. The latter probably results from reduction, the saw-like structure being lost. The difference in egg deposition amounts simply to position in which eggs are laid: in the first instance they are laid more or less within the tissue, in the second instance on the surface.

For the first group, Terebrantia, the common Thripidæ occur in clover, Compositæ, apple blossoms, milkweed, etc., also in wheat blossoms. The food plant is determined simply by the flowering season. The most abundant is the wheat thrips, Thrips tritici; this is an economic species, causing some damage.

In the spring they are found in apple bloom and a large proportion of the blossoms are infested, as high as 80 per cent. in one instance having been observed to be so damaged as to render blossoms infertile. They also occur commonly

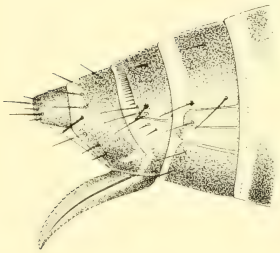

FIG. 48

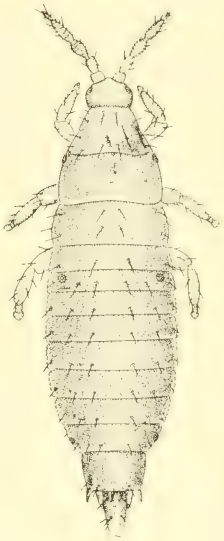

FIG. 49

FIG. 48.—The pear thrips (*Euthrips pyri*): ovipositor and end of abdomen from side. Much enlarged. (After Moulton, Bur. Ent., U. S. Dept. Ag.)

FIG. 49.—The pear thrips (*Euthrips pyri*): larva. Much enlarged. (After Moulton, Bur. Ent., U. S. Dept. Ag.)

in strawberry bloom, and the injury to the bloom appears to result in the distortion of the berry known as "buttoning." When exposed they can be killed by spraying with kerosene emulsion.

**Pear Thrips** (*Euthrips pyri*).—The pear thrips has been a serious pest in California, attacking beside pear a number of the related fruits. Its attack is directed largely against the bloom and the loss of fruit is serious. Contact sprays are only partially effective, as the insect is protected so much of the time within the parts of the bloom.

**Grass Thrips** (*Aphanathrips striata*).—The grass thrips is an extremely abundant species in the northeastern United

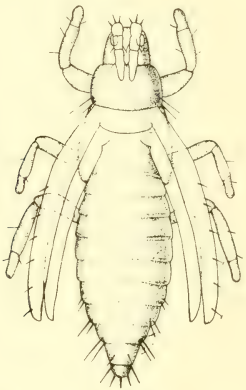

FIG. 50.—The pear thrips (*Euthrips pyri*): nymph or pupa. Much enlarged. (After Moulton, Bur. Ent., U. S. Dept. Ag.)

States, and has been reported as destructive to oats in Canada. It attacks the upper part of the plant and its injury shows, especially in the blasting of the heads of grass and oats. In grass this is called "silver top," a condition of whitening and withering of the upper stem and seed head which is probably produced by other insects as well as thrips, but which is no doubt in large measure to be credited to these almost invisible little pests.

Another species is *Thrips tabaci*—known now as onion

thrips. It occurs on quite a large variety of plants. It is similar to *Thrips tritici* in size, but different in some microscopic details. It is injurious to onions. Massachusetts, Iowa, Colorado, Rhode Island, and Ohio have all reported

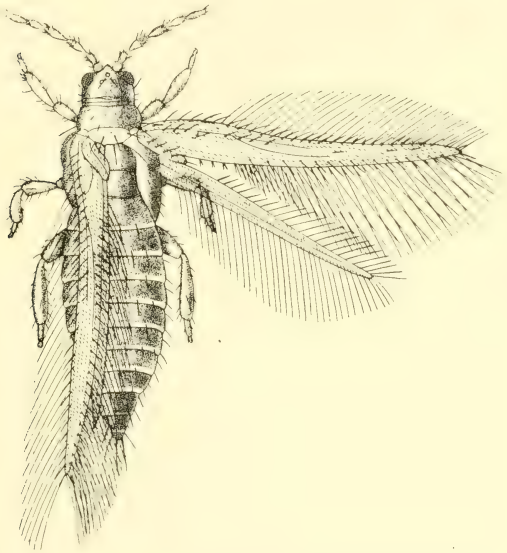

FIG. 51.—The pear thrips (*Euthrips pyri*): adult. Much enlarged. (After Moulton, Bur. Ent., U. S. Dept. Ag.)

extreme injury from this species. The degree of injury is determined in large part by temperature, moisture, etc. It occurs on many plants besides onions. In dry seasons it becomes very injurious to the onions. The leaves wilt and show whitening, and the injury is easily recognized.

The life history is a matter of adaptation to different plants. There are probably several generations in one summer and hibernation in mature larval or adult stage.

**Mullein Thrips** (*Phloeothrips verbasci*).—The mullein thrips has a definite restricted food plant and the herbivorous character of the insect can be easily established. It is a little black species found in mullein plants the year through. In early spring they are found among the bases of the mullein leaves. They seldom try to fly, but creep about among the fine hairs of the mullein leaf. They are very common in the mullein plants and there are very few plants without them, so examples may almost certainly be found wherever mullein occurs. The eggs are laid soon after the leaves are well started in the spring and there is a pretty definite brood.

The adults of this brood mature about the time the blossoms appear, this being the softest portion of the plant at this period. Later on adults in resting period are found in seed pods or secreted around the base of the plants. There are two generations in the summer; the adult individuals appearing first in the spring, then again in the summer, and again in the autumn. They do not do any great damage to the leaves, although they feed upon this plant exclusively.

Another species, *Phloeothrips nigra*, occurs in clover bloom. It is a black species and evidently restricted to clover. The larva is bright red and often found during the winter. They feed on part of the clover bloom and so far as it has any effect, is destructive to the clover. One species is credited with feeding upon the grape Phylloxera. If it does this it is an exception to the usual food habit of the family. It possibly may feed ordinarily upon the tissue of the gall and exceptionally on the plant lice that occur within the gall.

The group as a whole is to be considered as herbivorous rather than carnivorous, and injurious when occurring on useful plants.

## CHAPTER V.

## ORDER HEMIPTERA.

The Hemiptera constitutes one of the large orders of insects and includes some of the very important economic species, and some of the very striking specializations in insect life history including extremes in different kinds of environment, life habit, and one of the most striking extremes in the matter of reproduction and development.

The essential character of the order is found in the development of the mouth parts, there being also other distinct differences in the matter of wing structure and some other parts of the body. The mouth parts are adapted for suction in the larval as well as the adult stages. This represents a more radical change of these parts than when the mouth parts are different in different stages. The modification in the mouth parts consists in the change of the mandibles and maxillæ into bristles or setæ which serve to puncture the tissues of the plants upon which the insects feed by pumping out the juices. The labrum (epipharynx of some authors) is present as a rather aborted structure; the labium is modified into a sheath for the bristles or setæ and is usually three- or four-jointed. These segments are fitted together to form a sheath or tubular or furrowed organ within which the bristles or setæ play back and forth as they are driven into the tissues which constitute the food of the insects. Within the group there are differences in wing structure which enable us to separate the group into two very distinct suborders, and in some cases three are recognized, the third including only parasitic forms.

The two main suborders are the Homoptera and the Heteroptera, the first including those forms which have

membranous or opaque, but homogeneous wings; the second having the front wings thickened at the base and membranous at the apical portion. The Heteroptera are often given first as if more primitive, but the Homoptera appear to have the most fundamentally primitive character. The venation of the wings and the position of the head particularly seem of more primitive character than in the Heteroptera.

The third group, Parasita, includes the suctorial lice; the wings are lost, beak is single-jointed, and setæ are very much elongated and tubular. They are restricted to the warm-blooded vertebrates, mammals.

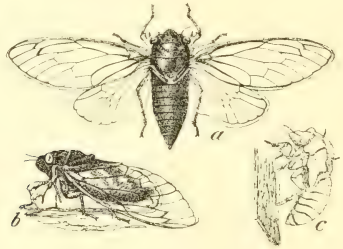


FIG. 52.—The periodical cicada (*Tibicen septendecem*): *a*, adult; *b*, same, side view; *c*, shed pupal skin. Natural size. (After Marlatt, Bur. Ent., U. S. Dept. Ag.)

The Homoptera are divided into two divisions, Auchenorhynchi and Sternorhynchi. In the first group the beak is free, not attached to the sternum, and may be moved readily from the head as its base. In the second group it is fused into the sternum and the base connected with the head at about right angles to the sternum. This latter is a specialized condition and must be derived from the simpler condition where the beak is free.

In the Auchenorhynchi the Cicadidæ are one of the most prominent families, which is apparently rather generalized in its features. They show specialization in their life his-

tory. The most common species, or, for the Homoptera, one of the most widely known, is the seventeen-year cicada, which is especially remarkable on account of its long life. The seventeen-year cycle is certainly known and well established by observation. The adults appear at these periodical intervals in the latter part of June and they are apparent

FIG. 53.—*Tibicen septendecem:* adults on two-year-old apple tree. (Photo from Ohio Exp. Sta.)

during this stage when they feed very slightly on vegetation, mate and deposit their eggs during a period of four or five weeks, though they are seen in great abundance for a period of only a few days. They are noticeable from their size and from the very loud note that is produced by the males. The song is a long-drawn-out sort of screech and is produced

by an organ located in the base of the abdomen, covered by the wings when folded and slightly covered from below by an operculum. The structure of the drum is somewhat flattened and inside is a cluster of muscles attached to the

FIG. 54.—*Tibicen septendecem:* adults ovipositing in apple tree. (Photo from Ohio Exp. Sta.)

abdominal wall. Their contraction serves to draw this membrane in, after which it immediately resumes its former position and when repeated rapidly this causes a vibration, producing a whirring or buzzing note which varies in intensity with the rapidity of the vibrations. Its purpose has

been interpreted as that of a mating call, but no auditory organ has been described. The females deposit eggs in twigs of trees, puncturing the trees with little furrows, which result in splitting the bark, and the twigs often die. The

FIG. 55.—*Tibicen septendecem:* twigs broken from egg deposition. (Photo from Ohio Exp. Sta.)

eggs hatch five or six weeks after their deposition. The larvæ drop from the twigs and pass into the ground and from that time on for almost the next seventeen years are out of sight and are growing gradually, moulting occasionally,

probably once a year at least. They feed for the most part on the roots of trees and shrubs and woody plants occurring in their location. When trees are cut away after the eggs are deposited, some of the nymphs doubtless fail to develop, but there are some that become mature.

The uniformity in their appearance may be accounted for by the fact that those that did not come out at a definite time had little chance of breeding and reproducing. They occur throughout the eastern United States and the seventeen-year form mostly to the north of the latitude of the Ohio river. To the south of that latitude there is a thirteen-year form. They do not occur over the whole area of the country in which they may be considered as native, there being portions where they do not occur at all, other places where they occur twice in seventeen years, and still other places where they occur three times in seventeen years. They may be descendants of a generalized mass of cicadas with a shorter life period. Just why they have been retarded is another problem. Their subterranean habit and consequent slow growth might serve to prolong their life.

The dog-day cicada which appears commonly in August, lays its eggs in twigs of various trees, but the growth of the nymph is much more rapid. The injury is the same as in the seventeen-year cicada. The attacks of the adults in young orchards are sometimes serious.

After the Cicadidæ the Membracidæ are perhaps the most generalized, though they present a specialized structure of the thorax. They are called treehoppers, the majority inhabiting trees and shrubs, a few only occurring on herbaceous plants. The specialization of the thorax is shown in various ways. The prothorax is the greatest part of the body visible from above. There are many variations and these result in a great many forms of mimicry and protective resemblance. Some forms have the posterior part of the prothorax broken up into globular pieces simulating the body of an ant. In some cases there are three large knobs which hang out from the central part and probably resemble parts of the tree on which it occurs. They take on the

greatest variety of forms, many very grotesque. The group is large and includes many species. There are probably fifty species in the latitude of the Northern States.

One of the most common is the buffalo treehopper, *Ceresa bubalus*, which abounds on thorn, apple and maple trees and is frequently found on other vegetation. It is of an apple-green color, with faint, light yellow mottlings

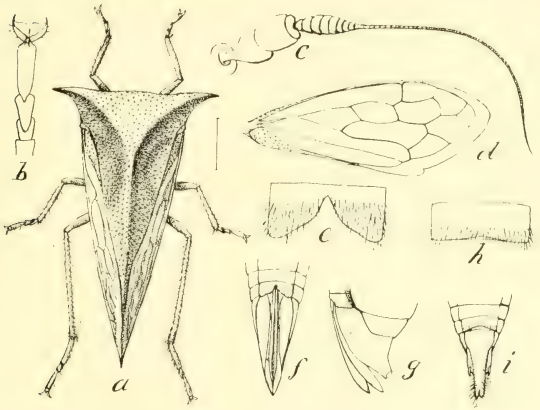


FIG. 56.—Buffalo treehopper: *a*, female; *b*, enlargement of foot; *c*, antenna; *d*, wing; *f*, *g*, ovipositor; *h*, *i*, terminal segment of male abdomen; *e*, terminal segment male *taurina*. (After Marlatt, Bur. Ent., U. S. Dept. Ag.)

or specks, distributed over the pronotum. The pronotum itself stands out in two prominent horns. It extends back in a very pronounced spine. The eyes are quite prominent and stand out at the sides of the head. There are four species closely related, but this one is the most abundant. Its life history is quite characteristic for the group. They are single-brooded and the winter is passed in the egg stage; the eggs are deposited in twigs of various trees in little slits

of the bark, with slightly crescent-shaped scars, and eggs are arranged in parallel rows, causing damage to the trees. The young hatch in the spring and early summer and as hatched they are quite grotesque. The body is shaped something like that of an adult, but along the dorsal line there is a series of sharp spines, the divisions of the body are fairly well marked and the divisions of the abdomen are distinct.

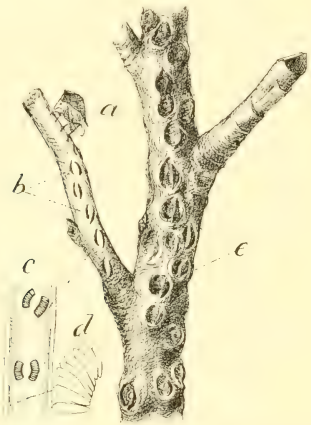


FIG. 57.—*Ceresa bubalus*. Twig of apple showing: *a*, female at work; *b*, recent egg puncture; *c*, bark reversed with eggs in position, slightly enlarged; *d*, single row of eggs still more enlarged; *c*, wounds of two or three years' standing on older limbs. (After Marlatt.)

There is no such expansion of the prothorax as in the adult. They moult several times and with the aquisition of the wings the pronotum becomes fully expanded. The moults occur mainly in June and July and the adults appear usually in the latter part of July. Deposition of eggs occurs rather early in the fall. A considerable part of the year is spent in the egg stage. Injury is caused by pumping the sap and

is limited to a rather short period, but the injury caused by puncturing the twigs for egg deposition does not fully appear for a year or two after the eggs are deposited. The scars and distorted growth of the twig may seriously disfigure and weaken the branch. It is rather difficult to apply any distinct remedy because they occur on so many different kinds of plants. Cutting off the infected twigs would be possible but hardly practicable on any large scale. The

FIG. 58

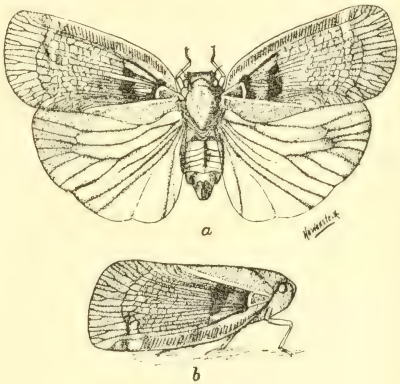


FIG. 59

FIGS. 58 and 59.—*Ormenis pruinosa* Say: at right, *a* and *b*, adults; at left, *a*, eggs, much enlarged; *b*, eggs in bark; *c*, twig with eggs. (After Lugger.)

application of kerosene emulsion would be effective at the same time that other forms are developing, thus killing off more than one species at one time.

**Family Fulgoridæ.**—The family *Fulgoridæ* presents extreme specialization in some directions. These occur in the head region instead of the prothoracic region. In one of the most extreme forms the head is spread out into a great peanut-like structure, and in one form there is an

appearance of a large spot on this head portion, and in one species there is stated to be phosphorescence. The thorax, wings and abdomen have for the most part normal character or some variation in the wings. It is an enormous family, especially represented in the tropics. There are few striking members of the group represented in northern latitudes. A good many of the forms are inconspicuous. A few special forms representative of the group may be mentioned.

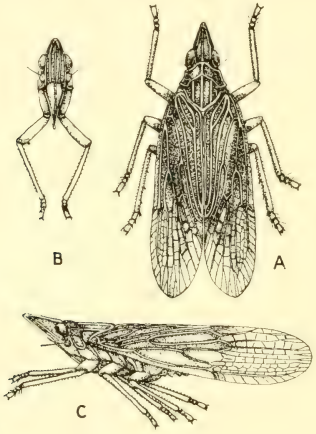


FIG. 60.—Fulgorid. (Original, from drawing by Miss Edith Hyde.)

**Otioceras.**—*Otioceras* is as elegant a little insect as can be found in any group of insects. They appear very much like delicate little moths. The head is drawn out into a plowshare-shaped form. The eyes are prominent and the antennæ very peculiar, with little flabella-like appendages. The eyes stand out at the sides of the head, the wings run back in a moth-like form and are quite delicately veined and marked. These occur mainly on hickories or closely

related trees, in August and September or October. They may be obtained by beating the trees over an umbrella with a stick. The genus includes six or eight common species. They are quite similar in general appearance.

**Delphacidæ.**—The Delphacidæ are characterized by the presence of a large, movable spur on the end of the tibia, and tibia and tarsal joint run out with spines. A specialized appendage for attachment to twigs, stems of grass, etc., enables the insects to jump more readily. This is a characteristic structure for this group. These hoppers occur abundantly in low vegetation, especially on grasses and some species are abundant enough to be detrimental, as for instance, the corn Delphacid (*Dicranotropis maidis*), and the sugar-cane hopper, which has been extremely destructive in the sugar plantations of the Hawaiian Islands. Our species occur sometimes in blue-grass meadows, and do some damage. They are minute, varying in size from one and a half to two millimeters, to four or five millimeters in length. They present a great variety of modification in wing development. Some are dimorphic. There are some in which the hind pair of wings are wanting or not full-sized, some in which front wings are reduced entirely or to mere rudiments. This occurs first in the females, but also in some species in the males. The greatest amount of reduction appears to occur in those which live where food supply is abundant and flight becomes unnecessary. There may be a summer generation without wings and a fall generation with wings. One other interesting feature is the fact that they are parasitized in a peculiar manner. Certain Hymenopterus parasites deposit eggs on the bodies of these and larvæ are produced in a sort of sack extruded between the segments of the abdomen, and within this sac the larvæ develop. These parasites may have some value in reducing the number of the hoppers.

The eggs are deposited in the leaf or stem of grasses, etc., and the larvæ hatch from these and feed on the plant attacked. The stages of development are gradual and there are one or two broods annually for the most of the species.

Some of the forms have adult hibernation and others egg hibernation.

**Family Cercopidæ.** The *Cercopidæ* is a family that has few economic species. They differ from the Fulgoridæ in having the head and thorax rather normal in shape, first pair of wings usually thickened opaque and venation not very conspicuous. The thorax is well developed, the tibia terminates in a prominent crown of spines and no spines

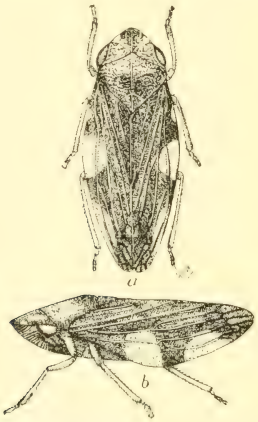


FIG. 61.—*Aphrophora 4-notata* Say: *a*, from above; *b*, from side. (From Lugger, Minn. Ann. Rept. 6.)

on the sides of the tibia. These include the little frog hoppers or "spittle insects." The larvæ suck the juices of the plants on which they occur and pump out more juice than they have use for and extrude it from the body in fluid form and set air free within this juice, making the frothy mass which covers the entire body of the larvæ. These masses are found hanging on the stems of plants very frequently during the summer. After they have passed through the

larval and pupal stages they do not secrete any such frothy masses.

**Superfamily Jassoidea.**—The superfamily *Jassoidea* includes several subdivisions of considerable importance. They abound particularly on low vegetation, and some are grass feeding, others tree inhabiting. They differ from the Fulgoridæ in the more specialized and compact head and thoracic region and in the more distinctive character of the hind tibia which is more prismatic in form and with two rows of spines and without any circle of spines at the tip. The subdivisions are separated by means of the venation of the wings, and by the head parts. There are four fairly distinct families.

The life histories are somewhat complex. Some species have a single brood each year, others two, others apparently three. Some hibernate as adults, many as eggs, some apparently in partially developed nymphal stages. Some of the striking examples are the grass leafhoppers, forms that live continually in the grass and suck the sap, causing a considerable decrease in the crop, reducing quantity and quality of the nutritive contents of the grass leaves. In some the individuals are extremely abundant, one to two millions to the acre.

The life histories are much the same throughout the group, but not many have been worked out in detail. The group stands as one of the most specialized of the Homoptera that have the primitive condition of the mouth parts.

The term vertex is used for the upper surface of the head between the eyes and extending to the front border, which may merge gradually into the front or the face. The frons, or front, is the part of the face lying between the sutures and extending down nearly to the lower border. At the sides of this are portions next the eyes, which are termed the cheek, and below the front a part called clypeus, at the sides of which are the loræ. The central part of the body which bears the wings and legs is termed the thorax, and the upper portion of the first segment is known as the pronotum. The front wings are termed elytra and are

usually thicker and stronger than the hind pair, which are concealed beneath the front ones when at rest. The abdo-

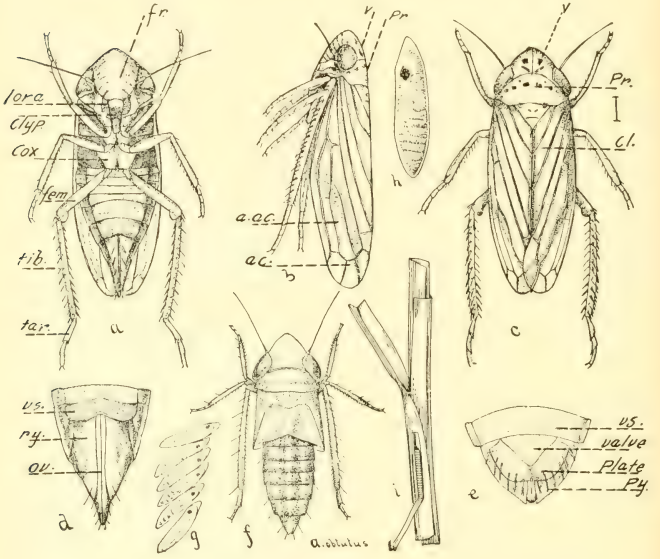


FIG. 62.—Explanation of terms, from drawing of *Athysanus obtutus:* *a*, female from beneath; *b*, from side; *c*, from above; *d*, female genitalia; *e*, male genitalia; *f*, larva or nymph; *g*, eggs, showing developing larvæ; *h*, egg, enlarged; *i*, eggs in position beneath sheath of grass stem. Structural details: *ac*, apical cells; *a.ac.*, anteapical cells; *cl.*, clavus; *clyp.*, clypeus; *cox.*, coxa; *fr.*, front; *fem.*, femus; *lora*, lora; *ov.*, ovipositor; *plate*, plate; *pr.*, prothorax; *py.* (♂), *ry.* (♀), pygofer; *tar.*, tarsus; *tib.*, tibia; *v.*, vertex; *vs.*, terminal ventral segment; *valve*, valve. All enlarged. (After Osborn and Ball.)

men may be entirely hidden above by the wings, but in short-winged forms is more or less exposed. The parts of greatest importance on the abdomen for purposes of descrip-

tion are the terminal segments, including the genitalia. In the female the last ventral segment is frequently of a particular shape or structure for different species and in many groups is of the greatest service for description. It is followed by the sheaths of the ovipositor, this latter being a narrow, saw-like pair of blades, extending to the tip, sometimes considerably beyond the tip of the sheaths. The males have a terminal segment beneath a modified segment, called the valve, which is followed by two movable pieces called plates. Above these, forming the sides of the last

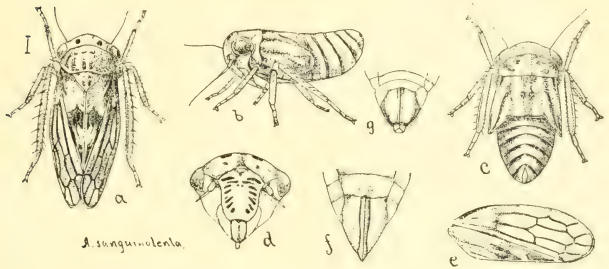


FIG. 63.—The clover leafhopper (*Agallia sanguinolenta*): *a*, adult; *b*, nymph, side view; *c*, nymph, dorsal view; *d*, face; *e*, elytron; *f*, female genitalia; *g*, male genitalia. All enlarged. (After Osborn and Ball.)

segment, are the pygofers. A ready understanding of these various parts will be helped by a study of the accompanying figure, in which they are located and named. For the different stages of insects the usual terms egg, larva, or nymph, pupa, and adult are used, as these are sufficiently definite in indicating the steps of development from the egg to the mature form.

**Bythoscopidæ.**—The *Bythoscopidæ* include forms which are for the most part found upon trees or woody plants, sometimes in great abundance and which doubtless occasion considerable injury, although the effect in any particular

case may not be very apparent. The common species affect willows.

**Idiocerus alternatus** lays eggs in the bark and passes through two generations each year.

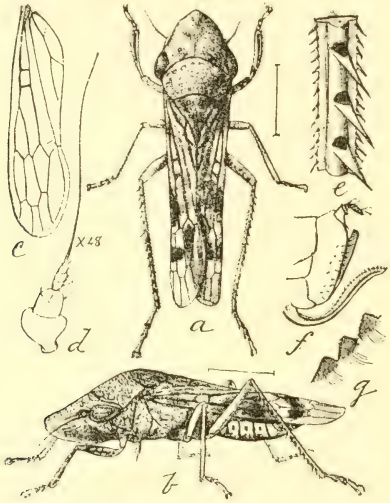


FIG. 64.—Glassy-winged sharpshooter: *a*, adult ♀, seen from above; *b*, side view; *c*, venation of forewing, enlarged; *d*, antennæ; *e*, section of hind tibia; *f*, ♀ genitalia, more enlarged; *g*, serration of ovipositor, still more enlarged. (From Howard, Bur. Ent., U. S. Dept. Ag.)

**Clover Leafhopper.**—Another form of considerable economic importance, the clover leafhopper, is a very common pest of clover and alfalfa and has been noted as troublesome in sugar-beet fields.

**Family Tettigoniellidæ.** — The family *Tettigoniellidæ* includes an enormous number of species occurring in the tropics and a considerable number of common forms through-

out the temperate regions, among them a particular species known as the sharpshooter, *Oncometopia undata*, which discharges droplets of liquid, so that when the insects are abundant, the tree in which they occur may shed consider-

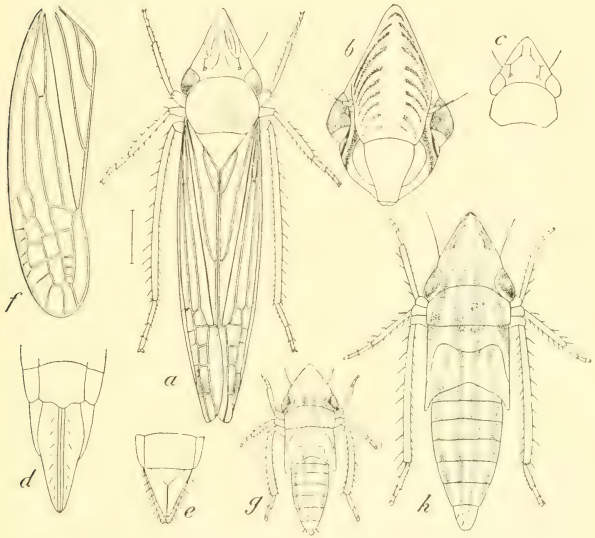


FIG. 65.—*Draculacephala mollipes: a*, adult from above; *b*, face, much enlarged; *c*, vertex and pronotum ♂; *d*, female genitalia; *e*, male genitalia; *f*, wing; *g*, *h*, nymphs. All enlarged. (After Osborn, Bur. Ent., Bull. 108.)

able liquid, and this leads to the name "weeping tree." The glassy-winged sharpshooter, figured here, has a similar habit.

**Tenderfoot Leafhopper.**—A species which is very abundant in grass lands is the tenderfoot leafhopper, *Draculacephala*

*mollipes*. This is light grass-green in color, quite slender, has a very sharply pointed head, and is very well protected on the blades of grass both by its color and form. It occurs on a great variety of grass plants and is known all the way

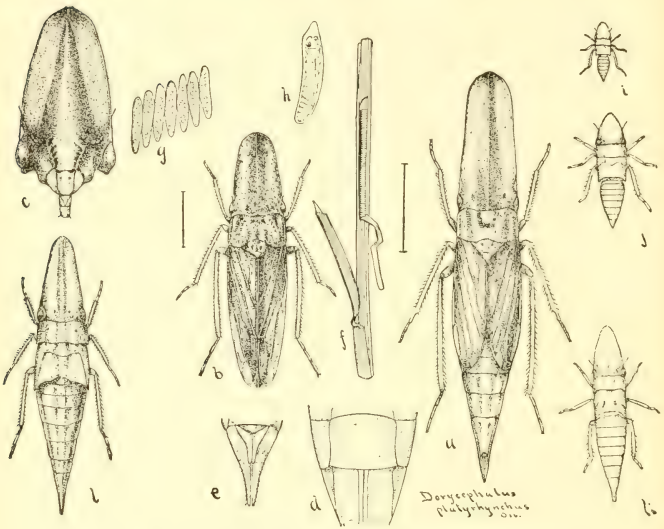


FIG. 66.—The shovel-nosed leafhopper (*Dorycephalus platyrhynchus: a*, female; *b*, male; *c*, face; *d*, female genitalia; *e*, male genitalia; *f*, eggs in grass stem; *g*, eggs; *h*, egg, more enlarged and showing developing nymph; *i*, *j*, *k*, *l*, different stages of growth of nymph. All enlarged. (After Osborn and Ball.)

from Canada to Central America. The nymphs have fairly well-marked longitudinal stripes arranged as shown in the figure, but are much less commonly observed than the adults.

**Family Jassidæ.**—The family *Jassidæ*, including the forms which have the ocelli located in the margin of the head between the vertex and front, is very largely represented in temperate regions and many of the species affect important cultivated crops.

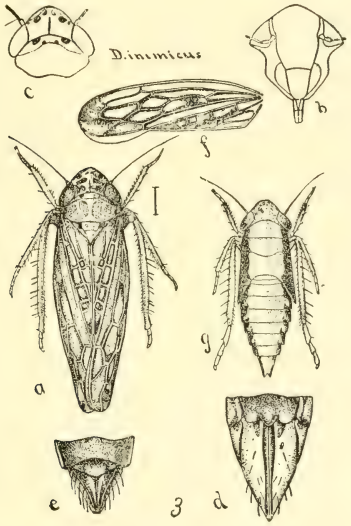


FIG. 67.—The inimical leafhopper (*Deltocephalus inimicus*): *a*, adult; *b*, face; *c*, vertex and pronotum; *d*, female genitalia; *e*, male genitalia; *f*, elytra; *g*, nymph. All enlarged. (After Osborn and Ball.)

**Shovel-nosed Leafhopper** (*Dorycephalus platyrhynchus*).—The shovel-nosed leafhopper is a rather large species with an enormous prolonged head and is found upon the wild oat, *Elymus canadensis*. The eggs are laid beneath leaf sheaths, a considerable number in a compact row and the

nymphs on hatching begin feeding at once upon the grass. The adult females have short wings and do not jump or fly rapidly.

**Inimical Leafhopper** (*Deltocephalus inimicus*).—The inimical leafhopper is perhaps the most abundant species throughout the northern United States where blue grass is a common pasture grass. While abundant and almost

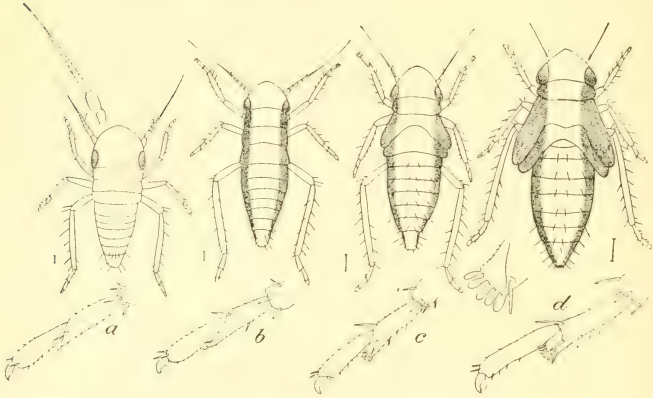


FIG. 68.—The inimical leafhopper (*Deltocephalus inimicus*): nymphal stages: *a*, newly hatched; *b*, *c*, *d*, later stages, the details of tarsal appendages shown below. All enlarged. (After Osborn, Bur. Ent., Bull. 108.)

universal in blue grass, it may also be found upon other species of grass and also in wheat and alfalfa. This species is so abundant and wide-spread that it is almost impossible to sweep a patch of blue grass in any locality from Maine to Washington, and south to northern Tennessee, without finding it in abundance. The nymphs pass through five distinct stages with differences in the shape of the head and development of wing pads and an increase in the number

of minute appendages on the first tarsal segment, as shown in the figure.

The destructive leafhopper (*Athysanus exitiosus*), was first noticed as a pest in grain fields in the Southern States,

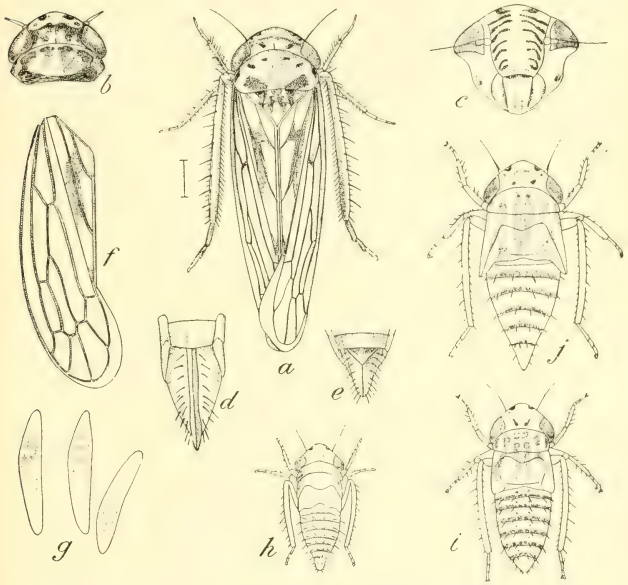


FIG. 69.—The destructive leafhopper (*Athysanus exitiosus*): *a*, adult female, dorsal view; *b*, head and pronotum of male; *c*, face of female; *d*, female genitalia; *e*, male genitalia; *f*, wing; *g*, eggs dissected from female; *h*, *i*, *j*, three stages of nymphal growth. All enlarged. (After Osborn, Bur. Ent., Bull. 108.)

but is now known to be distributed throughout the larger portion of the United States, which likely is the result of a dispersal from the southern localities with possible intro-

duction from the West Indies or Mexico in some not distant period.

**Six-spotted Leafhopper.**—The six-spotted leafhopper occurs in abundance throughout the country and is also a common species in Europe. Whether its common distribution is due to original extent of the species, or whether the species has been introduced into America in modern times, is impossible to say. It develops rather rapidly and apparently passes through two or three generations at least in northern localities, and possibly three to five in the more southern States. It is especially injurious in oat fields.

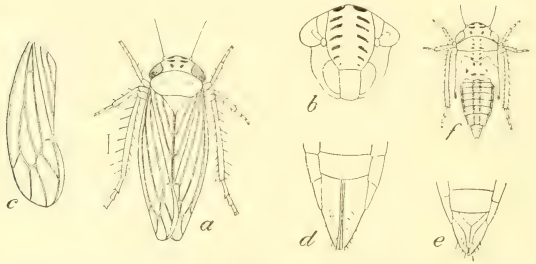


FIG. 70.—The six-spotted leafhopper (*Cicadula-6-notata*): *a*, adult; *b*, face; *c*, wing; *d*, female genitalia; *e*, male genitalia; *f*, nymph. All enlarged. (After Osborn, Bull. 108, Bur. Ent., U. S. Dept. Ag.)

Typhlocybidæ includes a group of minute forms most of which are found on trees or woody plants, but certain ones occur on grains or grasses. The most familiar and destructive forms are the group of leafhoppers which cause withering and whitening of grape-vines in the midsummer and autumn. *Typhlocyba comes* includes several varieties, all of which are destructive to grapes, the nymphal stages being found usually on the under side of the leaves, and the effect of their puncturing shows in minute white spots on the upper surface of the leaves.

**Apple Leafhopper** (*Empoasca mali*).—The apple leafhopper, another very destructive form, affects apple and other fruit trees. Occasionally it is destructive to alfalfa, cow peas, potatoes and beans.

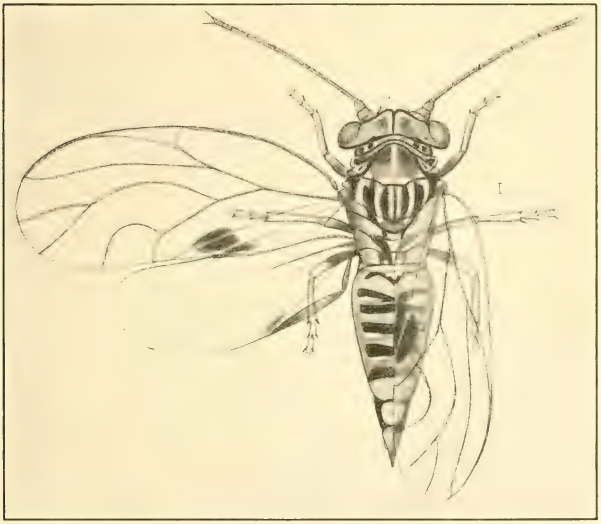

FIG. 71.—Pear-tree psylla: adult female—natural size indicated by side line. (From Marlatt, Div. Ent., U. S. Dept. Ag.)

The *Sternorhynchi* include those Homoptera that have the beak fused into the sternum. The group contains some remarkably specialized forms of insects and there are four distinct families, closely linked together by connecting forms.

**Psyllidæ.**—The *Psyllidæ* seem closely related to the cicadas. The shape of the body and head is like that in the

cicadas, wings specialized, and they differ in the beak being fused into the sternum. They are descended from a generalized insect like the cicada in character. The principal line of specialization has been in the fusion of the beak and sternum. It stands out at almost right angles to the prothorax, between the front legs.

All of the species are quite small. Some feed directly on the surface of plants. Others present a distinctly specialized food habit, producing galls on various trees, especially on the hackberry.

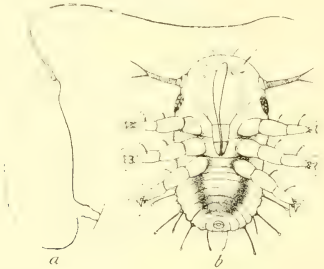


FIG. 72.—Pear-tree psylla: *a*, egg; *b*, larva, but greatly enlarged. (From Marlatt, Div. Ent., U. S. Dept. Ag.)

A common and destructive species in the Eastern States is the pear psylla which causes serious loss in pear orchards.

One of the most common is *Pachypsylla celtidis-mamma*. The larvæ are found in cavities in the galls; the galls are formed by the deposition of eggs on the surface of the leaves and the stimulation of the leaf cells. The life-cycle must be adapted to the growth of the leaf on which it occurs. In the gall, when dried up in the fall, are found either adults or mature nymphs. The adults usually emerge and secrete themselves in fallen leaves, etc. The adults appear in the spring at about the time that the hackberry leaves are expanding and deposit eggs on the surface of the leaves, and

during the rapid growing period of the leaf these galls are developed and the larvæ are growing within them. There is a single generation during the year. This is the plan of development for practically all of these psyllid galls. A number of different kinds occur on hackberry trees. They are readily identified by the character of the galls produced on the trees. Most species are located on the leaves, but some species form a structure on the twig by a modification

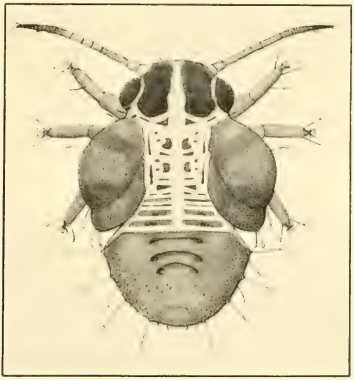

FIG. 73.—Pear-tree psylla: nymph greatly enlarged. (From Marlatt, Div. Ent., U. S. Dept. Ag.)

of the bud. There is a distinct specialization in the matter of food supply which characterizes a large part of the family Psyllidæ. Stimulation of the plant tissues is produced by the action of the larvæ in puncturing the cells.

**Family Aphididæ.**—This family is specialized particularly with reference to the mode of reproduction. It agrees with other forms of the Sternorhynchi in having the beak apparently fused with the prosternum, so that the beak appears to arise from the sternum. There is a reduction of

the venation in some genera. The forms with the most numerous veins are the more primitive and the fewer-veined forms must be regarded as specialized.

The *nectaries*, or so-called "honey tubes" or "cornicles," are structures peculiar to Aphididæ, located on the hinder part of the abdomen. Fluids may exude from their tips and much difference of opinion has existed as to their functions. Some think that the fluids are used as a means of defense. It is now generally accepted that the "honey dew" emitted by plant lice is discharged from the anal opening, and consists of slightly modified sap from the plant to which the aphid is attached. It is sweet and may form some sugar on evaporation and is much sought by ants and some other insects.

Aphids are characterized by the appearance of several successive generations which are devoid of wings and closely confined to their host plant. Reproduction is in large measure parthenogenetic, many generations occurring without the appearance of the sexual forms. A rapid rate of reproduction is provided for; sometimes as many as ten or twelve generations in a season. It has been estimated that, starting with one stem-mother in the spring, her progeny during the season, if not curtailed, would amount to billions or trillions of individuals, sufficient to overrun the world or to equal in bulk of organic matter the population of China. The agamic eggs are termed "pseudova," and are often developed and hatched before being extruded (ovoviviparous).

No general statement can be made which will properly cover the life history and development of all species, but in general, and in the temperate latitudes particularly, hibernation takes place in the egg stage. As the usual thing these eggs are fertilized and occur on the plant which was the last host of the species in the autumn. In the spring these eggs hatch into stem-mothers, which are asexual individuals and for which there is no corresponding male. They do not require fertilization and they produce either eggs or living young. The young produced are ordinarily wingless when

they mature and as many as two or three generations of these agamic apterous forms may be produced. Next, alate (winged) forms are produced, usually asexual, to provide for a migration of the species to another host plant. As a general thing these winged migrants usually produce mainly wingless, agamic forms. In the autumn a winged form appears (usually asexual) which permits the return of the species to its original host. Frequently with aphids having alternate food plants the spring and autumn host plants are perennials—woody or shrubby plants, the summer host plant an annual. A number of cases, however, of alternation between woody plants are known. An example of the former is seen in the case of an apple-plant louse, *Siphocoryne avenæ*, which winters over in the egg stage on apple trees, the spring forms occur for two or three generations on apple and then apparently disappear; in reality they migrate to wheat and breed on it during the summer. With the ripening of the wheat the lice leave and return to the apple. In the case of the hop-plant louse, *Phorodon humuli*, the spring and fall forms occur on wild plum and the midsummer forms by migration on the hop plants, which accounts for their very sudden appearance and in such large numbers in the hop vineyards in summer.

The return migration in autumn to the original host plant may be followed by two or three generations of asexual, agamic individuals. After that, a short time prior to the end of the breeding season, the sexual forms are produced. The appearance of the sexual forms may possibly be induced (or precipitated) by the ripening and hardening of the plant tissue of the host. The same factor, in case of the summer annual host plant, may determine the time of the return migration to the spring and autumn host plant.

The sexual forms are often wingless and very small and are less dependent upon the host plant for food than are the other forms. After mating, the female produces one or two eggs or at least a very small number of eggs and these eggs are usually attached to permanent parts of the tree, seldom to leaves or stems. These eggs are usually hard,

tough, usually black, polished and resistant to the weather. They are sometimes so abundant on the surface of apple twigs as to give the latter a shiny appearance. The following spring these eggs hatch into the stem-mothers.

*Control.*—Control measures in general resolve themselves into destruction of the over-wintering eggs, prompt application of insecticides in early spring, and such measures as are applicable through recognition of the alternate-host habit. The hop-plant louse control depends on elimination of the alternate host, wild plum.

To the general and usual method of hibernation in the egg stage there are exceptions. Thus the corn-root louse is carried over the winter on roots in the ground by its attendant ant. Through this dependence on the ant being long-continued this species has evidently become independent of the egg-depositing habit or produces eggs only at intervals.

Outbreaks of plant lice are often very destructive and and are more or less evanescent. The lice appear suddenly, to all appearances, and often seem to disappear as quickly. The aphids are victims to a multitude of predaceous enemies and Hymenopterous parasites, are susceptible to weather conditions, such as rains, low temperatures, etc.

Migrations in spring are usually for short distances, rarely over a mile or so, or until a suitable summer host is found. Fall migrations, involving many more individuals, are much more general and the insects more widely scattered, and are carried along by winds and may be quite widely distributed at that time. Among the important species are the corn-root louse, hop-plant louse, cherry aphis, apple aphis, etc.

An intimate relationship exists between the plant lice and ants, this being sometimes carried so far as to make the insects mutually dependent on each other. Such is the case with the corn-root louse and its attendant ant, in which the ant depends for its food upon the honey dew of the aphid and the latter in turn depends upon the ant for its transportation from one root to another. In this and other cases plant lice are definitely protected by the ants or carried over from season to season in order that the ants may get the

benefit of the honey dew which is extruded from the anal opening. There is no very definite glandular structure connected with the nectar tubes or cornicles but a liquid does come from them and its function is interpreted in various ways, one being that it serves the insect in defence against predaceous or parasitic enemies.

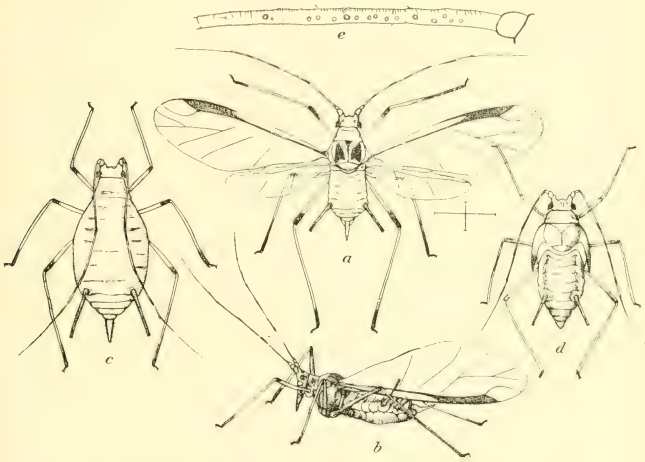


FIG. 74.—Pea aphis (*Macrosiphum pisi*): *a*, winged female; *b*, same from side, with wings folded in natural position, as when feeding; *c*, apterous female; *d*, nymph in last stage; *e*, third joint of antenna of winged form; *a* and *d*, much enlarged; *e*, more highly magnified. (From Chittenden, Div. Ent., U. S. Dept. Ag.)

The classification of the Aphididæ is based largely on the structure of the winged forms, and it is very desirable that the winged form of a species be obtained in attempting its identification.

Other characters of special value are found in the antennæ,

relative length and number of joints, location of sensoria in the honey tubes or nectaries, and the anal style.

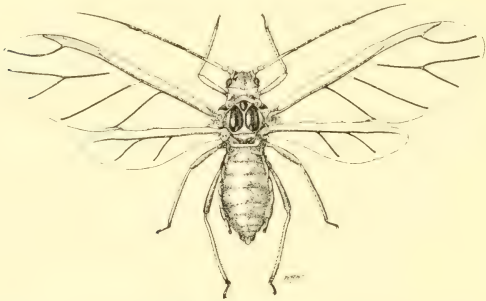

FIG. 75.—Spring grain aphis (*Toxoptera graminum*): male, greatly enlarged. (From Webster, Div. Ent., U. S. Dept. Ag.)

**Pea Aphis.**—The pea aphis is a species which occasionally multiples to an enormous extent and causes heavy losses

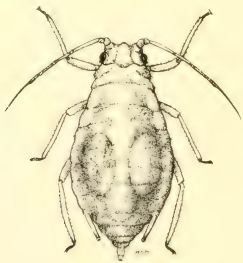

FIG. 76.—Spring grain aphis (*Toxoptera graminum*): egg-laying female with eggs in body, greatly enlarged. (From Webster, Div. Ent., U. S. Dep. Ag.)

in the pea crop. Another very destructive species at times is the one affecting melons.

**Spring Grain Aphis.**—The spring grain aphis or "green bug" (*Toxoptera graminum*) has attracted a great deal of attention, especially in the Southwestern wheat growing sections; in Texas, Oklahoma, and Kansas where it has caused severe injury to the wheat crop. It is an introduced species and seems especially adapted to the Southern wheat districts. It is extensively preyed upon by a small parasite

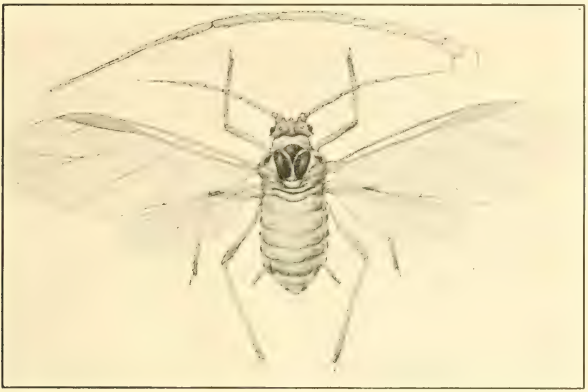

FIG. 77.—The spring grain aphis (*Toxoptera graminum*): winged migrant, much enlarged; above, antenna of same highly magnified. (After Pergande, Div. Ent., U. S. Dept. Ag.)

(*Lysiphebus*), and this parasite assists in a large degree in keeping it in check.

**Corn-leaf Aphis.**—The corn-leaf aphis (*Aphis maidis*) is injurious to the corn plant and occasionally appears in destructive numbers but ordinarily is less injurious than the related corn-root aphis.

**Corn-root Aphis** (*Aphis maidi-radicis*).—The corn-root aphis is a special pest of cornfields and a larger part of its attack is confined to this crop. It is a light green or bluish-

green, affected evidently by its subterranean habit. The species is notable on account of its dependence on the ant for its transfer from one food plant to another.

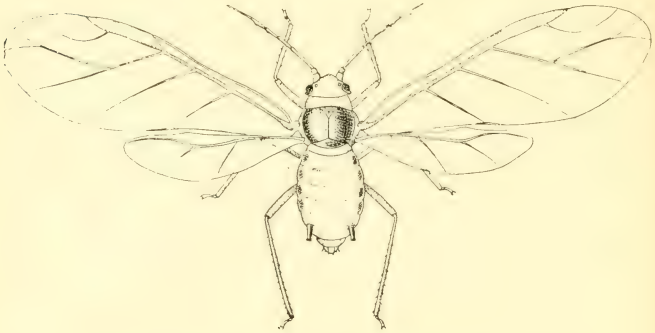

FIG. 78.—The corn-leaf aphis (*Aphis maidis*): winged female. Much enlarged. (After Webster, Div. Ent., U. S. Dept. Ag.)

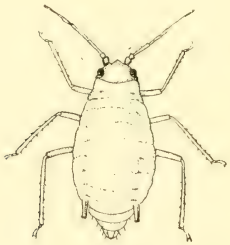

FIG. 79.—The corn-leaf aphis (*Aphis maidis*): wingless female. Much enlarged. (After Webster, Div. Ent., U. S. Dept. Ag.)

The eggs of this species are cared for by the ant through the winter time. When hatched the young are transferred to suitable plant roots, often to the roots of weeds in the

FIG. 80.—The corn-root aphis (*Aphis maidi-radicis*): winged female. Much enlarged. (Webster, Div. Ent., U. S. Dept. Ag.)

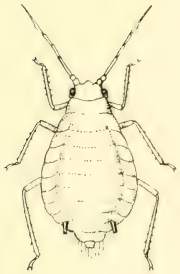

FIG. 81

FIG. 82

FIG. 81.—The corn-root aphis (*Aphis maidi-radicis*): wingless female. Much enlarged. (Webster, Div. Ent., U. S. Dept. Ag.)

FIG. 82.—Aphis on apple. (Photo from Ohio Exp. Sta.)

fields, upon which the lice maintain themselves until corn plants are available

This species appears to become so completely adapted for underground life and the association with ants that it does not necessitate producing any winged generation for distribution or for alternation with another food plant.

On account of this relation to ants, one of the measures of control is to plow and harrow the ground thoroughly

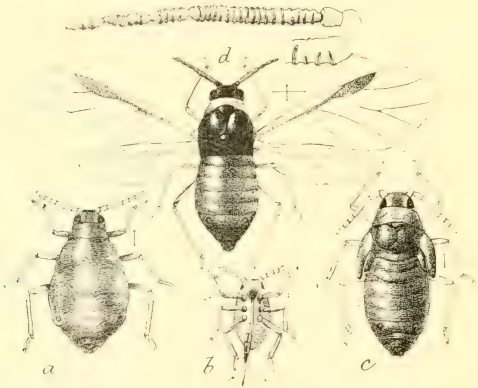


FIG. 83.—Woolly aphis (*Schizoneura lanigera*): *a*, agamic female; *b*, larval louse; *c*, pupa; *d*, winged female with enlarged antenna above; all greatly enlarged and with waxy excretion removed. (From Marlatt, Div. Ent., U. S. Dept. Ag.)

in order to break up the nests of the ants. This method adopted in the autumn together with a wider cultivation and destruction of weeds in the fields in spring will assist in keeping the pest in check. Perhaps the most important measure is a rotation of crops so that corn will not be cultivated for a number of years in succession on the same ground.

**Woolly Apple Aphis** (*Schizoneura lanigera*).—The woolly apple aphis is a very destructive species, its injury for the

most part being noted upon apple trees and is credited with attacks both on the roots and trunks of some trees, limbs or larger twigs near the ground. It is covered with a white cottony substance and this tends to shed water. On the

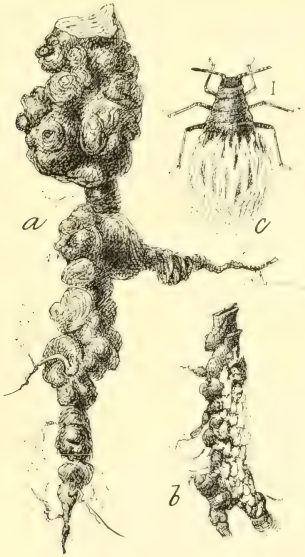


FIG. 84.—Woolly aphis (*Schizoneura lanigera*): *a*, root of young tree illustrating deformation; *b*, section of root with aphides clustered over it; *c*, root louse, female—*a* and *b*, natural size; *c*, much enlarged. (From Marlatt, Div. Ent., Circ. 20, 2d series, U. S. Dept. Ag.)

roots it produces large knotty swellings and these injuries cause serious effects upon the tree. Usually these insects are observed in a wingless form but in the autumn some of the individuals become winged and migrate to the elm,

where in the spring of the following season they produce rosette galls, later migrating back to the apple. The rosette gall has been separated from the leaf curl gall produced by *Schizoneura americana*, a species that is a frequent pest on elm trees.

Fig. 85.—Woolly aphis on apple twigs. (Photo from Ohio Exp. Sta.)

Remedies for the root form are difficult, but for orchard trees after removal of the earth, sprinkle tobacco dust on the roots and replace the soil. The use of 10 per cent. kerosene emulsion can also be recommended. Above ground

the use of tobacco extract or 7 per cent. kerosene emulsion may be used.

In another group of aphids we have the gall-making pemphiginæ which cause conspicuous deformations upon the leaves of many different plants. Some of the more conspicuous ones are the vagabond gall on cottonwood, and the poplar leaf galls.

**Grape Phylloxera.**—The Grape Phylloxera is one of the very destructive insects of the grape-vine and is known over a wide territory, having been carried from America to Europe, where it caused a great deal of destruction to the vineyards, especially in southern France. It affects the roots of the vines and occurs on these during autumn, winter and early spring, but during midsummer migrates to the leaves, causing the production of leaf galls, so conspicuous at that time. By the time these galls mature or the leaves ripen the insect migrates to the roots. The use of bisulphide of carbon injected into the soil is the most available remedy, but there is so much difference in the resistance of different varieties of grape that the cultivation of thick-leaved kinds is considered advantageous. Where flooding is practicable, the submergence of the insects for a period of two or three days is effective.

Numerous species of phylloxera occur on the leaves of hickory, walnut, and other trees, but for the most part are not considered of especial economic importance.

**Family Aleyrodidæ** —The next family in the series is the *Aleyrodidæ*. These are forms which have a mealy covering on the wings and have the eyes divided, each compound eye being divided into two, and the antennæ being located within the division of the eye. The adults are very similar but the larvæ and nymphs which form scale-like bodies on trees have very distinct characteristics so that the species are to be distinguished by the study of these stages rather than of the adults. They resemble somewhat the scale insects, but the adult characteristics are quite different. The scales are quite distinctive. In many cases there is a fringe of white, waxy material which seems to act as an attach-

ment to the surface of the bark. This often lifts the scale from the surface of the bark. There are distinct differences in the markings of the body and in the anal plates. A rather destructive form occurs on greenhouse plants, and is known commonly by the name of "white fly." In some instances it is very destructive. The eggs of the adults are laid on the leaves and the larvæ fix themselves after a short migration and develop until they have reached the pupal stage, and from this stage the adult winged form issues. The family is not so large nor so important as the scale insects—*Coccidæ*.

Two species occur on oranges in Florida; one, the orange white fly, is often the means of serious loss in orange orchards. They are treated by sprays and by cultivation of certain parasitic fungi.

## COCCIDÆ.

The *Coccidæ*, scale insects, or bark lice, are to be considered as the extreme branch along the line of specialization found in this group. There are several subdivisions with various kinds of specializations. The group is characterized by the absence of wings in the females and the reduction of wings in the males to one pair, they are usually firmly attached to the plant on which the larva has settled and even in forms not attached probable means of migration are limited. The males are winged but show distinct specialization in the reduction of the second pair of wings. These constitute simple, aborted, hook-like structures that can serve no purpose in flight. The same kind of reduction as in Diptera. The males also show a fairly distinct metamorphosis. The larvæ change to a quiescent pupal stage and this gives rise to an adult two-winged male. The females are wingless and usually immovable, mating depends entirely upon the migration and flight of the males.

Owing to the extent and the economic importance of this group, it seems desirable to give some account of the subfamilies and to discuss somewhat in detail certain of the especially important economic species. Their sedentary habits permit a ready distribution, yet make it easy to

control them by proper laws for exclusion. In determination, the appearance and color of the scale and the appearance it gives to the trees are very important. There are several subfamilies but the following include the American species of importance.

The *Dactylopiinæ*, including the mealy bugs and related forms, differs from other members of the family largely in the fact that the species are less fixed in habit. The mealy

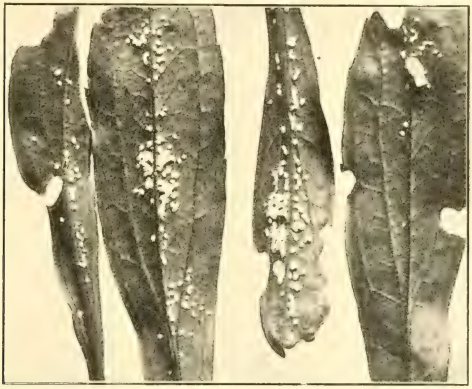

FIG. 86.—*Orthezia solidaginis* Sanders on goldenrod leaves. (Photo by author.)

bugs are particularly active and capable of traveling about readily. They are covered with a whitish, mealy secretion from which they derive their name, and in temperate regions are found for the most part in greenhouses but there are a few native outdoor species. The common mealy bug of greenhouses (*Pseudococcus citri*) is a very well-known pest and may be found in different stages of its life history in almost any greenhouse and frequently upon house plants if kept where there is moisture. Fumigation and the use of washes are available for their control.

An interesting subdivision of the group includes the *Orthezi'inæ* which secrete a white calcareous secretion which appears in plates or filaments extending from the body, often as long parallel bars extending back some distance from the body. A rather common species in the Northern States is *solidaginis*, occurring on goldenrod. There also is included in this group the very destructive cottony cushion scale, *Icerya purchasi*, which for a time threatened the fruit

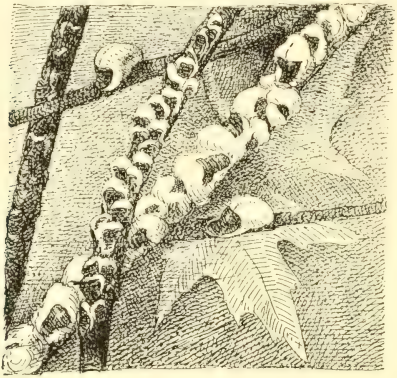

FIG. 87.—*Pulvinaria innumerabilis:* adult females in position on twigs with egg sacs—natural size. (Howard, Div. Ent., U. S. Dept. Ag.)

industry of California but which was brought under control by the importation of the Australian lady bird (*Vedalia cardinalis*).

The subfamily *Coccinæ* includes what are termed the soft scales. The bodies of these are covered more or less completely with a waxy secretion which adheres firmly to the body wall and furnishes a thick, more or less rigid protection to the body. Most of them adhere fixedly to the bark or leaves but in some cases a migration at the time of moult-

ing or when changing from the nymph to the adult stages may occur.

**Maple Scale** (*Pulvinaria innumerabilis*).—The maple scale is a wide-spread and occasionally abundant and destructive species, attacking particularly the soft maple and occurring at times on other trees or woody plants. In this species the adults mature in autumn and winged males issue from the scale and mate with the females, the latter remaining

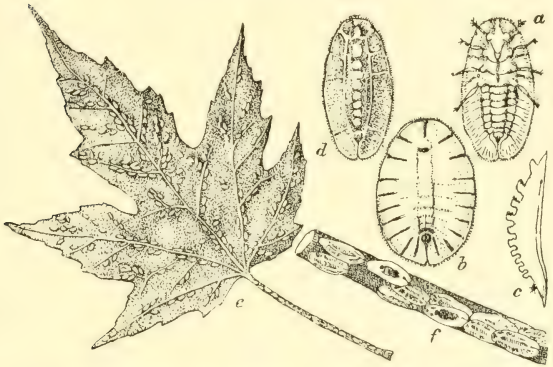


FIG. 88.—*Pulvinaria innumerabilis: a*, newly hatched young; *b*, female, third stage, from above; *c*, same, from side; *d*, male, third degree; *e*, same, natural size, on leaf and petiole; *f*, same, enlarged, on leaf petiole showing two specimens parasitized, all greatly enlarged except *c*. (From Howard, Bureau of Entomology, U. S. Dept. of Agriculture.)

unwinged. They may, however, migrate from leaves to twigs or branches and attach themselves firmly for the winter, which is passed by the adult female only. In spring the eggs are developed and by early June a very large cottony mass is formed beneath the scale, lifting it from the bark, except at the anterior end, and within this large cottony mass an enormous number of eggs are deposited. Hatching of the eggs occurs shortly after the deposition and the larvæ

travel rapidly for a day or two, going especially toward the outer and upper branches where they fix themselves, and during successive moults remain attached to leaf or bark until autumn, when the adults mature, completing the life-cycle.

**Diaspinæ.** The armored scales (*Diaspinæ*) differ from the preceding forms in that the waxy secretion separates from the body wall and forms an external shield or cover within which the scale insect is enclosed and within which there is some possibility of movements of parts, although the mouth parts are anchored quite permanently in the bark. Classification of the species in this division is complicated by the presence of this external scale, although in many species the external features of the scale are a fairly good basis for the recognition of the species.

A microscopic examination is required to determine the species in many cases. The pygidium (the fused terminal segments of the abdomen of the female) includes the characters most often used, as it is highly chitinous so that it holds its peculiar characters even after a long time in a dried state. Specimens kept dry twenty to thirty years may be used for examination. The dorsal surface may have glands that produce waxy secretion forming the scales. The anal opening is also on the dorsal side.

Upon the ventral surface the vaginal opening is a conspicuous landmark and ordinarily grouped around this are small spinnerets which appear under the microscope as strongly chitinized circles. There are generally four or five groups. These groups are named according to their relation to the vaginal opening. The median or anterior group is in front of the vaginal opening and on each side at about equal distances are the cephalolateral or anterolateral group and the caudolateral group. These spinnerets or grouped glands are entirely wanting in the San José scale.

The marginal structure of the pygidium takes second place in the determination of species and the number and shape and modification of the lobes are very important. In some cases there are thickenings of the margin that closely

resemble the lobes. The incision of the margin by their shape and extent afford characteristics of value.

Spines on the lobes are commonly present and afford quite serviceable characters. There are generally two for each lobe—one on each of the dorsal and ventral surfaces. In some cases these spines are tubular and threads may sometimes be seen issuing from them.

The plates are distinctly modified spines. They are generally flattened and frequently notched. The simple forms differ from spines in that they do not have a globular base. Wax ducts appear as hairs on spines which extend into the body.

**Chionaspis Salicis.**—The willow scale (*Chionaspis salicis*) possesses a dense waxy structure overlying and separate from the body of the insect. The mouth parts are imbedded in the bark and sap wood. The head is pretty well marked but antennæ and legs are reduced. There are two entirely different kinds of scales on the willow. The larger is an oval, somewhat elongated scale, the smaller narrow and with three rather fine ridges. The large scale is the female, the smaller the male. The growth of scales takes place during summer months; they increase in size by successive moults. As the larval scale is shed it is left attached to the new scale, and so on, often two or three are attached to the outer surface of the scale. By autumn these will have reached maturity, and mating will occur probably by early October. The males all die off immediately and the females deposit eggs and then shrivel up and die before winter. The female never leaves the scale at all.

At the beginning of winter there is this mass of eggs protected under a scale as the means of carrying the insect over to the spring. They hatch probably during early June, possibly the latter part of May. Eggs are reddish-purple. The larvæ crawl from under the scale and scatter out and make a special effort it would seem to get on new twigs and fresh growth of wood. They seem to travel upward in the lightest direction and this naturally carries them out to the ends of the twigs and leaves. During this migration period,

which lasts two or three days, they may be distributed in several ways. A good breeze might carry them some little distance. They may be carried by birds. They may be carried on pieces of plant on which they occur, which is the means by which most of the scale insects are distributed.

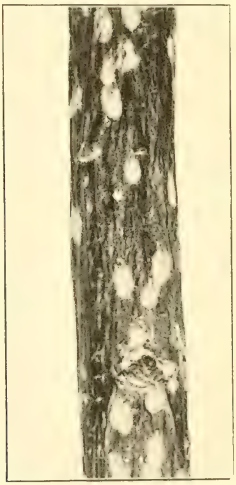

FIG. 89.—*Chionaspis furfurus.* Scurfy scale on apple. (Photo from Ohio Exp. Sta.)

Oyster-shell scale is named from the shape of its scale. It is a European species, but occurs as a widely distributed species in this country and affects a number of host plants, principally the apple. The adults mature in fall and white eggs are deposited under scales and survive the winter, hatching early in June. The larvæ then scatter and develop during the summer.

**San José Scale.**—The San José scale is an introduced species which has been the source of an immense amount of loss in orchards, nurseries, etc. It presents some modifications from the ordinary forms. It is small with an almost perfectly circular scale. The exuviæ remain near the centre, giving it a somewhat nipple-shaped appearance. When

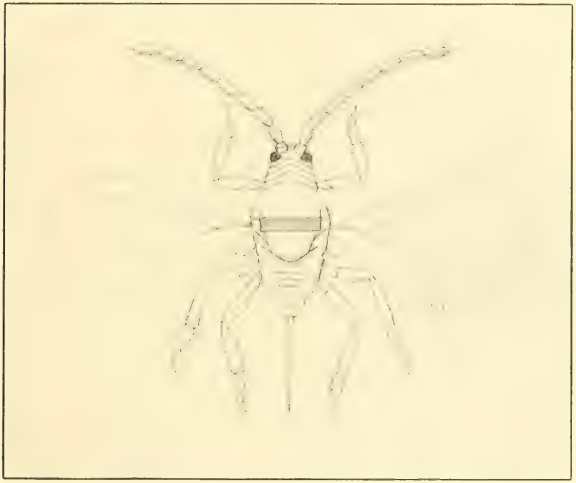

FIG. 90.—San José scale: male adult—greatly enlarged. (After Howard.)

abundant they give a very scurfy incrusted appearance to the twig on which they occur. The male scales are smaller and a little more oval in shape. The life history differs from most other species in that young are produced alive, the eggs hatching before extrusion, and the young develop rapidly, mature in a short time, and produce another generation. There may be as high as four to six generations in a

season. It has been estimated that a single female may be the parent of about three and a half billions in a single season. Since there is no egg, but young are brought forth alive, they must have constant nutrition, and unless the scale is attached to living tissue the insects must perish, except

FIG. 91.—San José scale: *c*, adult female containing young—greatly enlarged; *d*, anal fringe of same—still more enlarged. (After Howard.)

that mature females may assume a dormant condition during cold weather. The only means of transportation to distant points, therefore, appears to be upon living plant tissue, and this makes it possible to prevent its distribution by adopting restrictive measures through inspection and quarantine.

For measures of treatment where exclusion is not possible, there are two or three fairly effective remedies in the killing of the scale. One of these is kerosene emulsion, made by agitating kerosene and soapsuds. One gallon of water,

FIG. 92.—San José scale on leaves and fruit. (Photo from Ohio Exp. Sta.)

one-half pound of soap brought to the boiling point and then mixed (away from the fire) with two gallons of kerosene and then agitated into an emulsion by a force-pump or egg-beater. This is diluted with soft water, one part of emulsion to eight or nine parts of water.

Whale-oil soap is sometimes used, but the most favored remedy at the present time is lime-sulphur wash formed by boiling the ingredients together. This is applied by means of a spray-pump so that it covers the trees. If these applications are made thoroughly the scales may be killed off to a great extent, though it is is hard to completely exterminate them. Badly infested trees will seldom recover and it is about as well to cut out and destroy such trees. Remedies that can be applied when larvæ are travelling will be more effective, but in San José scale larvæ are travelling most of the summer months. In those species where there is a

FIG. 93.—Peach orchard injured by San José scale. Neglected, badly infested orchard at right and injured rows adjacent in spite of careful spraying with protection to rest of orchard at left. (Photo by author.)

definite period for the larvæ, spraying even with clear water if the pressure is great will reduce their numbers considerably. It is important to know the life histories perfectly.

The *Heteroptera* include those forms which have wings thickened at the apex and in which the mouth parts arise from the most anterior portion of the head, and both in this character and in the wing structure are evidently more specialized than the *Homoptera*. It is not possible to say that any of the *Heteroptera* present more specialization in certain lines than some of the *Homoptera*.

The families are pretty well marked, and a number of

the groups are aquatic, a number terrestrial, and some arboreal. The aquatic forms are derived from the terrestrial. Most of them are obliged to come to the surface of the water to secure air at various intervals and this shows that they are modified from terrestrial forms. The aquatic forms pass the larval stage in the aquatic life but in most of the aquatic families the adults are also aquatic, though they may issue from the water and fly readily out of water. The eggs of aquatic forms are deposited on aquatic plants distributed in the water and only in a few cases do they show marked peculiarities in the matter of egg deposition. In one of our common species, the smaller water bug (*Zaitha fluminea*), the eggs are deposited on the back of the male

*c* *b* *a*

FIG. 94.—Water bugs: *a*, water boatman, *Corisa harrisii*; *b*, *Notonecta irrorata*; *c*, *Notonecta undulata*. Enlarged × 1.42. (Photo by C. J. Drake.)

by the female in a rather large mass, the eggs being set on end attached to the wing covers and are carried in this way for some time until they hatch.

Of the terrestrial forms there are a considerable number of families. Some important species, chinch bug, squash bug, etc. The effect of the chinch bug on cereal crops is very damaging.

**Water Boatmen** (*Corisidæ*).—The water boatmen are small species. Their legs are modified for swimming, the hind ones being long, wide, and oar-like, having a series of cilia which aid much in swimming. The species are found in large numbers in ponds and streams, occasionally they fly in large swarms. Spring is the usual time when they are seen flying

and are attracted very much by lights. They constitute a food supply for fishes and they themselves feed on other aquatic organisms. One species in Mexico is dried and used for food by the natives and is also sold in the markets as bird food. There is some question as to their economic importance.

**Notonectidæ.**—These are generally larger than the *Corisidæ*. The striking thing about them is that they swim back downward, coming to the surface of the water at intervals for air. Our common species is *Notonecta undulata*. This species has a severe bite and it is best to handle it with care.

**Water Scorpions** (*Nepidæ*).—The water scorpions are characterized by a long respiratory tube at the end of the body; a very much elongated coxa in the forelegs so that the femur and tibia can be thrust out from the end of the body to catch prey. They are generally found in shallow water, secreted in dead leaves close to the bottom. However, they are strictly dependent on air for respiration and get it by sticking this respiratory tube up to the surface of the water. They are strictly carnivorous, puncturing their prey and sucking the blood. If they are touched they feint and their legs may be broken off without any motion on their part.

**Belostomidæ.**—These are the giant water bugs and are the largest bugs belonging to this order. They have a short respiratory tube and a strong and somewhat curved beak, and can inflict a very severe bite. They are quite predaceous, feeding on young fish, and sometimes even those larger than themselves. Thus they are of distinct importance as destroyers of fish. They go through all the stages of their life-cycle below the surface of the water. The eggs are laid under water on the stems of plants or in the case of one species on the back of the insect itself. The eggs are cemented so tightly that sometimes the shells remain long after the eggs are hatched. The young at first are nearly the form of the adults but without wings. They grow by successive moults and with gradual appearance of wing pads until they reach the adult stage.

Two species, one found in the Philippines and the other in South America, are much larger than those found here.

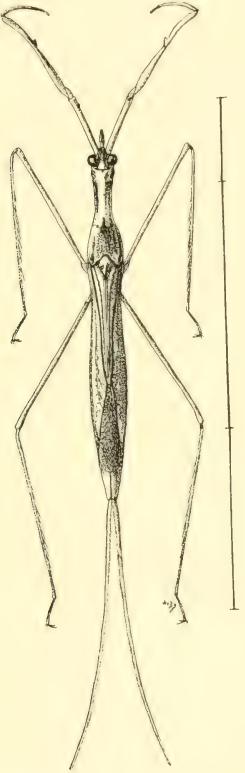

FIG. 95.—Water scorpion (*Ranatra americana*). (Drawn by Jos. D. Smith.)

There are two large species commonly found in the United States, the *Belostoma americana,* which has a groove along the inner margin of the forefemur, while the *Benacus griseus* has none. The latter is also slightly larger, has the hind tibiæ broader and the legs not so distinctly annulated with dark rings.

FIG. 96.—Giant water bug (*Benacus griseus* Say): dorsal and ventral views. Slightly enlarged. (Original photo by C. J. Drake.)

**Water Striders** (*Hydrobatidæ*).—This is a very interesting group. Their bodies are covered with a very fine velvety coat which sheds water, thus enabling them to live on the surface of water. They look somewhat like spiders, the legs are long and extend outward in a spider-like manner. The front pair are shorter than the others, being used to catch food. The antennæ are short and are hard to distinguish from the first pair of legs. Along with these forms

there are several little shore-living species, of no economic importance, however.

**Predaceous Bugs.—The Assassin Bugs** (*Reduviidæ*).—The assassin bugs are rather large-sized insects with slender bodies and legs. The beak is rather strong and short and

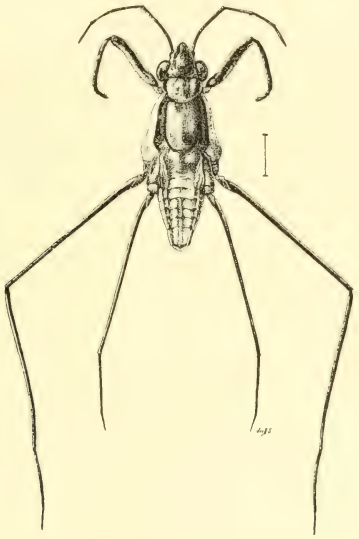

FIG. 97.—Water strider (*Limnogonus hesione*). (Drawn by Jos. D. Smith.)

is fitted for puncturing insects. The species generally are predaceous, feeding very largely on destructive insects. Several species, however, puncture warm-blooded animals and suck their blood. The most familiar one of this kind is the "kissing-bug" or blood-sucking cone-nose. This is a strictly Southern species and is rarely found north of

of the Ohio River. It occurs in the Southern States and occasionally in Ohio. The masked bed-bug hunter is com-

FIG. 98.—Blood-sucking cone-nose (*Conorhinus sanguisugus*): *b*, nymph; *c*, adult. Enlarged. (From Bur. Ent., U. S. Dept. Ag.)

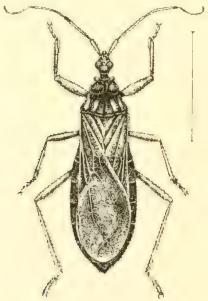

FIG. 99.—The "kissing-bug" or masked bed-bug hunter (*Reduvius personatus*). (After Howard, Div. Ent., U. S. Dept. Ag.)

mon in both Europe and America. The wheel bug, so-called on account of the round thorax, is also found in the South.

The thread-legged bug is a very thin insect which, like the water scorpion and praying mantis, has the coxa of the front legs elongated for grasping. The damsel bugs (*Nabidæ*) are serviceable in eating leafhoppers and like pests. While the ambush bugs (*Phymatidæ*) are serviceable in reducing the number of destructive insects, they also show protective coloration to a marked extent. *Phymata erosa* is our common species. It is commonly found in blossoms of goldenrod or other plants where it catches insects which visit the flowers.

**The Bed-bug Family** (*Acanthidæ*).—These bugs are much flattened and are pretty generally predaceous or blood-sucking. The most common species, bed-bug (*Cimex lectu-*

FIG. 100.—*Phymata erosa: a*, dorsal view; *b*, lateral view; *c*, front leg; *d*, snout—*a*, *b*, enlarged; *c*, *d*, more enlarged. (Riley, Div. Ent., U. S. Dept. Ag.)

*larius*), is restricted to houses and is quite largely dependent upon human blood for food. It is almost entirely wingless, the wings being very small, owing to disuse, and thus becoming entirely useless as organs of flight. This species is distinctly averse to light and hides during the daytime in cracks and crevices, coming out at night to feed. They are light colored when young and become darker with growth, and appear darkest just after a meal, which consists of blood. The feeding periods are far apart and the species is able to live for a long period without any supply of food. It is said that one can live a year without food. They cannot crawl, and depend upon being carried from place to place on clothing. They are commonly found in cheap hotels and board-

ing houses and when once established in a place it is very difficult to get rid of them. The life history of the species is not very definitely known.

The eggs, which are deposited upon furniture and in cracks and crevices, are white and rather long and cylindrical. They hatch in a few days, the young are of the same shape as the adult but are white. The young bugs moult five or six times before they are mature. The growth is very slow

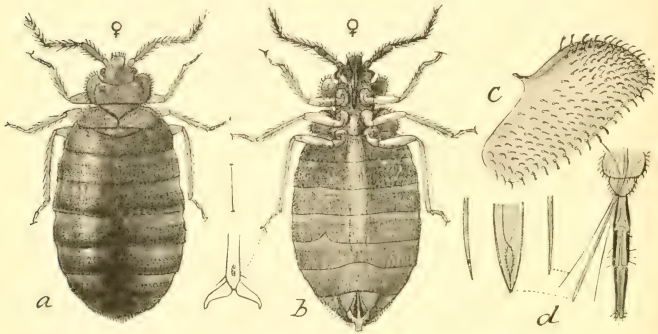


FIG. 101.—The bed-bug (*Cimex lectularius*): *a*, adult female gorged with blood; *b*, the same from below; *c*, rudimentary wing pad; *d*, mouth parts. *a* and *b* much enlarged; *c* and *d*, highly magnified. (Marlatt.) Relapsing fever and kala azar are carried by the bed-bug. (Rosenau.)

and irregular, all depending upon opportunities offered for getting food. This species does not have a regular life-cycle as insects which live out of doors under the influence of the seasons. Bed-bugs can be killed with sufficient effort, corrosive sublimate being one of the best remedies. Kerosene, gasoline, or hot water prove very effective. Constant attention to furniture and the destruction of those bugs which appear is the most essential thing in their destruction. Bed-bugs are of considerable importance from the fact that

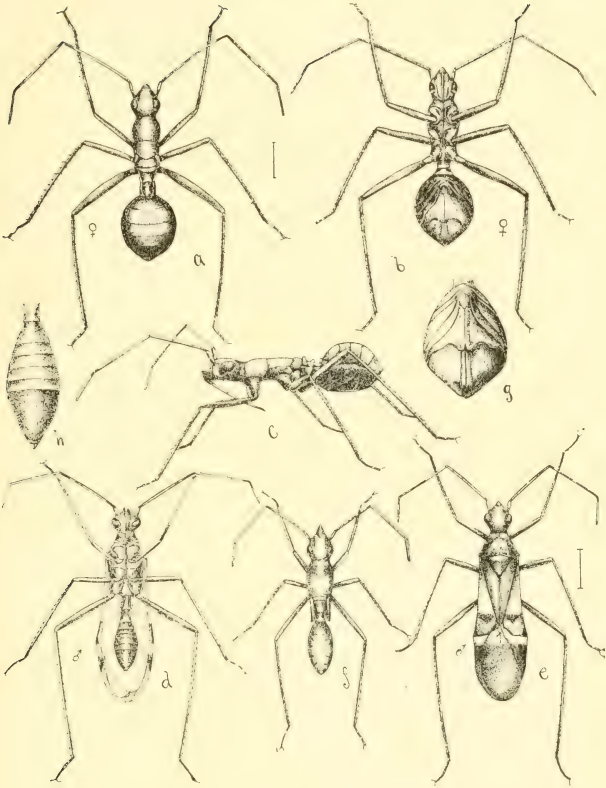


FIG. 102.—*Coquilletia mimetica* Osborn: *a*, female dorsal view; *b*, female, ventral view; *c*, female laterat view; *d*, male ventral view; *e*, male dorsal view; *f*, larva; *g*, female abdomen enlarged; *h*, male abdomen enlarged. (After Osborn. From drawings by Miss King.)

they have the power of transmitting blood diseases from one person to another.

The *Tingitidæ*, or lace bugs, are common on thorn bushes, sycamore, oak, walnut, and many other plants.

The leaf bugs (*Capsidæ*) are of some economic importance, from the fact that they attack the leaves of fruit trees in

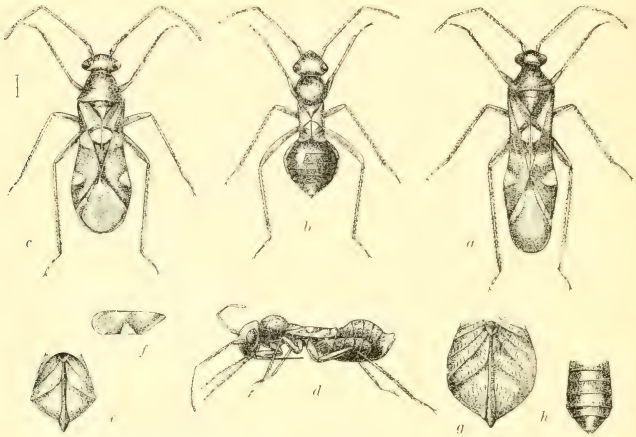


FIG. 103.—*Sericophanes ocellatus* Reut: dorsal views: *a*, macropterous male; *b*, micropterous female; *c*, macropterous female; *d*, side view micropterous female; *e*, macropterous female; *f*, wing of micropterous female; *g*, micropterous female; *h*, male abdomen beneath. (After Osborn. Drawn by Miss C. M. King.)

the spring, puncturing them and sucking the plant juices. They are also quite common in meadows and pastures.

The tarnished plant bug is a very important species affecting orchards where it attacks the buds and blights them. It also works on clover and does great damage to strawberries, causing "buttoning."

Certain species in this family show a very strict resem-

blance to ants, and this is especially so in the case of the species of *Pilophorus*, *Coquilletia*, and *Sericophanes*.

One of these species, *Coquilletia mimetica*, carries this resemblance to the extreme in the development of small elevations on the first and second abdominal segments which correspond closely to the first abdominal segment of the ant. The female in one form is entirely wingless, but a full-winged form of female also occurs, and the males are full-winged.

Another species, *Sericophanes ocellatus*, shows somewhat less modification in that the wings are not completely lost

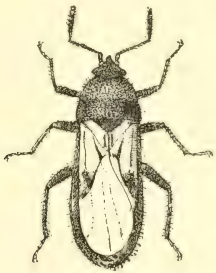

FIG. 104.—Chinch bug (*Blissus leucopterus*): adult of long-winged form, much enlarged. (From Webster, Div. Ent., U. S. Dept. Ag.)

but are retained as short rudiments which extend over the basal segments of the abdomen. The effect as a whole, however, closely simulates the appearance of an ant.

**The family Lygaeidæ** includes the chinch bug and numerous other small bugs, but few of which are of economic importance.

**Chinch Bug** (*Blissus leucopterus*).—The chinch bug is very important as a farm pest. It has a long, slender body with parallel sides and four-jointed antennæ. The body is black and the wings white. It occurs all over the Mississippi Valley and south to Central America but it is most serious

in Illinois, Missouri, Kansas, Nebraska, Iowa, and parts of Indiana, and occasionally in parts of Ohio. The losses due

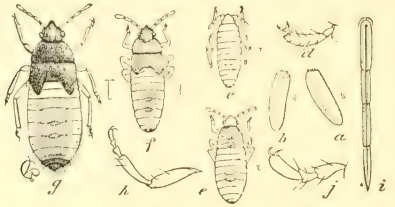


FIG. 105.—Chinch bug: *a*, *b*, eggs; *c*, newly hatched larva or nymph; *d*, its tarsus; *e*, larva after first moult; *f*, same after second moult; *g*, last-stage larva; the natural sizes indicated at sides; *h*, enlarged leg of perfect bug; *j*, tarsus of same, still more enlarged; *i*, proboscis or beak, enlarged. (From Riley.)

to this insect are large, being estimated as high as $60,000,000 and amounting to $20,000,000 in one State alone in one year.

FIG. 106.—Chinch bug. Adults of short-winged form, much enlarged. (After Webster, Bur. Ent., U. S. Dept. Ag.)

It has two generations a year and the winter is spent in the adult stage under bark of trees, bunches of grass, fence corners, etc. Often if a thicket is near they will migrate

to it. In the prairies they hide in the grass and emerge in the spring. The female begins to deposit eggs in April and May. This is done gradually and extends over a period of about three weeks. This early deposition is usually done about one-half inch under the ground on the stems of spring or winter wheat. The eggs are white and very minute and have four little projections at the head end. They hatch in three or four days after deposition, into minute little

Fig. 107.—Chinch bug on corn. (Photo from Ohio Exp. Sta.)

white bugs with small red spots, having the same shape as the adult but lacking in wings. They are unable to feed on plants outside of the grass family, migrate to corn after the wheat is cut and while some have wings fully developed they usually all move on foot. At this time they can be easily killed. The eggs of the second brood are laid on the corn stalks. Before cold weather comes there is an extensive migration, probably accompanied by mating, and the insects hibernate. One group matures in the summer and dies while

the second group matures and hibernates and produces a spring brood.

The control of the chinch bug is based on the use of barriers between the wheat fields and the corn, and a dust furrow is good, or the placing of a crop that they will not feed on,

FIG. 108.—Chinch bug. (Photomicrograph from Ohio Exp. Sta.)

such as potatoes, between the corn and wheat. When the bugs first go into the corn they stop on the first few rows and when there they may be killed with kerosene emulsion.

Rotation of crops is a good thing and the burning of waste grass and weeds in the late fall gets those that live there.

They may be ploughed under in the stubble but this must be at least five inches deep. The introduction of a fungus which was fatal to the bug was tried extensively but without success sufficient to warrant its recommendation as a reliable measure of control.

**Family Coreidæ.**—This family includes the squash bug and a number of other prominent species. They are distinguished by the robust body, numerous veinlets in the membrane and the four-jointed antennæ. The common

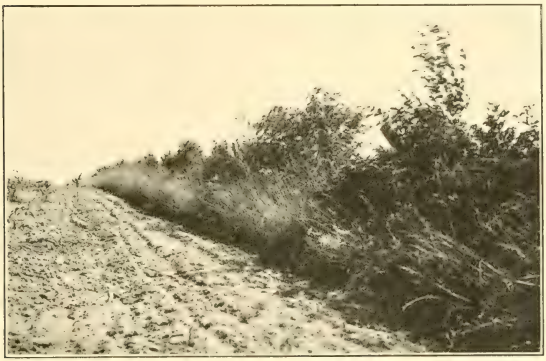

FIG. 109.—Chinch bug. Hibernating quarters. (Photo from Ohio Exp. Sta.)

squash bug is a very familiar species, a large dark colored insect about three-fourths of an inch long. It hibernates in adult form secreted around buildings or under débris on the surface of the ground and in early summer deposits eggs on squash or melon vines. The nymphs puncture the leaves, and their attack upon the plant often results in a complete withering, so that if the insect is numerous the crop may be seriously affected. The eggs are small glistening objects attached in loose clusters upon the under side of the leaf.

The nymphs are at first without trace of wing pads, but in successive instars the wing pads increase in size. The different instars are shown in the accompanying figure.

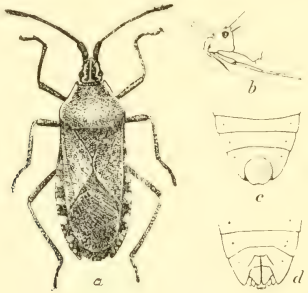


FIG. 110.—*Anasa tristis:* *a*, mature female; *b*, side view of head, showing haustellum; *c*, abdominal segments of male; *d*, same of female; *a*, twice natural size; *b*, *c*, *d*, slightly more enlarged. (From Chittenden, Div. Ent., U. S. Dept. Ag.)

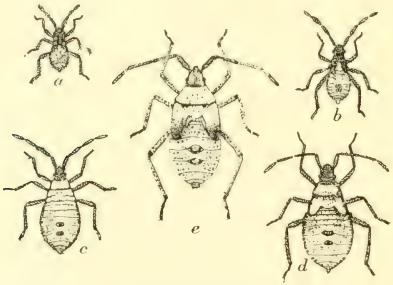


FIG. 111.—*Anasa tristis* nymphs: *a*, newly hatched; *b*, second stage; *c*, third stage; *d*, fourth stage; *e*, fifth stage—all about twice natural size. (From Chittenden, Div. Ent., U. S. Dept. Ag.)

**Box Elder Bug** (*Leptocoris trivittatus*).—The box elder bug is black with red lines, and since this species has been migrat-

ing eastward from an original westward habitat it is of interest to note its progress. In recent years it has been observed as far east as Ohio and it is quite likely to extend

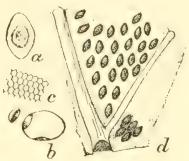


FIG. 112.—Eggs of *Anasa tristis:* *a*, from below, showing point of attachment; *b*, from side, showing place of escape of nymph; *c*, sculpture of egg; *d*, egg cluster; *a*, *b*, about five times natural size; *d*, one-fourth enlarged; *e*, greatly enlarged. (From Chittenden, Div. Ent., U. S. Dept. Ag.)

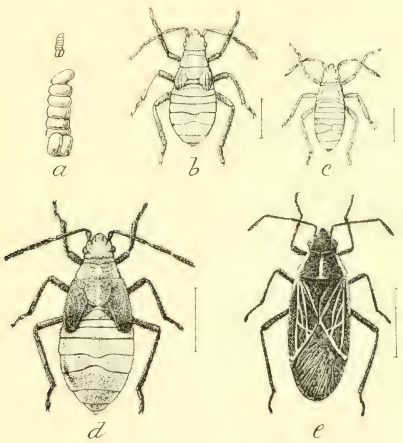


FIG. 113.—*Leptocoris trivittatus:* *a*, eggs enlarged, natural size above, *b*, *c*, *d*, different stages of immature bugs; *e*, adult; all enlarged; natural sizes indicated by hair lines. (All after Marlatt except *c*, which is after Howard, Div. Ent., U. S. Dept. Ag.)

its range to the Atlantic coast. It attacks particularly box elder trees and the young probably feed upon this in preference to other plants, but the adults in autumn scatter quite widely and in some instances are quite troublesome in

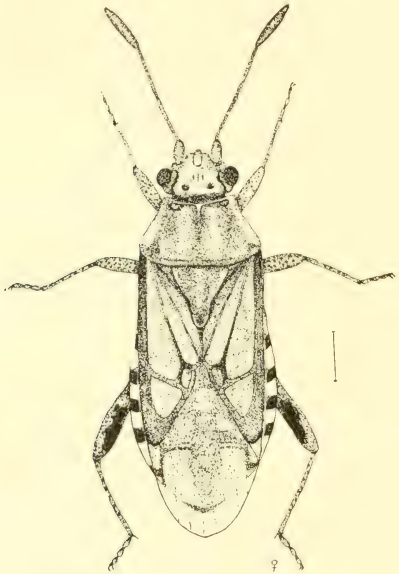

FIG. 114.—*Corizus crassicornis*. (After Hambleton.)

houses because of their tendency to fall into all kinds of objects such as milk pans and other food receptacles.

The species of *Corizus* are small, robust forms occurring on a very great variety of plants and commonly noted along roadsides and in clover fields.

**Stink Bugs** (*Pentatomidæ*).– Stink bugs are rather broad oval-shaped insects with four- or five-jointed antennæ, the wings lie flat and the membranous tip of the second pair are uncovered. They have a rather large scutellum lying between the bases of the wings. The characteristic odor of the stink bugs is not confined to this particular family. A few members of this family are of economic importance. The green soldier bug is very destructive to peaches in the northern part of the United States. The spined soldier bug (*Podisus*

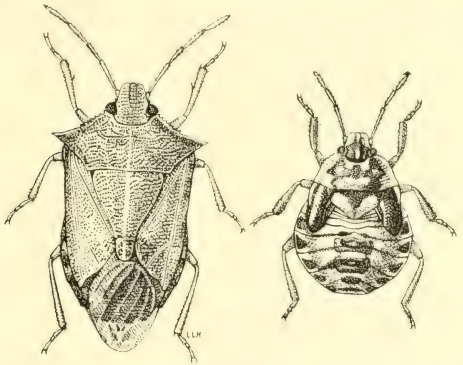

Fig. 115.—The spined soldier bug (*Podisus maculiventris*): adult at left, nymph at right; much enlarged. (Chittenden, Div. Ent., U. S. Dept. Ag.)

*maculiventris*) is not very large and is characterized by very distinct spines which project from the side of the body. It is very distinctly a predaceous bug. It is credited with killing the larvæ of the Colorado potato beetle, and it also feeds on caterpillars and other insects. On the whole it is counted as being very beneficial.

The harlequin cabbage bug (*Murgantia histrionica*) is one of the species common in the Southern States, and if it becomes abundant is a very serious pest. Ohio is its northern

limit. It can be controlled by spraying with kerosene emulsion during the larval stage.

The subdivision *Parasita* includes the suctorial lice, and they present perhaps the greatest divergence from the normal form, the extreme being in the direction of reduction due to parasitism. They are entirely wingless; they have a reduction of the mouth parts which is extreme. The beak

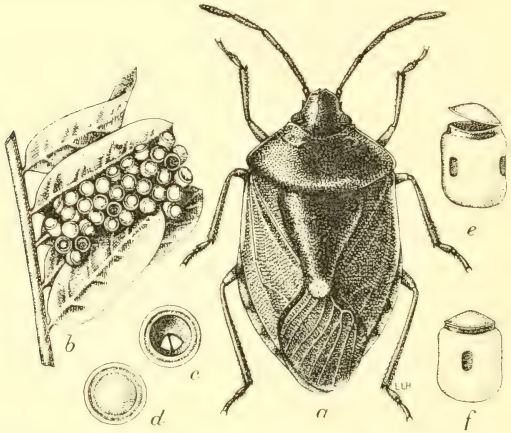


FIG. 116.—Stink bug: *a*, adult; *b*, eggs attached to leaves; *c*, *d*, *e*, *f*, details of egg structure. (Bur. Ent. U. S. Dept. Ag.)

is reduced to a single segment through which the tubular setæ are projected—a derivation from the three- or four-jointed beak of the normal forms. There is a distinct reduction or retrogression in the wings and mouth parts, but a distinct specialization in the structures by which they clasp the hairs or feathers of host forms. Tarsal claws are very large and strong and are provided with ridges or roughened areas which seem to strengthen the hold upon

the hairs, and in a few forms there are still other specialized clasping structures to strengthen this hold. In some the antennæ serve to help hold on. In one form there is a tubercle developed so that it fits against the pair of legs next forward so that it seems to act as a clasping organ. These suctorial lice are limited to mammals for their hosts. The mouth parts are doubtless adapted to the reaching of the capillary blood system in these hosts and in their life history they show adaptation to the parasitic habit, the eggs being glued to the hairs, the larvæ on first hatching being capable of attaching themselves to the hairs so that the entire life-cycle is distinctly parasitic. Their migrations from these host forms are simply for the purpose of scattering to other individuals of the same species. There is a rather distinct tendency for the individuals to migrate to younger animals of the same species. There is not a very evident series of broods in a year—they probably breed rather promiscuously. They have a constant host and constant warmth. Three species affect man and the horse, ox, sheep, hog, dog, and a great number of other mammals are known to support one or more species.

**Short-nosed Ox Louse** (*Hæmatopinus eurysternus Nitzsch*). —The short-nosed ox louse is the common species occurring on cattle. The full-grown females are about one-eighth to one-fifth of an inch long, and fully that in width, while the males are a little smaller and proportionately a little narrower. Aside from the difference in size the sexes differ very decidedly in the markings and structural features upon the under side of the body. The female is bluish leaden or gray in color. The males have a broad black stripe running forward from the end of the body to near the middle of the abdomen, as shown in Fig. 117. The females have no indications of this stripe, but the black, broken band of the upper side of the terminal segment extends slightly around on the under side. The most important character, however, is the presence of two little brush-like organs on the next to the last segment, as shown in Fig. 117.

The head is bluntly rounded in front, nearly as broad as

long, and with the antennæ situated at the sides midway from the posterior to the anterior borders; behind these are located slight eminences upon which may be found the small eyes, which are seen with considerable difficulty. At the front of the head may be seen the small rostrum or beak, the end of which is usually near the surface, but which is capable of extension or retraction. The end of this beak is armed with a double row of recurved hooks (see Fig. 115).

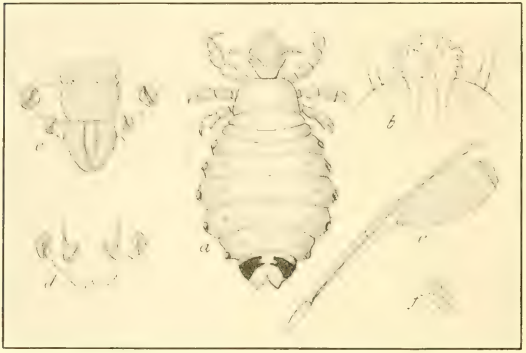

FIG. 117.—*Hæmatopinus eurysternus: a*, female; *b*, rostrum; *c*, ventral surface of the last segments of the male; *d*, same of female; *e*, egg; *f*, surface of same greatly enlarged. (Author's illustration, Bur. Ent., U. S. Dept. Ag.)

**Hog Louse** (*Hæmatopinus urius*).—The hog louse is one of the largest species of the family, full-grown individuals measuring a fourth of an inch or more in length. It is of a gray color, with the margins of the head and thorax and most of the abdomen dark. The head is quite long, the sides nearly parallel, with strong eminences just back of the antennæ, which are set on the sides of the head, midway from rostrum to occiput; the legs are lighter, with dark bands at the joints; the spiracles are inclosed by a black

chitinous eminence, and there is a broad black band on the last segment, broken near the middle. (See Fig. 118.)

The male has the abdomen marked beneath with a large black area extending forward from the end of the terminal segment, so as to occupy the central portion of the last three segments.

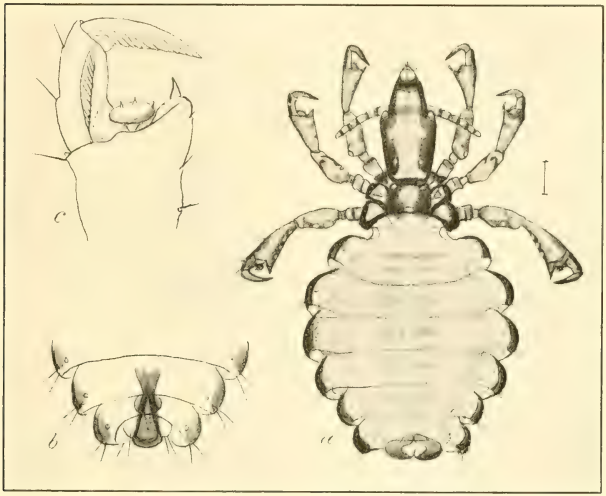


FIG. 118.—*Hæmatopinus urius:* *a*, female; *b*, ventral view of posterior segments of male; *c*, leg, showing protractile disk of tibia—enlarged. (Author's illustration, Bur. Ent., U. S. Dept. Ag.)

A curious provision is found in the feet for strengthening the hold upon the hair. It consists of a circular pad-like organ or disk in the outer portion of the tibia, which is received in a conical cavity in the end of the tibia, and which can be forced out so as to press upon the hair held between the claw of the tarsus and the end of the tibia.

On account of the thinness of the hair, the application of remedies, where necessary, is quite easy. Washes of tobacco water or dilute carbolic acid, and the application of kerosene in lard, or kerosene emulsion by means of a force pump, sulphur, ointment, etc., are recommended. The application of fine dust may be provided for naturally by allowing the hogs a chance to roll in a roadway or any place well supplied with fine dust. Where this is impracticable the dust, ashes, or powdered charcoal may be applied directly to the neck and back of the infested animal. The species is not known to attack any other of the domestic animals, and hence no precautionary measures in this direction are necessary.

## CHAPTER VI.

## NEUROPTERA AND ALLIES.

The insects with complete metamorphosis include first the *Neuroptera* which are represented by the lace-winged fly, ant lion, etc. These are separated from the preceding groups by the fact of the complete metamorphosis, and this order includes groups which are quite distinct from each other and have biting mouth parts and rather densely net-veined wings.

### Order NEUROPTERA.

Of the first family *Sialidæ*, the *Corydalis cornuta* is the most prominent. The larvæ live in running streams and under stones. Their structure and life-cycle furnish a good example for the group. The larva is strictly aquatic with gills which enable it to live in the water, but it can survive out of water if the gills are moistened. The adults appear in the summer, mainly in the early part of summer, and the eggs are laid during the summer months, generally about midsummer, and deposited in large masses on the leaves of trees overhanging water. The larvæ on hatching drop at once into the water and begin an aquatic existence. They feed on the larvæ of other aquatic insects, and their life-cycle occupies three years. They are in the water for about two years and eleven months; the pupa stage, passed in muddy banks, as well as the adult stage being short. The larva changes to a pupa which is quite different from the larval stage and different also from the adult. They are counted excellent as fish bait, and this is perhaps their most direct economic value.

The *Mantispidæ* have very prominent front feet, wings lie flat over the back and resemble a small form of the mantis.

The family *Chrysopidæ*, which includes the lace-winged

flies, has quite a different larval habit, being carnivorous but not aquatic. Larvæ are frequently called the "aphis lions" as they are destructive to aphids. They are most commonly found on trees on which aphids are abundant.

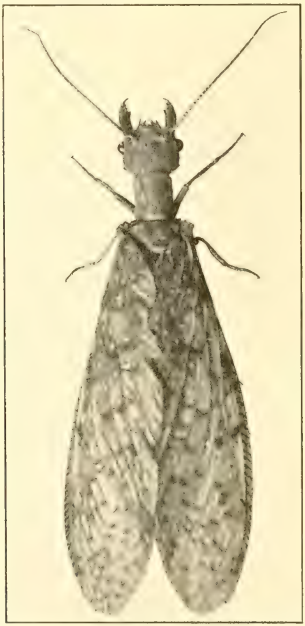

FIG. 119.—*Corydalis cornuta*, female. (Photo by author.)

The adults are very delicate with very thin, transparent, irridescent wings; brilliant golden eyes which stand out prominently (therefore called golden eyes); wings closely net-veined and bodies slender and cylindrical. The eggs are

deposited on leaves or twigs and are elevated on stalks, each egg standing up on a very distinct thread or pedicle. This is considered to be for protection of eggs from newly

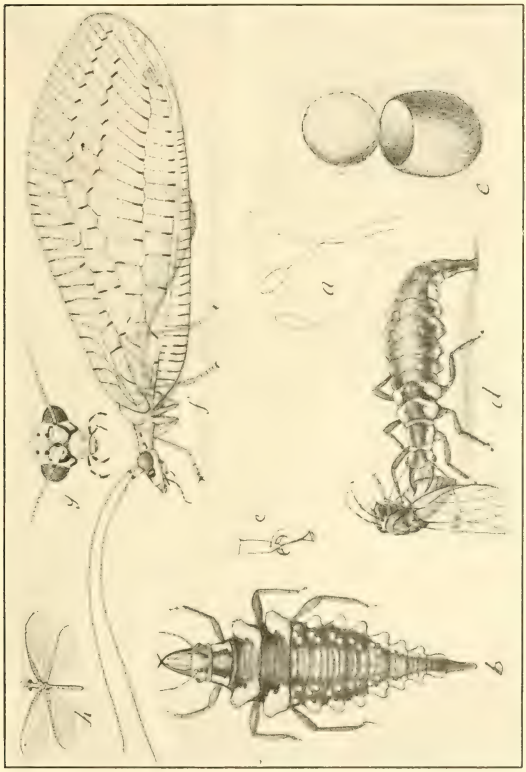

FIG. 120.—*Chrysopa oculata* Say: *a*, eggs; *b*, full-grown larva; *c*, foot of same; *d*, same devouring a psylla; *e*, cocoon; *f*, adult insect; *g*, head of same; *h*, adult, natural size. All enlarged except *h*. (From Marlatt, Div. Ent., U. S. Dept. Ag.)

hatched larvæ of the same colony. The eggs are deposited in this way by the adult touching the abdomen to the surface of the leaf, then raising it quickly so that a thread of glutinous secretion is drawn out. This hardens quickly and the egg is left at the tip of the thread. The larvæ on

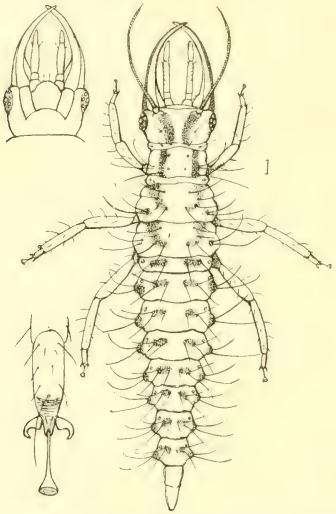

Fig. 121.—*Chrysopa oculata:* newly hatched larva, with under side of head and claw at side—greatly enlarged. (From Marlatt, Div. Ent., U. S. Dept. Ag.)

hatching eat up the plant lice in the immediate vicinity. They are active and run about readily and have prominent jaws which are sickle-shape, tubular, and adapted for sucking the body fluids of the plant lice. When they have passed the larval stage they form a small spherical cocoon in which they pass the pupa stage and from which the adults emerge

shortly afterward. They produce a number of generations each year.

**Ant Lions** (*Myrmeleonidæ*).—The ant lions are closely related to the preceding. They look much the same, and the only difference is the large antennæ which stand out and are thickened at the tip. They have large, equal-sized wings and long, cylindrical abdomens. The wings are distinctly net-veined. These ant lions appear in midsummer as adults and eggs are deposited presumably in the latter part of the summer. Whether they pass the winter in the egg stage or whether the larvæ are partially developed is uncertain. But during the early part of the season and a large part of the summer the larvæ may be found in sandy places forming little pits in the sand in the bottom of which they secrete themselves for the capture of ants and other small animals which may wander into the pits. They travel backward in changing their location, moving just beneath the surface and leave a very definite furrow on the surface of the sand. At one end of the furrow is usually a pit where the larva is secreted. After acquiring their growth they build a little spherical cocoon and within this they change some time later to the chrysalis stage. The adult stage is reached in, possibly, a two-year cycle.

### Order MECOPTERA (Scorpion Flies).

In this order the species are usually four-winged, although in some cases the wings are reduced or aborted. The wings when occurring are not folded, have numerous veins, and often are marked with distinct spots or blotches. The head is much modified, being elongated so as to form a sort of beak at the end of which are the small mandibles and the other mouth parts. The metamorphosis is complete and the larval stage is somewhat caterpillar-like in general structure.

The order includes the family *Panorpidæ* and in this family are a number of common species, but few of them have any particular economic importance. They have usually eight pairs of prolegs or abdominal legs so that they may

be distinguished from the lepidopterous larvæ which have, as a rule, only five pairs.

The species of *Bittacus* are somewhat common, usually found in woodland, and have some resemblances to the crane flies, but are easily distinguished by the presence of four wings. The genus *Boreus* is remarkable for appearing in the winter time and occurring in great numbers on the surface of snow.

### Order TRICHOPTERA (Caddice Flies).

This order is of particular interest scientifically because it appears to be the primitive group from which the order *Lepidoptera* has been derived. The mouth parts are mandibulate, the metamorphosis is distinct, the larval forms caterpillar-like but all the species are aquatic and show distinct specialization for aquatic existence. In the adults the body and wings are covered with minute flattened or scale-like appendages which approach the condition found in the *Lepidoptera* and except for the mandibulate mouth parts the group may be considered as distinctly connected with the *Lepidoptera*. In some forms the wings are opaque and the general appearance is extremely like some of the minute moths.

Perhaps the most notable feature in the group is the larval habit of forming cases or tubes within which they live. These cases are made of a variety of materials, in some species from minute pebbles, minute mollusk shells, and in many cases with fragments of aquatic plants or various kinds of débris occurring in the water. The cases are constructed shortly after the larvæ hatch and are enlarged with the growth of the insect. The head and thoracic legs are projected from the tube, and the tube moved around by its adherence to the posterior part of the body. Some species have a habit of making delicate nets or traps in the water by means of which they catch aquatic animals for food, but in most of the species the larvæ travel around freely and feed upon aquatic vegetation. The tubes or caddices formed

by these insects have been found in rocks of the tertiary period, so that it may be assumed that the aquatic case-making habit had developed as far back as this period in geological times. Aside from the fact that these may furnish food for other aquatic organisms there is little economic importance to be attached to them. The adults, while occurring in abundance, do not feed upon any cultivated crops, and they rarely appear in such swarms as the May flies, so that there is no especial annoyance from their abundance.

## CHAPTER VII.

## COLEOPTERA. BEETLES.

The *Coleoptera*, or the order of beetles, is one of the immense groups of insects, both in species and individuals. It is also one of the most distinctly marked groups. In some ways it is more specialized, in others more generalized. The wing structure is specialized, the horny front wings which are useless so far as flight is concerned being modified to serve as covers for the wings and for the abdomen. The hind wings are the organs for flight. Reduction of the front wings is to be noticed in a number of cases and in some species they cover only a small portion of the body.

The *Coleoptera* and *Diptera* so far as wings are concerned are about equally specialized. In the mouth parts the *Coleoptera* are very much less specialized than the *Diptera*—they retain the primitive structure. The mandibles are sometimes reduced but are functional in the adult stage and sometimes very strongly developed. They are not modified into suctorial organs.

The metamorphosis is complete and the stages quite distinct. There are the four stages common to insects with complete metamorphosis and in some groups the larvæ are further specialized, so that there are two or three different larval forms (hypermetamorphosis). The beetles have been studied perhaps more than any other group unless it be the *Lepidoptera*. They are more easily preserved than most insects and often of striking form or conspicuous colors. The beetles probably number at least 100,000 species, and in this country 10,000 or 12,000 species are recognized. A considerable number of these are of economic importance. The group is separable into two quite distinct divisions.

the *Rhyncophora* are the more specialized. The head is drawn out in a snout and the mandibles are much reduced in size. The larval forms are more specialized, usually fitted for living within seeds or parts of plants.

In the arrangement of families the tiger beetles are usually placed first, but it would seem fully as proper to place *Carabidæ* in this position.

**Tiger Beetles** (*Cicindelidæ*).—The tiger beetles are found along roadsides, bare ground, or sandy beach. It is not easy to get the larval forms. The larvæ are carnivorous and make little burrows in the earth and catch insects that come along at the surface.

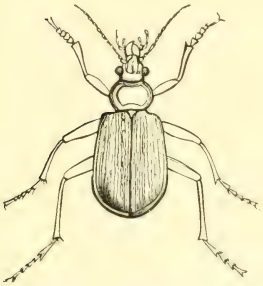

FIG. 122.—*Calosoma scrutatoi*.

FIG. 123.—*Lebia grandis*, an important enemy of the potato beetle. Enlarged. (Chittenden, Div. Ent., U. S. Dept. Ag.)

**Ground Beetles** (*Carabidæ*).—The ground beetles are less specialized. They live usually at the surface of the ground and the larvæ are provided with three pairs of normal legs and run about readily and are in fact quite primitive in appearance and habits. They are, as a rule, carnivorous, but a few species attack plants.

Some of the more important beneficial species are the common ground beetle (*Calosoma calidum*), a black species with a series of metallic golden spots, abundant over a large part of the United States, and which feeds commonly on

cut worms, caterpillars, etc. The searcher *Calosoma scrutator*, a brilliant green species with metallic border on elytra and margin of prothorax which, while a general feeder on ground-living insects, is also credited with climbing trees to feed upon canker worms. The *Calosoma sycophanta*, an old-world species that is especially useful in keeping the Gipsy moth in check, has been introduced into Massachusetts in hopes that it may assist in control of this pest.

There are several families of aquatic *Coleoptera* which live almost entirely in water, although at times the adults issue and fly. The carnivorous water beetles (*Dysticidæ*) have peculiar circular or oval sucking disks on the front legs, and are distinctly aquatic, the adults appearing out of water, and like the ground beetles, they feed quite exclusively upon other animal life and doubtless occupy a somewhat important place in the relations of aquatic forms.

The *Hydrophilidæ* are more distinctly herbivorous and may be considered as water scavengers, feeding upon vegetable débris and serving as important members of the aquatic association. It is a large family, including a great many genera and species, but from their habits are naturally of little economic importance.

The *Gyrinidæ* or whirligig beetles are quite remarkable for their movement on the surface of water. They dart around with the greatest rapidity, making all sorts of irregular movements but when a group of them are together they form a bewildering array of darting forms. Although dozens or even hundreds of them may be in a group they seldom if ever seem to have a collision among the different individuals in the cluster. A remarkable feature in their structure is the separation of the compound eye at the side of the head so that the upper portion is above water and the lower portion submerged. They are said to feed mainly upon flies and stranded insects of various kinds that are caught on the surface of the water. One of our common species is the *Dineutes americana*.

**Family Platypsyllidæ.** The *Platypsyllidæ* is a small family including a very remarkable parasite of the beaver.

The female is about 2½ mm. in length, and ovate in form with very short wing pads so that the abdominal segments are exposed. The eyes and wings are both aborted.

**Family Silphidæ.**—The *Silphidæ*, carrion beetles, are very distinctly scavengers and where there is an accumulation of decaying organic matter they doubtless serve a valuable function in disposing of such material that is detrimental.

**Sexton Beetles** (*Necrophorus*).—The sexton beetles are the largest of the family. They bury small mammals such as rats or mice and upon these lay their eggs. The larva then feed upon the decaying flesh.

The species of *Silpha* are commonly found about dead fishes or carcasses of dead animals and both the adults and larvæ feed upon the rotting material.

**Rove Beetles** (*Staphylinidæ*).—The *Staphylinidæ* are also largely scavengers. The group is a very large one including many hundreds of species. They are characterized particularly by the structure of the wing covers which extend only to the base of the abdomen. The hind wings are folded by means of hinges on the wing margin so that they can be attached under the short wing-covers. The abdomen is left exposed and as the joints are flexible it can be moved about readily and the tip is used in manipulation of the wings preparatory to flight, or when they are folded after flight.

Several other families related to this division must be passed over.

**Family Coccinellidæ.—Lady Bugs.**—These are abundant and very important insects, since practically all the members of the family are carnivorous and feed upon insects which for the most part are very destructive. They are especially serviceable in the control of plant lice and scale insects. The adults are short, generally hemispherical or oval, convex above with under side flattened. Usually they are rather conspicuous: some are red with yellowish or black spots, while others are black with red or yellowish spots.

The larvæ are very voracious insects and feed quite exclusively upon insects, so that they are considered of special

service and pains should be taken not to destroy them. They are short, flattened, rather broad, and usually with rather prominent spines or hairs as indicated in the accompanying figures.

FIG. 124.—A lady bug (*Hippodamia convergens*) which preys on the Colorado potato beetle. Enlarged. (Chittenden, Div. Ent., U. S. Dept. Ag.)

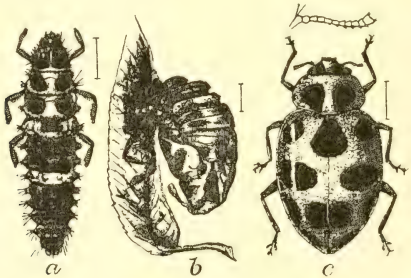


FIG. 125.—Spotted lady bug (*Megilla maculata*): *a*, larva; *b*, empty pupal skin; *c*, beetle, with enlarged antenna above. All enlarged. (From Chittenden, Div. Ent., U. S. Dept. Ag.)

A number of species are abundant and of special service in various parts of the United States. Some of these are figured, and further description will be unnecessary.

**Vedalia.**—One species of particular interest is the *Vedalia*. This was introduced into California for the purpose of controlling the cottony-cushion scale and was so efficient in this respect that the scale insect has become of little economic importance.

**Family Cucujidæ. Saw-toothed Beetle.**—The family *Cucujidæ* includes, with other pests, the saw-toothed beetle (*Sylvanus surinamensis*), probably one of the most frequently noticed pests of stored cereal foods, especially those in packages. It is a little, dark red-brown beetle with the

FIG. 126.—*Adalia bipunctata: a*, larva; *b*, mouth parts of same; *c*, claw of same; *d*, pupa; *e*, adult; *f*, antenna of same. All enlarged. (From Marlatt, Div. Ent., U. S. Dept. Ag.)

edges of the prothorax strongly toothed. It is found in a great variety of food substances, including breakfast foods, yeast cakes, nuts, and dried fruits.

All stages of the insect may occur in these substances, the larva being a slender, somewhat flattened creature, the pupa being about the shape of the adult. The adult tunnels through cases or migrates from place to place, depositing its eggs adjacent to the materials in which the larvæ will grow. There are probably several generations each year, especially in the food materials that are in warm situations. They should not be present in fresh-packed cereals, but owing to

the fact that they become very numerous in mills it is quite probable that eggs may be included in the package and the larvæ developed later.

**Family Lyctidæ.**—The family *Lyctidæ* includes a number of wood-feeding species, for which the powder-post beetle (*Lyctus planicollis*) will serve as a fair example.

**Dermestidæ.**—The *Dermestidæ* are forms that live on decaying animal matter. Good examples may be found by

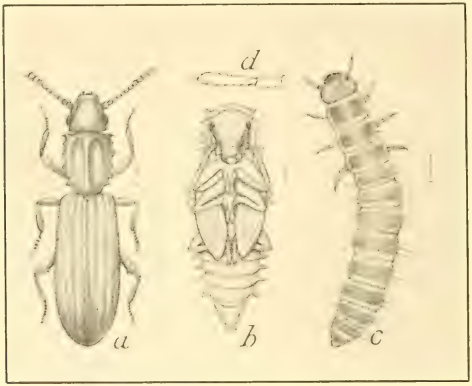


FIG. 127.—The saw-toothed grain beetle: *a*, adult; *b*, pupa; *c*, larva or grub. Greatly enlarged. (After Chittenden, Div. Ent., Bull. 4, n. s., 1896, U. S. Dept. Ag.)

examining dead fish and other decaying organic matter. Some of the species are museum pests, and troublesome in bird collections, and a very particular pest of insect collections. On account of this it is necessary to keep collections in insect-proof boxes or else fumigate with carbon bisulphide.

**Larder Beetles** (*Dermestes lardarius*).—The adults appear particularly in early summer and the eggs are deposited on or near materials that furnish food for the larvæ. The eggs

require probably only a few days for hatching, long enough when laid on insects, so that it is possible for the insects to be transferred from one box to another and to introduce them into new boxes. In case of hams and bacon, these eggs may be on the hams when they pass from one dealer to another. The larvæ grow most rapidly during the summer months and if there are any distinct broods it would be the rapidly developing generations in the summer time. But the broods are not very sharply marked. There may be two or three broods, but the development is irregular enough, so that they are developing at all times of the year. The larvæ do the feeding and devour the tissue, and the

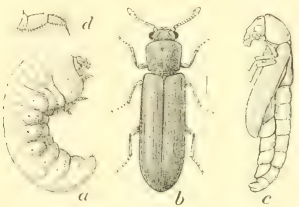


FIG. 128.—A powder-post beetle (*Lyctus planicollis*): *a*, larva; *b*, adult; *c*, pupa; line to right of adult represents natural length. (Chittenden, Div. Ent., U. S. Dept. Ag.)

pupation takes place early. The larvæ may burrow through paper or wooden cases and then give rise to adults in a comparatively short time.

**Museum Beetle.**—A related species—the museum beetle—is more a museum pest and less a pest in other ways. It lives in skins of mounted animals and other dried animal tissue.

**Carpet Beetles.**—Closely related is the carpet beetle, which is a pest in fur and woollen goods and seldom if ever known as a pest in museums. It is fond of woollen carpets and furs. These seem to be its particular food supply. It was introduced from Europe and has spread over the entire

country but is not very abundant for the most part. It is less abundant where rugs are used than where carpets are used.

**Click Beetles** (*Elateridæ*). Click beetles are interesting on account of structure and their habits which are of economic importance. They make a sudden click and throw themselves up into the air. This is produced by a little spur on the prothorax which fits into a little pit in the mesosternum. This is characteristic of the entire family and is not found in any other family. Its purpose is to throw the insect into the air and allow it to turn over. The larvæ are called

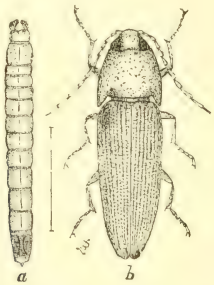


FIG. 129.—Click beetle and wire worm (*Melanotus communis*): *a*, larva; *b*, beetle. (After Bruner.)

wire worms. These are very troublesome pests. Many of them are primarily grass-root feeders and will be found as larvæ in grass lands, the larvæ living just below the surface of the soil, and feeding mainly on the roots of the grass. When the land is plowed and planted in corn or some other crop the wire worms attack this other crop, sometimes in a much more noticeable manner than they do the grass. The larvæ are not capable of migrating very great distances, and must depend on the vegetation that is present where they are hatched. The length of the larval period is shown by their presence in a field of corn three years after it has

been plowed from grass. Many of the species have never been traced through in detail, but those that have been traced show them to be grass-feeding species, and the eggs are deposited on grass lands. There are some species whose larvæ occur in rotten wood and a few have a phosphorescent property. These are not of economic importance.

**Buprestidæ.**—The *Buprestidæ* have larvæ that are wood-boring in habit and on account of their shape—the very broad anterior segment of the body—are called the flat-head borers. Destructive species occur in maple, apple, hickory, and a considerable number of common trees. The best-known is the flat-headed apple-tree borer (*Chrysobothris femorata*), which affects apple and also maple, and perhaps other trees. The adult is a somewhat flattened and elongated oval beetle with rather shallow metallic pits on the wing covers. They appear in early summer and will be found running about over the bark of the trees where the sun strikes them, and the eggs are deposited on rough spots of the bark and hatch in a short time. The larvæ burrow just beneath the bark and burrow out a shallow cavity, limiting themselves to the cambium at least in the earlier part of their lives. The cavity eaten out may be one-half to three-quarters of an inch wide. The head is small but the first segment of the body is quite large and flat and is perhaps rather naturally taken to be the head by ordinary observers. The remaining segments are slender and nearly cylindrical. It lies in the cavity in a flat position. The burrows never go down into the heart of the tree but they produce dead patches in the growing wood at the surface, and if they are numerous they may form a girdle and cut off the sap. The larvæ make their growth two or three feet from the ground on apple trees and occur about the lower branches and a few may girdle the tree. The cycle of the species is completed in a year. The larvæ burrow during the summer and autumn, are dormant through the cold weather, and pupate in the spring, the adults appearing in the summer. The species is usually restricted pretty closely to one kind of plant.

**Lampyridæ.**—The fire-fly family is quite an exceptional one, and is very interesting on account of the brilliant phosphorescent property. This is most commonly observed during June and early July and represents the time when the adults are most abundant. There are a number of species possessing the phosphorescent organs. The eggs are deposited and the larvæ probably develop during that same summer, and the pupa stage is reached and adults issue the following season. They pupate perhaps in fall or else in spring. They are subterranean and are carnivorous and feed upon the larvæ of other species.

**Lucanidæ** (*Stag Beetles*).—The lucanidæ are large forms with very prominent mandibles which in some species develop into antler-like structures. The *Lucanus dama* larva lives in rotten wood, old stumps, and logs, etc., and only incidentally feeds on living wood. The larvæ never start on living wood. The grubs are large, white, fleshy creatures with the body curved, almost coiled, and they pupate in the wood in which they are developed and the adults run over the ground in timber lands. The adults are quite common along the beach. They are not adapted for long flight.

A quite interesting species is the horned *Passalus* (*Passalus cornutus*) which lives in wood in almost the same manner as the last species, but the larva is flattened and the adult quite prominently flattened. The wings are considerably aborted and the species probably quite limited in its flight.

**Scarabæidæ.**—The *Scarabæidæ* are characterized quite readily by the structure of the antennæ. They have a very specialized form of antennæ consisting of a series of small joints and then a broad terminal structure which is made up of three or five leaves folded together like the leaves of a book. These may be separated when the insect is flying. They are presumed to be the organ of the sense of smell. There are many sensory pits, and they give evidence of having strong olfactory sense, in that they collect at any decaying matter. They are not all scavengers, but they all have an acute sense of smell. The tumble bugs and a host of scavenger beetles related to it are included in this family.

The Egyptian scarabs belong here. The tumble bugs simply enclose their eggs in little masses of refuse matter. This is to serve as food substance for the larvæ, and they shape it in a ball and roll it along until it becomes coated with earth. The balls are finally buried in the earth. The eggs hatch here and the larvæ develop and get their subsistence from the material in the ball.

FIG. 130.—*Corpris carolina*, under side. Enlarged. (From photo.)

**May Beetles or June Bugs.**—Important economic species are the leaf-eating species. These are species of the genus *Lachnosterna*—*Lachnosterna fusca* in particular. These are known as May beetles or June bugs. They are distributed all through the country. There are perhaps twenty-five or thirty common species which occur in great abundance about the same time of the year, but these differ in minute characters of genitalia. They were formerly all grouped

together in one species. They are leaf-eating in the adult stage. The adults appear rather early in summer, May or June. They are destructive in the adult stage by cutting off the leaves of trees. They do not eat the leaves much but cut them off at the petiole. Sometimes trees are completely stripped. They mate in the evening when they fly in great numbers. The eggs are deposited out of doors and in grass land particularly. The larvæ feed on grass roots, and if this remains available they develop there in

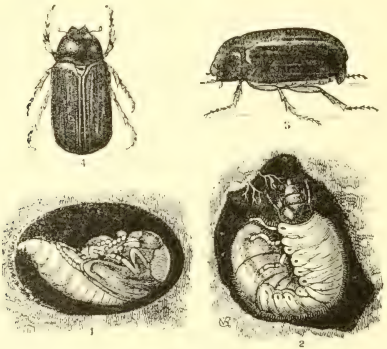

FIG. 131.—The common May beetle (*Lachnosterna fusca*): *1*, the pupa; *2*, the larva or white grub in its ground cell; *3* and *4*, the beetle, side and dorsal views. (After Riley.)

about three years and when they get fairly near maturity, about the spring of the third year, they cut off the roots of the grass pretty severely, sometimes cutting the turf off completely. This causes the same kind of loss as is caused by cut worms, grasshoppers, etc., or more severe because of injury below the crown. At this time they are known as white grubs and are similar in appearance to the larvæ of the stag beetles. If the grass is plowed under and the field is planted to some other crop the grubs starve or else attack

the other vegetation which sometimes suffers severely. Strawberry beds are quite likely to suffer. There are no satisfactory remedies. About the only thing that could be of much use is attention at the time of egg deposition. Application of kerosene has been reported in some cases as successful on small areas such as lawns or parts of park land.

**Rose-chafer** (*Macrodactylus subspinosus*, Fab.).—The rose-chafer is a small, yellowish-brown beetle, about one-third of an inch in length, with very long legs. It occurs in great

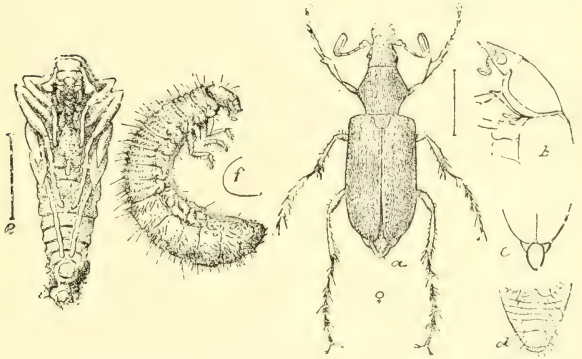


FIG. 132.—Rose-chafer (*Macrodactylus subspinosus*): *a*, female beetle; *b*, anterior part of male; *c*, pygidium of male; *d*, abdomen of male; *e*, pupa; *f*, larva. All enlarged. (From Riley, Div. Ent., U. S. Dept. Ag.)

numbers at the time of the blossoming of the garden rose, and will in a couple of weeks entirely strip the bushes of blossoms, leaves, and fruit. It also attacks the grape, apple, pear, cherry, peach, and other fruit trees, but is especially injurious to the rose and grape.

The ravages of the rose-chafer are common in eastern United States and Canada. The date of the first appearance of the rose-chafer varies with the season but it is usually as early as the first of June. They begin mating imme-

diately after emerging from the ground. They continue feeding from four to six weeks and are almost constantly paired during this time. The eggs are deposited singly a few inches below the surface of the ground, each female laying from

FIG. 133.—Rose-chafer work. (Photo from Ohio Exp. Sta.)

twenty-four to thirty-six eggs. The larva hatches in about two or three weeks and begins feeding on grass and tender shoots. The larva is mature in the autumn and digs down into the earth where it builds a small earthen case in which it

passes the winter, pupating in the early spring and emerging as adult early in June.

There have as yet been no very successful methods of control discovered. Heavy spraying with arsenate of lead when the beetles appear will kill those feeding on the poisoned leaves, but if very abundant, successive attacks of newly appearing individuals may make this of little avail.

**The Cerambycidæ.**—The wood-boring beetles show quite a different habit from the subterranean forms. They are called the long-horned borers and have very long antennæ with usually eleven joints. In the genus *Prionus* the number is greater. The length of the antennæ is produced by elongation of the joints. In some species the antennæ are two or three times the length of the body. They are typically wood-boring, and all except one or two genera are borers in the heart-wood of woody plants. Gradations between leaf-feeding and wood-boring are to be seen in a few species that live in the pith of softer plants, and in a few that are borers in the roots. The extremes are perhaps to be recognized in those forms that burrow into the heart-wood of the hickory, maple, etc., and that live in such wood after it has been cut and killed. The larvæ are the borers. Sometimes larvæ are found in furniture. They seem to require almost the minimum of moisture and of air.

**Hickory Borer** (*Chion cinctus*).—The hickory borer is another species which attacks particularly dead or recently felled trees. Eggs are laid on the dead timber. The borers will gather in large numbers on cord wood the first two or three years after cutting. They sometimes make the wood of comparatively small value for fuel. It is useless for manufacturing purposes. One remedy is to use the wood rather promptly after cutting, within a year. Cutting in the fall is recommended by woodmen, also stripping bark is said to act as a preventative. They do not work during the cold weather. The adults occur only in the summer.

**Round-headed Borers** (*Saperda candida*).—The round-headed borers are among the most common pests of orchards and their life-cycle includes about three years. The adult,

which is brown with two conspicuous white stripes, appears in early summer, May or June, deposits eggs at the lower

FIG. 134.—*Chion cinctus: a*, eggs, natural size; *b*, egg, enlarged; *c*, larva; *d*, pupa; *e*, adult male; *f*, antennæ of female. (After Osborn, in *Garden and Forest.*)

part of the trunk, near the ground. The larvæ on hatching burrow into the tree and for the first season live near the bark, then they burrow down and pass the winter in the

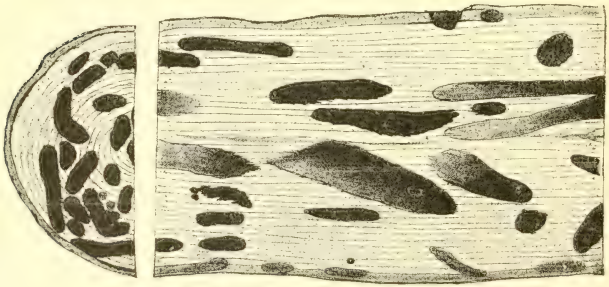

FIG. 135.—Work of hickory borer, showing longitudinal and cross-section of stick with burrows. One-half natural size. (After Osborn, in *Garden and Forest.*)

lower part of the burrow, perhaps below the surface of the ground. The next two summers are spent in boring upward

and inward to the heart of the tree and then boring toward the surface, leaving only a thin layer of bark. Before pupating the larva packs the burrow with chips, then withdraws a little from the surface to pupate. The fully grown larvæ, pupæ, and adults may all be found in the spring of the same year. All mature and become ready to deposit eggs about June. The adult has simply to work its way through the thin packing of chips and a little bark to reach the surface. It does no real boring in the wood. Few of the species have the ability as adults to cut away the heart-wood.

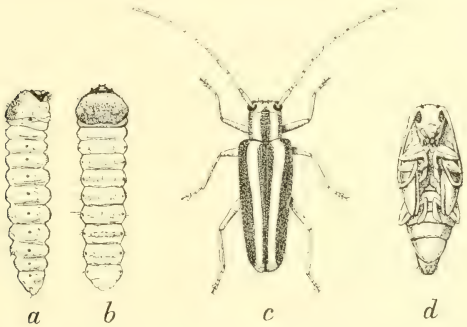


FIG. 136.—*Saperda candida: a*, larva, from side; *b*, from above; *c*, female beetle; *d*, pupa. All enlarged one-third. (After Chittenden, Div. Ent., U. S. Dept. Ag.)

There are two means of control. One is to protect the trunk of the tree by means of applications of alkali washes, paint, etc., to prevent the depositing of eggs. Barriers placed around the trunk are used, such as wire netting, tarred paper, and building paper, or even several thicknesses of newspapers. Where such material is used it is better to remove it later in the season (by September first) to give the bark its normal exposure. Another way is to cut out the larvæ in the autumn of the first season; the burrow close

to the bark can be found by means of the chips that are forced out and project from the burrow or drop to the ground and form little piles. The grub can be cut out with a clean sweep of the knife and the wound covered with a little wax, thick paint, or something of the kind to prevent entrance of water and formation of decaying spots.

**Leaf Beetles** (*Chrysomelidæ*).—The leaf beetles represent rather more primitive habits and have rather more primitive characters than *Cerambycidæ*, the antennæ being short and filiform, but are similar in the character of the tarsi. The larvæ of *Chrysomelidæ* with a few exceptions feed on the leaves of plants in a very exposed manner and the adults feed, so far as they feed at all, on the leaves of different kinds

FIG. 137.—Colorado potato beetle (*Leptinotarsa decemlineata*): *a*, beetle; *b*, larva; *c*, pupa. Enlarged. (Chittenden, Div. Ent., U. S. Dept. Ag.)

of vegetation. They are sometimes restricted to certain plants and sometimes have a variety of hosts.

The Colorado potato beetle (*Leptinotarsa decemlineata*) was at one time a much-dreaded pest but can now be easily controlled. It occurred originally in the Rocky Mountain region, feeding on wild plants related to the potato, but with the introduction of the potato and abundance of food it multiplied rapidly, migrated eastward and soon spread over the entire country. It has two generations each year, adults hibernating in the ground, appearing in early spring and laying eggs on first-appearing potato vines. The larvæ which hatch soon feed on the leaves, maturing in a short time, pupating under ground, and a summer generation of

beetles appears in midsummer. These lay eggs, and larvæ may be very abundant in late summer, pupate in early fall, and give rise to beetles that hibernate. Spraying with arsenical solutions is effective in their control.

Agriculturally a little group of beetles, the *Diabrotica*, are very important. They present an exception to the general habit of the family in that they attack roots under the ground. There are three species of interest. The best-known species is the striped squash beetle (*Diabrotica*

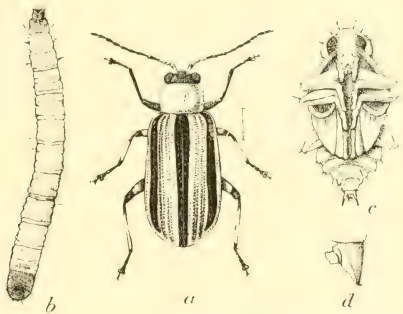


FIG. 138.—Striped cucumber beetle (*Diabrotica vittata*): *a*, beetle; *b*, larva; *c*, pupa; *d*, egg; *a*, *b*, *c*, much enlarged; *d*, more enlarged. (After Chittenden, Div. Ent., U. S. Dept. Ag.)

*vittata*), a pest to squashes and melons, which is an extremely well-known species. It feeds on stems and leaves close to the ground and, as larva, in the young squashes, and perhaps represents the intermediate stage between stem and root-feeding species.

*Diabrotica longicornis*, the corn-root worm, is distinctly a root-feeding species. The beetle appears in late summer and autumn and is a rather bright green little beetle with no markings. It is found in late summer on the corn stalks, on the fall flowers, such as asters, sunflowers, goldenrod,

etc., and feeds perhaps on the pollen of these flowers. In some cases it is quite remote from the corn fields. They deposit eggs in the ground. The eggs remain over winter and hatch the following spring shortly after the corn begins to grow, and the larva commences feeding on the corn roots. While the roots are small they commence at the end and work along the root; after the roots are larger they work into the roots. They cause the ears to be small and when numerous can kill out the entire plant. They get their growth by the middle of July or first of August, pupate, and spend a few days in the pupal stage, and issue as adults

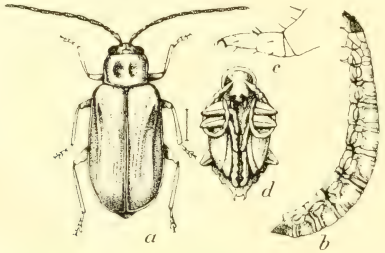


FIG. 139.—Western corn-root worm (*Diabrotica longicornis*): *a*, beetle; *b*, larva or root worm; *c*, enlarged leg of same; *d*, pupa—all enlarged; *e*, more enlarged. (Chittenden, Div. Ent., U. S. Dept. Ag.)

in autumn. There is a single brood in a year. Rotation of crops serves as an almost absolute means of prevention of injury from this species. It was most troublesome in the corn regions of Illinois where corn was planted year after year on the same ground.

The other species with this habit is also destructive to corn (*Diabrotica* 12-*punctata*). It is known as the Southern corn-root worm. It is also troublesome to some other plants, so that its control is not so easy or certain.

The elm-leaf beetle, an introduced species which has been a very serious pest in the Atlantic States, has recently

occurred in Ohio. It has worked westward from some infected centre in the east, and is apparently spreading over the country in general.

The cucumber flea beetle and grape-vine flea beetle also come in this group.

**Family Bruchidæ.**— The family *Bruchidæ* in some respects approaches very near the snout beetles. This includes the pea and bean weevil and the species are essentially seed-

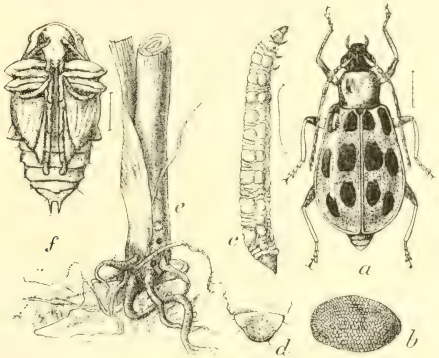


FIG. 140.—Southern corn-root worm (*Diabrotica* 12-*punctata*): *a*, beetle; *b*, egg; *c*, larva; *d*, anal segment of larva; *e*, work of larva at base of corn stalk; *f*, pupa. All much enlarged except *e*, which is reduced. (After Riley, except *f*, after Chittenden, Div. Ent., U. S. Dept. Ag.)

eating forms. In case of the pea weevil the eggs are laid out of doors on growing pea pods and they burrow into the pod and get into the growing peas, usually one to each pea. They grow with the growing pea and remain in the pea to pupate and then later the adults are found in stored peas in winter and spring. Immense numbers of these larvæ are destroyed by the eaters of green peas but the species holds its own. It does not become noticeable except in stored peas. The larvæ at the time of green peas are small

and soft, probably of a good flavor like the pea, and do not attract any attention at all. The way of preventing its occurrence is to pick out the infested peas and treat them before planting. Soaking in cold water for several hours

FIG. 141.—Elm-leaf beetle (*Galerucella luteola*): *a*, *e*, eggs; *b*, *g*, larvæ; *c*, *k*, adults; *f*, sculpture of egg; *h*, side view of segment of larva; *i*, dorsal view of same; *j*, pupa; *l*, portion of elytron of adult; *a*, *b*, *c*, natural size; *g*, *j*, *k*, somewhat enlarged; *e*, *h*, *i*, *l*, much enlarged; *f*, highly magnified. (From Riley, Div. Ent., U. S. Dept. Ag.)

kills the adults and prevents egg deposition. Warm water may be used and will hasten the death of the larva but it must not be so hot as to kill the germ. Buggy peas will germinate usually just as readily as the sound ones but have less material to grow on. Peas that are kept in bins

or sacks where the adult cannot get out can do no harm to the new fields. Fumigation of the seed is one method of destroying the beetles. In some places it is required by law.

The *Rhyncophora* or snout beetles are distinguished by the elongate head drawn out into a narrow and sometimes

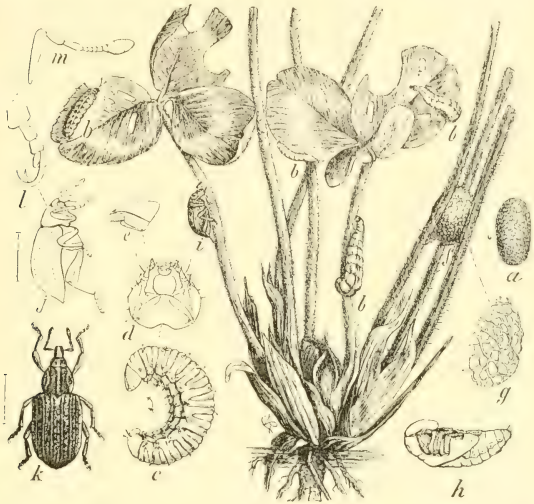


FIG. 142.—The clover-leaf weevil (*Phytonomus punctatus*): *a*, egg; *b*, *b*, *b*, *b*, larvæ feeding; *c*, recently hatched larva; *d*, head of same from beneath; *e*, jaw of same; *f*, cocoon; *g*, meshes of cocoon; *h*, pupa; *i*, beetle; *j*, same in outline; *k*, same dorsal view; *l*, tarsus of beetle; *m*, antenna of same; *b*, *f*, *i*, natural size; others more or less enlarged. (From Riley, Div. Ent., U. S. Dept. Ag.)

very long "snout" at the end of which the minute mouth parts are attached. The larvæ are commonly found as grubs in seeds, nuts, etc., but the clover-leaf weevil and the alfalfa weevil feed upon the leaves and stems of clover and alfalfa.

**Plum Curculio** (*Conotrachelus nenuphar*, Herbst.).—This pest is still one of the main difficulties in the way of raising good crops of plums, but it may be considered at least possible, by proper care, to secure good crops of perfect fruit. The beetles hibernate and appear on the trees shortly after bloom, feeding to some extent on the leaves and young fruit, and then laying their eggs in the young plums, the punctures indicating point of deposition being marked with a crescent-shaped cut. The larvæ burrow through the pulp

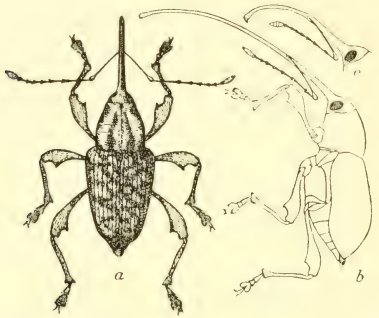


FIG. 143.—The larger chestnut weevil (*Balaninus proboscideus*): *a*, female beetle; *b*, same in outline from side; *c*, head, rostrum, and antennæ of male. Three times natural size. (Chittenden, Div. Ent., U. S. Dept. Ag.)

of the plum, not entering the stone. The infested fruit ripens prematurely and falls from the tree, and the larvæ for the most part leave the plums and pupate under ground. The adult beetles appear in late summer or early autumn and live over till the following spring.

The beetles drop readily when disturbed, and the well-known plan of jarring trees daily during the time of egg deposition in the morning and gathering the beetles on canvas spread under the trees is a valuable means of preventing

their injuries. Spraying with an arsenical solution has been found to be useful, and if the plum trees are thoroughly sprayed once soon after the bloom has fallen and again ten

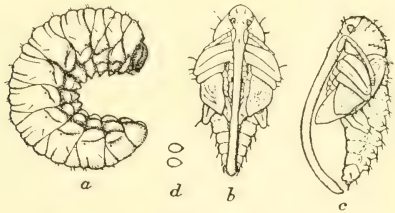


FIG. 144.—Larger chestnut weevil (*Balaninus proboscideus*): *a*, larva; *b*, *c*, female pupa; *d*, eggs. All enlarged. (Chittenden, Div. Ent., U. S. Dept. Ag.)

FIG. 145

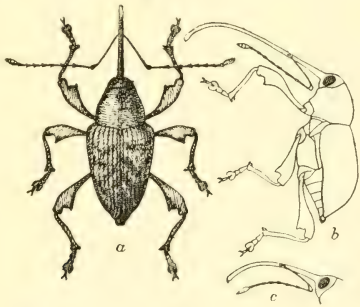


FIG. 146

FIG. 145.—*Balaninus proboscideus:* head of larva, much enlarged. (Chittenden, Div. Ent., U. S. Dept. Ag.)

FIG. 146.—Pecan weevil (*Balaninus caryæ*): *a*, female, dorsal view *b*, same, lateral view, in outline; *c*, head with rostrum and antenna of male. About two and one-half times size. (Chittenden, Div. Ent., U. S. Dept. Ag.)

days later, it will greatly help in securing perfect fruit. Some experiments have shown extremely valuable results in this direction.

The nut weevils have enormously elongated snouts. They infest chestnuts, pecans, acorns, hazel-nuts, etc.

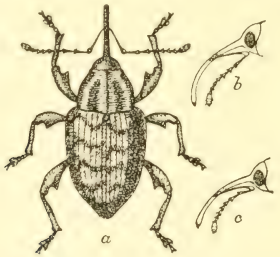


FIG. 147.—Hazel-nut weevil (*Balaninus obtusus*): *a*, adult female, dorsal view; *b*, head from side; *c*, head of male from side. Enlarged. (Chittenden, Div. Ent., U. S. Dept. Ag.)

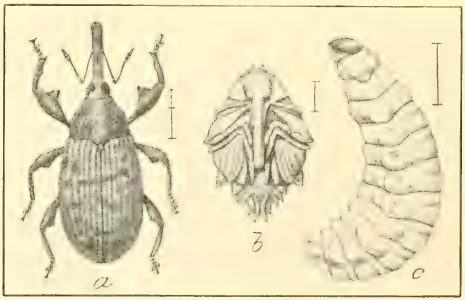


FIG. 148.—Boll weevil (*Anthonomus grandis*): *a*, adult beetle; *b*, pupa; *c*, larva. All enlarged. (From Howard, Div. Ent., U. S. Dept. Ag.)

**Cotton-boll Weevil.**—In the Southern States we have a most striking case of introduction and dispersal in the cotton-boll weevil, which came into southern Texas from Mexico about the year 1890 and has been making steady

FIG. 149.—Map showing annual advances of cotton-boll weevil from 1892 to 1913. (Reduced from map by Bureau of Entomology, U. S. Dept. Ag.)

progress throughout the cotton-growing States. It is a small beetle somewhat like the clover weevil but restricted to the cotton plant for its food and for the early stages is restricted to the bolls of cotton for its particular food. This means that it can develop only in places where cotton grows and at such time as the cotton bolls are in process of development. This species has practically revolutionized the agricultural conditions of the Southern States in which it has spread, and it is unnecessary to say that it must have had

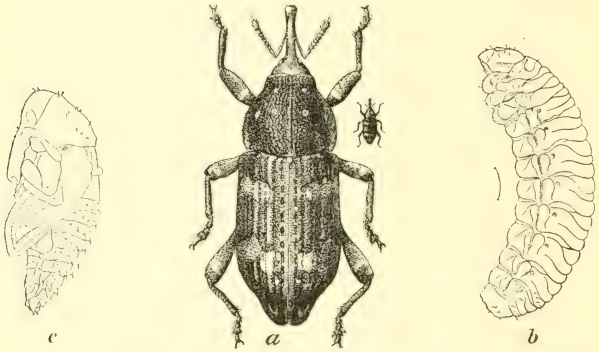


FIG. 150.—White-pine weevil (*Pissodes strobi*): *a*, adult, smaller figure natural size; *b*, larva, line at left natural length; *c*, pupa, small figure of adult showing natural size. (Hopkins, Div. Ent., U. S. Dept. Ag.)

a very pronounced influence upon the other kinds of insects or animals that occur in that region.

The map illustrates its progress from year to year and it is a matter of considerable interest and significance that the northern border of its distribution has remained inside the possible area of cotton growth. It may also be noticed that this line agrees remarkably for the northern distribution of the cattle tick and other insects which are of tropical derivation.

FIG. 151

FIG. 152

FIG. 153

FIG. 154

FIG. 151.—*Hylastinus obscurus:* adult insect—natural size at right. (Webster, Div. Ent., U. S. Dept. Ag.)

FIG 152.—*Hylastinus obscurus:* larva or grub—much enlarged. (After Webster, Div. Ent., U. S. Dept. Ag.)

FIG. 153.—*Hylastinus obscurus:* pupa—much enlarged. (After Webster.)

FIG. 154.—Clover root, showing work of *Hylastinus obscurus.* Slightly enlarged. (After Webster, Div. Ent., U. S. Dept. Ag.)

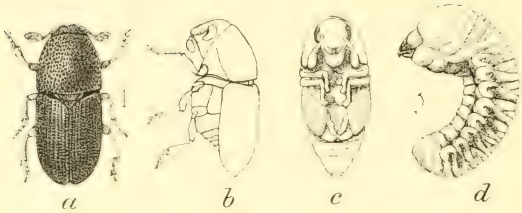


FIG. 155.—*Scolytus rugulosus*: *a*, beetle; *b*, same, in profile; *c*, pupa; *d*, larva. All magnified about ten times. (Bur. Ent., U. S. Dept. Ag.)

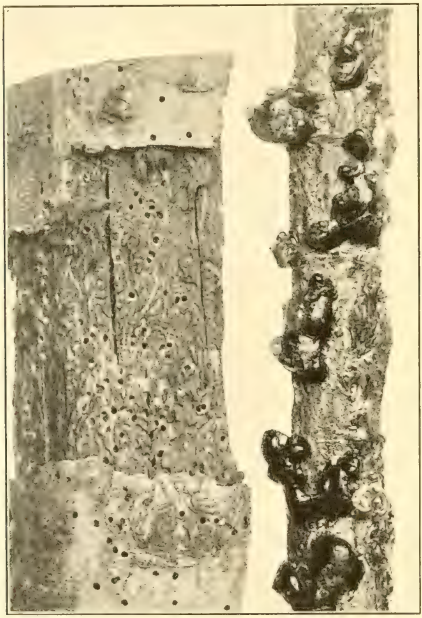

FIG. 156.—*Scolytus rugulosus*. Section of injured tree. (Photo from Ohio Exp. Sta.)

The insect hibernates as an adult and may be carried by shipments of cotton seed or other objects. The eggs are laid on cotton bolls in early summer and the larvæ feed within the bolls, ruining the fibers that would form the crop.

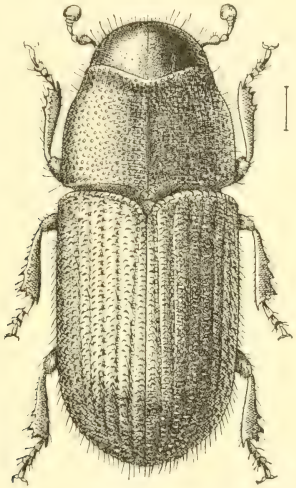

FIG. 157.—*Dendroctonus valens:* adult. (A. D. Hopkins, Bur. Ent., U. S. Dept. Ag.)

Diversified farming, the clearing up and burning of old cotton plants in the fall and early planting are some of the measures used in efforts to control the species.

The white-pine weevil is a destructive species in the pine forests of the Northern States and Canada and occurs southward along the Allegheny range to North Carolina.

**Scolytidæ or Engraver Beetles and Bark Beetles.**—These are interesting because of their forming characteristic mark-

ings between the bark and the wood. They are a great economic pest in forests. The pine forests of Virginia, Georgia, etc., and the Black Hills have been greatly injured.

FIG. 158.—*Dendroctonus valens*: work in bark at base of stump: *a*, entrance and pitch tube; *b*, egg gallery; *c*, boring dust and resin; *d*, pupal cell; *e*, pupa; *f*, larvæ at work feeding on inner living bark; *g*, exit burrows; *h*, resulting old scar or basal wound, often referred to as basal fire wound; *i*, inner bark with outer corky bark removed. (A. D. Hopkins, Bur. Ent., U. S. Dept. Ag.)

One of the destructive species (*Hylastinus obscurus*) is a borer in the roots of clover and occasions much injury to this crop.

**Fruit-tree Bark Beetle** (*Scolytus rugulosus*).– The fruit-tree bark beetle is a common pest of orchard trees and the cause of much injury. Its work becomes apparent in numerous small round holes in the bark. Shot-hole borer is one name for the species, based on this feature.

The species of *Dendroctonus* are mainly destructive to forest trees, and are responsible for extensive inroads on our forest resources.

## CHAPTER VIII.

## LEPIDOPTERA.

The *Lepidoptera* form one of the largest orders of insects including a great number of subdivisions and including some of the most brilliant forms and some of the extremes in size—moths, butterflies, etc. They are separated from all other insects by the mouth structure, it being adapted for lapping up nectar of flowers and this structure being developed largely from the maxillæ, the parts being elongated

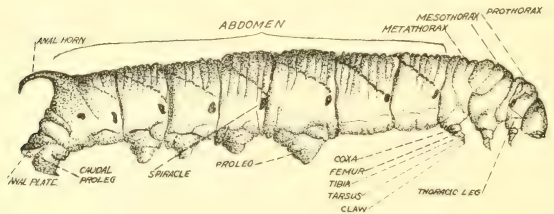


Fig. 159.—Tomato worm (larva of *Phlegethontius 5-maculata*), showing structure of lepidopterous larvæ. (Drawn by J. I. Hambleton.)

and extended for some length when in use and when not in use folded up like a watch spring. Some forms have remnants of rudimentary mandibles but in most cases these cannot be found. When they occur the mouth parts seem to be in their general structure related to the *Trichoptera*. The larvæ are all mandibulate. Another distinctive character is the complete covering of body and wings with minute scales.

The *Lepidoptera* show quite extreme condition in metamorphosis. The larvæ are known as caterpillars. They

usually have a series of prolegs or false legs developed on the abdominal segments. The more common number is ten, four pairs located on the central abdominal segments and one terminal pair. These are not homologous with the segmentally jointed appendages of insects generally. They stand out prominently and are fitted commonly with rows of small hooks or teeth at the margin. The larvæ are elongate and generally cylindrical and are followed by a pupa stage strikingly different from the larval stage and fre-

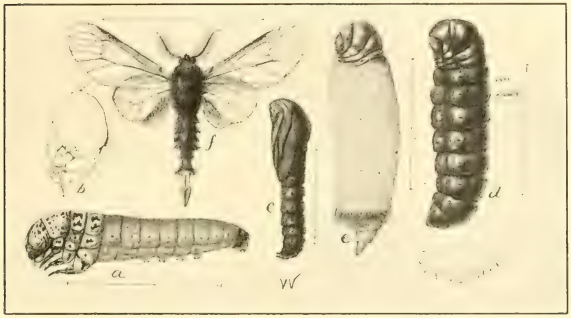


FIG. 160.—Bag worm (*Thyridopteryx ephemeræformis*): *a*, full-grown larva; *b*, head of same; *c*, male pupa; *d*, female pupa; *e*, adult female; *f*, adult male. All enlarged. (From Howard, Div. Ent., U. S. Dept. Ag.)

quently enclosed in a cocoon. This is a quiescent stage. The adult on issuing splits the pupal case along the dorsal portion and crowds its way out.

**Bag-worm Moths.**—Among the lower forms are the bag-worm moths. These are forms in which the larvæ construct a case or bag of bits of leaves or twigs with which to protect themselves. Almost parallel with the habit of the caddice flies. One of the most common is the evergreen bag worm (*Thyridopteryx ephemeræformis*). Its favorite food plants are conifera, red cedar, and arbor vitæ. It occurs com-

monly over a large portion of eastern United States. The bags which are formed by this insect are found abundantly in autumn and winter and early spring attached to the trees upon which they have developed. They may crawl some little distance from the trees and attach themselves to some other object. Each bag is made up of numerous bits of leaf and twig, making a regular structure. These bags in late summer and autumn furnish protection for develop-

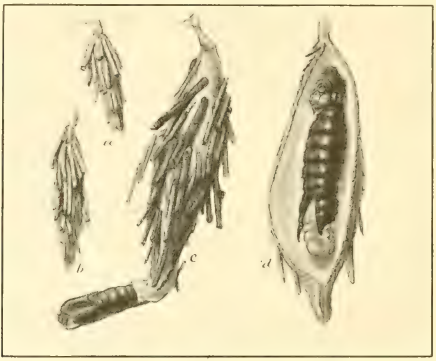


FIG. 161.—Bag worm (*a*, *b*, *c*) at successive stages of growth: *c*, male bag; *d*, female bag. Natural size. (From Howard, Div. Ent., U. S. Dept. Ag.)

ment of the adult. The females remain within the bag. They are wingless and grub-like with very large bodies. The males issue from the chrysalis and fly about with well-developed wings. After fertilization the females deposit eggs within the bag, filling the cavity of the bag with a mass of eggs. This forms the protective covering for the egg mass during the winter. The eggs hatch in the following season and the larvæ begin feeding upon the foliage of the tree and begin the construction of a case or bag almost as

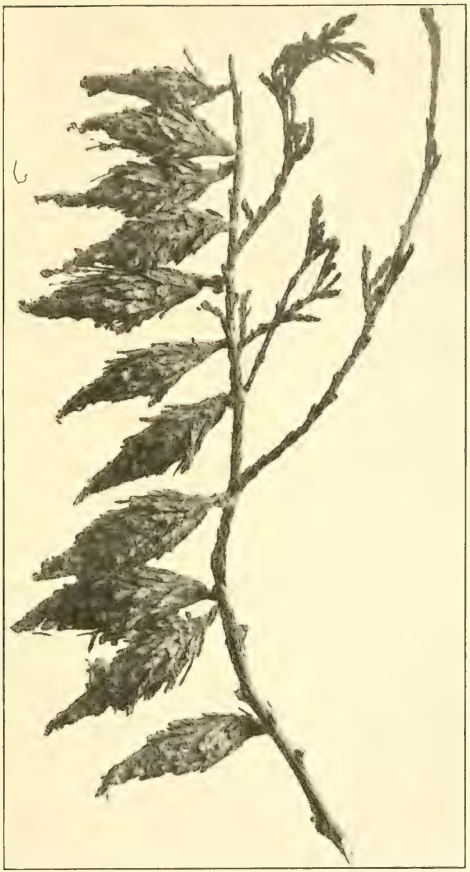

FIG. 162.—Bag worm (*Thyridopteryx ephemeraformis*) cases from cedar tree.

soon as they begin to feed. The bag is made of silk mixed with the bits of leaf, etc., and attached to the twig by silken threads. The metamorphosis to the pupal stage occurs within the case. There is a marked difference in the size, etc., of the males and females in the case. They are a source of injury to evergreen trees, stripping the foliage. They are a little difficult to contend with. Applications of poisonous arsenical solutions to the foliage where they are feeding will kill them. The cocoons may be gathered and destroyed. The migration from tree to tree is limited by the migration of the larvæ, as the females remain in the bag and do not travel about. The migrations of the caterpillars are limited to rather short distances. This is the best-known species of the family.

**Family Cossidæ.**—The family *Cossidæ* is another group presenting adaptations to special food and includes the carpenter moths—characterized by the wood-boring habit of the larvæ. This is a decided departure from the leaf-feeding habit. The leaf-feeding habit is the most primitive condition. They burrow into the heart-wood of various trees.

**Locust-tree Borer** (*Prionoxystus robiniæ*).—The locust-tree borer is the most conspicuous. It occurs in other trees besides the locust. The moths are strong-bodied and resemble the hawk moths in the shape of the body and in the narrow form of the wings. The adults appear in June and July and deposit their eggs upon various trees and the larvæ on hatching begin burrowing into the tree, living at first in the cambium and then burrowing deeper into the woody tissue. The larvæ are supposed to require three years for their growth. The larva is whitish and almost naked with only a few scanty, minute hairs and looks more like the grub of a beetle than like a caterpillar of a moth. It forms a rather large tunnel, the burrow when the larva gets full size being about one-half inch. These burrows frequently permit the entrance of moisture and so start decay and in many cases cause some distortion; they cause trees to break easily. Before changing to the pupal stage they bore out to

the bark, leaving only a thin layer that has to be pushed off by the pupa before issuing as a moth.

In another family, *Pyralidæ*, there is one species, the clover-hay worm (*Pyralis costalis*), which is very destructive. They injure the stored crop of clover. The moths of this species appear in summer, perhaps most abundantly about midsummer. Eggs are deposited largely in the newly stored hay and the larvæ feed upon this hay. Perhaps the majority continue their larval life through the winter—the hay becomes matted and filled with the silken webs they spin and with the black gunpowder-like excrement they discharge.

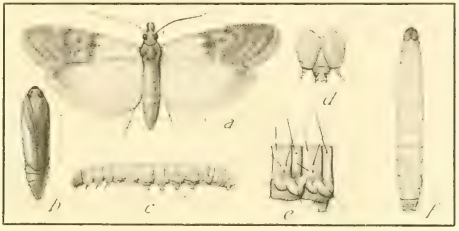


FIG. 163.—Indian-meal moth (*Plodia interpunctella*): *a*, adult; *b*, pupa; *c* and *f*, larva; *d*, head; *e*, first abdominal segment of larva. All enlarged. (After Chittenden, Div. Ent., Bul. 4, n.s., 1896, U. S. Dept. Ag.)

The hay, while not all consumed, thus becomes unfit for stock food. They get their growth in the hay and change to chrysalids and the adults issue and fly about in hay mows and about hay stacks.

Closely related is a species known as *Pyralis farinalis*, which feeds upon stored grain and also upon clover hay. The life-cycle is about the same as of the other species.

**Indian-meal Moth** (*Plodia interpunctella*).—This is another common pest of food substances. It occurs in somewhat the same materials as the saw-toothed beetle. It is quite different, however, the adult being a small moth somewhat similar to the clothes moth in appearance, although larger.

The eggs are laid in the various food substances, breakfast food, seeds, dried fruits, etc., and the larva which is a small, slender caterpillar feeds in this material and usually spins a web as it works so that the food is made quite undesirable. There are usually two broods each year in the latitude of Ohio, but with warmth, the number of generations may be increased to four or five. As with the preceding species, it is possible to sift out the insects from the flour or meal but if infested to any extent their presence is undesirable and infested packages are best returned to the grocer to exhange for fresh material. The prevention of their entrance into the packages of breakfast foods, etc., should be attended to at the mills or packing houses.

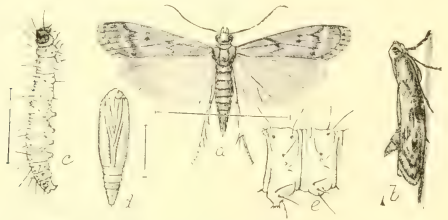


FIG. 164.—Mediterranean flour moth (*Ephestia kuehniella*): *a*, moth; *b*, the same from side, resting; *c*, larva; *d*, pupa; *e*, abdominal segments of larva; *a* and *d*, enlarged; *e*, more enlarged. (After Chittenden, Div. Ent., Circ. 112, U. S. Dept. Ag.)

The direct treatment of these insects in stored products where fumigation is possible is in store rooms, but cannot be done as advantageously as in the mills or warehouses or where the cereals are prepared.

**The Mediterranean Flour Moth** (*Ephestia kuehniella*). — This is a destructive insect, occurring in stored wheat and other grains, and particularly in mills and warehouses, and has now been distributed over all parts of the world where grains and their products are stored. It is one of the most serious pests in the large flour mills of the northern United States, in some cases clogging and stopping the machinery

and causing a considerable loss in the flour, meal, or other products. Its life-cycle is fairly continuous where buildings are warm enough to permit its growth.

The principal methods of control are by means of heat and fumigation. Where a heating system is present, and it is possible to raise the temperature of the building to 125°, this is a most effective plan and requires but a short suspension of the operations of the mill. Where this is not available the use of hydrocyanic gas or bisulphide fumigation is necessary, although frequent cleaning of the building and the careful disposition of insects which are found in the accumulated dust in different parts of the building will serve to keep them in check.

**Bee Moth** (*Galleria mellonella*).—The bee moth gets its name from the fact that it lives in the hives of honey bees. It is confined closely to this habit and all stages will be found in and around the hives. The adults are found during the summer months particularly and are commonly hidden under and around the hives, and if disturbed tend to slip away, crawling into corners or making a short flight to some safe place, almost as slippery as cockroaches. They gain entrance to the hives by slipping in at the entrance, especially if the entrance is not well guarded. they deposit eggs upon the comb doubtless in some corner where the bees are not numerous. The larvæ feed upon the wax and make long burrows around through the combs. According to Comstock, the larva feeds only at night and hides in its burrow during the day. They pupate generally within the hive and upon the tops of the frames or in the corners, and in some cases probably creep outside and get underneath the hive. They spin quite a tough silken cocoon within which they pupate. This stage gives rise later to the moth. There are at least two generations during the season. The first measure in the way of prevention is to keep the colonies in good condition and a part of the treatment may consist in looking over colonies and catching and killing any moths, larvæ, or pupæ that may be observed.

**Close-wings** (*Crambidæ*).—The close-wings are named from the position of the wings, which are folded down very closely at the sides of the body and in many cases they fit so close to the stem on which they rest that the moth is completely hidden. Many of them are light yellowish and straw-colored which blends quite well with the color of the straw or grass on which they rest. The genus *Crambus* includes fifty or sixty species, and most of them are grass-feeding species that are to be considered as distinct pests in pastures and meadows, though they only now and then multiply in such numbers as to attract universal attention. These different species present different life histories and these must be known in detail in order to treat them intelligently. The most abundant species in the Mississippi valley has the following life-cycle. The sod worm occurs in the adult stage about the latter part of May or the first of June and sometimes in very great abundance. They are attracted by light. They deposit eggs at the times of flights and normally deposit these over grass lands, and the eggs are evidently scattered very generally and are extruded singly, evidently with some force. They drop into the grass and on the surface of the ground, and the larvæ when hatched feed at or near the surface or burrow a little below the surface of the ground and form a silk-lined tube in which they live and are protected mostly during the daytime, coming to the surface at night to feed upon the fresh leaves. In this way they cut grass off very near the surface of the ground and it falls down and dries up, and is lost for hay and pasturage. The plants are not killed outright. The effect is similar to that of close pasturing of cows or sheep. If the insects eat down into the ground the grass may be killed. They attain their growth in the course of about four or five weeks and pupate in August and the second generation of moths appears during the middle or latter part of August. These may occur in large numbers if the season is favorable. These deposit eggs and the larvæ from these begin feeding in autumn and become partially grown but do not mature, remaining in the larval stage over winter.

In the following spring they finish their growth, pupating and issuing as moths in the latter part of May or early part of June. If the grass land is plowed and another crop put on it, especially corn, the crop may suffer very severely. The remedy is to plow the ground early enough in autumn to prevent egg deposition. If plowed in the spring, it should be plowed early. They are attracted very generally to light and trap-lights in fields ought to be very useful. In Iowa, where ground squirrels (13-striped squirrels) are common, it was noticed that the pupæ of these sod worms are eaten by the squirrels. They are also parasitized, and this would perhaps help to keep them reduced in numbers.

A species with a remarkably different food habit lives on the maple scale (scale insects) Coccid-eating.

**Family Tortricidæ.**—This family includes the leaf-rollers and bud moths. These are characterized by a broad form of the wing and are distinctly opposed to the slender, narrow wings of the Crambus. The costa is very strongly curved. The mouth parts are not very conspicuous; head small. The larvæ are mainly leaf-rollers and inhabitants of the buds of different kinds of plants. These forms have several injurious species. *Cacœcia rosœana* is quite common and troublesome to florists and rose growers. The insects appear very early in the season. The larvæ begin to work soon after the leaves have begun to unfold. The leaves will be tied together and the larvæ work within this protection and eat away the tissues of the leaf. In some cases they burrow into the opening buds and destroy the blossoms. They attain their growth rather rapidly and form a chrysalis often in the leaves they have tied together and from this the moth issues.

**Codling Moth.**—The worst pest in the group is the codling moth (*Carpocapsa pomonella*). This causes enormous losses to the orchard industry; millions of dollars being lost each year. Its life history is well known and can be found in almost any work on orchard insects, but stated briefly, consists in a spring brood of insects appearing and laying eggs shortly after apple bloom, a first brood of larvæ

is found in early summer, pupation in early July, second brood mates about August first, and second brood larvæ

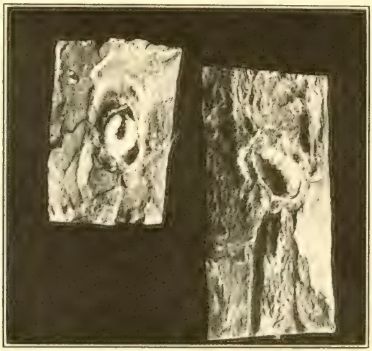

FIG. 165.—Codling moth (*Carpocapsa pomonella*): larvæ in cocoons upon bark of apple tree. (Photo by Ohio Exp. Sta.)

FIG. 166.—Spraying for Codling moth (*Carpocapsa pomonella*). (Photo by Ohio Exp. Sta.)

in fall and early winter. The essential basis for treatment lies in the time and place of egg deposition. The egg is deposited in the calyx of the fruit and the larva burrows into the fruit.

The whole secret of destroying the species is to have the poison applied placed so that it will get into this particular part of the apple and be there when the larva takes its first meal. Proper application of arsenical solution will prevent 95 to 98 per cent. of the injury. Application should be made very soon after the bloom falls while the fruit is still

FIG. 167.—Codling moth (*Carpocapsa pomonella*): young apples in condition for spraying. (Photo by Ohio Exp. Sta.)

open at the calyx end. There are two broods in a season. The larvæ seen in the apples in the winter are the ones from the second brood. They escape from the apples when stored and secrete themselves about the bins and change to pupæ, and the moths are ready to issue early in the spring. The insects may be captured as pupæ at the end of the first brood so as to prevent the issuing of the midsummer moths. This may be done by means of bands around the trees under which the larvæ will crawl to pupate. These bands may be examined every few days and the pupæ crushed.

The process is somewhat slower and less effective than spraying and is now seldom used.

FIG. 168.—Codling moth (*Carpocapsa pomonella*): apples too late for spraying. (Photo by Ohio Exp. Sta.)

A closely related insect, *Carpocapsa saltitans*, is the basis for the popular phenomenon known as jumping beans,

occurring in beans and some other seeds and causing these seeds to jump about in a very peculiar manner. This is caused simply by the jerking movements of the body of the caterpillar within the seed.

**Clover-seed Caterpillar** (*Grapholitha interstinctana*, Clem.). —The clover-seed caterpillar is often a serious pest to the clover seed. Its work, however, is not confined to the seed, but extends to the leaves, stems, or crown, so that on the whole its capacity for mischief is very great.

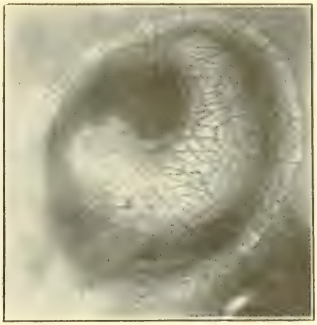

FIG. 169.—Codling moth (*Carpocapsa pomonella*): egg.

The moths are very small and may be generally described as dark brown or nearly black in color. The wing expanse is from 0.31 to 0.36 of an inch. The majority are marked by two small parallel, excurved, short, silvery lines at the middle of the hinder border of each forewing so that when the wings are closed the lines form a double crescent over the back. (See Fig. 167, *c* and *d*). Some, however, are found to have all traces of the crescents obliterated. Eight white silky lines are disposed along the front border of each of the forewings, which in common with the hindwings are delicately fringed. The wings beneath are shining and silky and have a greenish tinge in certain lights.

The larva (Fig. 170, *a*) is a small greenish-white caterpillar with a dark brown head, and is about 0.25 to 0.3 of an inch long when full grown. Many of them become tinged with red toward the hinder extremity as they approach the time of pupating.

The delicate white silken cocoons are spun in the head among the dried florets, grass, and bits of eroded but undevoured flowers, so covering them with brown as to make them difficult of detection. The pupæ work their way entirely out of their cocoons and drop to the ground before bursting their pupal cases, which may be found in abundance on the ground from which a brood has just issued.

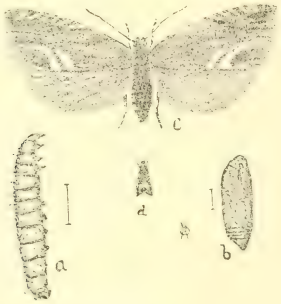


FIG. 170.—*Grapholitha interstinctana:* *a*, larva; *b*, pupa; *c*, adult; all enlarged; *d*, adult—natural size. (After Osborn.)

The remedies for the species are summed up as follows:

1. Rotation of crops, not keeping clover on the same ground over three years, and only two if the field becomes badly infested.

2. That the seed for a new crop be planted on land as remote as possible from old clover fields.

3. That infested fields from which seed is desired the following year be pastured in the fall to take up all late growths and leave the field free from vegetation, and that

no manure be applied at the time to furnish places for the larvæ to hibernate.

4. That clover infested during the spring be cut as early as practicable, while the larvæ are in the heads, handled as carefully as possible to prevent shaking larvæ from the heads and stored in stacks or barns, the larvæ being found to perish under such treatment.

5. When ready to change from clover to another crop plow under some time in October, November, or in early spring burying the larvæ as deeply as possible, and roll or harrow to pack the surface.

Several parasites have been reared which will assist in reducing numbers under ordinary conditions.

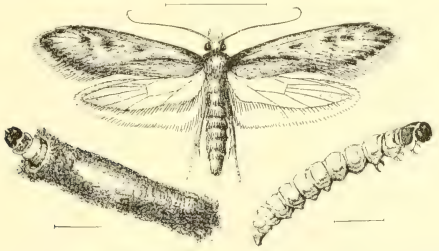

FIG. 171.—*Tinea pellionella:* adult; larva; larva in case—enlarged. (From Riley, Div. Ent., U. S. Dept. Ag.)

**Family Tineidæ.** The family *Tineidæ* includes very minute moths which have slender wings and usually with the wings very broadly fringed, and is a specialization or modification from the typical broader wings. They are very delicate, mostly very minute and the more abundant outdoor forms are leaf-miners, the larvæ living between the epidermal layers of the leaf and feeding upon the pulp of the leaf. Some form galls. The tough part of the leaf is protective at least to a degree. Some also construct cigar-shaped cases and are known as case-bearers. The best-

known species are the clothes moths, and they have quite a specialized food habit, being limited to dry woolen fabrics or furs. There are three common species, one the case-bearing clothes moth, one a naked species, and one the carpet moth which constructs a sort of burrow within the goods. The life histories are similar, adults appearing in spring or summer and the larvæ feeding in the carpets clothing or furs, especially during the summer months. Naphthaline or "moth balls" are a good repellent, cold storage and storage in moth-tight paper cases are helpful.

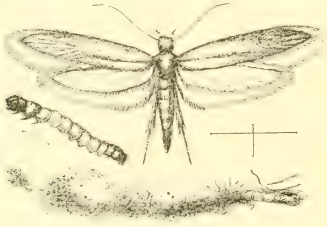

FIG. 172.—*Tinecola biscliella:* moth, larva, cocoon, and empty pupa skin—enlarged. (From Riley, Div. Ent., U. S. Dept. Ag.)

**Sesiidæ.**—These have a rather unusual condition for the Lepidoptera. In many the scales are wanting and the wings look glassy—like wasps' wings. Scales will usually be found on the veins of wings and on the body and legs, those on the legs being quite large. They fly in daylight rather than at night and there are a number of distinctly economic species. The larvæ are borers and live in the wood of trees and sometimes of annuals. The squash-vine borer is often very destructive to squashes, melons, and pumpkins.

One of the most common and destructive is the peach-tree borer (*Sanninoidea exitiosa*). This causes serious damage to peach orchards in the Eastern Central States and southward. The adults vary a great deal in the two sexes. The females are larger and a darker steel-blue with a broad orange-yellow

band about the middle of the abdomen. The males are banded dark and yellow with wings more glassy and body more slender and considerably smaller. They appear in the

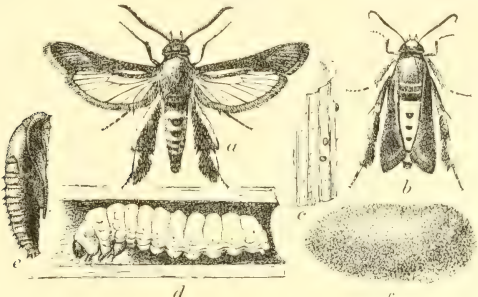


FIG. 173.—Squash-vine borer (*Melittia satyriniformis*): *a*, male moth; *b*, female, with wings folded at rest; *c*, eggs shown on bit of squash stem; *d*, full-grown larva, *in situ* in vine; *e*, pupa; *f*, pupal cell. All one-third larger than natural size. (From Chittenden, Div. Ent., U. S. Dept. Ag.)

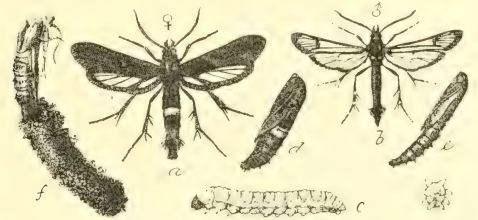


FIG. 174.—*Sanninoidea exitiosa:* *a*, adult female; *b*, adult male; *c*, full-grown larva; *d*, female pupa; *e*, male pupa; *f*, pupa skin partially extruded from cocoon. All natural size. (After Marlatt, Div. Ent., U. S. Dept. Ag.)

adult stage in midsummer, largely in late July or August, and deposit eggs near the ground around the trunks of peach trees and also plum, cherry, and other stone fruits.

The eggs are deposited in crevices or broken places on the bark. The great majority are within six or seven inches of the ground. The larvæ soon hatch and bore into the bark and into the soft sap wood. They live close to the bark for a good share of the time. In some cases they are almost exposed. They do not seem to have developed the habit of boring so deeply as some others. During the autumn they continue this boring, growing somewhat, and hibernating in the larval stage. They go as deep as possible in the winter. In the spring they continue feeding and extend the burrows and complete their larval growth in late spring, mostly during May. They pupate within the burrows and are usually so close to the surface that the pupæ have no particular difficulty in getting out of the burrows when ready to change to adults. The length of the pupal life is not very great. The adults commence appearing in midsummer. There is one generation for each year. Treatment for the species has never been very satisfactory. There is no method known at once cheap and effective that can be easily applied. The most effective plan is that of cutting out the larvæ from the burrows during the early autumn. A recent plan of mounding the trees and using a barrier applied close to the trunk with an adhesive that is pliable and non-injurious to bark, the collar flaring over the mound, is claimed to be effective.

In the same family are the currant-, maple-, and syringa-borers. The food plant is rather restricted usually.

**Handmaid Moths.**—Genus *Datana*, and species *Datana ministra*, have a quite peculiar habit as larvæ. The moths are rather neutral-tinted forms and the larvæ are quite conspicuous with a gregarious habit. They occur commonly on apple trees and other orchard trees, and where there is a nest of them the trees are badly stripped. They cluster in large masses and work in a company. At the periods of moulting they travel down the trunk to within a few feet of the ground and all moult at once and leave a large mass of moulted skins which adhere to the bark. After this moulting they travel back up the tree to the leafy portions and have

another period of feeding. There are probably four or five different moults. At the last moult they are two and a half or three inches in length and about as thick as a pencil. They pupate in protected places and remain over winter in this stage, and the moths issue in the early summer and deposit eggs. They are very easily controlled. When clustered during the moulting periods they may be easily gathered and killed.

**Family Geometridæ.** The family *Geometridæ* includes the loopers. The larvæ have a peculiar arrangement of legs, the abdominal legs being lost, except the last pair, and the movements being made with the thoracic legs.

FIG. 175.—*Palæacrita vernata: a*, male moth; *b*, female moth; both natural size; *c*, joints of female antenna; *d*, joint of female abdomen; *e*, ovipositor—enlarged. (From Riley, Div. Ent., U. S. Dept. Ag.)

**Canker Worm.**—The canker worm is one of the most important of these species economically. These are typical loopers and show some distinct specialization. There are two species closely related, and they are known as the fall and the spring canker worms. The spring form appears as an adult in early spring generally before the foliage is expanded on the trees, and the males and females are very different in their characters. The females are wingless and the males have broad, thin wings. The females can gain access to the trees only by crawling up the trunks, and the possibilities of distribution are limited by the distance which the females can crawl. They usually crawl up the trunks of the first tree they reach. The eggs are deposited on the twigs and hatch about the time the leaves are fairly opened. The larvæ are very destructive. In three or four weeks they

become fully developed, and drop to the ground by means of silken threads. They enter the ground for pupation and remain in the ground in the pupal stage through summer and fall and winter.

The fall canker worm is almost the same so far as the life-cycle is concerned, except that the adults issue in fall. In this species the eggs remain over winter and hatch early in spring. Development is quite rapid and pupating is practically the same as for the other species. The wingless condition, and the fact that they must crawl up the trees, gives one method of treatment. Anything that will prevent their going up the tree will protect the trees. Bands of tar

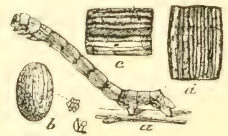


FIG. 176.—*Paleacrita vernata: a*, larva—natural size; *b*, eggs—natural size and enlarged; *c*, side view of segment of larva; *d*, dorsal view of same —both enlarged. (From Riley, Div. Ent., U. S. Dept. Ag.)

or oil on cotton will prevent their getting up the trunk of the trees. Small trees may be sprayed with arsenical solution as soon as they begin work in the spring.

**Noctuidæ** (*owlet moths*) include an immense number of common moths and a number of them very important species. The common name for the larval forms is cut worm. They differ from Geometers in adult characters and the wings are not so broad but fall close together on the back, sloping down the sides of the body. The hindwings are quite large but are not marked. The larvæ are mostly without distinct coverings of hair, usually smooth and some of them subterranean in habit.

One common and destructive species is the boll worm of the South, known in the North as the corn worm or tomato

worm. The larvæ burrow into corn or tomatoes and do a great deal of damage.

Another important species is the cotton worm (*Alabama argillacea*) which causes losses of millions of dollars in the cotton crop of the Southern States. Occasionally extensive flights of the moth bring swarms into the Northern States, and sometimes these adults attack fruits such as peaches, but it is not believed that the larvæ grow on any Northern plant.

FIG. 177.—*Alabama argillacia:* cotton moth on apple. (Photo by Ohio Exp. Sta.)

**Army Worm** (*Leucania unipuncta*).—The army worm is a widely distributed species in this country, only once in twenty or thirty years multiplying in such enormous numbers as to attract general attention. When it does become abundant grass land is stripped entirely of the green leaves and the insects travel into adjacent fields to complete their growth. They travel in immense hordes and devour all vegetation as they go. Normally they are grass feeders and are found in pastures and meadows and only when they are unusually abundant do they migrate into other crops—wheat,

oats, corn, etc., when they may occasion considerable loss. In oat and wheat fields they may simply cut off the heads. The life-cycle of the species is somewhat varied. It has been reported as passing the winter in various stages—egg, larvæ and pupæ. The moths appear in the summer and eggs are deposited in late summer or in autumn and probably a good many of the individuals pass the winter in the egg stage. Others become practically grown and then secrete themselves

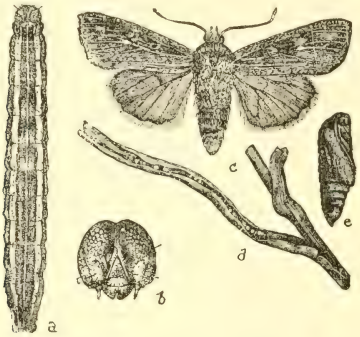


FIG. 178.—The army worm (*Heliophila unipuncta*): *a*, full-grown army worm; *b*, enlarged view of front of head; *c*, parent moth; *d*, eggs in natural position on grass leaf; *e*, pupa; *c*, *d*, *e*, about natural size; *a*, enlarged about one-third. (Rearranged after Chittenden, Bull. 29, Div. Ent., and Comstock, Report of U. S. Ent. for 1879.)

under the surface of the ground and hibernate. Others may reach pupal stage and still others may reach adult stage before winter. The great majority of the larval forms reach their maturity during May and June, and the greatest devastation usually occurs during the latter part of June and early July. Eggs are always laid in grass land and the larvæ begin their growth in the grass. One brood is apparently the rule throughout the northern United States, and the difference in the stages observed during the year

are due to irregularities and not to the appearance of more than one brood. The insect is rather hard to treat economically because of its ordinary grass-feeding habit. When the enormous increase in numbers occurs, the time for checking them is really past. Something can be done for treatment. One way is to use trenching methods for capturing the larvæ as they travel over grass land—trenches put across their line of travel and in this way large numbers may be captured and destroyed. It is also possible to spray the grass in the line of their march with arsenical solutions. These should not be used to pasture stock until the poison has had time to be washed out and no harm will be done. The trenches serve to prevent also the migration into wheat and corn or oat fields if adopted early enough. The species is parasitized quite extensively and when they become abundant the parasites also increase rapidly. Their increase is greater than that of the army worm. In this way there is a great check of the army worm. One of the most important of these parasites is the tachina fly which is closely related to the house fly, blow fly, etc. There are other parasites which are quite valuable also.

**Cut Worms.**—The species known generally as cut worms are distributed through several genera and there are a great many species that occur in pastures and meadows, corn lands, and cotton, some of them are very abundant and destructive and some may be considered as annual pests. They usually live primarily upon grass and in the early spring migrate into gardens and cultivated ground, where their destruction becomes very evident. One of the most important preventives is attention to grass land in autumn adjacent to or upon the area that is to be planted in garden or field crops. Tomato plants may be protected by tin cans, or metal strips bent into cylinders and placed around the plants and the cut worms may be killed by distributing bunches of poisoned clover among the plants to be protected. Some of the species are also attracted to light, and captures of the adults will serve some purpose in reducing the numbers. A feature of the work of cut worms not usually recognized

is the regular loss in grass lands. In autumn and spring they feed on the grass plants and destroy a much larger amount of the growth of the grass than just what they eat themselves. They cut off the grass and it withers and is lost for either pasture or hay. The plant goes on growing and the injury is often unnoticed by the cultivator even where the cut worms occur by the thousands and the pasture lands must suffer a great deal of loss.

The life history varies a little in different groups but most of the species that are troublesome occur in the adult stage in midsummer, depositing eggs which hatch in early autumn, and the larvæ become practically grown and form little cells in the earth where they hibernate through the winter and issue in the spring and feed upon spring vegetation. Then they pupate in the ground in earthen cells and issue as adults in midsummer, any time from the first of June to the first of August. Different species may occur at different dates and in some cases it is important to determine the exact time of appearance for the particular species.

**Tussock Moths.**—The tussock moths come in a different family and one species which is widely distributed is the white-marked tussock moth (*Notolophus leucostigma*). It is pretty troublesome in orchards and on shade trees, and occurs through the eastern United States and west to the plains region. The larvæ drop off from shade trees on the sidewalks and on people who pass beneath. The larva is the most conspicuous form and much more beautiful than the adult. It is about two inches in length with rather bright yellow markings along the sides and with conspicuous tufts of yellowish hairs on the back and three quite conspicuous long black pencils of hairs, two near the head and one on the tail end, several red spots and numerous whitish hairs. This larva when mature constructs a rather loose cocoon and pupates during midsummer and early autumn and in some cases the moths issue in a few days, in other cases not until the following spring. There are two broods in most cases, in others only one. In the case of two broods, those that appear late in the summer deposit eggs which hatch

and the larvæ pupate and the moths appear late in the autumn. There is always an autumn deposition of eggs. The females are wingless and the males are winged with plu-

FIG. 179.—White-marked tussock moth (*Notolophus leucostigma*): larva forming cocoon. (Photo by Ohio Exp. Sta.)

mose antennæ. They are gray in color. The females crawl out of the cocoon and do not leave it. After mating the eggs are deposited on the surface of the cocoon. They make a

large white mass, the eggs being included in a frothy substance which hardens and forms a varnish-like coating which glues them to the cocoon and protects them through the winter. The eggs hatch in late spring or early summer and the larvæ grow, passing through several moults and reaching maturity in midsummer or perhaps a little late in summer. This is an insect that is single-brooded in a Northern locality but may easily become double-brooded in a Southern locality. This species is one for which the means of control may be readily seen. Egg masses are quite conspicuous in the winter and it is an easy matter to gather these in the winter or late fall or early spring, and to destroy them by burning or crushing. The insect's eggs are frequently parasitized by minute hymenopterous parasites which lay eggs in the eggs of the tussock moths. These can be allowed to mature and provide another generation of parasites by putting the eggs where there is no vegetation. The parasites when matured escape and the larvæ of the moths from unparasitized eggs will die.

**Gipsy Moth.**—Closely related is the Gipsy moth (*Porthetria dispar*), an important species from Europe. It was introduced about forty-five years ago (1868 or 1869) and its importation was for experimental purposes and not with malicious intent. Eggs or possibly larvæ may have been blown out of an open window and the species thus given its freedom. It did not attract much attention for several years. It became abundant near Malden, Mass., and in the early nineties became quite destructive and attempts were made to exterminate it. In 1898, when its range had been

LEGEND FOR PLATE.

Gypsy moth (*Porthetria dispar*, Linn). (After Massachusetts State Board of Agriculture.)

*1*, female with wings expanded; *2*, female in resting position; *3*, male with wings expanded; *4*, male in resting position; *5*, pupa; *6*, dorsal view of one of the larger caterpillars, presumably a female; *7*, dorsal view of one of the smaller full-grown caterpillars, presumably a male; *8*, egg cluster on a piece of bark; *9*, a few eggs greatly enlarged; *10*, one egg still more enlarged.

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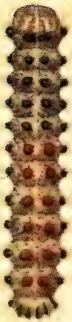

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much restricted, the State discontinued its efforts, and in a few years it had spread over a large area and its extermination was deemed impossible. A few years later State and National efforts for control were inaugurated and have been pushed vigorously in several different ways. The species has caused great losses, and both State and National governments have spent great sums in attempting to keep it from spreading and increasing.

The life history of the species is an important factor in control. The moths appear in midsummer and autumn and the males and females differ in appearance but both have wings, though those of the female are weak and their flight is limited. Distribution of the species by the flight of the females seems to be almost nothing, and the spread of the species is mainly by the distribution of caterpillars. The eggs are deposited in late summer and the egg masses survive the winter attached to trees, bark, etc. They hatch in spring or early summer and the larvæ make their growth during the early summer months. They may be so numerous as to almost completely strip the foliage of plants. At such times the caterpillars make every effort to scatter, attaching themselves to vehicles, etc. There are several parasites for the species, but none which are distinctly effective in this country in keeping the species down. Different methods adopted by the Massachusetts Commission are extremely interesting. A volume has been published on the Gipsy moth. Spraying, burning, scraping of trunks of trees, etc., have all been used. In one instance every inch of an immense elm tree was gone over. Extended efforts have been made to introduce parasites and predaceous enemies to aid in control of the species.

**Brown-tailed Moth.**—Another species of rather recent introduction is the brown-tailed moth which was first observed in Massachusetts in the vicinity of Boston about the year 1890 or 1891. This is a native of central Europe and is particularly common in France and Germany where it is recognized as a destructive species. The female flies readily, and thus it has spread more rapidly than the Gipsy

moth, and now occurs throughout the eastern part of Massachusetts, New Hampshire, and eastward into New Brunswick and Nova Scotia, south and west into Connecticut. It is quite certain to spread by degrees throughout a large part of the entire forested portion of North America. The adults are white with the hinder portion of the abdomen brown. The eggs are laid on trees in small clusters and have a brown appearance. The larvæ hatch in early autumn and the caterpillars become about half-grown before winter and then spinning up in clusters, form a nest of leaves and web in which they secrete themselves for the winter. In spring with the opening of foliage they wander from these nests, attacking the foliage and causing serious injury, completely stripping the trees, so that they may be killed especially if the attack is repeated for two or three seasons. The larvæ complete their growth by early summer, pupate, and produce moths in late summer, thus completing the annual cycle. The larvæ feed exposed on the foliage and may be killed by the arsenical sprays when occurring on orchard or shade trees, where it is possible to reach them with the spraying machinery. An evident means of control is to destroy the overwintering insects during fall, winter or early spring when they should be conspicuous on leafless trees. They are easily shipped from place to place on twigs or small trees and should be excluded by inspection of shrubs, trees, or cuttings that are imported.

While not at present established as pests outside of the New England States, these insects deserve to be watched and particular pains taken to prevent their dispersal. Such watchfulness may serve to greatly retard the distribution and postpone the time when they may be destructive in any particular region.

**Web-worm Moths.**—The web-worm moths are little, white, with femur of front legs of yellow or orange tint, and the legs and feet with little touches of black. These moths are plentiful during the summer—about the last of June. They deposit eggs in masses on the under surface of the leaf. When the young hatch they usually first attack the leaves

on which the eggs were deposited, enclosing it in a web and the whole colony begins to feed on a single leaf adjacent to it. After the first moult they pass to other leaves and include large numbers of leaves and sometimes the whole tree. The entire colony feeds within the silken web. None of them go away to scatter over the tree. There are several moults, about five. They pupate a little later in the season and the adults issue in the following spring. Two broods are known in some localities. It is a great pest in orchards

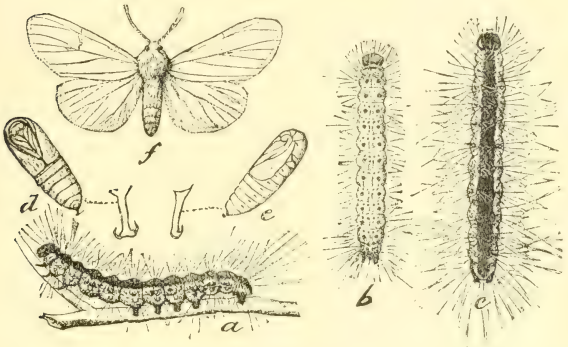


FIG. 180.—The fall web worm (*Hyphantria cunea*): *a*, dark larva from side; *b*, light larva from above; *c*, dark larva from above; *d*, pupa, ventral view; *e*, pupa from side; *f*, adult. All slightly enlarged. (After Riley.)

and occurs on more than one hundred kinds of plants. The web worms are so conspicuous that there is little excuse for neglecting them and clipping off the newly formed web with the end of the twig infested, or crushing or burning the colony is so simple a matter that no one should permit them to multiply.

**Tent Caterpillar** (*Clisiocampa americana*).—This is sometimes called the American tent caterpillar. The Western form is called the Western tent caterpillar. They are more com-

mon in orchards than in forests. They differ from the fall web worm both in life history and in the character of the tent or web and in the habits of the larvæ. The adults are heavy-bodied and hairy, with long slender scales. They

FIG. 181.—Web of fall web worm enclosing colony. (Photo by Ohio Exp. Sta.)

appear rather early in the autumn, depositing masses of eggs in circles around the twigs, usually completely encircling the twig. The eggs are glued together very firmly with a varnish-like substance that covers and protects them for the winter season. The largest part of the time is spent in the egg stage, that is, through autumn and winter and

FIG. 182.—Webs of fall web worm (*Hyphantria cunea*) on defoliated walnut tree. (Photo by author.)

through early spring. The eggs hatch quite early, about the time the foliage expands or a little in advance of the foliage, and the larvæ construct a nest generally in a crotch of a rather fair-sized branch perhaps an inch and a half in diameter. The web fits into the crotch and extends out beyond it. The web is not much increased after first formed. The larvæ scatter when feeding on the leaves and retire to

the tent for protection when not feeding. In this they differ from the fall web worm. They have fairly distinct times of feeding and of resting, the feeding being perhaps more commonly done in the early, cooler part of the day, perhaps more or less at night, and protection in the web being sought in the middle of the day or the hottest portion. They get their growth pretty rapidly, requiring only a few weeks in early spring for their development, and then they scatter mainly

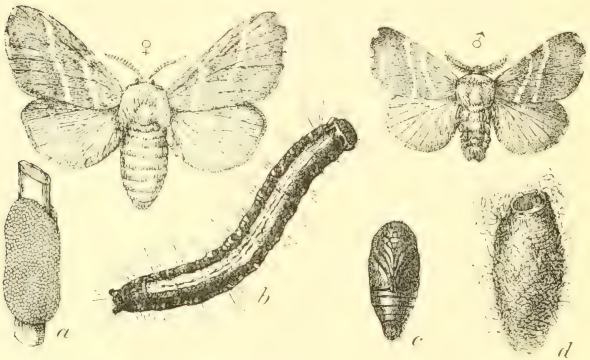


FIG. 183.—Stages of the apple-tree tent caterpillar: *a*, egg mass; *b*, larva; *c*, pupa; *d*, cocoon; ♀, female moth; ♂, male moth. About natural size. (After Quaintance, Div. Ent., U. S. Dept. Ag.)

from the nest and construct cocoons in all sorts of protected places, under bark, under boards, on fence posts, under ground, etc. The cocoon is rather irregular, not very compact and within the cocoon they change to pupæ. This pupation or change to the pupal stage takes place soon after the cocoon is formed. They remain in the pupal stage only about three weeks and then issue as moths, coming out in the summer. They do a great deal of damage which is rather more pronounced because of the early attack on the foliage

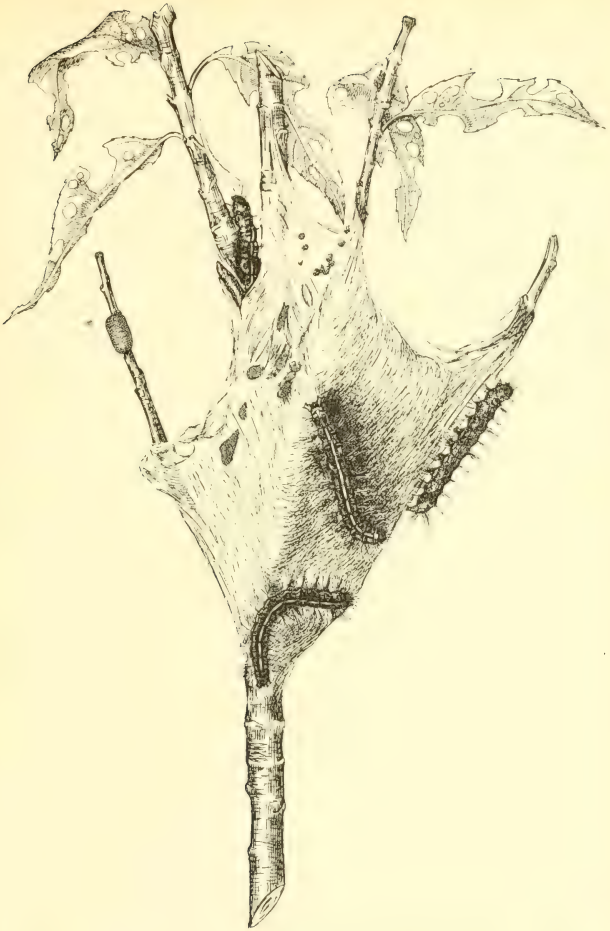

FIG. 184.—Apple-tree caterpillars (*Malacosoma americana*) and "nest;" egg mass or belt on small twig at left. "Nest" considerably reduced; caterpillars one-half natural size. (After Quaintance, Div. Ent., U. S. Dept. Ag.)

before it is fully expanded. A single nest may serve to defoliate an entire tree of ordinary size. The method of destroying them will be a little different from that of the fall web worm on account of the habit of scattering over the tree. To kill the entire colony it is necessary to take the time they are all in the nest, when they can be destroyed as easily as the fall web worm. The best way is to destroy the egg masses. The egg masses are conspicuous enough to be readily seen and by destroying them the injury for the following season can be prevented. They are readily controlled in this manner. When foliage is on the tree the egg masses are not so readily seen. A little attention for a year or two will practically rid an orchard of these pests. They are heavy-bodied and although winged, do not travel far. The moths are a dark gray or slightly rusty brown and are much like a number of other moths. Two light bands extend across the wing a little obliquely to the axis of the wing. These are bordered by a slightly darker stripe.

The forest tent caterpillar is very similar in the appearance of the larvæ and in the building of the tent but differ in the egg masses. The eggs stand straight out; and this species is not so important as the tent caterpillar.

**The Cecropia moth, Luna and American silk worm** are also quite prominent, but are not as important economically as the preceding species. All are silk-making forms, but their silk production does not compare with that of the Chinese worm. The silk worm is the most important insect considered from a stand-point of producing an important product the honey bee is the only other of great importance. The silk industry will perhaps come into greater prominence in this country if labor is cheaper or there is a larger class of unemployed, as it requires a great deal of attention but no great skill of labor. Too much time and trouble are necessary to rear silk worms profitably in a greater part of the United States. In France, Italy, China, and Japan it is a very large industry.

This finishes what are known as the moths proper the Lepidoptera which have antennæ without any knob at the end and which are almost all night-flying.

The next group are day-flying, butterflies, etc., and have a different form of antennæ. The skippers are somewhat intermediate. Their antennæ are slender and run out, sometimes into a hook, or end in a thread-like structure. The butterflies have a thickening at the tip of the antennæ. Butterflies are strictly diurnal and are contained within four or five distinct families. Hesperidæ are intermediate not only in these antennæ but also in the wings. In the

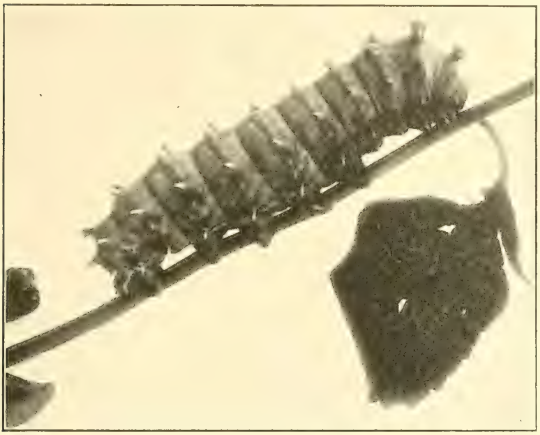

FIG. 185.—Cecropia moth, larva; natural size. (Photo. Ohio Exp. Sta.)

butterflies the wings are folded up vertically over the back. In Hesperidæ they are about half and half. Some fly at twilight—the yucca-borer—others in the daytime.

*Superfamily Papilionidæ* includes the swallow-tailed family. There is a tail-like appendage on the hindwings, which varies considerably in different species. The larvæ are most of them characterized by the presence of peculiar fleshy organs which are projected from the segment behind

the head. This fleshy organ is thrown out when they are irritated. It gives off a very peculiar odor characterized by some as like the flavor of ripe peaches. This is presumably a protective device. The caterpillars are many of them banded distinctly and others have rather neutral colors and eye-like spots on the body. A large black form with yellow stripes on the wings is one of the most common here. In the South it feeds on the orange and is known as the orange dog. In Northern localities it feeds on the prickly ash and the pawpaw. The caterpillar of this species, *Papilio cresphontes*, has much the appearance of the excrement of birds. In most of the Northern States the species is rather rare, but in the South is quite abundant.

**Pieris rapæ**, in the family *Pieridæ*, is the common cabbage worm or cabbage butterfly. This species was introduced from Europe into America some forty or fifty years ago, probably in the vicinity of Quebec, and has spread over all the eastern United States and practically over all the country. Its life-cycle is pretty definite and the broods are pretty well marked, there being two broods each year. Starting with the adults that appear in spring or early summer, eggs are laid on cabbage or other cruciferous plants and after hatching from the eggs, the larvæ develop by midsummer and adults of this generation lay eggs that hatch the latter part of July or in August and develop during August and September or October. This brood feeds particularly on the cabbage heads which may be tunneled through quite well into the interior or at least well through the outer leaves, damaging them for use. The larvæ are green in color and well protected either outside or inside of the leaves. The larvæ develop through autumn and mature by cold weather by the time that the plants give out and then change to pupæ, the chrysalids being formed in fence corners, sides of buildings, and other protected places. Sometimes they get into buildings and sometimes simply under rubbish. They are likely to travel considerable distances from the plants on which they have fed. They pass the winter in this stage and the butterflies issue in spring and deposit eggs for the first brood

of larvæ upon any of the crucifers available. Early cabbages may be attacked, the larvæ feeding simply on the leaves. Eggs are commonly deposited on wild mustard, etc., and the larvæ develop on these plants. The pupal stage for the first brood is quite short, about two weeks to twelve days. There is enough variation in the time of appearance, so that the butterflies may be present for three or four weeks in both spring and summer, and so they are to be found pretty well through the summer months up to the middle of August or the first of September. The great bulk of them come at about the time vegetation is opening up and again about the first of August. The species is not very easily controlled. It lives on a variety of food plants and is two-brooded and this helps in sustaining it. If the first brood could be destroyed it might be controlled, but it is hard to do this. Trap crops may be planted, as mustard, etc., and then the entire crop destroyed after the eggs are deposited on it. Butterflies can be captured while depositing eggs, a cheaper method than applying insecticide. Remedies can be applied to the cabbages, especially before they have headed without any danger to the eating of the cabbages after they have grown. It should be done with precaution, especially after the cabbages have reached some size. If the solution is the right strength, there is practically no danger, as twenty-eight cabbages would have to be eaten at one meal to poison a person. The best way is to apply poison before the cabbages are headed out. If the treatment is pretty thorough for the first brood and the early part of the second, the effect will be pretty successful. Gathering of the pupæ is possible, but is not practicable on a large scale. It is better not to destroy these, but to pass them into a receptacle with a wire screen so that the parasites may escape while the butterflies do not. The parasites are sometimes abundant and greatly reduce the numbers and in some seasons render the use of remedies unnecessary.

**Alfalfa Caterpillar** (*Eurymus eurytheme*).—The alfalfa caterpillar is a common species over most of the United States and has attracted attention as a serious pest in the

alfalfa-growing districts of the West and Southwest. In the Eastern States it is less abundant but still plentiful enough,

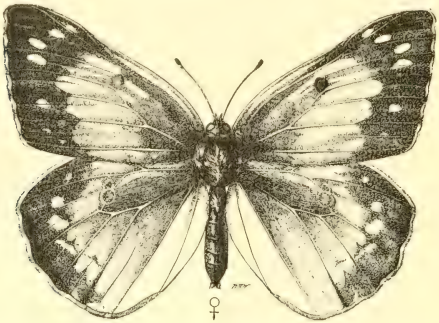

FIG. 186.—The alfalfa caterpillar (*Eurymus eurytheme*): female in the adult or butterfly stage. One-half enlarged. (After Wildermuth, Bur. Ent., U. S. Dept. Ag., Fig. 2.)

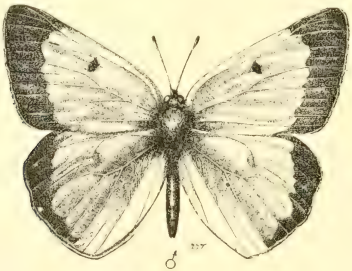

FIG. 187.—The alfalfa caterpillar (*Eurymus eurytheme*): male in the adult or butterfly stage. One-half enlarged. (After Wildermuth, Bur. Ent., U. S. Dept. Ag., Fig. 3.)

so that it must have an effect on the clover crop on which the larva feeds.

In the Eastern Mississippi Valley and Atlantic Coast States it is perhaps less common than the related sulphur butterfly, *Colias philodice*, which is so plentiful as adults that it is fair to assume an abundant progeny feeding in clover fields.

FIG. 188

FIG. 189

FIG. 188.—The alfalfa caterpillar: egg—greatly enlarged. (After Wildermuth redrawn from Scudder, Bur. Ent., U. S. Dept. Ag., Fig. 4.)

FIG. 189.—The alfalfa caterpillar (*Eurymus eurytheme*): larva or caterpillar stage—about twice natural size. (After Wildermuth, Bur. Ent., U. S. Dept. Ag., Fig. 1.)

FIG. 190.—The alfalfa caterpillar (*Eurymus eurytheme*): pupa or chrysalis stage—twice natural size. (After Wildermuth, Bur. Ent., U. S. Dept. Ag., Fig. 5.)

**Monarch Butterfly** (*Anosia plexippus*).—The monarch butterfly (family *Danaidæ*) is interesting in two or three ways, though not of any special importance economically. It is one of the largest butterflies outside of the Papilios, and it

is pretty readily recognized by the dark reddish-brown color with black bands and stripings and the border including a number of white spots. It deposits eggs on milkweed as its host plant. These eggs hatch very shortly and the larvæ develop during the latter part of the summer and pupate and become adults in autumn, and it is quite common in October to see immense swarms of these butterflies. They gather along hedge rows and on trees, sometimes appearing by millions. Late in the afternoon they will cluster on the branches in immense numbers. At the time of their gathering in immense numbers they seem to have a general southerly movement and they are known to migrate at least to some extent during the autumn, though the migrations probably do not cover as long distances as that of birds—not over 200 to 500 miles. They appear in great abundance in the South in the winter. It is not possible to follow individuals for very great distances, but evidently they hibernate in the adult stage in the South and it is pretty generally believed that the hibernating individuals in Northern localities are likely to perish. Individuals that start the first generation must have travelled from the South. The spring individuals are frayed and give evidence of having travelled some distance. The spring-appearing individuals deposit eggs and from these the generation of caterpillars comes that mature during midsummer. The adults appear in the latitude of New York about the middle or last of July. There are two distinct generations for each year. The caterpillar is quite prominently banded and has some striking thread-like appendages. It reaches the length of one and a half or two inches and is nearly as thick as a pencil. It is found particularly on the milkweed. Their pupation occurs by attachment to the leaves of the milkweed or plants or objects convenient or adjacent to the host plant. The pupa cases are attached by a sort of spur or hook at the posterior end of the body caught into a little web that has been spun on the leaf. The larvæ locate on a suitable object and spin a little web and then the larva contracts and the larval skin splits along the back and this larval skin is held by the pos-

terior segment in such way that it can twist the pupa case around and catch the hook of the pupa case into the web. The pupa case lasts only a week or ten days and then gives rise to the adult form. It is mimicked by a species which has an additional black band on the hindwing and there are differences in the legs. This, the viceroy (*Basilarchia archippus*) has evidently gained protection by taking on the appearance of the monarch.

One other species in the family *Nymphalidæ* that should be noticed is the common mourning cloak vanessa (*Euvanessa antiopa*) which is interesting because of its very wide distribution and its very great hardihood. It is said to occur over practically all of the northern hemisphere from 30° to the Arctic Circle. It occurs here in the winter time, hibernating as an adult and has been found secreted in hollow logs, bridges, and in almost any sheltered place, and if taken indoors will revive and feed on sweetened water quite readily. They begin to fly quite early in the spring. It is double-brooded—the eggs deposited in early spring produce larvæ which mature in midsummer. They breed on willow particularly and the larvæ are dark-colored and rather conspicuous. They also infest poplar, elm, and dogwood, but willow seems to be the favorite. The chrysalis is attached to the twigs of these plants and the adults appear in midsummer. These adults deposit eggs and a second generation appears in autumn which hibernates and carries the species over winter. In some places they have an economic importance, but ordinarily they are not a serious pest, and the butterfly is such a handsome species that it may be counted as deserving immunity.

# CHAPTER IX.

## ORDER DIPTERA.

This is a very large and important order and includes a number of important economic species such as the house fly and the mosquito. They are separated from all other insects by the wing structure, the front wings only being fully developed as means of flight and the second wings being modified into knob-like structures which seem to have some use in sustaining the insect in a certain position. They vibrate but cannot serve any distinct function as a means of flight. They are modified wings. This is a case of specialization, reduction in size. This is coördinated with the centralization of the nervous system. There is distinct metamorphosis whose stages are usually sharply marked. The larvæ are usually called maggots, those of the mosquitoes "wrigglers." The larvæ occur in all manner of situations. Some are aquatic, some terrestrial, some subterranean, etc. The group is separated mainly by larval characters—one group including mosquitoes and gnats, another the more specialized flies. The larva contracts and the skin hardens and forms a pupal case whose end splits off like a cap.

The Orthorapha, mosquitoes and gnats, are the less specialized or the more primitive group.

Of the groups in the first series the mosquitoes (*Culicidæ*) are the most in evidence, if not the most important, and are receiving more attention lately because of their association with the transmission of various diseases. The mosquito is not a single species. There are a great many different species and they differ a great deal in life history and habits and in their relation to disease. The most general statement to be made regarding their cycle is that the eggs

are deposited on the surface of the water and perhaps in some species in mud or damp earth. The larvæ are essentially

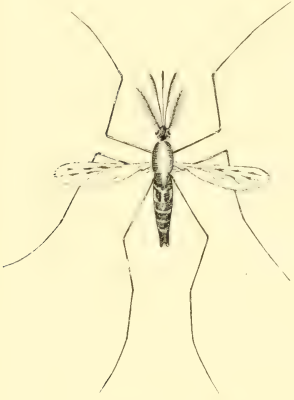

FIG. 191.—*Anopheles maculipennis:* male. Carrier of malaria. (Harrington.)

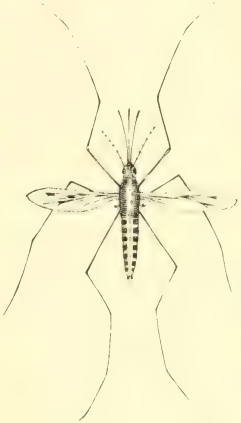

FIG. 192.—*Anopheles maculipennis:* female. Carrier of malaria. (Harrington.)

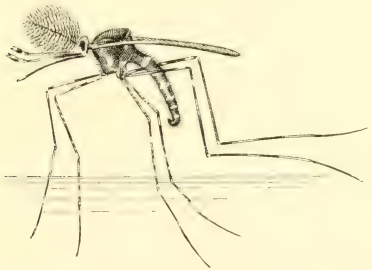

FIG. 193.—*Anopheles punctipennis:* male. Carrier of malaria. (After Howard.)

aquatic and air-breathing, with the trachea opening at the end of the abdomen. The pupæ are also aquatic but keep near the surface and spiracles open near the head. The pupa case splits on the dorsal side and the mosquito rests on the

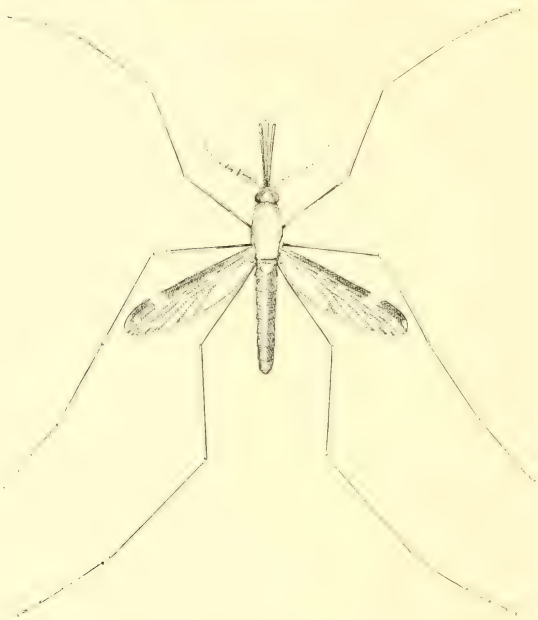

FIG. 194.—*Anopheles punctipennis:* female. (From Howard, Div. Ent., U. S. Dept. Ag.)

surface of the water until its wings are dried enough for flight. One species has been observed whose eggs may remain over winter in mud, and hatching and development depends upon the presence of water. Mosquitoes breed in minute quanti-

ties of water if they have it for a few days, and especially those that are more common about towns depend on small pools, tanks, and rain barrels rather than larger bodies of water. More breed in small pools than large, because there are usually no fishes in the small pools. They fly for a few rods but for no extreme distance—one-half mile or a mile.

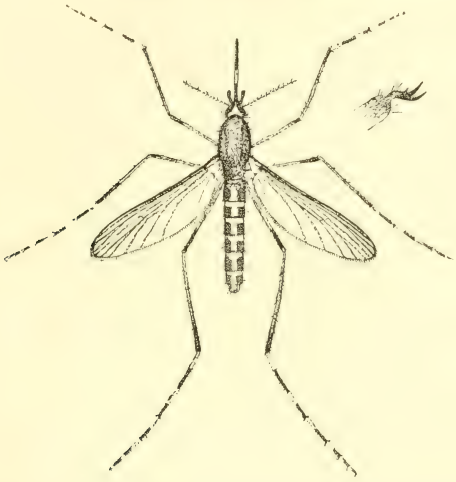

FIG. 195.—*Culex tæniorhynchus:* female showing the short palpi which distinguish *Culex* from *Anopheles;* toothed front tarsal claw at right—enlarged. (From Howard, Div. Ent., U. S. Dept. Ag.)

They may be transported, but most annoyance comes from those bred close at hand. The connection between mosquitoes and malaria has been fully established. The parasite seems to be dependent upon two distinct hosts. Unless there is a case of malaria in the near vicinity they cannot communicate it to another. The relation of mosquitoes to yellow fever has also been worked out very carefully. One

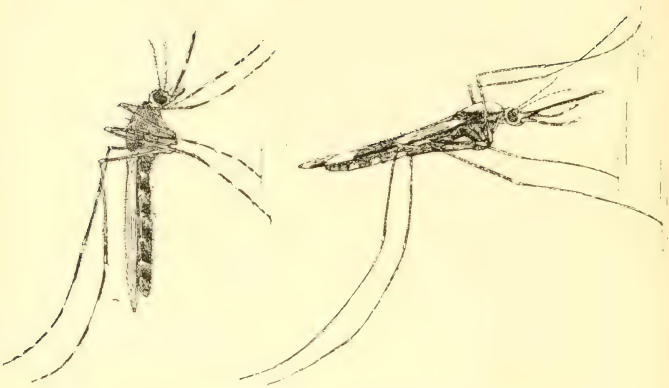

FIG. 196.—Resting positions of *Culex* (at left) and *Anopheles* (at right)—enlarged. (Redrawn from a rough sketch published in the *British Medical Journal*.) (From Howard, Div. Ent., U. S. Dept. Ag.)

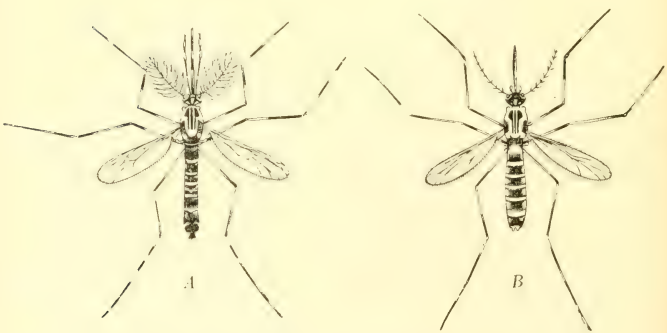


FIG. 197.—Yellow-fever mosquito (*Stegomyia fasciata*): *A*, male; *B*, female. (After Howard.)

striking thing is the discovery of the immense number of species of mosquitoes. There have been many new species discovered in the last few years.

**Gnats** (*Chironomidæ*).—Gnats are related to mosquitoes and are interesting partly because of their close resemblance to mosquitoes and partly because they occasionally multiply so as to cause annoying contamination of reservoirs or obstruction in water tanks. The antennæ are plumose as in the mosquitoes but the mouth parts are different. The larvæ are more distinctly aquatic than the mosquito larvæ—can survive down in the water without coming to the surface for air. Some live in mud—slender red, worm-like creatures. One species is quite plentiful in the Northern States especially near lakes and sometimes as abundant as the May flies.

**Gall Gnats.**—The next group is the one including the gall gnats. It is a very important family with two or three very important species. The most conspicuous of the galls produced by these is the cone gall produced on willow trees—the pine cone willow galls. These are the result of the work of the larvæ of the gall gnats. They are made up of a series of leaves which overlap in the form of a pine cone. These correspond with the leaves that would have come out along the twig had it grown out normally. The leaves are developed close together and the larvæ of the gall gnat is found in a little cell in the centre of the gall. It issues in the spring and deposits its eggs in the willow buds before the twigs have started to grow, and the larvæ hatch and form the galls by feeding. There are a good many things in these galls besides these larvæ. Other insects find them a convenient shelter, and other insects deposit eggs there. The tree crickets are an example of this. These may be a little misleading but they have nothing to do with the formation of the gall. The pine cone gall is most conspicuous. There is another species which simply produces an aborted growth that looks like Brussels sprouts.

The other species in this family to be mentioned are the clover and wheat midges and the Hessian fly.

**Clover-flower Midge** (*Dasyneura leguminicola*).—The clover-flower midge lives within the heads of clover and feeds upon the clover bloom and seed. Its life-cycle is adapted to the

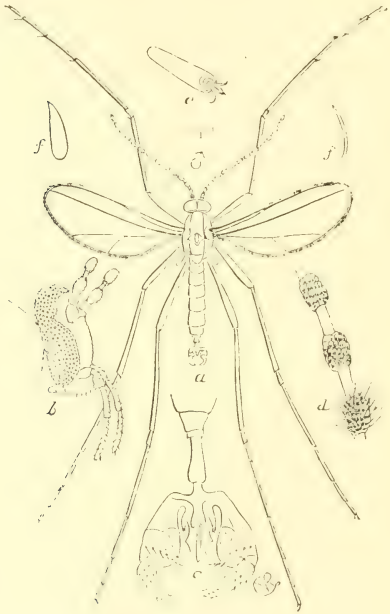


FIG. 198.—The clover-flower midge (*Dasyneura leguminicola*): *a*, enlarged dorsal view of male with scales denuded; *b*, head; *c*, genitalia; *d*, antennal joints, more highly magnified, to show structure; *e*, tarsal claw; *f*, *f*, forms of scales. (From Riley, Div. Ent., U. S. Dept. Ag.)

blooming of the clover, so that the larvæ appear at the proper time for feeding upon the clover seed. There are two fairly distinct broods each season, the first brood of larvæ develop

in early summer and mature in midsummer, the larvæ issuing from the clover heads and pupating in the ground and the second brood appearing later in the summer and depositing eggs which produce the second generation of larvæ which develop in the later blooming clover. These hit the crop of clover grown for seed. They mature with the late autumn and either maggots or the mature puparia would be found during the winter time and the larvæ particularly which are caught before they have completed their growth may be included in clover seed. The fully developed larvæ pass into the pupa stage at the surface of the ground. It is doubtful if the midge can be transported from one place to another by means of the clover seed. Just how it is introduced into remote districts is uncertain. Its means of locomotion is by its own flight. It is pretty generally dispersed throughout the portion of the country where clover is now grown. The means of treatment would lie more in the direction of cutting the clover at the time to cut short the growth of the larvæ—a little earlier cutting of the clover, catching the larvæ before they have issued from the clover heads.

**Hessian Fly** (*Mayetiola destructor*).—The Hessian fly is the most destructive of the family. It is an introduced species and was first described from materials in this country in 1820. It probably originated where wheat did. It was never described scientifically until by Say. It had been known as a destructive insect earlier than 1820 and the name was given to it about the time of the Revolution, when the Hessian soldiers were in this country, either because the insect was thought to have been introduced by them or as an obnoxious name. The name was adopted over the entire English-speaking world. The evidence that it is an old-world species is from its food plants and that it spreads from one centre. There are a number of other evidences. Its natural food plants seem to be limited to wheat, rye, and barley, though there is a question as to barley. It was proved by a Frenchman that it does not occur on oats. At one time it was thought to breed in various grasses, but later

studies show that this was not the true Hessian fly. If any attempts are made to control it by rotation of crops its restriction of food plants should be well known. Its life-cycle is quite similar to that of the clover-flower midge and it has become very distinctly adapted to the crop it infests. Any great change in ordinary methods of raising wheat would likely prove destructive to the insect. The winter is

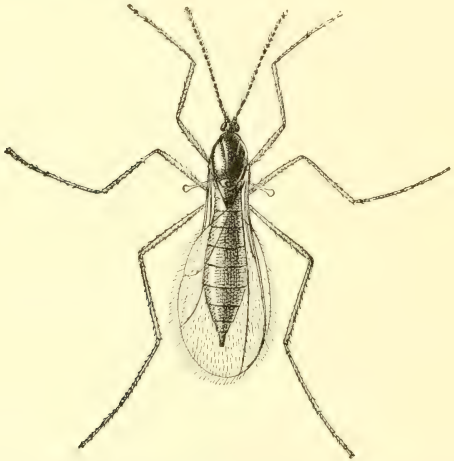

FIG. 199.—The Hessian fly (*Mayetiola destructor*): adult female—much enlarged. (After Webster, Div. Ent., U. S. Dept. Ag.)

passed in the flaxseed stage—the puparium stage. The larval skin shrinks and forms a tough, dark brown covering about the size and shape of a flaxseed. Within this there is formed a real pupa that has the outline and features of the adult insect. There is a distinct metamorphosis. These hibernating puparia give rise in early spring to adult midges that deposit eggs on the stems and leaves of wheat plants—

winter wheat. In spring wheat regions the flies appear at about the time of the coming up of the wheat and deposit eggs on it. There is not necessarily much difference in the time and method of deposition except that those on winter wheat are apt to be a little higher on the stems and farther from the ground. These burrow into the stem in such a way as to cause weakening of the stalk, which is apt to bend

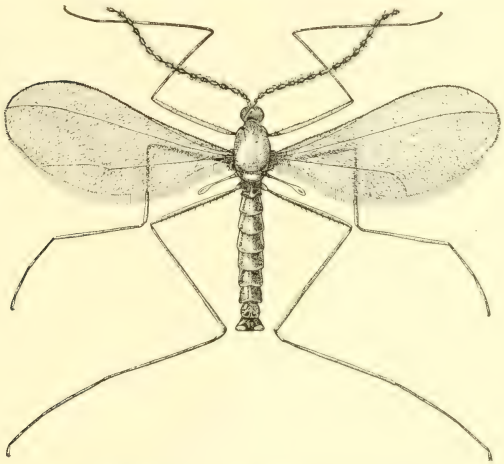

FIG. 200.—The Hessian fly: adult male—much enlarged. (After Marlatt, Div. Ent., U. S. Dept. Ag.)

and break as it approaches maturity and falls to the ground, so that it cannot be harvested. Sometimes only 1 or 2 per cent. of the field will be infested and in other fields one-third or one-half of the crop will be lost. As the wheat matures the larvæ mature and change to the flaxseed stage and remain protected between the sheath and the stem of the plants down near the ground. Sometimes they are high

enough to be cut off and carried with the straw when the wheat is harvested, but more commonly are left in the

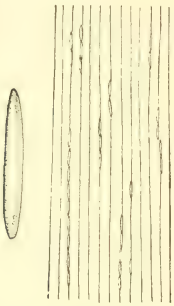

FIG. 201.—Egg of Hessian fly—greatly enlarged; section of leaf of wheat, at right, showing eggs as usually deposited, less enlarged. (After Webster, Div. Ent., U. S. Dept. Ag.)

FIG. 202.—The Hessian fly: larva before "flaxseed" is formed—much enlarged. (Webster, Div. Ent., U. S. Dept. Ag.)

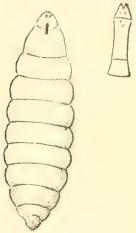

FIG. 203.—The Hessian fly: larva taken from "flaxseed," much enlarged with "breast-bone" still more enlarged at right. (After Webster, Div. Ent., U. S. Dept. Ag.)

FIG. 204.—The Hessian fly: puparium or "flaxseed," much enlarged. (After Webster, Div. Ent., U. S. Dept. Ag.)

stubble. They survive the midsummer in this condition and are apparently dependent more or less on conditions of

temperature and moisture. They come out in the fall and are ready to deposit eggs on wheat plants accessible in the

FIG. 205.—The Hessian fly: pupa taken from "flaxseed," greatly enlarged. (After Marlatt, Div. Ent., U. S. Dept. Ag.)

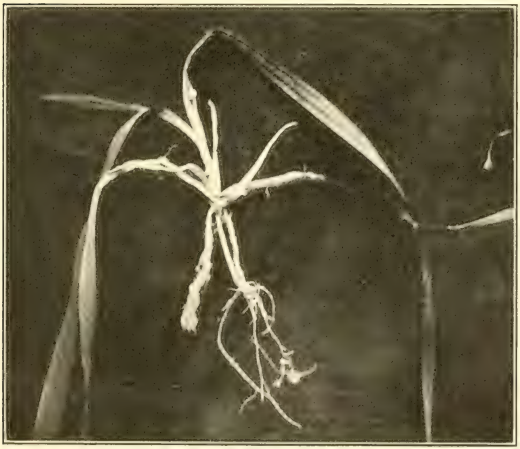

FIG. 206.—Injured plants and flaxseeds. (Photo by Ohio Exp. Sta.)

autumn. The eggs deposited in the autumn give rise to larvæ which develop and pass into the flaxseed stage to hibernate. If they are accelerated in their development and are provided with food material—volunteer wheat—there may be one or more extra broods in the summer. As high as five or six extra broods were observed by Marchal. There are ordinarily two broods adjusted to the occurrence of young wheat plants. One important thing is the distribution of the species by means of the shipping of infested straw. This must be the main or only means by which the species is taken from one country to another. It has been introduced into most wheat-growing countries of the world. The natural distribution of the species is limited to about 20 miles a year. Flight aided by the wind might carry it some little distance. For local measures attention to the stubble is one of the most important things. If it is thick and dry enough to burn over during midsummer, it can be destroyed in this manner. Plowing under very deeply is another method but must be done early enough to bury the stubble before the flies have issued. The most generally practised method, and most highly recommended, is to adjust the time of planting so as to avoid the period of egg deposition. If the time of planting wheat can be deferred for a week or two after the appearance of the flies, it will escape. Flies will not deposit eggs on the bare plowed field. If the wheat comes up after the flies have issued and passed the egg-laying period, it escapes attack. For the Central States the time of appearance has been pretty definitely determined, and it has been shown at what time wheat can be planted with the greatest security. For the latitude of Columbus, Ohio, it is about the first of October. It is possible to plant trap crops so as to catch the flies as they appear and the whole crop can be plowed under after the eggs are deposited on it. This is not particularly popular. If planting is done with reference to temperature and to different seasons, results will be better. Hot, dry weather seems to prevent the issuing of the flies.

**Family Simuliidæ.**—The family *Simuliidæ* includes the black flies and buffalo gnats. These constitute extremely

injurious pests and occasion many losses to agriculturists, so that they deserve a paragraph at this point, although for most of their existence they have very little in common with farm life. They have had an added interest in recent years on account of the effort to prove them the carrier of the disease known as pellagra, but proof of such a connection is still wanting. The adults are short, small, thick-bodied insects; the thorax especially heavy, and the humped appearance of the whole body has given rise to the name buffalo gnats. They are all small species, scarcely any of them a quarter of an inch in length. The larvæ are distinctly aquatic, usually living in swiftly running water. They are so fully adapted for aquatic life that they attach themselves by silken threads to submerged objects and depend for their food upon minute organisms floating or swimming in the water. The pupal stage is also passed under water, a thin cocoon being spun upon the under side of the leaf or other submerged object. When the adults emerge from these they rise rapidly to the surface of the water, the wings expanding promptly, and they are ready for flight almost instantly. At times they occur in enormous swarms and the females are very blood-thirsty, attacking all kinds of warm-blooded animals, sometimes with very disastrous results. In the Northeastern States and in parts of Canada, especially in Labrador, there is a species known as the black fly. They occur at times in such abundance as to make it practically impossible to remain out of doors, and domestic animals will seek any possible shelter in order to avoid the attacks of the insect. In the Southern Mississippi Valley there are two common species which have been studied in detail. One of these, the turkey gnat, is said to make its attacks very generally upon poultry, although it is not limited to these animals.

The other species which is credited with the greatest amount of loss in the Mississippi Valley region may be considered somewhat in detail and as a representative for the family.

**Southern Buffalo Gnat** (*Simulium pecuarum*, Riley).—The investigations of 1885–86–87, which have been reported very

fully in the Department publications, and from which the statements here made are mostly compiled, have shown that the extent of territory invaded by these insects is much greater than formerly supposed. It may be stated to comprise, in the worst years, the whole of the Mississippi Valley from the mouth of the Red River, in Louisiana, to St. Louis, Mo. All the adjacent land to the many rivers and that empty from the east and the west into the Mississippi River

FIG. 207.—*Simulium pecuarum:* larva—enlarged. (From Annual Report of Department of Agriculture, 1886.)

is invaded by swarms. They are driven about by the wind and reach points far away from their breeding places.

The extent of the losses due to this species has already been stated, though it is, of course, impossible to separate the losses due to this species from those caused by the turkey gnat. In a general way the latter may be said to be more destructive to poultry, while the attacks of this species are more particularly directed against the larger domestic animals.

The larva is not differeint in general appearance from that of other species. The annexed cut (Fig. 207) shows it considerably enlarged and will make a detailed description unnecessary. It is translucent when living; the body in

FIG. 208.—*Simulium pecuarum:* head of larva: *a*, beneath; *b*, side; *c*, above—greatly enlarged. (From Annual Report of Department of Agriculture, 1886.)

FIG. 209.—*Simulium pecuarum:* pupa—enlarged. (From Riley.)

FIG. 210.—*Simulium pecuarum:* female, side view—enlarged. (U. S. Dept. Ag.)

some individuals is without markings, while in most it is distinctly marked with dark cross bands on the back in the middle of the joints, while at each side is a white space; the under side is more or less irregularly spotted with brown.

The head is yellowish-brown, nearly square, horny, and marked as in the figure (Fig. 208).

The tip of the abdomen is crowned with rows of hooks, and on the upper side of the abdomen is the set of breathing organs, which have been mentioned heretofore.

The larvæ are found more particularly attached to submerged logs, wholly or partly submerged stumps, brush, bushes, and other like objects in the larger creeks and bayous of the region to which they are common.

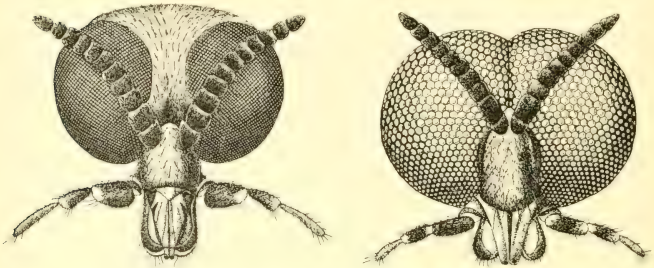

FIG. 211.—*Simulium pecuarum:* head of male at right; head of female at left—greatly enlarged. (From Annual Report of Department of Agriculture, 1886.)

When fully grown the larvæ descend to near the bottom of the stream, sometimes eight to ten feet, to make their cocoons.

The cocoon upon these leaves is conical, grayish or brownish, semitransparent, and has its upper half cut square off, more or less ragged, as if left unfinished. Its shape is irregular, the threads composing it very coarse, and the meshes rather open and ordinarily filled with mud. They are not always fastened separately, but frequently crowded together, not forming, however, such coral-like aggregations as in some of the Northern species. The larva in spinning does not leave its foothold, but running in the centre of its work, uses

its mouth to spin this snug little house. In it, it changes to a pupa, which has its anterior end protruding above the rim.

They remain in the pupa state but a short time. Both larval and pupal skins remain in the pouch for some time.

The adult fly on emergence from the pupa rises quickly to the surface, and the wings expanding almost instantly, it darts away.

The time of the appearance of the swarms is regulated by the earliness or lateness of the spring, and consequently it is much earlier in the southern parts of the Mississippi Valley. As a rule they can be expected soon after the first continuous warm weather in early spring. In 1885 the first swarms were observed in Louisiana March 11, in Mississippi and Tennessee May 1, and in Indiana and Illinois May 12.

**Horse Flies** (*Tabanidæ*).—Horse flies are pretty well known and quite important economically. They cause annoyance to domestic animals and to man. They are not credited with carrying any disease, but seem to be well adapted to such a performance. They are aquatic in the larval stages so far as the larvæ have been studied, and the larvæ are carnivorous and seem to feed on a variety of aquatic life, dead or alive. They pass through pupa stages in the mud or deeper in the marshes of pools and ponds. The adults are very active and swift flying. The eyes occupy practically the whole head and are composed, especially in the males, of an enormous number of facets. The females are the biting members of the family, having the mouth parts much more fully developed. The males live on plant juices, but probably do not feed extensively in the adult stage. The females seem quite blood-thirsty, though perhaps this is not a necessary food. The eggs are deposited in little clusters or masses on aquatic plants, usually just above the surface of the water, so that the larvæ on hatching at once enter the water. The insects of this group are much more abundant where there is an area of water surface to provide the water habitat. The females gather to the water probably to secure water in connection with the deposition of the eggs, and a Russian entomologist proposed the plan of putting kerosene on the surface

of the pools to destroy the adult females, and this seems to have been very successful. The trouble in this is that the kerosene kills other forms of life which are not obnoxious. There are several species in this locality. The species common about horses are the green heads and the big black flies. The green heads sometimes cause a great deal of trouble.

The remaining families of the order come in the suborder Cyclorhapha. This group includes an immense number of flies, many different families and some of the families an immense number of species.

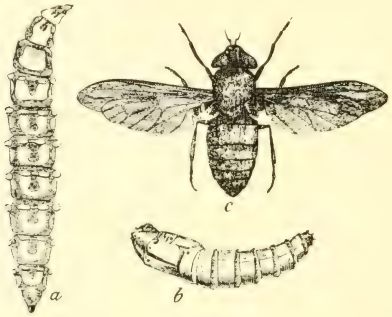


FIG. 212.—*Tabanus atratus:* *a*, larva; *b*, pupa; *c*, adult. (After Riley.)

The first important family in the group is that known as the *Syrphidæ*. This one family presents about as great a variety of life, habit and conditions as any in the order. There is everything from aquatic to arboreal species in the larvæ. The rat-tailed forms which live in liquid have a long tube extending to the surface of the liquid. Another species occurs on trees. The more important economically are the ones that feed on plant lice, and these are a most important factor of control. Many species mimic members of other groups of insects. Some look very much like wasps,

others like bees, and the rat-tailed species (*Eristalis tenax*) looks like a drone bee.

**Bot Flies** (*Oestridæ*).—The bot flies are parasitic in various mammals, occupying the body tissues and primarily the alimentary tract. The adults are bee-like, with rounded heads and small eyes, and are hairy. The antennæ are sunken into little pockets or pits in the front of the head, and the mouth parts are aborted. The adults do not feed. The females are

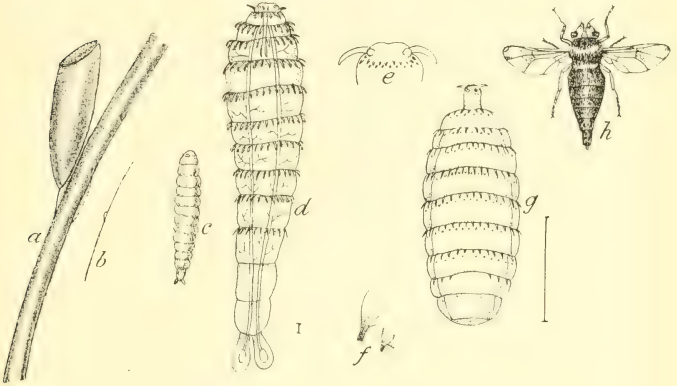


FIG. 213.—Horse bot fly (*Gastrophilus equi*): *a*, egg, enlarged; *b*, natural size; *c*, larva, newly hatched, enlarged; *d*, more enlarged; *e*, oral hooks; *f*, body spines; *g*, mature larva, twice natural size; *h*, adult female. (Author's illustration, Bur. Ent., U. S. Dept. Ag.)

the more commonly seen and they deposit their eggs on the animals that are to serve as hosts for the larvæ. The males generally remain in shady places among grass, etc., so that they are much less likely to be observed. The larvæ seem to have adjusted themselves to the parasitic condition from a more primitive condition, possibly that of living in organic matter of some kind. It seems most likely that some form with habits perhaps like the blow fly might in some cases deposit

eggs in such places that the larvæ would survive and the habit gradually acquired of living within the host tissues. They reach maturity without destruction of the host form and the habit gradually becomes fixed. This habit is now definitely fixed among all the species of the family and they are restricted to mammals as hosts. Some infest the alimentary canal, some the nasal passages, some the tissue beneath the skin. The larvæ as parasites have undergone considerable modification from the primitive forms. They are usually provided with rows of spines or sharp spurs that assist their movements when they leave the host forms and for those that live in the alimentary canal there are hooks, modifications of the mouth parts, that serve to attach them. They may feed to some extent upon the secretion of the host, but most of the nutrition is absorbed through the body walls.

**The Horse bot fly** (*Gastrophilus equi*) is one of the best examples and probably represents most nearly the primitive condition for the family. The adult occurs through the middle and last of summer and the eggs are deposited on the hairs of the horse, small yellow eggs glued very firmly to the hairs. In depositing the eggs the female darts toward the animal and thrusts the egg against the hair without alighting. The abdomen is thrust forward under the body. A glutinous secretion is discharged with the egg and binds and hardens almost immediately. The eggs are very thick-walled with chitinous walls and have a little operculum or cap at the end of the egg which is easily detached after a certain stage in the development. The time for hatching varies from three days to forty, but usually ten to fifteen days after deposition. Before that time they are hatched with a great deal of difficulty, and the larvæ are rather inactive. After fifteen to twenty days the activity begins to diminish. The majority die if not hatched in thirty to forty days. They do not hatch without the assistance of moisture, friction, and warmth to stimulate the larvæ. With a little moisture and friction the cap slips off easily and the hooks of the larva fit it to attach itself immediately to the tongue or other part of the body of the horse. The egg shells remain on the hair

after the hatching occurs. The time for the hatching of the eggs is rather important with regard to the treatment of the animal. It has been studied pretty carefully. Different statements as regards the period of incubation may mean different species observed. Egg deposition may go on until quite late in autumn, but is usually at its height about August or early September. The activity is retarded by cold weather and the larvæ may survive longer then. The method by which they get into the stomach of the horse is by the horse licking itself or some other animal on which there are eggs. At first they are long and slender but after attachment in the stomach become thicker and fasten themselves by hooks to the stomach and remain there through late autumn and winter and early spring. They are sometimes very thickly set in the stomach of the horses. They must cause considerable interference with the activity of the stomach, and if massed together at the pyloric orifice may act as an obstruction. The effect on the animal is in some cases quite evident. The damage is doubtless different in different animals. The worst infested are those that have been in pasture. When they have completed their growth in the stomach they loosen their hold and pass out of the stomach. They burrow into the ground and pupate and remain in this condition several weeks—six or seven—and issue from midsummer to early autumn. There is one generation a year and the longer period is spent in the body of the animal.

Treatment for the larvæ is rather severe. They may be killed with turpentine, but care must be used not to injure the horse by an overdose. The means of prevention are indicated by the life-cycle—condition of the egg and length of time it may develop. If eggs are removed every week or ten days there is no danger of serious infection. Horses curried regularly are not apt to be infested. They may be shaved off, and this is the most ready means of preventing the infection. Washes could be used to kill the larvæ—kerosene, carbolic acid, etc.

There are three or four species of this parasitic genus in the horse, but no other so common as *Gastrophilus equi*.

They cause a good deal of annoyance. One is called the chin fly (*Gastrophilus nasalis*), which lays eggs on the jaws. Another, the red-tailed bot fly (*Gastrophilus hæmorrhoidalis*), also deposits eggs in the vicinity of the mouth.

**Bot Fly of the Ox** (*Hypoderma lineata*).—The bot fly of the ox illustrates another method of development, but seems to have been derived from that of the one occurring on the horse. It is known in some parts of the country as the Texas heel fly. It occasions a great deal of loss to the cattle

FIG. 214.—*Hypoderma lineata:* female—natural size indicated by side line. (From *Insect Life.*)

industry. The larvæ perforate the hides. They develop under the skin and on maturing pass through the skin, leaving a lot of openings. Such hides are docked one-third in the market. Eggs are laid on the hairs of the legs, and as he found none on the hairs of the back, Dr. Curtice concluded that the larvæ were taken into the mouth and travel by way of the œsophagus and through the tissues of the thoracic region up through the tissues of the back as their normal route. The puncture is made after the larva is under the

FIG. 215.—*Hypoderma bovis*—enlarged. (After Brauer.)

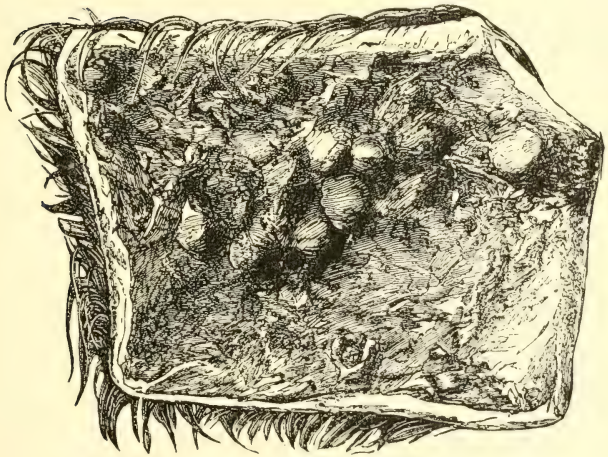

FIG. 216.—Piece of warbled hide—warbles about half size. (After Omerod.)

skin and some time before it is ready to issue. The adults appear quite early in the season and the larvæ in the backs of cattle are never seen until in the winter time—January first to March or April. They cause the muscles to have a jelly-like consistency. They injure the cattle in regard to growth and to milk conditions. The annoyance of the flies

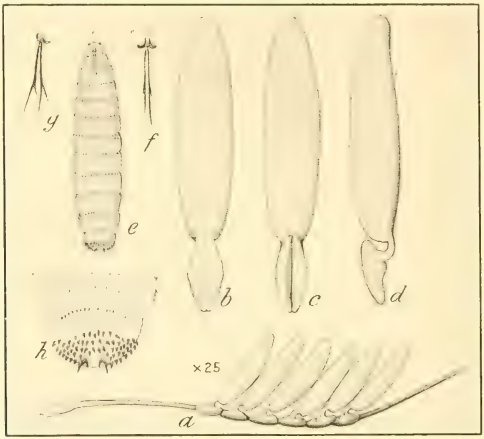


FIG. 217.—*Hypoderma lineata: a*, eggs attached to hair; *b*, *c*, *d*, dorsal, ventral, and lateral view of egg; *e*, embryonic or first larva, as seen in egg; *f*, *g*, mouth parts of same enlarged; *h*, anal segments of same still more enlarged. (From *Insect Life.*)

when they deposit eggs and also the injury caused by their presence in the back of the cattle is in England estimated at about $5.00 a head. Eggs are attached to the hairs, and the larvæ, according to Curtice, pass into the mouth and through the esophagus and through its walls into the adjacent tissue and migrate by slow degrees to the dorsal portion of the body, finally reaching the subcutaneous tissue along

the backbone, about six or eight inches from it and between the shoulders and the hips. The time of the appearance in that location and the time when the larvæ are taken into

FIG. 218.—*Hypoderma lineata:* ovipositor of female: *a*, from side; *b*, tip, from below—enlarged. (From *Insect Life.*)

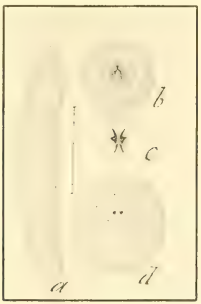


FIG. 219.—*Hypoderma lineata:* second stage of larva from esophagus: *a*, larva; *b*, enlargement of cephalic segments, end view; *c*, mouth parts; *d*, enlarged end view of anal segment, showing spiracles and spines. (From *Insect Life.*)

the mouth are separated by quite a period. Curtice claims to have found larvæ at all points between these two positions. This cannot be purely accidental. More recently an Irish investigator has reached the conclusion that the larvæ bore into the skin and migrate to the wall of the esophagus from which point they travel to the position under the skin of the back. The adults emerge in early summer, in Texas as

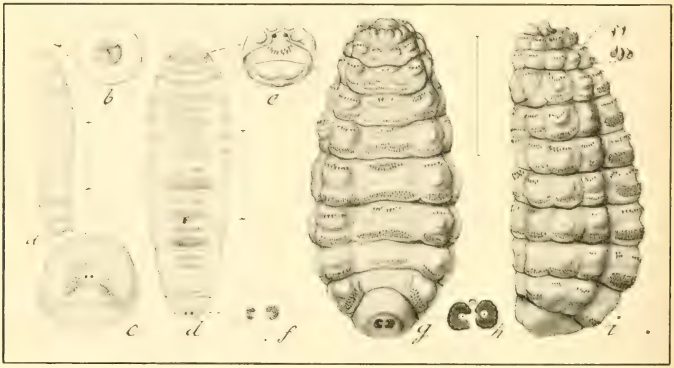


FIG. 220.—*Hypoderma lineata:* *a*, second stage of larva from back; *b* and *c*, enlargement of extremities; *d*, ventral view of third stage with details of extremities at *e* and *f*; *g*, dorsal view of mature larva with enlargements of anal spiracles at *h*; *i*, the same, lateral view. Natural size indicated by side lines. (From *Insect Life*.)

early as May, in northern States May or June. The larvæ are pretty well grown by February, and by early March they have practically reached maturity and the grubs issue during March and early April, drop into the ground and pupate and remain in this stage for five, six, or seven weeks, and the adults come on from May to early June or the first of July.

The European species which has now been studied with

special reference to its mode of introduction is believed to follow the same method, but Miss Ormerod persisted in the belief that the eggs were deposited on the back and that the larvæ bored through the skin, and claims to have seen channels through the skin through which the larvæ travelled. It is not likely that there would be this difference in the two species. This species causes a great deal of loss in the old world. The one method available for controlling either of these species is the destruction of larvæ during the late winter and early spring when they are conspicuous along the back, and the method of extermination of the species would be to have all animals examined and all the grubs found destroyed. This is feasible theoretically, but impossible practically. They do not migrate far, and any stock owner can by close attention secure a large measure of immunity for his own herd. Coöperation would secure a more extended extermination.

**Sheep Bot Fly** (*Oestrus ovis*).—The sheep bot fly illustrates another method of development. It deposits eggs or newly hatched larvæ in the nostrils of sheep and these work their way up the passages. This entrance occurs during summer time and the development of the larvæ goes on through fall and the larvæ work their way back in spring and pupate in the ground and the flies issue in midsummer. They cause the greatest irritation and most serious symptoms occur during the time the larvæ are working themselves back. The sheep sneeze, etc., and sometimes show a dizziness or stagger. They may be cut out of the frontal sinuses but the cost of the operation is too great for general use. Prevention consists in avoiding the deposition of eggs in the nostrils. Applying tar to the noses is one method, and another method is by furnishing plowed places or dusty places so that the sheep can bury their noses when the flies try to deposit eggs, or by giving the sheep a shed, as the flies are active in the sun and not in the shade.

**Family Tachinidæ.**—The family *Tachinidæ* has a very important economic position on account of the large number of species that are parasitic upon destructive insects. The

adults appear much like the house flies or the stable fly but have usually numerous prominent bristles and spines, the bristles (arista) of the antennæ lack the fine hairs which are characteristic of most of the *Muscidæ*.

These insects show some very striking adaptations in their parasitic life, some of the species depositing their eggs directly upon the bodies of the caterpillars which are to be the hosts of the larvæ. The larvæ on hatching bore at once into the caterpillar and develop within its tissues. In cer-

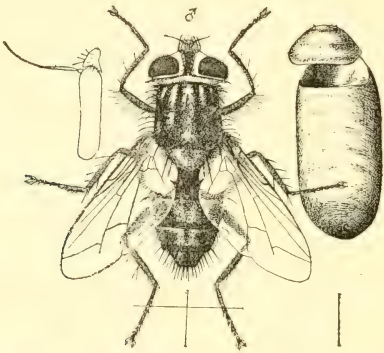


FIG. 221.—*Euphorocera claripennis*, a parasite of the alfalfa caterpillar: adult and enlarged antenna of same; puparium—enlarged. (From Howard, Bur. Ent., U. S. Dept. Ag.)

tain species the eggs are laid upon the leaves and depend for their entrance to a host insect upon the leaf being eaten by some herbivorous form and in this case it would seem as if there would be some chance of the eggs being crushed or the larvæ being destroyed in the process of swallowing. In one rather remarkable form the eggs are evidently deposited within the burrows of wasps which are stored with spiders. The *Tachinidæ* follow the wasps as they drag their victims to the burrow and when the wasp enters they no doubt

deposit their eggs upon the spider, the larva feeding upon the food intended for the wasp larva or possibly upon the wasp larva itself.

The typical Muscid flies (*Muscidæ*), house fly, blow fly screw-worm fly, all live in organic matter in a state of decay, and all of them show very rapid rate of development, the larvæ acquiring their growth in a few days' time, though longer time is usually passed in the pupa stage. The adults may live for a long time. House flies, for example, conceal themselves about houses and survive the winter, possibly also as pupæ, and deposit eggs which start the summer

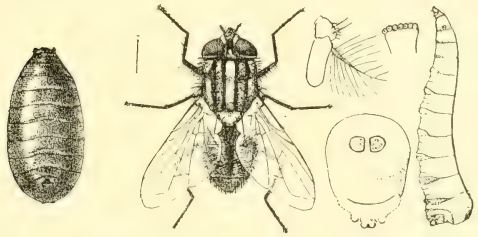

FIG. 222.—Common house fly (*Musca domestica*): puparium at left; adult next; larva and enlarged parts at right. All enlarged. (After Howard, Div. Ent., U. S. Dept. Ag.)

generations which follow each other with a great deal of rapidity. Twelve to fifteen days is all that is required for the complete cycle of many of the species. They are scavengers and in this may be looked upon as beneficial. They present also certain dangerous aspects as carriers of disease, especially typhoid, and deserve all the opposition they are receiving.

The screw-worm fly deposits eggs occasionally in the nostrils of individuals, and in the case of wounds of animals the larvæ work into the living tissue. It causes losses in cattle industry in the South.

**The house fly** (*Musca domestica*) is perhaps the most universal, and occurs wherever civilization extends, and presents an important feature in its possibilities of carrying disease germs. One of the first cases establishing this con-

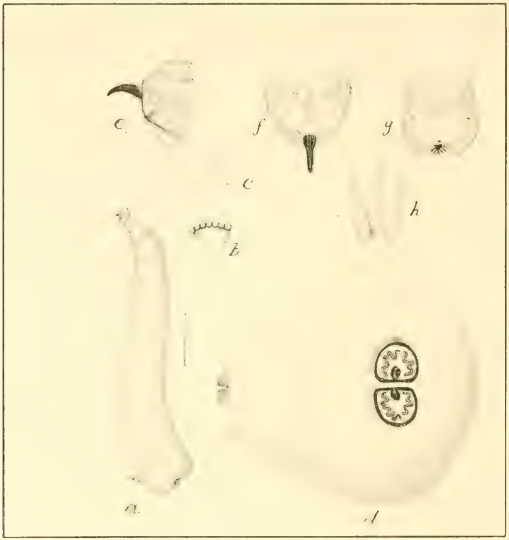


FIG. 223.—The common house fly: *a*, full-grown larva; *b*, one of its anterior spiracles; *c*, antenna; *d*, hind end of body showing anal spiracles; *e*, side view of head; *f*, head from above; *g*, head of young larva; *h*, eggs. All enlarged. (From Howard, Div. Ent., U. S. Dept. Ag.)

nection was that determined during the Spanish-American war, where the source of the typhoid was traced to house flies. It is known to serve as a carrier for tuberculosis, dysentery and other diseases. Flies breed in filth, especially horse manure, the eggs requiring a few hours to hatch, the mag-

gots from four to six days to grow, and pupation six to eight days, so there may be many generations in a summer. Protection may be readily gained by community effort. Their flight is sufficiently restricted to make individual effort on a farm well worth while, even if some nearby farms are neglected.

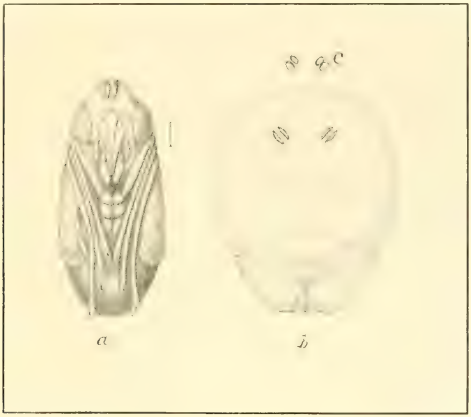


FIG. 224.—The common house fly: *a*, pupa removed from puparium; *b*, hind end of body of larva in second stage; *c*, anal spiracles of larva in first stage. All enlarged. (From Howard, Div. Ent., U. S. Dept. Ag.)

**Horn Fly** (*Hæmatobia serrata* Rob.-Desv.).—In the introduction and rapid spread of this insect we have an excellent illustration of the importance of giving attention to the injurious insects of other countries and of taking all possible means to prevent their importation.

The species in hand has been a common insect in Europe, and with other members of the same genus recognized as a troublesome insect, though apparently no careful study of its life history has been made there.

It was first noticed as troublesome to cattle in this country in 1887, and while we cannot say with certainty just when it was introduced, we may be pretty sure that it was during the year 1886, or at most not earlier than 1885. It is even possible that it may have been brought over in the spring of 1887, as its powers of reproduction are such that a few weeks would suffice to make it a conspicuous pest in a limited area.

Within two years from the time it was first recognized in serious numbers it had become so numerous and had spread over so large a region that it was made the subject of a very careful and successful study by Messrs. Howard and Marlatt of the Division of Entomology. The results of these investigations were published in *Insect Life* (vol. ii, p. 93) and in the Annual Report of the Commissioner of Agriculture for 1889.

As to its introduction and spread in America, all accounts agree in placing the first serious occurrence of this insect in the vicinity of Philadelphia, and it appears probable that it was at that port that the flies first landed.

From there as a centre it spread in all directions, though at first mainly southward, and by 1889 it had covered most of the State of New Jersey, portions of eastern Pennsylvania, a considerable area in Maryland, and also a portion of northern Virginia.

In 1891 it had been reported from New York, Ohio, Kentucky, Georgia, Florida, and Mississippi, and in 1892 from Connecticut, Massachusetts, Canada, Michigan, Indiana, Iowa, Louisiana, and Texas.

The adults of the horn fly are about half as large as the common house fly and very much like it in shape and color. The accompanying figures will serve to distinguish it. The larval stages are passed in from four to six days.

The pupa stage may last from five to eight or ten days, so that the full time from egg deposition varies from ten to seventeen days, estimated for the average as about two weeks. As the flies doubtless begin laying soon after issuing from the pupa stage, there is room for a number of generations

during even a northern summer, probably from six to eight being common.

For the destruction of the larvæ, which is probably the most effective way of preventing damage, two principles have been established. The first involves the killing of the maggots by introduction of some destructive agent; the other, the prevention of their maturing by the rapid drying

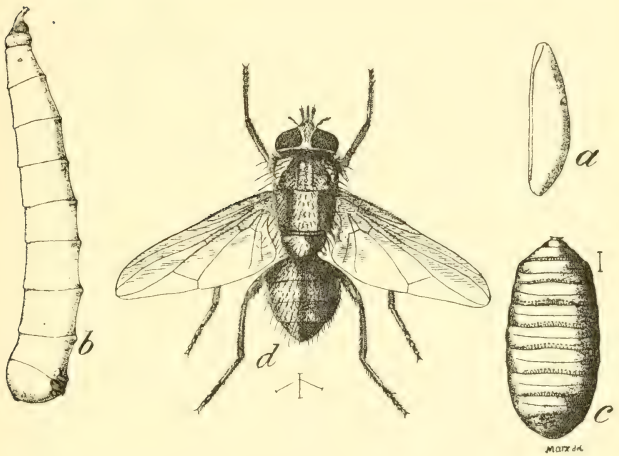


FIG. 225.—Horn fly (*Hematobia serrata*): *a*, egg; *b*, larva; *c*, puparium; *d*, adult in biting position. All enlarged. (From Riley and Howard.)

of the mass of dung which supplies their food. The use of lime, as originally suggested in *Insect Life*, is a very effective plan, and where not prohibited by expense, should be generally adopted. Prof. Smith's suggestion to spread out the droppings of manure so that they may dry rapidly is applicable during dry weather and in some localities is accomplished by drawing brush across the fields, a method which must

necessarily fail to be complete in its operation, but much less expensive than the use of a shovel by hand.

**The Stable Fly** (*Stomoxys calcitrans*, Linn.).– The stable fly is a well-known species which is widely distributed and a familiar pest in many countries. Its bite is severe and it causes a great amount of annoyance to cattle, horses and other domestic animals, and is frequently very troublesome to people working in places where it abounds. It is not confined to stables or to the quarters of domestic animals, but occurs frequently in shady places, groves and in dwell-

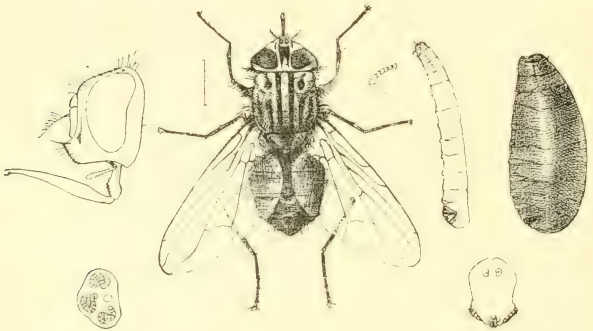

FIG. 226.—*Stomoxys calcitrans:* adult, larva, puparium, and details—all enlarged. (From Howard, Div. Ent., U. S. Dept. Ag.)

ings, especially in cloudy weather, and puts the occupants to great inconvenience. Its bite is not poisonous, and aside from the pain given and the possibility of it disseminating disease, it is less injurious than some other members of the group. When abundant, however, this annoyance may be very great, and they all deserve attention. Indeed, it is especially charged against this species that they have been the means of transmitting glanders from diseased to healthy horses, and anthrax among cattle, a charge which appears very reasonable from the fact that it inflicts a deep bite and

does not gorge itself at a single animal, but may fly from one to another in securing a meal.

In late years it has come into especial prominence as a a carrier of disease. It was at one time thought to be the carrier of infantile paralysis but this relation has not been substantiated.

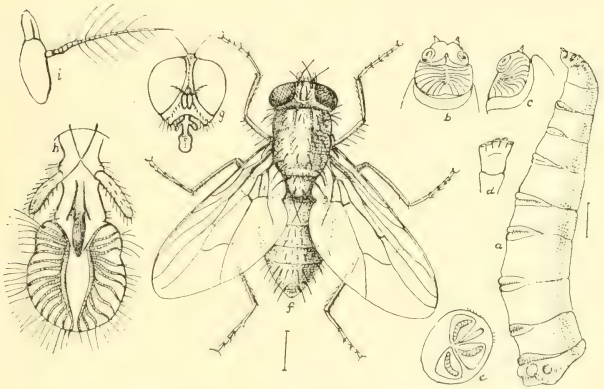


FIG. 227.—*Muscina stabulans: a*, larva; *b*, head below; *c*, head, side view; *d*, thoracic spiracle; *e*, stigmatic plate; *f*, female; *g*, head of female; *h*, mouth parts; *i*, antenna. All enlarged, *d*, *e*, *h*, *i*, greatly enlarged. (Bur. Ent., U. S. Dept. Ag.)

**Tsetse Flies.**—The tsetse flies have been notorious for a long period as extremely serious pests in parts of Africa and were described by early explorers because of heavy loss to domestic and wild animals. In recent years these have been connected with the transmission of certain kinds of diseases, and are now looked upon as having a most important bearing from the medical standpoint.

The species longest known, *Glossina morsitans*, has been especially connected with loss among cattle, and horses. *Glossina palpalis* which has been determined as the cause

FIG. 228.—*Glossina palpalis* ($\times 3\frac{3}{4}$), the carrier of the trypanosome of sleeping sickness. (Bruce.)

FIG. 229.—*Phormia terræ-novæ*—enlarged. (Howard, Div. Ent., U. S. Dept. Ag.)

of sleeping sickness in man has received perhaps the greater attention in recent years.

It can easily be seen that the introduction of either of these species into this country or even into South America, with the opportunity for further distribution would be a most serious menace, as there would be every possibility of the introduction of the diseases which are associated with it. These are perhaps examples of insects which deserve most careful attention from the stand-point of possible exclusion, and every effort made to learn their habits in detail and to

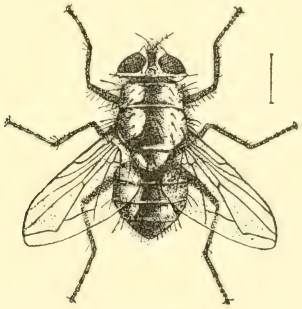

FIG. 230.—*Lucilia cæsar*—enlarged. (Howard, Div. Ent., U. S. Dept. Ag.)

avoid such means of transportation as might possibly serve to transfer them to this country. It is reported that such an introduction has occurred in Australia.

**Blue-bottle Fly** (*Lucilia cæsar*).—The blue-bottle fly is another species which is very abundant and almost universally distributed. Its attacks are made upon any available fleshy material such as carcasses of dead animals, fish, and so on. The female deposits eggs on living animals that have bruises or wounds or attractive points for deposition. Sheep are especially subject to attacks of this sort. The maggots of the flies do not limit themselves to the external

parts but burrow into the flesh and may perhaps cause very serious injury.

**The meat fly** or blow fly is another species that falls in the same group with regard to its habits, and against which it is important to protect domestic animals.

**Flesh Flies** (*Sarcophagidæ*).—Flesh flies are quite familiar objects around houses, especially if there is any exposure of

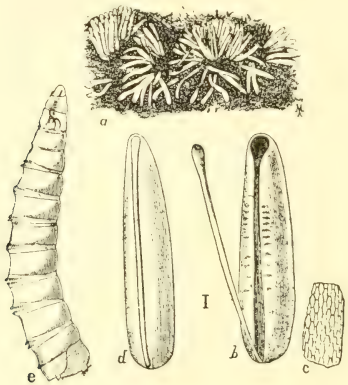


FIG. 231.—The green-bottle fly: *a*, egg masses in cow dung; *b*, hatched egg; *c*, a portion of the egg surface seen under the microscope; *d*, unhatched egg; *e*, larva. All enlarged except *a*. (From Ann. Rept., U. S. Dept. Ag., 1890.)

fresh meats to attract them. The eggs are laid on meat by preference and hatching occurs within a very short time, in fact in some species it is stated that larvæ are extruded from the adult. Aside from their deposition upon meats, however, there is often a deposition upon fresh wounds or abrasions so that the larvæ may make a serious attack upon domestic animals or even human beings, if there is an opportunity for the attack. As a protection against this kind of

injury it is important that all bruises or scratches should be treated promptly so that domestic animals will not serve as an attraction for the species.

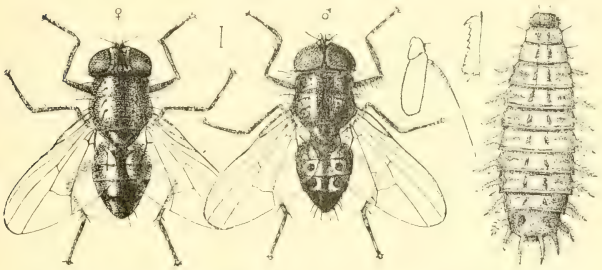

FIG. 232.—*Homalomyia brevis:* female at left; male at centre, with antenna enlarged; larva at right. All enlarged. (After Howard, Bur. Ent., U. S. Dept. Ag.)

FIG. 233.—Apple maggot (*Rhagoletis pomonella*): *a*, adult; *b*, larva or maggot; *c*, funnel of cephalic spiracle; *d*, puparium; *e*, portion of apple showing injury by maggots; *a*, *b*, and *d*, enlarged; *c*, still more enlarged; *e*, reduced. (After Quaintance.)

In the genus *Drosophila* are a number of species, the "pomace flies" which feed principally upon decaying fruits.

They are perhaps of slight economic importance as they do not attack growing plants, but on account of the great ease with which they may be bred in captivity they have been the basis of some most important investigations concerning the transmission of hereditary characters.

Another species is one that occurs as a pest in apples and is known as the apple maggot (*Rhagoletis pomonella*), which differs in its method of work from the codling moth larvæ in that the larvæ work near the skin and make tunnels through the apple. It punctures the skin and deposits eggs inside. This goes on during the summer and the larvæ mature in autumn with the maturing of the fruit. They hibernate as pupæ. This species occurs now and then in Ohio, but is not so universally common as the apple worm. It is more distinctly a northern species, sometimes a serious pest in New England and parts of the States and Canada bordering on the Great Lakes.

**Family Hippoboscidæ.**—The family *Hippoboscidæ* includes sheep ticks, and forest flies. They have the wing structure of the Diptera, suctorial mouth parts, but a very remarkable method of reproduction. Instead of extruding eggs, they are retained in the oviducts and developed through the larval stage, being nourished by nutritive fluids. They are not extruded until they are ready to pass into the pupa stage. They take no nutriment as pupæ after leaving the oviducts. There is no food taken until as adults. There is an adaptation for the parasitic habit. This is a different sort of adaptation than is found in any other group of Diptera except the succeeding group. They are different from any other group of animals.

**Sheep Tick** (*Melophagus ovinus*, Linn.).—The sheep tick is a common pest of sheep. It differs from the most of the other members of the family in never possessing wings. The head is small and sunken into the prothorax. The middle portion of the prothorax is rather slender, contrasting with the development of this region in the winged forms.

It is of a reddish or gray-brown color, about one-fourth of an inch long, and easily detected when present in any num-

ber on sheep. They never migrate from the original host except it be to attach to another animal of the same species, and probably the principal movement is that which occurs after sheep are sheared, when the ticks tend to migrate to lambs. On the sheep, if abundant, they may cause considerable damage, indicated by lack of growth or poor condition, and when massing upon lambs they may cause great damage, resulting in the death of the victims if not promptly relieved.

They are distributed over the world generally where sheep are kept, and are too well known by sheep breeders to make it necessary to emphasize the injury they may cause. All breeds of sheep seem alike subject to attack, but I know of no record of their occurrence upon other animals.

While the ticks may be greatly lessened in number by the vigorous use of pyrethrum—a most available remedy during winter—the most practical plan to adopt, and one which if thoroughly followed will make all others unnecessary, is to dip the sheep each year after shearing.

A flock once freed from the pests will not be again infested except by the introduction of infested animals: hence care should be taken in making additions to the flock to free the newcomers from parasites. It is also well to keep the sheep for a few days after dipping in a different inclosure from that occupied before, to avoid possible infestation from any stragglers that may have been caught on wool upon posts or brush, and if the wool is charged with them when clipped, it should be stored where the ticks could not easily return to the sheep. The ticks cannot travel any distance independently, and will soon die when removed from the sheep, and proper care here will insure success.

## Order SIPHONAPTERA.

Another order is the *Siphonaptera*. The fleas are wingless or have the wings so aborted that they are practically wingless. Vestiges of wings may occur but are useless as organs

of locomotion. The adults have suctorial mouth parts and puncture various kinds of animals, sucking the blood for a food supply. The larvæ are slender and live in refuse and rubbish, litter of dog kennels, etc., and when mature change to a very distinct pupa stage and then to adult flea. The pupa stage is like the adult in shape but the legs, etc., are encased in the rigid pupa case. The hindlegs are specially

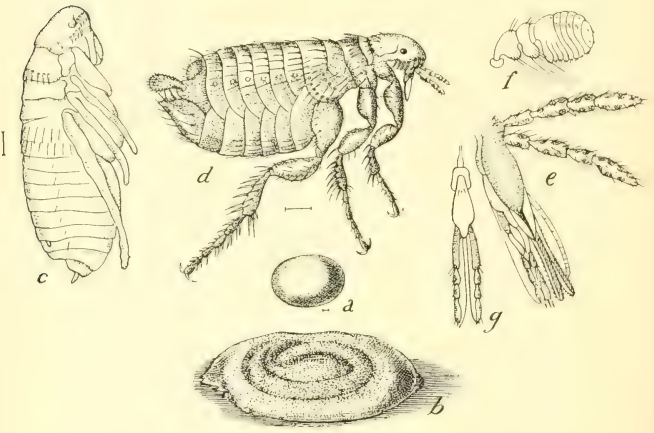


FIG. 234.—Cat and dog flea (*Ctenocephalus canis*): *a*, egg; *b*, larva in cocoon; *c*, pupa; *d*, adult; *e*, mouth-parts of same from side; *f*, antenna; *g*, labium from below; *b*, *c*, *d*, much enlarged; *a*, *e*, *f*, *g*, more enlarged. (After Howard.)

developed and their mode of progression is by leaping. They occur on different kinds of animals, as the dog and cat, and there are species that occur in houses, on squirrels, rats, mice, and various mammals. It is mainly on the smaller species of mammals, and one species occurs on birds. One species attacks poultry. It buries itself in the skin something like a jigger, though not so extreme in the extent to which it will burrow.

# CHAPTER X.

## BEES AND WASPS.

### Order HYMENOPTERA.

The Hymenoptera are in some respects the culmination of the group of insects. They are specialized in several ways but the species are all characterized by having the mouth parts developed into both biting and sucking structures. In some respects they seem more specialized than all other orders and in some respects they seem less specialized than the Diptera and Lepidoptera. As a matter of fact in the evolution of the groups of insects there are several orders that must be looked upon as having evolved along divergent lines at the same time and none can be said to really outrank the others. The Coleoptera, Diptera, Lepidoptera, and Hymenoptera, all have a high degree of specialization. It is better not to try to consider them as in the line of a series of steps running up, but as parallel or divergent branches from a general trunk, all of them extending to extreme distances from the primitive stock.

The Hymenoptera have four wings, and these are provided with rather few veins and pretty highly specialized in the venation, and in a few groups the veins are practically reduced to nothing. The mandibles are present for the most part in the adult forms but are almost lost in some forms that are fed by the adults in communal forms. They are both mandibulate and haustellate. The larvæ are usually footless, fleshy, grub-like animals which depend on their food being supplied for them in one way or another and are incapable of moving about and securing their own food supply. This represents a high degree of specialization and reaches its

culmination in the community habit of ants and bees. In no other group except the white ants is there such development of the community habit.

The pupa stage is generally included in the nest or cells formed for the larval stage, and the forms are seen to be quite highly specialized when the cocoon is cut open. The larvæ moult but the moults are not so conspicuous as in exposed forms. The group exhibits quite a variety of habit, some leaf-eating forms, some wood-boring forms, some that develop in galls, many that are parasitic internally on other insects, and many store food in their nests, such as spiders, caterpillars, etc. These are sometimes stored in the ground, sometimes in mud cells, sometimes in channels in the wood, sometimes in paper cells.

There are two large divisions, the Phytophaga, leaf-eating or plant-feeding free caterpillar-like forms, and the Aculeata which represent the other forms of the group, the larvæ of which are dependent on a food supply provided by the adult. The adults of this group have a sting.

The group *Tenthredinidæ* is a large family of leaf-eating and gall-making insects and the typical ones being the willow saw fly and the gall-making willow forms.

The willow saw fly (*Cimbex americana*) is one of the largest species that we have. The adult is steel blue, the wings smoky. It is quite conspicuous and lays its eggs on the leaves of the willow along the midrib and principal veins of the leaf. The larvæ hatch in a few days and grow during the midsummer and are noticed as large yellow caterpillar-like forms clinging to the twigs and leaves of willow particularly or sometimes also to elms and a few other kinds of of trees. Some of the larvæ have a prominent black dorsal line. They coil themselves quite a little especially when resting. While feeding the body is stretched out and they cling by means of the prolegs of the abdomen as well as by the thoracic legs. Prolegs are similar to those of the caterpillar. There are certain similarities with some of the very generalized Lepidoptera and the prolegs might possibly be taken to indicate some affinity. However, it is probably

better to look upon it as an independent development of a similar structure based on similar habit. The number of prolegs varies from twelve to sixteen. There are twenty-two legs altogether. The saw fly larvæ become fully grown by the latter part of the summer and secrete themselves near the surface of the ground, generally among dead leaves and rubbish. They spin a quite strong silken cocoon with a papery texture, somewhat more dense than is common for the caterpillars of the silk-making moths. In this cocoon they remain as larvæ for quite a period. They finally pupate and the adults issue in the spring and deposit eggs so as to produce the summer generation of willow worms. They become of economic importance where the shade trees they feed upon are of importance—willow trees, elm, etc. They are parasitized and the cocoons are eaten by mice and so kept down generally to a moderate number and are not usually very destructive.

**The pear slug** (*Eriocampoides limacina*) occurs quite commonly in orchards and attacks not only the pear, from which it dervies its name, but also apple and other orchard trees. The larva has a strict resemblance to the mollusks called slugs, as the body is covered with a dense slimy secretion which hides the segmentation and external features of the body. They feed upon the surface of the leaves, just leaving ribs and veins. The trees attacked often have the appearance of being scorched by fire.

They are best treated by the application of arsenical solutions, applied as soon as their work appears.

**The American rose slug** (*Endelomyia rosæ*) is frequently troublesome in its attacks on the leaves of rose bushes which are stripped or skeletonized so that the bushes are rendered quite unsightly.

Arsenical solutions can be used, or if these are not desired, hellebore may be used for their control. Other species affect gooseberry, strawberry and other such crops. Many instances being of considerable importance.

The *Urocerida*e are wood- or stem-boring species and more specialized than most of the preceding family.

One form is particularly interesting, *Tremex columba*, or horn tail or pigeon tremex. It has a rather peculiar shape both in the larval and adult stages. The adult is an inch or more in length and with a prominent ovipositor which extends back about one-half inch from the back of the abdomen; both larvæ and insects are cylindrical, the result of the boring habit. These adults appear in summer and deposit eggs on the bark of different kinds of forest trees—sycamore, maple, and others. The larvæ burrow in, form-

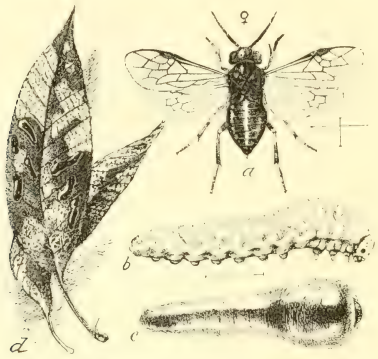


FIG. 235.—Pear slug: *a*, adult saw fly, female; *b*, larva with slime removed; *c*, same in normal state; *d*, leaves with larvæ, natural size; *a*, *b*, *c*, much enlarged. (From Marlatt, Div. Ent., U. S. Dept. Ag.)

ing tunnels through the heart wood pretty well down into the tree. Sometimes the trees are extensively perforated. Boring continues in through the tissue of the wood till they get their maturity and then they burrow out through the bark. Pupæ are formed in the burrow near to the surface of the tree and the adult works its way out from the cocoon after the pupa is split open. Occasionally the adults will be found with the ovipositor fast in the bark of the tree or in the wood. They burrow in to deposit eggs and seem

unable to withdraw the ovipositor. Presumably they deposit a single egg in each perforation. There are two common parasitic species, *Thalessa atrata* and *lunator*, which are the natural check upon the multiplication of this form and which ordinarily keep its numbers down to narrow limits. Without this check the species would probably multiply to a great extent. The parasites are representatives of another family, *Ichneumonidæ*. They are rather slender-bodied and with extremely long ovipositors. In *Thalessa atrata* they are four or five inches long. These are driven into the burrows of the tremex and the eggs are deposited in the burrow and presumably at some point close to the tremex larva. The larva of the *Thalessa* is said to attack the tremex larva externally and not to be internally parasitic —a little variation from the general habit of parasitism for the family.

**Cynipidæ.**—The *Cynipidæ* are in one sense a vegetable-feeding group, though some are hosts or guests of gall-makers. The primary feature is that they make galls and the larvæ develop within these galls. Galls are not a normal plant product, nor a product of the insect alone, but a combination product of the insect and the plant. A stimulus given to the plant cells results in a definite specific form of growth which is just as specific as the form of the leaf or the fruit of the plant on which it is formed. Species can be determined accurately from the form and structure of the gall. The most familiar of these galls are the oak apples. These are rich in tannic acid which gives the gall a decided flavor. A globular structure is built out by a great growth of plant cells. The gall grows and develops more rapidly than the larva. The larva gets its growth by eating the cells which are close to it and all the rest of the structure is apparently developed purely as a protective device for the larva. The greatest number of species occur on oaks, some on roses, etc. There are dozens of different kinds on oaks and many different species on a single species of oak and some restricted to one certain species of oak alone.

Parasitica includes several families: *Ichneumonidæ*, a large group; *Braconidæ*; *Chalcididæ*, a large group; and *Proctotrupidæ*.

All of these are distinctly parasitic in habit. *Braconidæ* and *Ichneumonidæ* are the more generalized kinds of parasites and parasitize such forms as the caterpillars of the Lepidoptera in immense numbers. They constitute a very important check upon a number of very important species. It is hard to do much in the way of encouragement of them, though they may be transported from one country to another. One subfamily is pretty commonly parasitic on plant lice.

*Chalcididæ* form a specialized group with much reduced venation for the wings and the *Proctotrupidæ* are minute and largely egg parasites.

**Family Ichneumonidæ.**—The Ichneumon flies include many of the larger species of parasitic Hymenoptera and a number of species which have important economic bearing on the abundance of destructive species. Good examples are to be noted in the species of *Thalessa* which parasitizes the pigeon tremex and in species of *Ophion* which attack a number of different kinds of caterpillars. The species of *Pimpla* are also conspicuous members of the group and their attacks are made especially upon injurious species of moths, so that they are to be counted distinctly serviceable.

**Pimpla conquisitor** is one of the parasites of the tent caterpillar and it is possibly due to this species that the tent caterpillar is less destructive than it otherwise might be. In this species the parasite lays its eggs in the cocoon of the host and its larva develops within the pupa, so that it serves to prevent the development of the adult and the deposition of the eggs which would follow.

**Family Braconidæ.**—The family *Braconidæ* is quite similar to the preceding but the species are on the average smaller and many of the species parasitize the minuter kinds of insects such as plant lice. A quite common species is *Apanteles glomeratus* which is a parasite of the common cabbage worm and which no doubt serves as a quite important factor in assisting to keep this pest in check.

Perhaps one of the most important species is the little *Lysiphlebus tritici* which is a very abundant parasite of

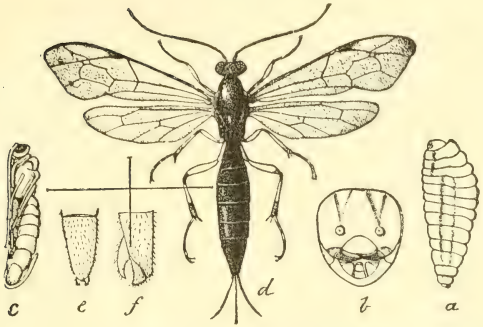


FIG. 236.—*Pimpla conquisitor*, an important parasite of the tent caterpillar: *a*, larva, enlarged; *b*, head of same, still more enlarged; *c*, pupa; *d*, adult female, enlarged; *e*, *f*, end of abdomen of adult male, still more enlarged. (From Fourth Report, U. S. Ent. Con.)

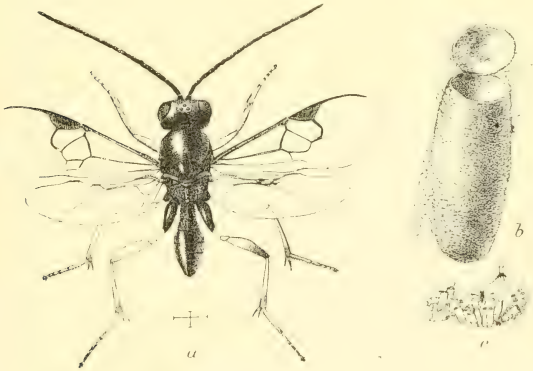


FIG. 237.—*Apanteles glomeratus:* *a*, adult fly; *b*, cocoon; *c*, flies escaping from cocoons; *a*, *b*, highly magnified; *c*, natural size. (After Chittenden, Div. Ent., U. S. Dept. Ag.)

aphids. It is a minute species and its larva maintains its entire growth within the body of an aphid, the entire con-

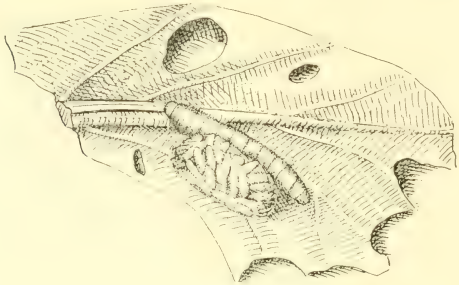

FIG. 238.—Parasitized cabbage worm (*Pontia rapæ*), showing cocoon mass of *Apanteles glomeratus* below. (From Chittenden, Div. Ent., U. S. Dept. Ag.)

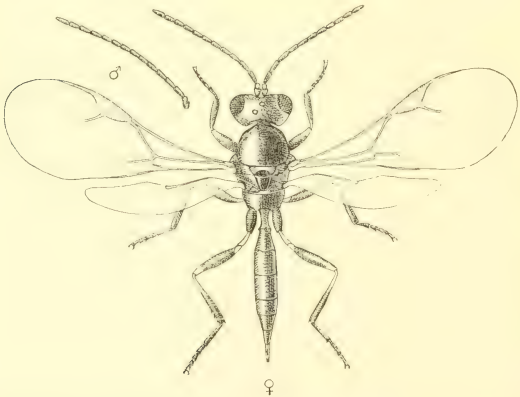


FIG. 239.—*Lysiphlebus tritici*, principal parasite of the spring grain aphis: adult female and antenna of male, greatly enlarged. (Webster, Div. Ent., U. S. Dept. Ag.)

tents of which are not equal to a drop of water. However, the parasite may feed upon the aphid during some little time and is supplied with food from the efforts of the aphid

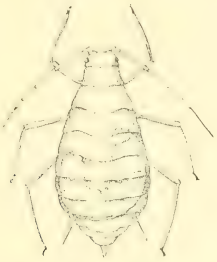

FIG. 240.—Wingless female of "green bug" containing larva of the parasite *Lysiphlebus tritici*. Much enlarged. (Webster, Div. Ent., U. S. Dept. Ag.)

sucking nutriment from the plant. This species is considered one of the principal agents in control of the spring grain aphis or the "green bug" which during recent years has

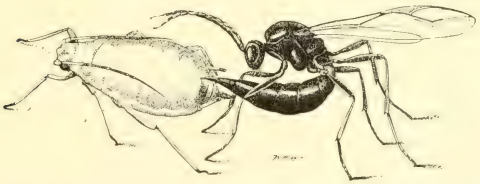

FIG. 241.—*Lysiphlebus* depositing its eggs in the body of a grain aphis. Much enlarged. (Webster, Div. Ent., U. S. Dept. Ag.)

caused extensive injury to the wheat crop in the southwestern part of the country. Its attack seems to be distributed, however, over a number of species and it is therefore

able to maintain itself even in the absence of any one species of plant louse.

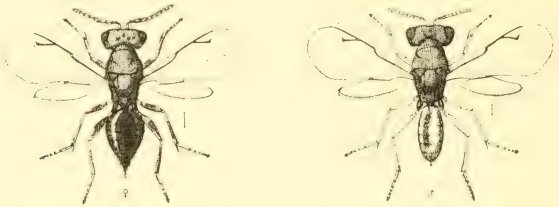

FIG. 242.—*Pteromalus puparum:* female at left; male at right—highly magnified. (Chittenden, Div. Ent., U. S. Dept. Ag.)

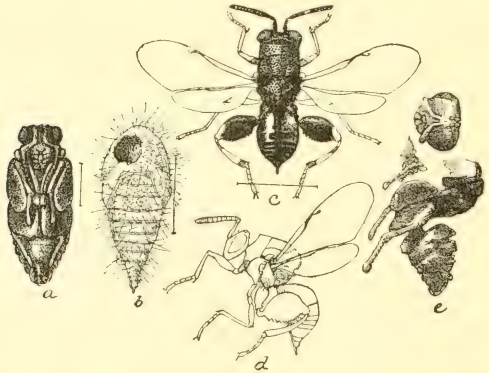


FIG. 243.—*Chalcis ovata*, a parasite of the alfalfa caterpillar: *a*, pupa; *b*, parasitized pupa of tussock moth (*Hemerocampa leucostigma*); *c*, adult; *d*, same in profile; *e*, pupal exuvium. Enlarged. (From Howard.)

**Family Chalcididæ.**—The family *Chalcididæ*, one of the groups which includes extremely minute insect forms which parasitize insects, such as the plant lice, scale insects, and

many other forms. They have broad heads, rather thick jaws and are quite generally of brilliant metallic colors. A distinctive character is found in the reduction in the veins in the wings so that only the costal vein borders the front margin of the wing and is so developed as to be rigid. In larger insects a great number of these parasites may develop in a single individual. In the smaller species usually a single parasite is found in the host. They are especially

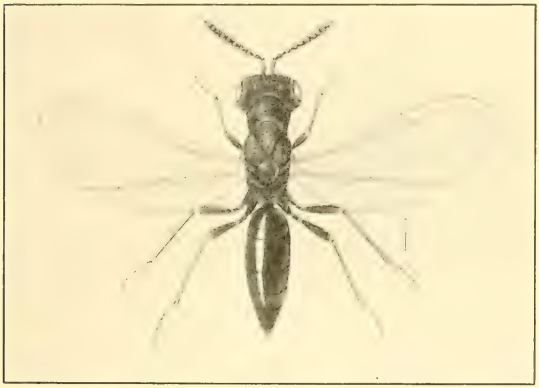

FIG. 244.—*Isosoma tritici:* adult of the joint worm—much enlarged. Howard, Div. Ent., U. S. Dept. Ag.)

effective in the destruction of scale insects, and some of the species are parasitic in the eggs of other insects. In some cases they become secondary or tertiary parasites in which case their value is changed.

**Pteromalus puparum,** one of the parasites of the cabbage worm, is apparently distributed well over the area occupied by this species and its attacks upon the host form serve as one of the quite constant checks upon the abundance of that species. The parasitized pupæ usually show a different

color, and if observed these may be allowed to remain in the fields with the expectation of the parasite serving a good purpose for a later generation. If possible it is well to assist them somewhat by putting the pupæ under screens which will permit the escape of the parasites, without allowing the escape of butterflies which might issue from healthy pupæ.

While most of these species are parasitic, there are a few which are plant feeders, and notable among these is the

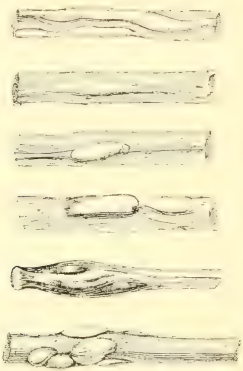

Fig. 245.—Bits of hardened straw remaining with the grain after thrashing. (After Webster, Div. Ent., U. S. Dept. Ag.)

wheat joint worm (*Isosoma tritici*), which is the cause of a great deal of damage to wheat in many parts of the country. The presence of the joint worm is evidenced by the formation of woody places in the stem, within which the worm is found and the effect of its injury is to cause the stems to become weakened so that frequently the grain will be broken down, especially if there are severe winds. The insects pupate within the stems and remain in the pupal stage all winter. This accounts for their frequently being found in chaff or

straw. Sometimes the hard pieces of straw are carried over in the threshing and mixed with the grain. It is evident

FIG. 246.—*Isosoma tritici*: female ovipositing. (Photo by Ohio Exp. Sta.)

that burning of the stubble in the fall or early spring will destroy the pupa in the fields and it is considered that the use of straw and chaff in the bedding of stock or as fodder

is an excellent plan to reduce the infestation. Of course burning chaff or straw would accomplish the purpose, but

FIG. 247.—*Isosoma tritici:* adult male. (Photo by Ohio Exp. Sta.)

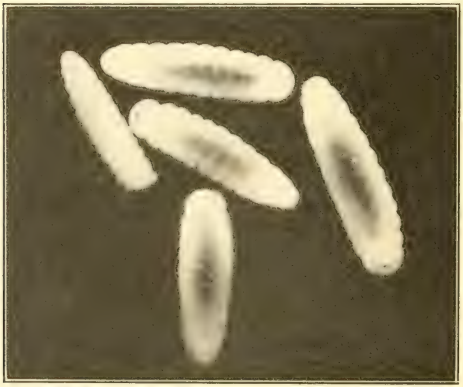

FIG. 248.—*Isosoma tritici:* larvæ. (Photo by Ohio Exp. Sta.)

this is not deemed necessary if the straw passes through the barnyard, as most of the pupæ are killed by this treatment.

The egg parasites (*Proctotrupidæ*) are extremely small, most of the species being parasitic in the eggs of insects. Eggs of web worms are parasitized and the whole development of the *Proctotrupid* is contained within the egg. One species is described as one-nintieth of an inch in length, another one one-hundred-and-fiftieth of an inch and the body very slender. These serve a most important function in the destruction of other insects, those that would otherwise hatch from the eggs. When the parasites feed on the caterpillars the damage is only partly checked, but when the parasite feeds on the eggs the damage is all prevented. One of the important lines of economic entomology is to study such forms and their life histories with regard to other species, as primary parasites, secondary parasites, tertiary parasites, etc., since their value depends on whether they directly control a pest or whether as a secondary parasite they reduce the numbers of a primary parasite which is useful.

**Ants** (*Formicina*) are one of the most interesting groups of insects. They are sometimes given the rank of a superior family, but the principal family is that called *Formicidæ*. The name is associated with the secretion of formic acid. The name of the group probably gave the name to the chemical. The secretion is one of the characteristics of the *Hymenoptera*. Ants present striking habits of family life; the formation of different classes among the individuals of a colony. This separation into classes is paralleled in other groups, as the bee family and among wasps, and expecially the termites. The result of community life is that it presents certain relations in the community in the way of division of labor. The primary forms are males and females, and then a class which are not sexual but are derived from a modification or suppression of the reproductive factor in one of the sexes. Occurring with this is the reduction or complete absence of wings. These constitute the so-called workers or soldiers of a colony. They have no wings whatever. This feature reaches far back into the ancestry of the group, or else shows parallel evolution. Sexual individuals have wings primarily but in the case of

the queens the wings are broken off or dropped off after the flight associated with mating. Then the females are unable to travel and remain fixed in a certain colony and furnish offspring for the colony. A group of ants is called a formicary. It may vary in number of individuals from a few hundreds to thousands. A single queen ant may survive for a great number of years and the same colony may go on for many years. The usual course of the life-cycle is for winged females to issue from some colony and make their flight that is connected with mating, and then to burrow into the ground or select a suitable nest to place the eggs and begin the formation of a new colony. The fertilized queen is capable of producing workers and in some cases the queen alone will start a colony. In some forms perhaps the help of other ants is needed. With the starting of the colony and the deposition of eggs a colony becomes more populous. Differentiation has not gone quite so far in ant colonies as in some others. The workers take care of the eggs and the young and shift the young about, and if the nest is disturbed they carry the pupæ to a place of safety. The pupæ are, of course, helpless. The workers and soldiers die off pretty rapidly. They survive through the working period and when they die are replaced by other workers. The colony retains its individuality year after year. The life of the colony is probably at least as long as the life of the queen and probably continues longer than that. Otherwise the colony would have to terminate soon after the death of the queen. The multiplication of colonies is provided for by the issuing of new queens from the colonies and the ability of the ant to survive depends as much on its ability to form new colonies as on new individuals. There is just as much reproduction of colonies as of individuals. The cycle is probably for annual periods in each season and the females are probably produced annually. The food of the ants is primarily plant food. They collect nectar and various substances of vegetable origin, and the workers are responsible for the collecting and storing and using of the food supply. Indirectly they get such supplies

from the aphids. They store up grain in some instances, and use this grain to some extent at least as a food supply.

One of the species—the honey ants—collect honey and store it in the stomachs of certain individuals of the colony. The bodies of these individuals become very much distended and the abdomen becomes large and spherical and these keep the food for a part of the year. This ant occurs in the plateau regions of Colorado, particularly in the Garden of the Gods. The volume by McCook on these ants is an especially interesting account of animal adaptation. Also Lubbock's book on *Ants, Bees and Wasps* gives many interesting experiments, but his observations indicated that while there is an adaptation to complex conditions they are not comparable to the activities of human beings.

There are many species—little red ants, those occurring in gardens, and walks, the house ants, and the large carpenter ants, which form nests in hollow logs. The queen is quite a large insect and usually with wings entirely wanting. Large red ants and large black ants construct hills for their nests, sometimes three to six or eight inches high, and perhaps twelve to eighteen inches across the top. This red ant is a slave-making species, going out on forays and capturing black ants which they force to carry on the labor of the colony. Some species are said to have carried the slave-making habit to such an extreme that they are unable to get along without the slaves and even require slaves to go out and capture new slaves.

**Field Ants.**—One of the important species is the little field ant which is associated with the corn-root louse and which has been named in connection with the discussion of the aphid. This species is very widely distributed throughout the United States and wherever corn is grown and the corn-root louse is present it constitutes an important factor in the abundance and destructiveness of the root louse.

**The Argentine ant** (*Iridomyrmex humilis* Mayr) is one of the recently introduced pests and one which is liable to become distributed to cover the Southern States and possibly

to occupy at least the cotton-growing region if not a greater extent of the country.

The species is thought to have been introduced from Argentina and was first noticed in New Orleans where it was reported as occurring in fair numbers in 1891. It is now known throughout most of Louisiana and in eastern Texas, and also occurs in California. Within the range of its distribution it has become a very serious pest and its further distribution will naturally be a matter of serious consequence to other localities. Without assistance the ant migrates slowly but with the opportunities afforded by commerce its dispersal may be quite rapid.

As with the other ants there are males, females, and neuters; the males and females being winged, the neuters wingless but the females lose their wings after the mating flight.

The size of the colonies varies from a few individuals to many thousands and a number of queens may be present in each colony. The nests are built in various places underground, seldom occurring at any great depth.

This species is a most difficult one to control and experiments with poisonous materials, repellants, etc., have met with only partial success.

**Wasps** (*Sphecina*).—In this group we have a considerable number of solitary forms of those which preserve the primitive conditions of males and females without workers or with large broods raised at one time in one nest. Mud, paper, pith, etc., are used as building materials. The sand wasp (*Bembecinæ*) burrows into the sand for its nest. They stock these nests with insects of different kinds such as May flies. The larvæ develop by feeding upon the bodies of these stored insects. It is strange that they can keep a burrow complete enough so that they can pass in and out a number of times. They are very common here and are protected to some extent by the coloration of the body. Their burrows are constructed along through the summer and the larvæ develop during the summer and presumably all reach the pupa stage before winter and live over as pupæ, issuing

the following season. The adults will be found flying around all through the midsummer months. Perhaps they are a

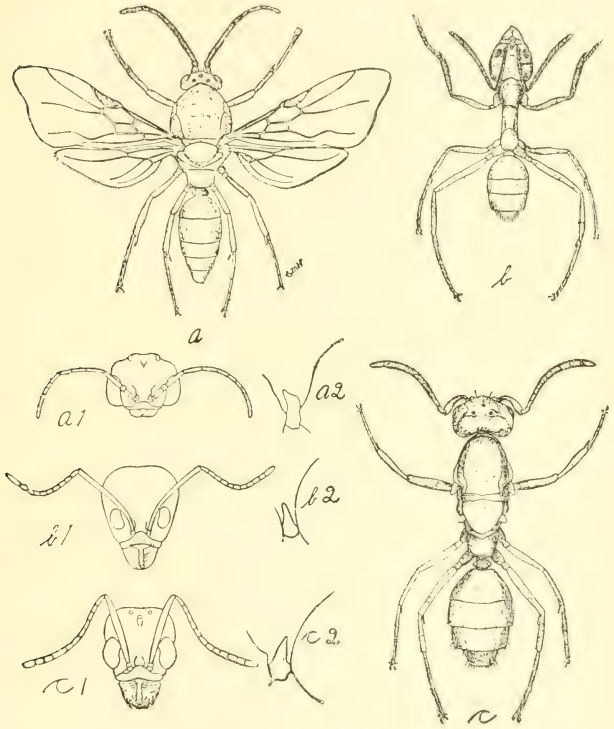


FIG. 249.—The Argentine ant, adult forms: *a*, adult male; *a1*, head of male; *a2*, petiole of male; *b*, worker; *b1*, head of worker; *b2*, petiole of worker; *c*, fertile queen; *c1*, head of queen; *c2*, petiole of queen. All greatly enlarged. (After Newell.)

little more abundant in the later part of July. They belong to the *Bembecidæ*. One of the large members of the family is called the "cicada killer" *Sphecius speciosus*.

**Social wasps** (*Vespidæ*) make large nests and large colonies and show some degree of differentiation into classes or castes of individuals in that there may be smaller individuals at the end of the season which live through the winter.

**The Hornet** (*Vespa maculata*) builds up a large paper nest which is made up of a series of combs with the aperture at the lower part. This becomes very populous during the latter part of summer. The survivors are adults that secrete themselves under leaves and rubbish and start a fresh colony the succeeding year. They do not live in the large nest through the winter. This common species is social.

**The yellow jacket** (*Vespa germanica*) is also a social species, its nests are found in hollow trees.

It is interesting to compare the materials used by these species. They use wood or paper which is a pulp worked up from the wood fiber and is to be compared with manufactured paper in the tissue of which it is made and in the manner of manipulation.

In the bees, *Apidæ*, there is an elongation of the beak for getting the nectar from the flowers and the more specialized forms secrete wax for the formation of the cells. This is worked up into a gum or built into cells for the rearing of the larvæ. There is a gradual culmination in the development of community life in this family from the wild bees that are practically solitary up to the bumble bee and honey bee. The honey bee is probably the best-known because kept under domestication. A bee colony consists of a queen, which is a constant factor in the colony—a queenless colony cannot survive any length of time—and drones or males which occur during the summer. These are the normal-sexed individuals. Then we have the workers or neuter forms which are undeveloped females and these carry on all of the complex work of the colony, providing food, caring for the larvæ and for the rearing of new queens.

The cycle as applied to the queen would involve three to five years. They live that long and deposit millions of eggs during that time. The drones live but a short period. The workers live a few weeks or months through the summer and in the more inactive parts of the year. The queens from the egg stage to the adult stage occupy about sixteen days, the workers twenty-one days, the drones twenty-four days. There is a distinct difference in the eggs that produce workers and drones. The worker eggs are fertilized and the drone eggs are unfertilized. This is apparently controlled by the queen and dependent upon the kind of cells in which the eggs are laid. The exact method of control by the queen is not fully understood. The size of the cells may have some effect by the pressure on the abdomen. The acceleration of the queen may be because the workers feed them with a richer sort of food. They develop more rapidly and the reproductive organs are fully developed. There is colony reproduction as well as individual reproduction, that is, an increase in the number of colonies. They die off from old age, loss of queen, cold weather, etc., and if there were no process for increasing the number of the colonies they would be exterminated. This is provided for by swarming. The queen and a large number of workers issue from the colony and form a new colony. The old colony is provided for by other young queens in the cells or else fertilized. There is a loss of honey but no break in the life of the colony. Bee-keeping is an important industry and there are many books dealing with the subject. Among those of special value are the following:

Cheshire, Honey Bee. Root, Bee-keeping. Langstroth, Hive and Honey Bee. Snodgrass, Anatomy of the Bee. Benton, The Honey Bee. Cook, Manual of Bee-keeping. Comstock, How to Keep Bees. Phillips, Bee-keeping. Pellett, Productive Bee-keeping.

## CHAPTER XI.

## PRINCIPLES OF ECONOMIC ENTOMOLOGY.

While it cannot be assumed that we have at present a complete knowledge of those underlying principles which are to be recognized in the prevention or control of insect ravages, enough has been done to make an attempt at a brief statement of such principles in order. Many of these principles have been stated in greater or less detail in the writings of different entomologists but no comprehensive statement has been attempted —especially since the marked advances of the past quarter-century. Applied entomology today is a totally different structure than that which existed twenty or even ten years ago. In many respects it is getting nearer to the fundamental laws of biology, and there is a more general appreciation that its successful application involves thorough acquaintance with biological principles. In the broadest sense economic entomology involves a recognition of the relation existing between insects and other organisms, but finally, the relation they bear to the human species.

### RELATION OF INSECTS TO OTHER ORGANISMS.

Considering the great multiplicity of insect forms, their world-wide distribution in almost every condition open to the support of life, it is not strange they occupy a most important relation to other organisms. This relation may be serviceable or inimical, directly or indirectly from the stand-point of any particular organism, and may indeed differ totally at different times or under different conditions. From the stand-point of any particular species it is detri-

mental if the insect feeds upon the plant or animal or interferes with its successful existence. It is beneficial, if it contributes to its success by warding off other dangers or assisting pollination or contributing in any way to its better growth and development.

## ECONOMIC ENTOMOLOGY.

Economic entomology is based upon the relation of insects to mankind and all species that interfere with his welfare are considered injurious, and those that may serve him in any way are considered beneficial. The relation, however, may become very complex. An insect that feeds upon a cultivated crop, or destroys the products of a crop, or injures a domestic animal, or worries man himself, or menaces his health by inoculating him with disease, is injurious from the human stand-point. While if it produces a valuable material such as silk or honey, wax, dyes, etc., or serves to destroy injurious species as predaceous and parasitic forms, or feeds upon noxious plants, weeds, or disposes of noxious substances, as the scavengers, it is directly useful, and we term it beneficial. Many cases are very clearly in one class or the other; many have little apparent importance one way or the other, and in many cases the relation may change with circumstances. For example, a parasitic insect preying on an injurious species is useful to us, but if it destroys a useful insect it becomes injurious. A parasite on a parasite, that is, a secondary parasite is detrimental if the primary parasite attacks an injurious insect, and a parasite upon this secondary parasite, that is, a tertiary parasite would be useful, since its effect would be to check the secondary and favor the primary parasite. Still further, a quaternary parasite, and this is I believe as far as this relation is known, would be injurious. The reverse in each case would be true if the original host were useful.

We should not forget that these three terms refer strictly to mankind, for in the broader biological sense each kind of

animal is doing its best to perpetuate itself and multiply its kind, and every interference is from its stand-point injurious.

## FOOD HABITS.

It is very evident that one of the first and most important relations concerning an insect is to be found in its food habits.

Insects, like other animals, may be considered primarily herbivorous. That is, the most general plan of nutrition for them would be to feed upon fresh, growing leaves of plants, with feeding upon fruits, seeds, bark, wood, roots, decaying wood as adaptations, while the assumption of carnivorous habits either as predaceous or parasitic species, or to go further, sucking blood of higher animals may be considered adaptations in another direction.

It is on this broad, general basis that we may consider herbivorous insects in the main injurious, and carnivorous insects, especially if predaceous and parasitic on other insects, as beneficial.

In this connection we may refer to the principle which has been termed "unity of habit" and treated by Dr. B. D. Walsh. This is in effect that in any given group we may expect to find similar habits among all the species, and if for any species the habits are unknown, they may be expected to follow those of the known species. To this law there may be striking exception, however, and along certain lines peculiarities should be considered the rule and not the exception. To find the most certain action of the law we may, I think, say that in all particularly specialized groups "unity of habit" is practically general. In less specialized groups variation is more frequent. For example, in the bark beetles, *Scolytidæ*, we would be astonished to find a leaf-eating larva, or in *Aradidæ* a species that does not live under bark is exceptional. In *Lepidoptera*, the larval diet is generally herbivorous and the two or three carnivorous species notably the exception. We safely assume that all plant lice are plant feeders and treat them accordingly. The

weevils are reckoned invariably as plant feeders, almost entirely confined to fruit or seeds, while *Carabidæ*, though largely carnivorous, show too much variation in food and too many herbivorous species to make it safe to draw conclusions without the study of each species. In the application of this principle, therefore, it becomes necessary to consider the nature of the group as a whole, not merely the habits of certain ones.

## MEASURES FOR INSECT CONTROL.

There have been a great many different remedies and plans of treatment for the control of injurious insects and it would be impossible to discuss them all, even those which have general application, in a short course. The attempt will be to select some of the most universal and useful and give them with such rules as to make it possible to apply them without further instruction.

In general the methods of control for insects may be separated into those which are direct and have in view the destruction of the insect with some destructive agent or mechanical application, and those methods that depend upon some plan of cultivation or sequence of crops to prevent or modify the insect attack.

**Direct Methods. Insecticides.**—Substances used in such manner as to kill directly are termed insecticides, and insecticides may be classed broadly into two large groups: (1) those which are poisonous in character and depend for their effect upon the insects swallowing them with their food and (2) those which affect the insects by contact or penetration, such as the oils and fumigants.

Of the poisonous materials some preparations that are among the most important may be mentioned.

**Paris Green.**—Paris green is a bright green arsenical powder which should contain at least 50 per cent. arsenious oxide and not over 3.5 per cent. soluble arsenic. The formulæ for its use are as follows:

| | |
|---|---|
| Paris green . . . . . | 5 ounces |
| Lump lime . . . . . | 1 pound |
| Water . . . . . | 50 gallons |

For small quantities use:

| | |
|---|---|
| Paris green | 1 heaping teaspoonful |
| Lump lime | 2 or 3 ounces |
| Water | 3 gallons |

For dry application the powdered Paris green may be mixed with flour or air-slaked lime and dusted upon the plants by enclosing the powder in a muslin sack and shaking this over the plants it is desired to treat.

**London purple** is a by-product in the manufacture of aniline dye and is an effective poison but somewhat less certain in its effect and more likely to injure foliage. It is at present not so common on the market as Paris green, it is, however, somewhat cheaper and when properly diluted is a desirable insecticide.

**Arsenate of Lead.**—Arsenate of lead, available in two forms —paste or as a white powder—may be secured on the market, or the arsenate may be formed by chemical combination of arsenic and lead. Formulæ for the use of this substance are as follows:

| | |
|---|---|
| Arsenate of lead (paste) | 3 to 10 pounds |
| Water | 50 gallons |

or

| | |
|---|---|
| Arsenate of lead (powder) | 1 to 4 pounds |
| Water | 50 gallons |

For small quantities use:

| | |
|---|---|
| Arsenate of lead (paste) | 1 teaspoonful |
| Water | 1 gallon |

If used as a spray this can be applied to a great variety of plants for the destruction of leaf-eating insects, and since it can be used at high strength without injury to foliage it may be used for the most resistant kind of insects. Its killing power is not equal to that of Paris green and consequently somewhat stronger solutions must be used.

Like Paris green, it may be used in the dry form as dust or with a powder gun.

**Hellebore.**—Hellebore is a white powder destructive to insects but not poisonous to domestic animals or man, unless

in large doses. It may be used as a spray or in a dry form and is applicable to currant bushes or other kinds of fruit, for saw-fly larvæ and other leaf-feeding insects where it is undesirable to use arsenic.

**Arsenical Bran Mash.**—This is used as a bait for cut worms and other insects which endanger vegetation and which it is desirable to kill before the vegetation has been attacked. Formula as follows:

| | |
|---|---|
| Bran | 25 pounds |
| Paris green | ½ pound |
| Cheap molasses | 1 quart |
| Water, as needed to moisten. | |

For small quantities use:

| | |
|---|---|
| Bran | 1 quart |
| Paris green | 1 teaspoonful |
| Cheap molasses | 1 tablespoonful |
| Water, as needed to moisten. | |

For grasshoppers the attractiveness of this bait is very much increased by the addition of lime juice or orange or lemon flavor.

**Contact Insecticides.**—Insecticides of this group depend upon immediate contact with the insects to be affected, different kinds of sprays, direct applications and the use of fumigants which are distributed to the insects to be reached.

Lime-sulphur wash is the most important of the insecticides now in use against the scale insects, especially the San José scale. The commercial lime-sulphur preparations on the market generally may be secured at seed-stores or from dealers in nursery or orchard supplies and depended upon as containing the correct proportions and if used according to directions should give very certain results. These can be secured at reasonable prices and are often preferable to the solutions of home preparation. However, directions for the preparation of the compound may be of service and two formulæ will be given, one for the concentrated solution to be diluted when used and the other for immediate use.

FIG. 250.—Making lime-sulphur solution (Photo. Ohio Exp. Sta.)

FIG. 251.—Plant for making lime-sulphur solution in large quantities. (Photo. Ohio Exp. Sta.)

*Concentrated Lime-sulphur.*

| | |
|---|---|
| Lump lime | 50 pounds |
| Sulphur | 100 pounds |
| Water (hot) | 70 gallons |

Dilute as directed.

For exact preparation the use of the hydrometer is desirable and the following scale of proportions is recommended.

| Reading on hydrometer in degrees (Baumé). | Number of gallons of water to 1 gallon of the concentrated lime-sulphur. |
|---|---|
| 35 | 9 |
| 34 | $8\frac{3}{4}$ |
| 33 | $8\frac{1}{4}$ |
| 32 | 8 |
| 31 | $7\frac{1}{2}$ |
| 30 | $7\frac{1}{4}$ |
| 29 | $6\frac{3}{4}$ |
| 28 | $6\frac{1}{2}$ |
| 27 | 6 |
| 26 | $5\frac{3}{4}$ |
| 25 | $5\frac{1}{4}$ |
| 24 | 5 |
| 23 | $4\frac{1}{2}$ |
| 22 | $4\frac{1}{4}$ |
| 21 | $3\frac{3}{4}$ |
| 20 | $3\frac{1}{2}$ |
| 19 | $3\frac{1}{4}$ |
| 18 | 3 |
| 17 | $2\frac{3}{4}$ |
| 16 | $2\frac{1}{2}$ |
| 15 | $2\frac{1}{4}$ |
| 14 | 2 |

*Regular Lime-sulphur Wash (for winter spray).*

| | |
|---|---|
| Lump lime | 20 pounds |
| Sulphur | 12 pounds |
| Water | 50 gallons |

**Kerosene.**—The use of kerosene or petroleum combinations has given some of the most useful combinations and they still have a wide range of usefulness, although at present less used than the lime-sulphur solutions for scale insects. Generally they may be applied to practically all kinds of insects which are suctorial in habit and cannot be reached by arsenical sprays, but they are especially efficient against the scale insects at time of migration and against such soft-bodied insects as the plant lice. In the preparation of the kerosene emulsion it is extremely important that a thorough emulsion be obtained so there will be no separation of oil from the water, as there is much damage to the foliage if this occurs.

The standard formula for kerosene emulsion is as follows:

| | |
|---|---|
| Hard soap | ½ pound |
| Hot water (soft) | 1 gallon |
| Kerosene (coal oil) | 2 gallons |

To form the emulsion take a gallon of soft water and dissolve in it a half-pound of soap, then remove from fire, add two gallons of kerosene, which should be thoroughly mixed and agitated at once. One of the best methods is to run the solution through a spray pump, driving it back into the bucket from which the solution is drawn, and about five or six minutes of this mixing will produce a perfect emulsion. It should be carried to such completion that there will be no tendency for the oil to separate. Small quantities may be made rapidly in the proper proportions by the use of an egg-beater or by a process which produces a violent agitation which may be maintained for some length of time. This strong emulsion should be kept in a cool place and covered or in a tight receptacle and may be diluted as wanted with soft water, the amount of dilution depending upon the insects to be reached. For scale insects, one pint of strong emulsion to nine parts water. Soft plant lice are readily killed by a solution of one part of stock solution to fifteen parts of water.

**Tobacco Extract.**—This is a very efficient contact insecticide and may be used against many kinds of insects but especially such forms as plant lice, thrips, and the better-protected sucking insects. Various solutions are on the market but the one termed Black Leaf 40, containing 40 per cent. nicotine sulphate, is one which seems to have proved one of the best; this is used in dilutions of 1 part to 300 of water to 1 part to 600 parts of water—for use in winter time, when plants are dormant, and for summer use, dilutions—1 to 500, to 1 to 1000 are recommended for tender insects such as plant lice. Similar solutions may be used for parasitic lice and mites on domestic animals.

Tobacco dust may be used or an extract prepared from this by steeping or soaking in water overnight. In making the preparation boil one pound of dust or stems to a gallon

of water, and this may be diluted, one to two parts of water and applied for leaf-sucking insects.

**Pyrethrum or Persian Insect Powder.** – This is a very powerful insecticide when properly prepared, but loses its strength when exposed to air, so that particular care should be taken to keep it in a tightly closed receptacle or it must be used when quite fresh. It is a powdered material derived from the grinding of the leaves or flowers and buds of the *Pyrethrum* plant, the main supply coming from Dalmatia, but a consider-

FIG. 252.—An orchard demonstration in spraying.
(Photo. Ohio Exp. Sta.)

able amount being produced in California. It is a volatile oil and it is the vaporization and contact of this which is destructive to the insect. It may be used as a spray by the dilution of one ounce of powder to two gallons of water, and is available for saw-fly larvæ and other pests upon currants, gooseberries, etc., being especially valuable on account of its not being poisonous to man or domestic animals. The powder, blown into rooms is effective for the killing of mosquitoes and flies, but for this purpose does not compete

with some other measures. It may be used upon dogs and cats for the killing of fleas by dusting in the hair.

**Machinery.**—For the application of these various insecticides, a great many forms of spraying outfits, dusting machines, etc., have been devised. These are now so thoroughly standardized and handled by reputable firms that anyone may secure such outfits as may be needed for his individual purpose.

**Cultural Methods.**—Another distinct group of measures for insect control (the indirect methods) may include those which have to do with methods of culture and alternation of crops and various cultural methods which incidentally have an effect upon the activities of insects.

First among these may be mentioned the general practice of crop rotation which for a good many insects serves in an admirable way to prevent undue multiplication of injurious forms. Aside from its advantages in other ways, rotation serves to dislodge or starve out a great number of insects which are not able to migrate readily and which become established in any field only after several years of uninterrupted development. For such forms the plowing up of the fields or a change from one crop to another may prove an almost perfect control. A striking example of this has been noted in the case of the corn-root worm. In somewhat lesser degree the process is available for many of the pasture and meadow insects which are dependent upon grasses as their main food supply and which when grass is plowed under, especially if this is done at a time when the insects are in larval or in a known migratory stage, serves to destroy them very effectively.

In a general way plowing will cut off the food supply, sometimes will bury the insects to such a depth that they do not extricate themselves. In this connection, however, it is sometimes very important that the condition of the insects be known, as there are cases, such as white grubs, sod worms, and wire worms, which if plowed under with the sod will, if a second crop is planted soon, transfer their attack to the new crop with very disastrous consequences. It frequently

happens that corn planted on sod land is in this way very seriously injured. The precaution should be to plow under long enough before the new crop is planted to allow opportunity for the starving out of insects which may be present in the grass.

Another practise in this line is for such an arrangement of crops that insects which naturally migrate from one crop to another will be separated by a crop of different character, something that will not serve them as a food supply. For instance, the migration of the chinch bug from wheat fields into corn fields may be prevented by the introduction of a strip planted to potatoes, beans or some crop which is not available as chinch bug food.

The use of an early planted crop for the purpose of attracting insect egg deposition with the view of destroying the insects so attracted and thus protecting the later crop, has been in vogue for many years and is applicable to such species as have several generations in a season. A good example of this is the corn-ear worm which if attracted to a small area of early planted corn which is fed to hogs at the time the worms begin work will assist much in the prevention of attacks on adjacent fields.

In some cases where an insect is especially destructive in a certain area, resort may be had to the suppression of the cultivation of a crop for one or two seasons, thus eliminating food. This will largely diminish if not practically exterminate such insects as are strictly dependent upon this crop for existence. Naturally such a method is limited in application, as the complete suppression of any crop in a certain district is a difficult matter to accomplish.

Clean culture is often recommended as an important aid in the suppression of insects, and there is no doubt that for many species attention to the elimination of food plants which assist them to survive and the cleaning up of litter in which they may hibernate will accomplish a great deal in the reduction of numbers and the consequent extent of injury. Clean culture, however, must be taken in connection with a study of the habits of the species which it is

desired to control and cannot be considered as an efficient practise for many insects that are troublesome on the average farm. In this connection it may be stated that it is good entomological practise to use wire fences in place of the old rail or board fences, and it is a good plan to cultivate as close as possible to fence lines with the consequent reduction of the growth of weeds, bushes, and so on.

Another matter which deserves attention is a close guarding against the introduction of pests in seed or along with introduced plants, as many of the serious pests are readily transferred from place to place in such materials as straw and various kinds of seed packages and thus gain a foothold in a locality in which they have not been troublesome before.

## NATURAL ENEMIES.

Insects are preyed upon by many natural enemies—birds, reptiles, toads, spiders, and these serve as checks to their inordinate increase. Bird protection has been strongly urged as an aid in insect control and certainly all or nearly all of our common field birds are best allowed all the protection possible. Especially the small insectivorous birds such as wrens, swallows, chickadees, titmice, etc., should be given all the protection possible. Spiders are also generally useful rather than injurious and should be undisturbed.

## PREDACEOUS AND PARASITIC INSECTS.

The position of the predaceous and parasitic insects is one of considerable complexity, since their attacks may be directed against both injurious and beneficial forms, and their relation to human interests depends, of course, upon the nature of the insects which they attack. In a general way the carnivorous species feed upon the herbivorous ones, and the herbivorous ones being ordinarily the most destructive to valuable crops, the average result may be looked upon as advantageous. The study of these natural enemies of the injurious insects has formed a considerable part of

economic entomology, and the importance of the subject has been pretty generally recognized, though different workers have assigned quite different value or importance to to the subject.

Predaceous insects are those which attack and devour other insects, possibly quite different kinds of insects, and do it without sacrificing their own activity or independence. Parasitic insects, using this term as it applies more particularly to economic entomology, are those which are dependent for a larger or smaller part of their existence upon some particular kind of insect host. Nearly all are internal parasites and in a great majority of cases the entire development of the individual from the egg to pupa or adult stage is passed within the body of a single individual host. Sometimes a large number of individuals will develop within a single host, as in case of the minute ichneumons which parasitize the larger caterpillars.

It must be noted here that a parasite itself may be parasitized by another species called a "secondary" parasite which, by reducing the numbers of the parasitic species, would become from the economic stand-point injurious. This, again, in some instances may support still another parasite, a so-called "tertiary" parasite, which by reducing the numbers of the secondary parasite would be detrimental, and a fourth, where such occurs, again assumes the opposite role. It is evident where such a complex condition of parasites exists that it is practically impossible to adopt any means of encouraging the beneficial or destroying the injurious ones, and that this complex system of wheels within wheels must be allowed to work out its own conclusion in the balance of nature.

For most species there is perhaps but little that can be done in the way of preserving the beneficial parasites or of facilitating their work. We simply allow them to go on unmolested, serving so far as they may, as a natural check upon the injurious species. Many of our destructive insects are insects that without this check would be seriously destructive, the regular attacks of these parasites serving very

effectively to keep the destructive species in reasonable bounds and often preventing it from causing any serious loss. The Hessian fly is certainly kept in check during a considerable portion of the time by just such agencies, and we can scarcely doubt that if the parasites of this species were eliminated and other conditions unaffected, the losses incurred would be enormously increased.

With some species it may be possible to assist the parasitic forms or to preserve them in such manner as to get the advantage of their service. For instance, the cabbage butterfly is very commonly parasitized by a small ichneumonid (*Pteromalus*) which issues from the pupæ, and it is evident that if the pupæ were gathered and instead of being crushed were enclosed in wire screen of such mesh as to retain the issuing butterflies but allow the free escape of the minute parasites, there would be a destruction of the healthy butterflies without any reduction in the numbers of the parasites. Again, in the case of the Hessian fly, care as to the time when the stubble is burned or plowed under in order to allow opportunity for escape and survival of the parasites, might be of special service in their protection. In California extensive shipments of lady bugs from the northern part of the State to the Imperial valley to prey upon the plant lice affecting melons is claimed to have accomplished much in their control.

On the whole, however, the utilization of parasites in a direct manner can hardly be depended upon as a very great advantage, especially because of the difficulty in so training the average cultivator that he will be able to distinguish between parasites and non-parasitic forms, and adapt his practice to accommodate them.

A more important phase of the subject perhaps is found in the transportation of parasitic species from one country to another where an injurious species has been introduced without the introduction of its native enemy. It has already been suggested that the original habitat of an injurious insect is a matter of great importance, especially with reference to its natural parasites, and a number of instances

are now in evidence showing the possibility of controlling injurious, introduced species by means of the introduction of the native enemies. The most conspicuous is that of the cottony cushion scale, introduced into California several years ago, and in more recent years the very extensive introduction of predaceous and parasitic enemies of the Gipsy and brown-tail moths in the New England States for the control of these very destructive imported pests.

## EXCLUSION AND RESTRICTION.

These are most important means of controlling insect depredations. Formerly the entomologist devoted his entire attention and effort to the study of native species but now his attention is largely directed toward exclusion from and restriction in the United States of new insects. Until recently in the introduction of new plants from foreign countries, no attention has been paid to the new insects introduced with them. An important part of the work of the entomologist in the future will be to study the insects of other countries—not only those that are now destructive there but those that do no particular damage, yet when the natural checks are removed, are likely to become destructive.

Special attention must be paid to those insects which are native in those countries from which we import a greater part of our plants. Some of the foundation principles in the study are:

1. An insect, coming from another country, is more likely to become destructive here if it comes from a somewhat similar climate, and if the food plants are somewhat closely related to those of its native country.

2. Insects coming from different climates may, if they have a wide range of food plants, adapt themselves to the new climate. It will then be proper to consider tropical species, especially if their food plants are widely distributed and have nearly related species in the country to which they are brought.

3. Tropical insects that are limited to tropical plants for food, will have little importance in temperate regions except in greenhouses.

Most of the scale insects are tropical and in this climate are on the borderline of their destructive region, but on account of their general food habits they constitute a general pest.

The question of the control of the distribution of the destructive species is yet a new problem and one over which there is considerable dispute; any measure intended to exclude a foreign species must be adapted to a particular species, as a general law will not suffice. Even the general exclusion of the food plant will not alone be effective in keeping out the pest, as it may have other means of dispersal.

Inspection and enforcement of restrictions at the port of entry are being quite generally adopted. Inspection is most effective when applied to plants. Sometimes it is necessary to introduce a foreign species to prey on another foreign insect that is already here, as was the case with cottony cushion scale in California.

# GLOSSARY OF THE TERMS USED IN ENTOMOLOGY.

Abdomen. The posterior region of the insect body.

Abiogenesis. Spontaneous generation.

Abraded. Scraped or rubbed.

Acalyptrata. Those muscid flies in which alulæ are absent or rudimentary.

Aculeate. Prickly; armed with a sting.

Acuminate. Tapering to a long point.

Addorsal. Close to but not on the middle of the dorsum.

Adephagous. Belonging to the Adephaga; pentamerous, predatory, terrestrial beetles with filiform antennæ.

Adpressed. Contiguous or pressed to.

Agamic. Reproducing without union with a male.

Agamogenesis. Reproduction without fertilization by a male; parthenogenesis.

Agglutinate. Glued together in a mass.

Aggregated. Crowded together.

Ala (pl. Alæ). Wing or wings.

Alary. Relating to wings.

Alate. Winged.

Alternation of Generations. Periodic production of parthenogenetic females in a species that occurs in both sexes. These females produce both sexes. Examples occur in Cynipidæ and in some Homoptera.

Alulæ. A pair of membranous scales above the halteres, behind the root of the wing, one above or before the other; the anterior attached to the wing and moving with it, the posterior fastened to the thorax and stationary. Occurs in Diptera. Synonyms calyptra; squama; squamula; lobulus; axillary lobe; aileron; scale; tegulæ. In Coleoptera, a membranous appendage of the elytra which prevents dislocation.

Alulet. The lobe at basal portion of wing in Diptera.

Ametabola. Insects not having obvious metamorphosis, the larvæ resembling the adult and the pupæ being active.

Amnion. The inner of the two membranes enclosing the embryo.

Amphimixis. The mingling of the germ plasm of two individuals.

Ampulla. In Orthoptera, an extensile sac between the head and prothorax, used by the young in escaping from the ootheca, and later in moulting. In Heteroptera, a blister-like enlargement at the middle of the anterior margin of the prothorax.

Anal. Pertaining or attached to the last segment of the abdomen.

Anal angle. That angle on the secondaries nearest the end of the abdomen when the wings are expanded. The angle between the inner and outer margin of any wing.

Anal appendages. The external genital parts.

Anal area. In Orthoptera and Neuroptera, the hinder or anal portion of a wing within the anal vein.

Anal field. That area on the tegmina of Orthoptera corresponding to the anal area of the secondaries.

Anal plate. In caterpillars, the shield-like covering of the dorsum of the last segment.

Annulate. Marked with colored rings or bands.

Annulus. A ring.

Ante-apical. Before or in front of the apex.

Antennæ. Two-jointed organs of sensation situated on the head.

Antepectus. The lower surface of the prothorax.

Antigeny. Sexual diversity.

Anus. The posterior opening of the digestive tract.

Apex. The terminal portion of any organ of body, the part farthest away from the base.

Appendiculate. Bearing appendages.

Appendix. A part added or attached to another part.

Apterous. Without wings.

Aquatic. Living in the water.

Araneiform. Spider-like in appearance.

Arboreal. Living in or on trees.

Arborescent. Branching.

Arcuate. Bowed or curved.

Arenose. Sandy, not smooth.

Areola. A small cell on the wings of certain Hemiptera.

Arista. A specialized bristle or process on the antenna of certain Diptera.

Arolium. Cushion-like pads on the tarsi of many insects.

Arthropoda. Jointed animals having jointed appendages.

Articulate. Divided into distinct joints.

Articulation. Joint; place where two joints meet.

Asexual. Without sex. Reproduction which does not involve the union of individuals of different sexes. Reproduction by budding, etc.

Ater. Deep black.

Atomarius. With minute points or dots.

Bifid. Split, two parts.

Bifurcate. Divided; forked.

Bionomics. The habits, breeding, and adaptations of living forms.

Biserrate. Saw-toothed on two edges.

Bivittate. Having two longitudinal stripes.

Brachycerous. Having short three-jointed antennæ, Diptera.

Brachypterous. Short-winged.

Bristle. A short, stiff hair.

Buccal. Relating to the mouth cavity.

Bulla. A blister or blister-like structure.

Cæcum. A blind sac or tube opening into the alimentary canal.

Calypter. In Diptera, the alula when it covers the haltere.

Campodeiform. Resembling campodea.

Canaliculate. Grooved longitudinally, with a concave line in the middle.

CANCELLATE. Cross-barred; latticed.
CAPILLARY. Hair-like; long and slender.
CAPITATE. Terminating in a little head or knob.
CAPRIFICATION. Process of fertilization of Smyrna figs by Blastophaga through the medium of "caprifigs."
CARABIDOID. Resembling a Carabid.
CARINA. An elevated ridge.
CARNIVOROUS. Flesh-eating.
CAUDA. The tail; any process resembling a tail.
CAUDAD. Toward the posterior region of the body.
CAUDAL. Pertaining to the posterior end of the body.
CAUDAL SETÆ. Thread-like processes at the end of the abdomen.
CAUDATE. Having tail-like extensions.
CAVERNICULOUS. Cave-inhabiting.
CELL. Space within the veins on the wing.
CELLULE. A small space included between the veins on the wing.
CEPHALAD. Toward the head.
CEPHALIC. Belonging to the head.
CERVICAL. Relating to the neck.
CHAETOTAXY. The science dealing with the arrangement and nomenclature of the bristles on the body of insects.
CHELATE. Having a claw.
CHITIN. The material of which the hard parts of the insect body are formed.
CHITINOUS. Composed of chitin or similar to chitin.
CHRYSALIS—ID. The intermediate stage between larva and adult; see pupa.
CICATRIX. A scar; an elevated, rigid spot.
CILIA. Fringes.
CILIATE. Fringed; set with parallel hairs or bristles.
CLASPER. A chitinized process, free or attached to the inner sides of valves or other lateral pieces and serving to hold the female parts during copulation; the harpes.
CLAVAL SUTURE. Indentation separating the clavus at the base of the hemelytra in Hemiptera.
CLAVATE. Club-shaped; thickening gradually toward end.
CLYPEUS. The anterior median portion of the head to which the labrum is usually attached.
COARCTATE. Contracted; compact.
COCOON. Silky covering enclosing pupa.
COLLUM. The neck or collar.
COLON. The large intestine.
CONNATE. United at base, or along the whole length.
CONNEXIVUM. The prominent abdominal margin of Heteroptera at junction of dorsal and ventral plates.
COPROPHAGUS. Feeding on excrement on or decaying vegetable matter of an excrementitious character.
CORDATE. Heart-shaped.
CORIACEOUS. Leather-like.
CORIUM. The elongate middle section of the hemelytra which extends from base to membrane below the embolium.
CORNICLES. The honey-tubes in plant lice.

Costa. An elevated ridge that is rounded at its crest; the thickened anterior margin of a wing.
Costal area. The area behind the costal vein.
Costal cell. The area inclosed between the costal and subcostal veins.
Coxa. The basal segment of the leg.
Coxal cavity. The opening or space in which the coxa articulates.
Crenate. Scalloped.
Crepuscular. Active at dusk.
Cristate. Crested.

Dentate. Toothed.
Dentate-serrate. Tooth-serrated: the denticulations themselves being serrated on their edges.
Dichoptic. Eyes separated by front, not contiguous.
Dichotomous. Forked, dividing by pairs.
Dimorphic. Occurring in two well-marked forms.
Dimorphism. A difference in form, color, etc., between individuals of the same species, characterizing two distinct types.
Dioecious. Having distinct sexes.
Discal. On or relating to the disk of any surface or structure.
Distad. Toward the distal end.
Distal. That part of a joint farthest from the body.
Divergent. Spreading out from a common base.
Dominant. A character more constant and conspicuous than any other.
Dorsad. Toward the upper surface.
Dorsal. Of the back.
Dorsum. The upper surface.
Drone. The male bee in Hymenoptera.

Ecaudate. Without tails or tail-like processes.
Ecdysis. Moulting or casting of the skin.
Ecology. The science of the relation of organisms to each other and to their surroundings.
Ectad. Extending outwardly from within.
Ectal. Relating to the outer surface.
Elytra. The anterior leathery or chitinous wings of beetles.
Embolium. The narrow sclerite extending along the anterior margin of the hemelytra, from base to cuneus or membrane, in Heteroptera.
Empodium. The small process between the pulvilli in Diptera. The bifid pseudotarsi between the claws in Coleoptera.
Ensiform. Sword-shaped.
Entad. Extending inwardly.
Ental. Pertaining to the centre of the body cavity.
Entire. With an even, unbroken margin.
Entomogenous. Growing in or on an insect.
Entomophagous. Insect-feeding.
Episternum. The anterior and larger lateral thoracic sclerite between the sternum and notum.
Epizoa. Insects that infest the body surface of animals.
Ergatoid. Wingless ants, sexually developed.

ERUCIFORM. Caterpillar-like in appearance.
EXOTIC. An introduced species, not native to the place found.
EXSERTED. Protruded.

FACET. One of the small divisions of the compound eye.
FASCIATE. Banded.
FEMUR (pl. FEMORA). The thigh between the coxa and tibia.
FILIFORM. Thread-like.
FLABELLATE. With long, flat processes folding like a fan.
FORMIC. Pertaining to or derived from ants.
FORMICARY. An ant's nest or ant hill.
FRONT. Anterior portion of the head between the base of antennæ and below the ocelli.
FUMOSE. Smoky.
FUNGICOLOUS. Living in or on fungi.
FURCA. A fork or forked process.
FURCATE. Forked.
FUSCOUS. Very dark brown.

GENA. Cheek; that portion of the head below the eyes on each side extending to the gular suture.
GENERATION. Brood.
GENITALIA. External organs of reproduction and their appendages.
GRANULATED. Covered with small grains.
GREGARIOUS. Living in groups or communities.
GRISEUS. Light gray.
GUTTATE. Spotted, light spots on dark ground.

HABITAT. The locality in which an insect lives.
HAUSTELLATE. Formed for sucking.
HAUSTELLUM. Sucker; the part of the mouth through which liquids are sucked.
HERMAPHRODITE. A bisexual individual.
HETEROGAMY. Alternation of generations, two sexual or a sexual and a parthenogenetic.
HIBERNACULUM. A tent or sheath in which a larva hibernates.
HIBERNATE. To pass the winter in a dormant condition.
HYPERMETAMORPHOSIS. The case in which an insect passes through more than the normal stages of development.
HYPERPARASITE. A parasite that is parasitic upon another parasite.

IMAGINAL Pertaining to the adult or imago.
IMAGO. The adult or sexually mature insect.
INFUMATED. Clouded.
INFUSCATED. Smoky gray-brown, with a blackish tinge.
INQUILINE. A species living in a gall made by another species, not as a parasite but as a guest.
INQUILINOUS. Living as guests in the homes of others.
INSECTARY. A place where insects are bred for the purpose of study.
INSTAR. The period or stage between moults in the larva.
INTEGUMENT. The outer covering to the insect body.
INTIMA. The lining membrane of the trachea.

Invaginate. When a tubular or vesicular part is turned inward or retracted within the body wall.
Iridescent. Reflecting the prismatic colors.
Iris. The circle which, in an ocellate spot surrounds the pupil.
Irrorate. Marked with fine points.
Iso. Equal.

Juga. The lateral anterior lobes of a Heteropteron; each side of the tylus.

Labellum. The sensitive ridge tip of the mouth structures of certain Diptera; a prolongation of the base of the rostrum in Coleoptera and Hemiptera.
Labial. Pertaining to the labium.
Labium. The lower lip.
Labrum. The upper lip.
Lacinia. The inner lobe of the first maxilla, articulated to the stipes, bearing brushes of hairs or spines.
Lacunæ. Irregular cavities.
Lamella. A thin plate.
Lamellate. Divided laterally into distinct leaf-like plates.
Lanceolate. Spear-shaped.
Larva. The second stage in the development of the insect, follows immediately after the egg stage.
Larvarium. The shelter-case of the larva.
Laterad. Toward the side and away from the median line.
Lateral. On the side.
Littoral. Living along the seacoast or in the shore débris.
Lora. The chitinous bands connecting the submentum with the cardo of the maxilla.
Lumen. The cavity or hollow part of an organ or tube.
Lunula. A small crescent-shaped mark.
Lunule. A lunate mark or crescent.

Macrochætæ. The long bristles occurring singly on the body of Diptera.
Macropterous. Long or large winged.
Macula. A colored mark larger than a spot and of no definite shape.
Maggot. The footless larva of Diptera.
Mammilate. With nipple-like protuberances.
Mandible. The lateral upper jaws of a biting insect.
Mandibulate. Having jaws or mandibles.
Maxilla. Jaws; one on each side of the mouth immediately beneath the mandibles.
Maxillary. Belonging to the maxilla.
Meconium. The substance excreted by certain metabolic insects soon after their emergence from the chrysalis.
Mediad. Toward the middle.
Medial. Referring to or at the middle.
Median. Middle.
Melanic. Blackish.

MELANISM. An abnormal darkening.
MELLIFERA. Honey-makers.
MENTUM. A labial sclerite bearing the movable parts.
MESENTERON. The middle portion of the primitive intestinal canal; the midgut.
MESO–. Middle.
MESONOTUM. The primitively upper surface of the middle thoracic ring.
META–. Posterior.
METABOLISM. Transformation, changes of food into tissue and of tissue into waste products.
METANOTUM. The primitively upper surface of the third or posterior thoracic ring.
METATHORAX. The third thoracic ring or segment.
METOPIDIUM. The anterior declivous surface of prothorax in Membracidæ.
MICROCHÆTÆ. Small bristles, as opposed to macrochætæ, in Diptera.
MICRON. The unit of microscopic measurement.
MIMETIC. Mimicry of appearance but not structure.
MIMICRY. The resemblance of one animal to another not closely related.
MONOECIOUS. The combining of both sexual elements in one individual.
MOULT. The transformation of a larva from one instar to another; the cast skin of a larva that has moulted.

NEARCTIC. Temperate and arctic North America, including Greenland.
NECROPHAGOUS. Living in or on carrion.
NECTARIES. Honey-tubes.
NEOTROPICAL. That part of the earth's surface embraced in the greater part of Mexico, West Indies and South America.
NOCTURNAL. Night-flying.

OBSOLETE. Indistinct, nearly or entirely lost.
OBTECT. Wrapped in a hard covering.
OBTECTED. Covered with a chitinous case which conceals appendages but through which their outlines are revealed.
OCELLI. Plural of ocellus.
OCELLUS. A simple eye.
ONTOGENY. The development of the individual as distinguished from that of the species.
OÖTHECA. The covering of an egg mass.
OPERCULUM. A lid.
OPTIC. Relating to the organs of vision.
ORAL. Pertaining to the mouth.
ORIENTAL. In geographical zoölogy as used by Wallace, that part of the earth's surface including Asia east of the Indus River, south of the Himalayas and the Yangtse-kiang watershed, Ceylon, Sumatra, Java, and the Philippines.
OVA. Eggs.

Ovum. An egg.
Oviposition. The act of depositing the eggs.
Ovipositor. The structure by means of which the eggs are placed.

Pædogenesis. Reproduction in the larval stage.
Palearctic. Relating to that part of the earth's surface including Europe, Africa north of Sahara, and Asia as far as the southern edge of the Yangtse-kiang watershed and the Himalayas, and west to the Indus River.
Pallid. Pale.
Palmate. Like the palm of the hand with finger-like processes.
Palpus. Articulated moveable appendage in the mouth of insects.
Parasitic. Living on or in another animal or insect and dependent on the host for food and support.
Parthenogenesis. Reproduction by direct growth of germs from egg-cells without fertilization by the male.
Parthenogenetic. See asexual.
Pectus. The ventral portion of the thorax.
Pelagic. Living in the open sea.
Pellucid. Colored, but transparent; sometimes no color.
Petiolate. Placed on a stalk.
Phylogeny. The developmental relationship of a genus, family, or other group.
Pile. A fur-like covering.
Piliferous. Having a covering of pile.
Plicate. Folded like a fan, plaited.
Plumose. Feathered, like a plume.
Pollinose. Covered with a pollen-like dust.
Polyandry. Mating of one female with more than one male.
Polyembryony. Production of more than one embryo from one egg.
Polygamy. Mating of one male with more than one female.
Posterior. Hinder or hindermost; opposed to anterior.
Predaceous. Living upon other organisms.
Predatory. Predaceous.
Primaries. The anterior or fore-wings.
Primitive. Simple in character; of an early or ancient type.
Pro-. Anterior to.
Proboscis. The extended mouth structure.
Proximad. Toward the proximal end.
Proximal. That part of an appendage nearest the body.
Pruinose. Hoary, covered with fine dust.
Pseudimago. Subimago.
Pseud- or pseudo-. Prefix meaning false.
Pseudogyne. A female that reproduces without impregnation.
Pseudova. Egg-like germ cells capable of development without fertilization.
Pulverulent. Powdery.
Pupa. The intermediate stage between larva and adult.
Puparium. The thickened larval skin within which the pupa is formed.
Pupate. To become a pupa.
Pupation. Becoming a pupa.

PYGIDIUM. The last dorsal segment left exposed by the elytra.
PYGOFER. The last segment of the abdomen in certain Homoptera, especially the lateral margins which appear in ventral view.

RADIAL. Pertaining to the radius or radial vein.
ROSTRUM. A snout-like prolongation of the head.

SCABER. Rough, uneven.
SCAPE. The second articulation of the antennæ, often elongated.
SCUTUM. The second dorsal sclerite of the meso- and metathorax.
SENSORIA. The circular openings covered by membrane on the antennæ or legs of plant lice.
SERRATE. Like the teeth of a common saw.
SESSILE. Closely attached.
SETACEOUS. Bristle-shaped, slender, tapering.
SOCIAL. Living in communities.
SPERMATOGENESIS. Development of the spermatozoa.
SPINNERET. Any organ consisting of an internal tube, terminating in a pore, spine or process, producing a silky or waxy fiber.
SPIRACLE. A breathing pore opening to the trachea.
STAGE. A period in the course of development.
STELLATE. Star-shaped.
STERILE. Incapable of reproduction.
STERNITE. The ventral piece in a ring or segment.
SUBIMAGO. The stage in ephemerids and some other insects just after emergence from the pupa and before the final moult during flight.

TENENT HAIR. Specialized hair adapted for clinging or clasping.
TENERAL. That state of the imago just after its exclusion from pupa or nymph, in which neither coloring nor clothing is fully developed.
TERES, TERETE. Cylindrical.
TERGAL. Belonging to the primitively upper surface.
THORAX. The second or middle portion of the insect body, bearing the true legs and wings; made up of three sections, the pro-, meso- and metathorax.
TRACHEA—Æ. The breathing tubes of insects.
TRACHEATE. Supplied with a trachea.
TRACHEOLES. The capillary trachea of the adult as they develop in masses in the larva; very small, slender tracheæ.
TRANSITION ZONE. The transcontinental belt in which the austral and boreal elements overlap; it is divided into a humid or Alleghanian area, a western arid area, and a Pacific coast humid area.
TROCHANTINE. The basal part of the trochanter when it is two-jointed.
TUMID. Swollen.
TYLUS. The anterior central lobe of the head in Hemiptera.

UNICOLOROUS. Of one color throughout.

VAGINATE. Inclosed in a bivalved sheath.
VALVE or VALVULÆ. The expanded plate-like galea of the maxilla in many Hymenoptera.

VALVE. A small, transverse or triangular piece behind the last full ventral segment, at the base of plates in male Jassidæ and allies.
VENATION. The system of chitinous framework supporting the wings.
VENTER. The inferior or under portion of the abdomen.
VESTIGIAL. Undeveloped or degenerate; the trace or remnant of a previously functional organ.
VESTITURE. The surface covering.
VISCERA. The internal organs of the body.
VISCERAL. Pertaining to the viscera.
VITTA. A longitudinal, colored line.
VITTATE. Striped.
VIVIPAROUS. Bearing living young.

WING PADS Undeveloped wings of pupa or nymph.

# INDEX.


A

Abdomen of insects, structure, 42
Acanthidæ, 147
Acarina, 25
Acrididæ, 59
Adalia bipunctata, 177
Adult stage of insects, 47
Agallia sanguinolenta, 107
Alabama argillacea, 227
Aleyrodidæ, 129
Alfalfa caterpillar, 243
  weevil, 195
American silk worm, 240
Ametobolic, 48
Anasa tristis, 156
Anatomy of grasshopper, 39
Anopheles maculipennis, 249
  punctipennis, 249, 250
Anosia plexippus, 245
Antennæ, 38
Anthonomus grandis, 198
Ant lions, 169
Ants, 305
Apanteles glomeratus, 296, 297
Aphaniptera, 50
Aphanothrips striata, 90
Aphididæ, 117
Aphids, 117, 118
Aphis maidis, 123
  maidi-radicis, 123
Aphrophora 4-notata, 104
Apidæ, 310
Appendages of insects, head, 38
Apple aphis, 126
  leafhopper, 115
  maggot, 287, 288
Apterygota, 48
Arachnida, 22
Aradidæ, 314
Araneida, 24
Argas miniatus, 31
  persicus, 31
  reflexus, 30
Argentine ant, 307, 309
Armored scales, 134
Army worm, 227
Arphia sulphurea, 67
Arsenate of lead, 316
Arsenical bran mash, 317
Arthropoda, 17
Aspidiotus perniciosus, 137
Assassin bugs, 145
Athysanus exitiosus, 113
  obtutus, 106
Atropos, work of, 82
  divinatoria, 83
Auchenorhynchi, 94

B

Bag-worm moths, 207
Balaninus obtusus, 198
  proboscideus, 196, 197
Bark beetles, 203
  lice, 130
Basilarchia archippus, 247
Beach locust, 65
Bed-bug, 147
Bee moth, 213
Bees, 310
  and wasps, 291
Beetles, 172
Belostoma americana, 144
Belostomidæ, 142
Bembecidæ, 310
Bembecinæ, 308
Benacus griseus, 144
Bird lice, 83

Bird tick, 28
Bittacus, 170
Black flies, 260
Blattidæ, 55
Blissus leucopterus, 151
Blood-sucking cone nose, 145
Blow fly, 277, 286
Blue-bottle fly, 285
Body structure, 38
Boll weevil, 198
  worm, 226
Book lice, 81
Boreus, 170
Bot flies, 267
Box elder bug, 156
Braconidæ, 296
Bran mash, arsenical, 317
Bristle tails, 48
Brown-tailed moth, 233
Bruchidæ, 193
Buffalo gnats, 260
  treehopper, 99
Bumble bee, 310
Buprestidæ, 181
Butterflies, 241
Bythoscopidæ, 107

## C

Cabbage butterfly, 242
Cacæsia roseana, 215
Caddice flies, 170
Calosoma calidum, 173
  scrutator, 173, 174
  sycophanta, 174
Camnula pellucida, 63
Campodea, 48
Canker worm, 225
Capsidæ, 150
Carabidæ, 173
Carpet beetles, 179
  moth, 222
Carpocapsa pomonella, 215
  saltitans, 218
Carrion beetles, 174
Cat flea, 290
Cattle louse, biting, 85
  tick, 31
Cecropia moth, 240
Cerambycidæ, 185
Cercopidæ, 104
Ceresa bubalus, 99
Ceuthophilus, 68
Chalcididæ, 296, 300
Chalcis ovata, 300
Chestnut weevil, 196
Chiggers, 26
Chilopoda, 17
Chinch bug, 151
Chionaspis furfurus, 136
  salicis, 135, 136
Chion cinctus, 187, 188
Chironomidæ, 253
Chrysobothris femorata, 181
Chrysomelidæ, 190
Chrysopa oculata, 167
Chrysopidæ, 165
Cicada killer, 310
Cicadidæ, 94
Cicadula 6-notata, 114
Cicindelidæ, 173
Cimbex americana, 292
Cimex lectularius, 147, 148
Circulatory system of insects, 43
Classification of insects, 48
Click beetles, 180
Clisiocampa americana, 235
Close wings, 214
Clothes moth, 222
Clothilla, 82
Clover-flower midge, 254
  leafhopper, 107, 108
  -leaf weevil, 195
  -root borer, 205
  -seed caterpillar, 219
Clypeus, 40
Coccidæ, 130
Coccinæ, 132
Coccinellidæ, 175
Cockroaches, 55
Codling moth, 215
Coleoptera, 50, 172
Colias philodice, 245
Collembola, 48, 54
Colorado potato beetle, 190
Conocephalus, 67
Conorrhinus sanguisugus, 146
Conotrachelus nenuphar, 196
Contact insecticides, 317
Control, insect, 315
Copris carolina, 183
Coquillettia, 151
  mimetica, 149, 151

Coreidæ, 155
Corisa harrisii, 141
Corisidæ, 141
Corizus, 158
  crassicornis, 158
Corn delphacid, 103
  -leaf aphis, 123
  -root aphis, 123
  worm, 191
Cornicles, 118
Corrodentia, 49, 81
Corydalis cornuta, 165, 166
Cossidæ, 210
Cotton boll weevil, 198
  worm, 227
Crambidæ, 214
Crambus, 214
Ctenocephalus canis, 290
Cucujidæ, 177
Culex tæniorhynchus, 251
Culicidæ, 248
Cultural methods, 322
Cut worms, 229
Cyclorhapha, 266
Cynipidæ, 295
Cyrtophyllum concavum, 68

D

Dactylophinæ, 131
Daddy-longlegs, 23
Damsel flies, 74
Danaïdæ, 245
Dasyneura leguminicola, 254
Datana, 224
  ministra, 224
Delphacidæ, 103
Deltocephalus inimicus, 111, 112
Dendroctonus, 205
  valens, 203, 204
Dermacentor albipictus, 33
  venusta, 32, 33
Dermanyssus avium, 28
  gallinæ, 29
Dermaptera, 49, 70
Dermestes lardarius, 178
Dermestidæ, 178
Destructive leafhopper, 113
Devastating locust, 60
Diabrotica, 191
  longicornis, 191, 192
Diabrotica 12-punctata, 192, 193
  vittata, 191
Diapheromera femorata, 58
Diaspinæ, 134
Dicranotropis maidis, 103
Digestive system of insects, 42
Dineutes americana, 174
Diplopoda, 18
Diptera, 50, 248
Direct methods for insect control, 315
Dissosteira carolina, 66
Dog-day cicada, 98
  flea, 290
Dorycephalus platyrhynchus, 110, 111
Dræculacephala mollipes, 109
Dragon flies, 74
Drosophila, 287
Dytiscidæ, 174

E

Earwigs, 49, 70
Economic entomology, 17, 302, 313
Ectobia germanica, 57
Eggs of insects, 45
Elateridæ, 180
Elm-leaf beetle, 192
Empoasca mali, 115
Endelomyia rosæ, 293
Enemies, natural, of insects, 324
Engraver beetles, 203
Epeira scolopetaria, 24
Ephemerida, 49, 72
Ephestia kuehniella, 212
Eriocampoides limacina, 293
Euphorocera claripennis, 276
Euplexoptera, 70
Eurymus eurytheme, 243
Euthrips pyri, 89, 90
Euvanessa antiopa, 247
Exclusion and restriction method of insect control, 327
Eyes of insects, 39

F

Fall canker worm, 226
Field ants, 307

Fire fly, 182
Flat-headed borer, 181
Fleas, 289
Flesh flies, 286
Food habits of insects, 314
Forest flies, 288
Formicidæ, 305
Formicina, 305
Fruit-tree bark beetle, 205
Fulgoridæ, 101

G

Galerucella luteola, 194
Galleria mellonella, 213
Gall gnats, 253
Gamasidæ, 28
Gastrophilus equi, 267, 268
  hæmorrhoidalis, 270
  nasalis, 270
Geometridæ, 225
Giant water bug, 142
Gipsy moth, 232
Glassy-winged sharpshooter, 109
Glossary of terms, 329
Glossina morsitans, 283
  palpalis, 283, 284
Gnats, 253
Grain aphis, spring, 123
Grape leafhopper, 114
  phylloxera, 129
Grapholitha interstinctana, 219
Grass thrips, 90
Green-bottle fly, 286
  bug, 123
Ground beetles, 173
Gryllidæ, 69
Gryllotalpa columbia, 70
Gula, 40
Gyrinidæ, 174
Gyropus, 84

H

Hackberry-gall psyllids, 116
Hæmatobia serrata, 279
Hæmatopinus eurysternus, 161, 162
  urius, 162
Handmaid moths, 224
Harlequin cabbage bug, 159
Harvestmen, 23
Harvest mites, 26
Hazel-nut weevil, 198
Head of insects, structure, 38
Heliophila unipuncta, 228
Hellebore, 316
Hemiptera, 49, 93
Hesperidæ, 241
Hessian fly, 255
Heterometabolic, 48
Heteroptera, 93, 140
Hexapoda, 38
Hickory borer, 187
Hippoboscidæ, 288
Hippodamia convergens, 176
Hog louse, 162, 163
Holometabolic, 48
Homalomyia brevis, 287
Homoptera, 93
Honey bee, 310
  dew, 118
  tubes, 118
Horn fly, 279
Hornet, 310
Horse bot fly, 268
  flies, 265
  louse, biting, 86
House centipede, 17
  fly, 277, 278
Hydrobatidæ, 144
Hydrophilidæ, 174
Hylastinus obscurus, 201, 205
Hymenoptera, 50, 291
Hyphantria cunea, 235
Hypoderma bovis, 271
  lineata, 270

I

Icerya purchasi, 132
Ichneumonidæ, 295
Idiocerus alternatus, 108
Imago, 47
Indian meal moth, 211
Inimical leafhopper, 111, 112
Insect control, 315
  powder, 321
Insecticides, 315
Insects, relation, 312
  structure, 38
Internal structure of insects, 42
Iridomyrmex humilis, 307

Ischnoptera, 55
pennsylvanica, 55
Isoptera, 49, 76
Isosoma tritici, 301, 302
Itch mite, 36
Ixodidæ, 30

J

Jassidæ, 111
Jassoidea, 105
June bugs, 183

K

Katydid, 68
Kerosene as an insecticide, 319
Kissing bug, 145

L

Labia minor, 71, 72
Labium, 40
Labrum, 40
Lace bugs, 150
Lachnosterna, 183
fusca, 183, 184
Ladybird beetles, 175
Lampyridæ, 182
Larder beetle, 178
Larval period, 47
stage, 46
Lead arsenate as an insecticide, 316
Leaf beetles, 190
bugs, 150
rollers, 215
Leafhopper terms, 106
Lebia grandis, 173
Legs of insects, structure, 41
Lepidocyrtus purpureus, 53
Lepidoptera, 50, 206
Lepisma, 48
domestica, 51, 53
saccharina, 52, 54
Leptinotarsus decemlineatus, 190
Leptocoris trivittatus, 156, 157
Leptus americana, 27
irritans, 27
Leucania unipuncta, 227
Leucotermes flavipes, 76, 77, 81
Libellula pulchella, 75, 76
Lime-sulphur as an insecticide, 318
Limnogonus hesione, 145
Liotheidæ, 84
Locustidæ, 67
Locusts, 59
Locust-tree borer, 210
London purple as an insecticide, 316
Lucanidæ, 182
Lucanus dama, 182
Lucilia cæsar, 285
Luna moth, 240
Lycidæ, 178
Lyctus planicollis, 178, 179
Lygæidæ, 151
Lysiphlebus, 123
tritici, 296, 298

M

Machinery for the application of insecticides, 322
Macrodactylus subspinosus, 184
Macrosiphum pisi, 121, 122
Mallophaga, 49, 83
Mandibles of insects, 40
Mantidæ, 57
Mantispidæ, 165
Maple scale, 133
Margaropus annulatus, 31
Masked bed-bug hunter, 146
Mating of insects, 45
Maxilla of insects, 40
May beetles, 183
flies, 72
Mayetiola destructor, 255, 256
Meat fly, 286
Mecoptera, 50, 169
Mediterranean flour moth, 212
Megilla maculata, 176
Melanoplus atlanis, 62, 65
femur-rubrum, 61, 62
spretus, 60
Melanotus communis, 180
Mellitia satyriniformis, 223
Melophagus ovinus, 288
Membracidæ, 98
Menopon pallidum, 84
Mentum of insects, 40
Metamorphosis of insects, 47

Micropyle, 45
Mole cricket, 70
Monarch butterfly, 245
Monomera blatchleyi, 59
Mosquitoes, 248
Mouth structure of insects, 40
Mullein thrips, 92
  nigra, 92
Murgantia histrionica, 159
Musca domestica, 277, 278
Muscidæ, 277
Muscina stabulans, 283
Museum beetle, 179
Myriopods, 17
Myrmeleonidæ, 169

N

Nabidæ, 147
Natural enemies of insects, 324
Necrophorus, 175
Nectaries, 118
Nepidæ, 142
Nervous system of insects, 43
Neuroptera, 49, 165
Noctuidæ, 226
Notolophus leucostigma, 230
Notonecta irrorata, 141
  undulata, 141, 142
Notonectidæ, 142
Nut weevils, 198
Nymphalidæ, 247

O

Ocelli, 39
Odonata, 49, 74
Œcanthus, 69
  fasciatus, 69
  niveus, 69
Œstridæ, 267
Œstrus ovis, 275
Oncometopia undata, 109
Onion thrips, 90
Onycophora, 17
Ophion, 296
Orange dog, 242
  white fly, 130
Oriental cockroach, 56
Ormenis pruinosa, 101
Orthezia solidaginis, 131, 132
Ortheziinæ, 131
Orthoptera, 48, 54
Orthorapha, 248
Otioceras, 102
Owlet moths, 226
Ox bot fly, 270
Oyster-shell scale, 136

P

Pachypsylla celtidis-mamma, 116
Paleacrita vernata, 225
Palpus, 40
Panorpidæ, 169
Papilio cresphontes, 242
Papilionidæ, 241
Paraglossa, 40
Parasita, 94, 160
Parasitica, 295
Parasitic insects, 324
Paris green as insecticide, 315
Parthenogenesis in aphids, 118
Passalus cornutus, 182
Pea aphis, 121, 122
  weevil, 193
Peach-tree borer, 222
Pear slug, 293
  thrips, 90
  -tree psylla, 115, 116
Pedipalpi, 23
Pentatomidæ, 159
Periplaneta orientalis, 56
Perla, 49
Persian insect powder, 321
Phalangida, 23
Phasmidæ, 58
Phasmomantis carolina, 57
Philopteridæ, 84
Phlegethontius 5-maculata, 206
Phlœothrips verbasci, 92
Phormia terrænova, 284
Phorodon humuli, 119
Phylloxera, grape, 129
Phymatidæ, 147
Phytonomus punctatus, 195
Pieridæ, 242
Pieris rapæ, 242
Pigeon tick, 30
Pilophorus, 151
Pimpla, 296

Pimpla conquisitor, 296, 297
Pissodes strobi, 200
Plant lice, 117
Platypsyllidæ, 174
Plecoptera, 49, 72
Plodia interpunctella, 211
Plum curculio, 196
Podisus maculiventris, 159
Podura, 48
Porthetria dispar, 232
Praying mantis, 57
Predaceous bugs, 145
  insects, 324
Principles of economic entomology, 312
Prionoxystus robiniæ, 210
Prionus, 185
Proctotrupidæ, 296, 305
Proventriculus, 42
Pseudococcus citri, 131
Pseudoscorpionida, 23
Pseudova, 118
Psocidæ, 81
Psoroptes communis, 34
  var ovis, 35
Psyllidæ, 115
Pteromalus puparum, 300, 301
Pterygota, 48, 54
Pulvinaria innumerabilis, 132, 133
Pupa stage of insects, 47
Pyralidæ, 211
Pyralis farinalis, 211
Pyrethrum as an insecticide, 321

R

Ranatra americana, 143
Red spider, 25
Reduviidæ, 145
Reduvius personatus, 146
Relation of insects, 312
Reproduction of insects, 44
Reproductive organs of insects, 44
Respiratory system of insects, 43
Restriction as a method of insect control, 327
Rhagoletis pomonella, 287, 288
Rhyncophora, 195
Rocky Mt. locust, 60
Rose chafer, 184
Rose slug, 293
Round-headed borer, 187
Rove beetles, 175

S

San José scale, 137
Sanninoidea exitiosa, 222, 223
Saperda candida, 187, 189
Sarcophagidæ, 286
Sarcoptes scabiei, 36
Sarcoptidæ, 35
Saw-toothed beetle, 177, 178
Scale insects, 130
Scarabæidæ, 182
Schizoneura americana, 123
  lanigera, 126
Scolytidæ, 203
Scolytus rugulosus, 202, 205
Scorpionida, 22
Scorpion flies, 169
Scorpions, 22
Screw-worm fly, 277
Scutigera forceps, 20, 21
Sericophanes, 151
  ocellatus, 150
Sesiidæ, 222
Seventeen-year cicada, 95
Sharpshooter, 109
Sheep bot fly, 275
  scab mite, 35
  tick, 288
Short-nosed ox louse, 161
Shovel-nosed leafhopper, 110, 111
Sialidæ, 165
Silk worm, 240
Silpha, 175
Silphidæ, 175
Silvertop, 90
Simuliidæ, 260
Simulium pecuarum, 261
Siphocoryne avenæ, 119
Siphonaptera, 50, 289
Six-spotted leafhopper, 114
Skippers, 241
Smynthurus, 48
Snowy tree cricket, 69
Social wasps, 310
Sod worm, 214
Solpugida, 23
Southern buffalo gnat, 261

Special senses of insects, 44
Sphecina, 308
Sphecius speciosus, 310
Spined soldier bug, 159
Spiracles, 42
Spotted-fever tick, 32
Spraying codling moth, 216
Spring grain aphis, 123
Spring tails, 48
Squash beetle, 191
  bug, 155
  -vine borer, 222
Stable fly, 282
Stag beetle, 182
Staphylinidæ, 175
Stegomyia fasciata, 252
Sternorhynchi, 94, 115
Stink bugs, 159
Stomoxys calcitrans, 282
Stone crickets, 68
  flies, 72
Structure of insects, 38
Submentum, 40
Sugar-cane hopper, 103
Swallowtail butterflies, 241
Sword bearers, 67
Sylvanus surinamensis, 177
Syrphidæ, 266

T

Tabanidæ, 265
Tabanus atratus, 266
Tachinidæ, 275
Tarnished plant bug, 150
Tenderfoot leafhopper, 109
Tent caterpillar, 235
Tenthredinidæ, 292
Terebrantia, 88
Termites, 76
Termitidæ, 76
Tetranychus bimaculatus, 25
  gloveri, 26
Tettigoniellidæ, 108
Thalessa, 296
  atrata, 295
  lunator, 295
Thorax structure of insects, 41
Thread-legged bug, 147
Thripidæ, 88
Thrips tabaci, 90
Thrips tritici, 89
Thyridopteryx ephemeræformis, 207, 209
Thysanoptera, 49, 87
Thysanura, 48, 52
Tibicen septendecim, 94, 95
Tick, cattle, 31
  spotted fever, 31
Ticks, 30
Tiger beetles, 173
Tinea pellionella, 221
Tineidæ, 221
Tineola biselliella, 222
Tingitidæ, 150
Tobacco extract, 320
Tomato-worm larva, 206
Tortricidæ, 215
Toxoptera graminum, 122, 123
Trachea of insects, 43
Transformations of insects, 45
Tree crickets, 69
  -hoppers, 98
Tremex columba, 294
Trichodectes, 84
  parumpilosus, 86
  scalaris, 85
Trichoptera, 50, 170
Trimerotropis maritima, 64, 65
Trombidiidæ, 26
Tsetse flies, 283
Tussock moths, 230
Typhlocyba comes, 114
Typhlocybidæ, 114

U

Unity of habit of insect groups, 314
Uroceridæ, 293

V

Vedalia, 177
  cardinalis, 132
Vespa germanica, 310
  maculata, 310
Vespidæ, 310
Viceroy butterfly, 247

W

Walking-stick, 58
Wasps, 308
Water beetles, 174
  boatmen, 141
  bugs, 142
  scorpions, 142
  striders, 144
Web-worm moths, 234
Wheel bug, 146
Whip scorpion, 23
Whirligig beetles, 174
White ants, 76
  fly, 130
  -marked tussock moth, 230
  pine weevil, 200, 203
Willow saw fly, 292
  scale, 135
Wings, structure of insects', 41
Wire worm, 180
Wood borers, 185
Woolly aphis, 126

Y

Yellow-fever mosquito, 252
Yellow jacket, 310

Z

Zaitha fluminea, 141

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