Insect Enemies of Eastern Forests

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AUTHORSHIP

This publication is the work of various specialists in their individual fields of entomological research. Their responsibilities were as follows: F. C. Craighead, introductory and control sections, Coleoptera (in part), and general supervision of the entire publication; M. W. Blackman, Scolytidae and Platypodidae; J. V. Schaffner, Jr., Hymenoptera (in part) and Lepidoptera; P. B. Dowden and William Middleton, Hymenoptera; J. N. Knull, Buprestidae (in part); W. L. Baker, P. W. Oman, and T. J. Parr, sucking insects; R. A. St. George, Coleoptera (in part); H. J. MacAloney, Coleoptera (in part); T. E. Snyder, termites; R. T. Webber, Diptera; N. D. Wygant, Orthoptera; L. E. Yeager, Lamellicornia; S. F. Potts, spray formulas; and R. C. Brown, beneficial insects.

J. V. Schaffner, Jr., also rendered valuable assistance by his critical review of the entire compilation.

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INSECT ENEMIES OF EASTERN FORESTS[1]

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INTRODUCTION

This publication is a companion volume to Miscellaneous Publication 273, "Insect Enemies of Western Forests," by Keen (*262*).[2] Its purpose is to treat in a practical manner the more important forest insects of that part of the United States lying east of the Great Plains or treeless areas, roughly the 100th meridian. There is necessarily some overlapping of the eastern and western regions, particularly in the more arid parts of Texas and the Southwest and along the watercourses traversing the Great Plains where the eastern hardwoods extend westward.

In the publication on the western insects, emphasis is placed on bark beetle control, for in the western forests there still remain great reserves of overmature timber, which are subject to enormous bark beetle losses. Naturally, bark beetles and measures for suppressing their outbreaks are of overshadowing importance in those areas.

In the eastern part of the United States, where there are practically no reserves of mature timber, the forester has before him the matter of growing new forests. Here, the forest-insect problem is principally the prevention of outbreaks. Therefore in this volume considerable emphasis is placed on the possibilities of so adjusting silvicultural practices as to avoid losses, as well as on direct control. Also, in the eastern forests there exists a preponderance of deciduous or hardwood species, which are more subject to attack by insects during logging and manufacturing operations, and even after being placed in use, than are the conifers. The protection of logs, lumber, and crude and finished forest products is consequently a more important phase of forest entomology in the East.

Again, in the East there is a much greater variety of forest trees infested by a much greater number of insect species than in the West. This fact has caused more specialization among the workers in forest insects and, in turn, a greater number of contributors to the manual.[3] It has been found more practical, therefore, to treat the general text systematically than to treat it by type of injury, as was done in the western manual. For the convenience of those not familiar with the systematic grouping of insects, however, practical keys based on type of injury and more obvious characters are also given.

In some places where the text of Miscellaneous Publication 273 (Keen, *262*) is equally applicable to eastern conditions, it is utilized verbatim or with minor adaptations.

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[2] Italic numbers in parentheses refer to Literature Cited, pp. 637–658.

[3] See Authorship, p. II.

RELATION OF INSECTS TO FOREST AND ORNAMENTAL TREES

Insects are among the most abundant forms of life in the forest. They exert a continuous influence through all stages of the growing and mature forest. For example, some attack the fruit or seed, often limiting reproduction of certain species; some injure or kill seedlings and young trees, thus exerting an important influence on the composition of the young forest; others frequently harvest, so to speak, the mature forest and set the stage for the development of a new stand; and some even play a large part with their allies, the fungi, in the decomposition of the dead trees that otherwise would litter the ground.

The manner in which the entomological factors operate in any forest is extremely complex, depending on such things as the proportion of certain species of trees in the forest at any given time, the relative abundance of the numerous species of insects, the presence and abundance of parasites and predators of the injurious insects, and weather conditions. In virgin timber stands, particularly those that are overmature, a normal loss is going on steadily as the result of insect activity and other factors, but such loss for the most part is offset by growth. The wonderful forests that the white man found in this country were not static but continually dying and re-forming. Insects, disease, and fire are nature's chief tools in removing the old and weakened trees in this process of renewal.

On the Kaibab National Forest, Ariz., there are reliable records in the trees themselves, going back nearly 400 years, of repeated insect outbreaks. Large blocks of timber were killed by the Black Hills beetle, but these areas were later reseeded and restocked. In more recent times extensive areas of lodgepole pine in the northern Rocky Mountain region have been devastated by the mountain pine beetle; and in those sections where the outbreak passed some 20 or 25 years ago, a new stand is forming from the remnants left by the beetles. Should fire sweep through the dead debris, it would destroy everything and necessitate a new start from seed. The great majority of insect species are neutral or even beneficial in that they play a role in the gradual disintegration of the dead and dying trees and help make way for new growth.

There are no species of trees that are not fed on by some insects, although several kinds are relatively free from serious injury. Usually those species of trees that are most abundant or most prolific suffer the greatest losses.

The question is frequently asked, "Where did these destructive forest insects come from?" Most of them have been here as long as the trees on which they feed. Most species of forest insects, both injurious and beneficial, are native to these forests and are usually distributed throughout the range of their favorite host. Given favorable conditions for their increase, their populations can suddenly build up from the few individuals normally present to epidemic numbers. On the other hand, a number of foreign pests have been introduced and have become established in the eastern part of the United States, where the food supply and climatic conditions are favorable for them.

Some of these, such as the gypsy moth, the European pine shoot moth, and the European spruce sawfly, are among our most serious forest pests.

PREVALENCE AND ACTIVITY OF FOREST INSECTS

The abundance of individuals of an insect species is never constant, but varies greatly from time to time. Some injurious species, as the southern pine beetle, are at times so rare, even during their active season, that a single individual can scarcely be found in the forest, and yet a few months later there will be literally millions of them in a limited forest area. Great outbreaks of the spruce budworm in the Northeast occur only at long intervals. Other species, as the Columbian timber beetle, working in the sapwood of living trees, may be more or less static, causing a small amount of injury each year for a century or more. General discussions of forest insects and their relation to the trees will be found in the following publications: Doane et al. (*133*), Graham (*194*), Keen (*262*), Fitch (*158*), Craighead (*115*), and Chamberlin.[4]

DESTRUCTION OF STANDING TIMBER

Notable outbreaks of forest insects have from time to time taken a tremendous toll in our forests. In the Eastern States the greatest depredations to mature timber have been caused by bark beetles of the genus *Dendroctonus* and a few defoliators.

The southern pine beetle is the most destructive eastern bark beetle, killing all species of pine from Maryland and Virginia west to the Ozarks, and south to the Gulf of Mexico. One of the earliest recorded outbreaks centered in Virginia and West Virginia about 1891. A great quantity of spruce was killed, as well as enormous numbers of pines. Other widespread outbreaks occurred in the Carolinas and Georgia in 1910 and 1911 and in Virginia and North Carolina in 1922 and 1923. Lesser and more localized outbreaks developed in 1925, 1926–27, and 1930–31 in north-central Virginia, where 5 million board feet were destroyed on one holding, and again in 1936, 1937, and 1938 there was an outbreak that caused the destruction of some 10 million board feet of loblolly pine in northeastern Virginia on two lumber companies' holdings.

Depredations in mature stands of spruce in the Northeast, assumed to have been by the spruce bark beetle, were reported as far back as 1830. From that time to the present there are records of repeated destruction of this tree species in the forests of Maine, New Hampshire, and Vermont. A particularly extensive outbreak of the beetle occurred from about 1897 to 1901 in New Hampshire and Maine and was investigated by A. D. Hopkins during the latter part of this period. Little evidence of destructive activity of this beetle occurred again until 1936 and 1937, when 5 or 6 million board feet of spruce was destroyed in the Green Mountains alone. Unfortunately the records of these outbreaks in eastern forests are not accompanied by accurate figures of losses.

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[4] CHAMBERLIN, W. J. THE BARK AND TIMBER BEETLES OF NORTH AMERICA NORTH OF MEXICO. THE TAXONOMY, BIOLOGY AND CONTROL OF 575 SPECIES BELONGING TO 72 GENERA OF THE SUPERFAMILY SCOLYTOIDEA. Oreg. State Col. Coop. Assoc., 513 pp. 1939. [Processed.]

Defoliating insects likewise destroy considerable bodies of mature timber. These outbreaks, however, usually appear at rather long intervals and are of comparatively short duration. An exceptional instance is that of the spruce budworm in the Northeastern States and Canada, which ravaged the spruce and fir forests for a period of about 10 years (from 1910 to 1920). It has been estimated that in the spruce-fir types of Maine, Ontario, Quebec, and New Brunswick from 40 to 70 percent of the timber was destroyed and that the equivalent of more than 25 years' supply of pulpwood for current annual American paper requirements was lost.

Certain species, even if they do not kill the timber, cause a cessation or retarding of growth, which may increase the rotation period of the stand from 5 to 10 years or more. Such defoliations may be local and may be confined to only a single species of tree, or they may spread over enormous areas, involving several species. The most recent outbreak of the pandora moth in the ponderosa pine stands of southern Oregon occurred between 1918 and 1925 and covered approximately 400,000 acres. Growth measurements from plots in this area showed that for a period of 11 years the normal forest growth on this area was reduced an average of 32 percent, or a loss of increment of approximately 100 million board feet. The weakening of these trees was followed by heavy loss from bark beetles which killed as much as 30 percent of some stands. Hopkins (*230*, *231*); Swaine, Craighead, and Bailey, 1924 (*403*); St. George and Beal (*371*), Peirson (*350*), and the United States Bureau of Entomology (*417*), have given valuable information on the injury to standing timber.

LOSSES FROM FOREST INSECTS

Various attempts have been made to express in monetary values the annual loss occasioned by forest insects. Such estimates must of necessity be based on inadequate data. For the most part, it is necessary to use information based on special cases and apply it with modifications to the whole field. In only a few instances has it been possible to obtain a fair sampling of the entire timber supply subject to damage. That the combined losses in all timber resources of the United States for the wood-using industries and for park and shade trees must be very large is indicated by the preceding examples of specific losses. On the other hand, it must be borne in mind that in the case of mature forests many insect outbreaks occur in out-of-the-way places, where the timber will not be accessible or merchantable for 25 to 50 years or more, and consequently the losses there will be largely offset by new growth before the stand can be utilized.

For a number of years systematic surveys have been conducted over considerable areas, especially in the mature timber stands of the Western States. From these, a fair sampling of the supply and of the losses from bark beetles makes possible a very accurate estimate. The killed timber has amounted to from 1 to 6 billion board feet, annually, which at a stumpage value of at least $3, would represent up to 20 million dollars.

Detailed estimates of the losses caused by the southern pine beetle in the East have never been available because of the scattered ownership of the timber, but the stumpage value of the pine killed in the last 50 years probably exceeds $50,000,000.

Defoliating insects likewise cause extensive losses to standing timber, roughly estimated at about 20 million dollars annually for the entire country over a period of 25 years. Damage from insect attack to felled timber, logs, lumber, poles, ties, and wood in buildings is probably in excess of $60,000,000 annually.

Damage to trees valued for esthetic reasons is extremely difficult to estimate. Street and shade trees around homes, in parks, and on recreational areas have values far beyond the lumber they contain. Various estimates of insect damage to the trees of city parks and streets throughout the country, based on the supposed number of such trees and a nominal value for each tree are available. A conservative selection from these estimates would indicate a monetary loss of about $100,000,000.[5]

The principal annual losses caused by forest insects are as follows:

Bark beetles	$20, 000, 000
Defoliators and other losses to standing timber	20, 000, 000
Insects affecting forest products	60, 000, 000
Insects affecting shade and ornamental trees	100, 000, 000

EFFECT OF INSECTS ON THE COMPOSITION OF GROWING STANDS

The reproduction of the forest is often influenced and sometimes completely changed in character by the activities of insects. Cone beetles in the white pines and some of the western yellow pines, certain moths in the yellow pines, seed chalcids in Douglas-fir, and nut weevils in acorns and hickory nuts destroy at times nearly 100 percent of the seed crop. During periods of excessive activity of these insects, the reproduction in mixed stands may contain a preponderance of the less desirable species.

After the seedlings are established, certain insects such as white grubs (the larvae of June beetles) may cut off the roots, or the Pales weevil may girdle the young plants above ground, and thus again alter the proportion of a particular species becoming established. Not infrequently after logging operations in the Northeast, white pine reproduction is completely destroyed by the Pales weevil.

During the sapling stage of a stand, when competition is keen among individuals or species composing a mixture, modifications of the stand by insects become more apparent. The white-pine weevil in the Northeast frequently determines the final character of the stands seeded on old fields or clearings. Malformation of the trees is most severe in nearly pure pine. Curiously enough, as the percentage of hardwood increases, the weevil damage in the pines decreases—a good argument for mixed forests.

In our mixed coniferous-hardwood forests of the Northeast, defoliators periodically appear and remove high percentages of certain conifers. Conifers succumb readily to heavy defoliation, whereas hardwoods resist repeated defoliations. In these forests fir and spruce are largely protected from spruce budworm outbreaks as long as the hardwood canopy is dominant. But as the percentage of softwood

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[5] HYSLOP, J. A. LOSSES CAUSED BY INSECTS, MITES, AND TICKS IN THE UNITED STATES. U. S. Bur. Ent. and Plant Quar. E–444, 57 pp. 1938. [Processed.]

increases, the spruce budworm may attack, killing much fir and some spruce and bringing about a higher percentage of spruce. Ultimately, when the spruce becomes mature, the spruce bark beetle may attack and again alter the picture. In those areas where white pine is an important species of the mixture, all these factors work toward the survival of the dominant white pine and no doubt were important aids in the production of the pine stands of early logging days—giant pines from 300 to 500 years of age overtopping a fir-hardwood mixture beneath.

EFFECT OF INSECTS ON FOREST PLANTATIONS

Forest plantations are particularly subject to the destructive activities of insects, chiefly because a plantation is usually made up of a single species and is even-aged. Many plantations are established on soils not especially suitable for the tree species used; therefore the growth is slower and the trees are predisposed to insect attack. Soil-infesting insects, such as white grubs, make difficult the establishment of plantations in some regions. Bud and twig moths, tip weevils, and twig beetles not only damage and deform the terminal shoots of young trees but at times become so numerous as to kill out or badly set back the stands over large areas. Often young pines near logging operations are severely damaged by infestations of engraver beetles and the Pales weevil. Sawflies in the Northeast and Lake States and *Colaspis* beetles in the Gulf States cause serious defoliation and death of small trees.

INTERRELATIONS BETWEEN INSECTS AND FIRES

When extensive outbreaks of insects develop in forest types composed chiefly of one species of tree, a high percentage of the stand may be killed. These standing dead trees go down after a period of years, making an almost impenetrable tangle of logs and tops which may be set afire by lightning and result in a widespread conflagration almost impossible to fight. Past experience has shown that epidemics of the mountain pine beetle in lodgepole pine have been followed by fires more often than not. Similar fires have followed spruce budworm damage in the Northeast.

The old snags of insect-killed trees scattered throughout our mature forests greatly increase the cost, difficulty, and danger in fire control. Snag felling is required in the terms of many sales of national-forest timber, and many private operators have already adopted this as a practice. The increased cost of combating fires that have spread from burning snags within fire lines would alone justify insect control even at a high cost.

Trees scorched or recently killed by forest fires are particularly attractive to many species of forest insects which may be drawn to them from a radius of several miles. Subsequent insect damage augments the fire losses, as bark beetles often kill many trees which otherwise might have survived. Wood-boring species enter beneath the bark of scorched trees and riddle the sapwood so that within a short time it may become degraded or valueless for lumber purposes, thus limiting salvage operations on burns.

In the slash and longleaf pine belt of the South, fires burning turpentine faces are directly responsible for the attack of *Buprestis apricans* Hbst., the turpentine borer.

Burning the woods is often suggested as an insect control measure. At present, the information available is not sufficient to warrant such recommendations (see Beal, *25*, and Craighead and St. George, *118*).

EFFECT OF FOREST SLASH ON INSECTS

Extensive areas of slash, particularly of stumps, cull logs, and large branches, resulting from logging operations and road or telephone-line construction, offer material for rapid reproduction of many insects. Most of the insects breeding in this material are harmless species, though occasionally some species of *Ips* or *Dendroctonus* become abundant and often the green trees left on the area are attacked and killed by the influx of bark beetles attracted by the slash. (On this subject see also discussion under Control of Forest Insects, p. 14, and the reports in 1927 by the United States Bureau of Entomology (*415*) and by Patterson (*345*).

EFFECT OF INSECTS ON THE FORMATION OF ANNUAL RINGS

Defoliating insects greatly modify the growth of the annual rings, both in size and structure. Ordinarily great reliance is placed on the determination of the age of a tree by counting its annual rings at the stump. Recent studies have shown that these rings by no means always give a reliable determination. Defoliation by insects, drought, or fire may result in the loss of from 1 to 5 rings on the lower part of the stem, and this may occur several times during the life of a tree. In the southern pineries, where fires are frequent, and in the northern coniferous regions, where defoliation occurs periodically, any sudden variation in the size of rings must be viewed with suspicion. In trees 100 years or more of age it is not uncommon to find from 5 to even 10 rings missing at the stump. For more information on this subject the reader is referred to Craighead (*112*, *113*, *114*).

INSECTS AND FOREST PRODUCTS

All kinds of forest products, from the time the tree is felled and for many years after the wood is in use, are subject to destruction by insects. Insects also cause injuries in the living tree which show up as defects in the lumber, thus greatly reducing its value. Green sawlogs and storm-felled timber, green-sawn and seasoned lumber, rustic construction, poles, posts, cross ties, mine props, and all manner of finished products from flooring to furniture are subject to attack.

The losses in finished products are particularly heavy in that the cost of manufacture and replacement must be taken into consideration. The avoidance of such damage demands constant thought and adjustment of routine practices by the logger, lumberman, and builder. A tie-up of the green logs in the woods or drive may result in heavy damage by ambrosia beetles and borers, and defects in the green logs require special methods of sawing to obtain maximum utilization. The farmer or builder must properly creosote certain timbers that are to be in contact with the ground, and the furniture manufacturer must treat his articles to avoid powder-post beetle attack. St. George (*368*), Hopkins (*232, 233*), Burke (*74*), and Snyder (*389*) have published articles on this subject.

THE RELATION OF INSECTS TO SHADE AND ORNAMENTAL TREES

The value of shade and ornamental trees in our home grounds, city streets, and parks ranks hardly less than that of the homes and buildings themselves. They are so much an integral part of the whole property that their protection from insects is as essential as the protection of the buildings from fire. Insect attacks have brought about the development of trained organizations and elaborate equipment for the care of trees. In some sections of the country, particularly the Northeast and California, the organization of this protective service has been elaborately developed, and it is rapidly expanding in other regions, particularly where large areas are given over to high-class residential development.

THE EFFECT OF INSECTS ON SCENIC AND RECREATIONAL AREAS

The rapid development in recent years of large areas of State or national forests and our national parks for recreational purposes, has made it necessary to consider insect outbreaks from a somewhat different standpoint than from where only commercial values of the forest crop are at stake.

The importance of the forest cover in national parks, game preserves, and recreational areas cannot be estimated in monetary values. Here the esthetic and protective values far exceed that of the commercial timber. Although not so directly appreciated by the visitor, the forest is one of the greatest attractions in these areas, since much of the natural beauty of parks or camp sites is in reality dependent upon a green forest cover. Trees are also important in giving protection to the birds and other animals.

The protection of trees on camp grounds from insects is becoming very important. These small areas are intensively used, the soil becomes packed and heated by exposure to the sun, roots are exposed and injured, the trunks of the trees are damaged, and it is little wonder that the trees do not survive the attacks of bark beetles and borers.

Recently outbreaks of the forest tent caterpillar in the Lake States and other places have been of particular importance from an unexpected angle. As defoliation of the trees becomes complete, the caterpillars migrate in great numbers, crawling over and inside buildings, getting into food, dropping onto sleeping people, and in general so irritating the sensitive temperament of summer tourists as to drive them from the locality, much to the regret of local tradesmen and resort owners.

For these reasons the effects of insect outbreaks which mar the scenic beauty or destroy the protective value of the forest cover, or interfere with its use for recreation, are often more serious than injury to timber values. The National Park Service in recognizing this has made it a policy to procure and maintain so far as practicable, efficient protection from insect epidemics in areas of the following character within the national parks and monuments:

(1) Areas of intensive use, such as camp grounds, roadsides, and other developed areas.

(2) Areas of important scenic or esthetic attraction (unless the partial loss of the tree species attacked within a mixed stand will not materially affect the general appearance of the stand and its scenic or esthetic value, nor materially add to the fire hazard).

(3) Areas of prospective intensive use within the next 10-year period.

(4) Areas within the national park threatening protected areas within or outside the national park.

(5) Areas of unusual fire hazard.

(6) Areas set aside for study and research (unless natural agencies are to be left undisturbed).

(7) Areas of especial historical significance, such as historical and military parks, monuments, and cemeteries.

INSECTS IN RELATION TO CONSERVATION

Recent interest in the reclaiming of eroded soils, in the protection of wild life, and in game management has developed the need for information where forest entomology contacts these fields. Like the forester, the entomologist in the past has given little thought to investigations within these bordering interests. It is evident that there is a growing need for the study of the problems connected with these relationships.

Some insects destroy sod cover and forest seedlings. The locust borer has proved a limiting factor in the use of black locust for reclaiming poor soils. Other insects infest and worry game to the point of emaciation and death, and in many cases transmit epidemic diseases. The fire ant (*Solenopsis geminata* F.) is a pest of quail in Florida, killing the young birds in the nest. Plant-feeding insects occasionally defoliate extensive areas of some particular food crop needed by game.

On the other hand, many species of game fish are largely dependent on the insect life of the streams, according to Bishopp (*32*), and arthropods are known to play an important role in making the soil more pervious and thus increase its water-retaining capacity.

INSECTS AND DISEASES

An up-to-date treatment of forest entomology cannot avoid a consideration of interrelated fungi. In fact, as research proceeds in this field, it is becoming more and more evident that many of our destructive pests have a link in their life history where fungi are indispensable, and many fungi are only destructive through the presence of their special insect vectors.

Many years ago Hubbard (*247*) pointed out the dependence of the ambrosia beetles on certain fungi that they cultured in their galleries. Since then it has been demonstrated that many more species of bark beetles are more or less directly dependent on associated fungi. *Dendroctonus frontalis*, for example, introduces a certain blue stain fungus, *Ceratostomella pini*, as it attacks. This fungus rapidly develops in the sapwood and cuts off water conduction, so that death of the tree and normal development of the bark-beetle broods result. Without these blue stains it is doubtful if the insects alone could kill the trees. Similar relations exist between *Scolytus ventralis* in western firs and the fungus *Trichosporium symbioticum*. It is likely that similar relationships exist between many other bark beetles and fungi.

The Dutch elm disease, caused by *Ceratostomella ulmi*, is dependent on certain insects for its spread from tree to tree. At present the two species of insects known to be of greatest importance are *Scolytus multistriatus* and *Hylurgopinus rufipes*, both bark beetles.

Future research will bring to light many more cases and possibly demonstrate that fungi are necessary for many other types of insect feeding. Further information on insects and fungi may be found in the following: Craighead (*114*); Leach, Orr, and Christensen (*271*); Caird (*79*); Rumbold (*362*, *363*, *364*); Bramble and Holst (*54*); Craighead and St. George (*120*); and Leach (*270*).

THE CONTROL OF FOREST INSECTS [6]

In the insect world a constant struggle for survival is going on. On the one hand, the insects themselves are provided with potentialities for tremendous increase. The females lay hundreds of eggs, and some species produce many generations a year. If all individuals survived, the world would soon be overrun with the progeny. On the other hand, insects must contend with many adverse conditions, which serve to hold their numbers in check. Weather conditions, abundance or lack of food, prevalence of natural enemies, and many other factors have an influence in determining their abundance. Some of the more important of these factors are considered in the following paragraphs.

NATURAL CONTROL FACTORS AND INFLUENCES

Climatic factors such as temperature, moisture, and unusual weather conditions have an important bearing on the activity, periodic abundance, and distribution of insects.

TEMPERATURE

As a rule there is a rather short range of temperatures (50° to 95° F.) within which insects are most active, and the optimum for many of the Temperate Zone species appears to be between 75° and 80°. Temperatures either above or below this optimum range limit their activity. Few insects can withstand temperatures above 120°, and this makes possible the control of many species of bark- and wood-boring insects merely by exposing the infested logs to direct sunlight.

Low winter temperatures often act as effective checks on insects that hibernate as immature stages in exposed locations above the snow line.

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[6] Prepared from material supplied by all authors and partly adapted from U. S. Dept. Agr. Misc. Pub. 273 (Keen, *262*). This manuscript was prepared in 1941, but its publication was delayed by World War II. With the research energies of the Division turned to immediate war problems, no opportunity was offered to fully revise the manuscript to include the uses of the new insecticides and of aerial spraying. Some revision has been attempted in the section on chemical control to introduce these newer developments and this section should be referred to in considering chemical control of the various species discussed.

Infestations of the beech scale and fir-bark louse in the Northeast are periodically reduced to a minimum when an abnormally cold winter occurs. In regions where the minimum temperatures are −10°, or lower, the European pine-shoot moth need not be feared in pine plantations. The southern pine beetle is killed at temperatures of from 10° to −15°, depending upon the stages concerned; thus, extremely cold winters prove fatal to a high percentage of the broods of these bark beetles and definitely limit the northward extension of their range.

Severe late frosts or freezes, occurring after the new growth of the trees has begun in the spring, frequently completely check outbreaks of defoliators dependent on tender foliage for development in the early instars. But late frost also causes much damage to the tree, preparing it for borer attack as described under Defoliation (pp. 15–16).

Altitude and exposure, by modifying temperature, regulate insect activity, determine the number of insect generations per year, and control the distribution of insect species. This has been fully discussed by Miller (*303*), Chamberlin,[7] and Beal (*26*).

MOISTURE

Moisture has an important bearing on insect abundance, both through its direct effect on the insects and indirectly through its influence on the hosts. Some insects require very moist conditions in order to work to the best advantage and are killed by dryness; others require very dry conditions and are killed by moisture. Moreover, moisture, through precipitation, has an important influence on the growth of trees and their resistance to bark beetle attack; and flooding or excessive soil moisture may weaken the trees.

DROUGHT

Several recent droughts in the East have given clear-cut evidence of the importance of this factor on subsequent insect outbreaks. During the summer of 1924, in eastern Texas and western Louisiana, and more locally in Mississippi, there was a deficiency in rainfall for several months, resulting in the severest drought on record for these areas. Pine trees infested by bark beetles (*Ips* spp.) began dying late in the fall and continued to die through the winter, resulting in the death of over 100 million board feet of mature longleaf pine.

From October 1931 to May 1932 northern Florida and southeastern Georgia experienced a similar drought, resulting in the death of many million board feet of timber, largely second-growth stands. Both round and turpentined stands were affected. *Ips* beetles attacked much of this timber, and there was considerable agitation by lumbermen and timber owners for undertaking widespread control operations. At that time the Bureau of Entomology of the United States Department of Agriculture pointed out, however, the secondary character of the attack and recommended against such measures. With the return of rains, all trouble subsided.

Throughout the Northeastern States there was a marked drought in 1930, so severe in some places that hardwood trees lost their foliage during the summer. The following year hemlocks began to die in many sections, and the losses continued to increase for several years. In

[7] See footnote 4, p. 4.

some areas practically all the mature hemlocks have since died. The hemlock borer increased enormously in numbers and attacked practically all these dying trees, which called forth many inquiries as to the importance of this beetle. The hemlock stands on the Menominee Indian Reservation, Wis., likewise suffered in the drought period of 1930 to 1937 in that region. The drought, combined with overmaturity of the hemlock, death of the root systems, Armillaria root rot, and windthrow, made conditions ideal for an outstanding increase in the abundance of the hemlock borer. By 1938 the estimated mortality due to all these factors exceeded 100 million board feet on this reservation alone (Secrest, Lorenz, and Mac Aloney, *376*).

Extensive outbreaks of the southern pine beetle and hickory bark beetle have always occurred in drought years—1890–92, 1910–11, 1922–24, 1930–33, and 1936–39, for example. Local outbreaks coincide with local deficiencies of precipitation for the summer months; in fact, this is so invariably the case that of recent years it has been possible to predict local outbreaks on the basis of deficiencies in rainfall. This relationship between drought and insect attack has been treated by Blackman (*39*), St. George (*367*, *369*), Craighead (*111*), and Wygant (*437*).

Oaks are also affected by drought, but the association of insect attack is not so clear, often being delayed 2 or 3 years, by which time the trees show attack by a root rot (*Armillaria*), or readily become infested with *Agrilus* beetles, and die.

Black locust is easily affected by drought, particularly a spring drought which permits development of a high percentage of the locust borer larvae in the phloem and consequent girdling and death of the tree (Craighead, *116*).

STORMS

Severe beating rainstorms are known to have controlled outbreaks by knocking the young larvae of defoliators off the foliage of trees, or by drowning bark beetles during flight periods. Hailstorms, like rainstorms, beat insects off the foliage of trees and effect a measure of control. The stones often bruise the upper side of branches, however, causing lesions which become infiltrated with resin. This cuts off conduction and may sometime later cause the death of twigs on coniferous trees.

Many bark- and wood-boring insects that are dependent on dead wood are kept well supplied with breeding material by broken branches, tops, or wind-thrown trees; and occasional tornadoes and hurricanes leave swaths of fallen timber. This material is quickly attacked by bark beetles and borers. Sometimes the bark beetles multiplying in these logs attack and kill adjacent green timber.

FIRE

Fire-scorched or fire-killed trees have a marked attraction for certain insects, as they are especially favorable for the breeding of many species. Adults attracted into the area lay eggs in the dead and dying trees, and the insects increase enormously in numbers. This attraction is so pronounced that every tree in suitable condition over the entire burn, often covering many square miles, may be attacked in a few weeks' time. For the most part, insects attacking these trees are of secondary importance, and only under special conditions does this sudden increase result in the destruction of green, standing timber. On the other hand, fire-scorched trees offer unsatisfactory breeding material for other destructive bark beetles and may serve as traps, actually reducing the numbers of beetles in the area.

FOOD AND BREEDING MATERIAL

The abundance or scarcity of the food supply is an important factor governing the distribution and successful development of insects. Most of the insects that prey upon living forest trees are limited in their distribution to that of their favorite host; those that feed on dying or dead trees are apt to be more widely distributed through forest regions, because they will often attack various species with little or no discrimination.

Leaf-eating insects that attack healthy forest trees have an abundant food supply at their disposal, and their numbers are controlled primarily by biological and climatic factors. At times, however, starvation checks very effectively the progress of an outbreak of defoliators and renders the weakened, underfed caterpillars more susceptible to certain diseases. Outbreaks of many defoliators occur only in areas where there is an abundance of their favored host material or where it is dominant in the stand. Stripping of the foliage by the gypsy moth, the spruce budworm, or forest tent caterpillar coincides with the distribution of a high percentage of favored hosts in the forest.

A great many insects, such as most of the bark beetles, can develop in large numbers only when a sufficient quantity of their host plant is available in a suitable condition for attack. Thus, the development of destructive bark-beetle outbreaks is dependent to a large degree on the supply of overmature or decadent trees, fire-weakened trees, slash, windfalls, snowbreaks, lightning-struck trees, or trees weakened by drought, high water, smelter smoke, filled-in earth, disease, or other causes. Such material is probably the natural habitat for many species which at times become excessively abundant and attack more healthy trees.

SLASH

The debris left from the cutting of trees in the forest is a suitable and attractive breeding material for a great many forest insects, some of them beneficial and some harmful species. When the slash is fresh, the dying inner bark is attractive to many species of bark beetles that are commonly found breeding in dying trees still standing. Usually these bark beetles select slash or stumps of a type and size similar to the parts of standing trees in which they would normally breed. Thus the limb- and twig-feeding bark beetles go into the brush and smaller pieces of slash; trunk-breeding bark beetles go into the cull logs and butts, while those that normally work at the base of the tree attack the stumps. The abundance of the progeny depends a great deal on how the moisture and temperature conditions within the slash meet the requirements of the different species of beetles.

The red turpentine beetle frequently develops in such numbers in pine stumps as to do serious injury to adjacent living trees. Large numbers of trunk-breeding pine bark beetles attack cull logs and butts, but they rarely find conditions suitable for developing large broods, and the progeny they produce under such circumstances seldom cause any trouble in neighboring forests or to the reserve stand, especially where logging operations are continuous (Patterson, *345*). The engraver beetles and twig beetles, which breed in the smaller pieces of slash, frequently emerge in such enormous numbers as to kill larger patches of reproduction and sometimes the tops of older trees.

The wood-boring species which breed in slash must be considered generally beneficial, as they help to decompose the wood and reduce the fire hazard that accompanies a large quantity of slash. Occasionally they may become injurious, however, and in order to reduce or avoid the menace from slash-breeding insects, special thoroughness in slash disposal is sometimes necessary. When a logging operation is continuous, and a fresh supply of slash is furnished throughout the period of attack, the emerging progeny are repeatedly absorbed in the slash and in the logs removed to the mill, and no special precautions need be taken. But if a cutting operation ceases or is intermittent, as in the case of road and power-line development or forest thinnings, then some damage to adjacent trees from insects attracted into the area can be expected and should be prevented if possible.

Burning the slash is beneficial, provided the large limbs, cull logs, and stumps are included and the burning is done before the adults emerge. In many cases this means that the burning must be done in the middle of the summer or early in the fall, and this may not be safe. Spreading the slash so that it will receive the direct rays of the sun will dispose of a high percentage of the insects, especially in the more southern latitudes where high bark temperatures can be obtained in this way. Normally in the East, losses in standing timber from the influence of slash occur only in very dry weather. In general the only precaution necessary is to avoid cutting green timber and creating slash at a time when a deficiency in rainfall has existed for a month or more. The United States Bureau of Entomology and Plant Quarantine (*415*) has issued a circular on the slash problem.

EFFECT OF DEFOLIATION

Defoliation is a common and widespread factor in the weakening of both hardwood and coniferous trees, making them readily susceptible to attack by bark beetles and borers. Where the line of demarcation between fatal injury by defoliation and the possibility of recovery occurs, seems impossible to determine. One defoliation of 75 to 100 percent will kill most conifers, except larch, regardless of subsequent insect attack, but the more thrifty trees are more resistant, and many might recover were it not for bark beetles or borers, which almost invariably enter such material.

Many years' observations on various hardwoods have shown that deciduous trees can stand as many as 5 to 10 years' defoliation, depending on site and previous vigor, before they succumb. Secondary borers and root fungi (especially *Armillaria*) often enter into the final picture. Dry summers and severe winters also play a part.

Late spring frost is a common defoliator of new growth, particularly on oaks in the southern Appalachians. Such defoliations are especially damaging and invariably are followed by a high mortality of the trees from 1 to 3 years later. Conclusions based on general observations and specific records on thousands of numbered trees lead to the belief that it is best to regard defoliation as the primary factor in the death of the trees and consider the subsequent attack by bark beetles or boring insects as secondary and not justifying control measures. In other words, it is of little avail to treat a symptom when the seat of the trouble cannot be attacked.

NATURAL ENEMIES

By R. C. Brown

Insects, like other living things, have natural enemies which prey upon them and tend to hold them in check. These include other insects, birds, small mammals, bacterial, virus, protozoan, and fungus diseases, and parasitic nematodes.

Birds

Many species of birds are insectivorous. Nuthatches, chickadees, creepers, warblers, kinglets, and many other species search for insects on tree trunks and foliage, and the woodpeckers dig through the bark and feed on the larvae of bark beetles and wood borers. Over 75 percent of the broods of the eastern spruce bark beetle and southern pine beetle have been destroyed in patches of bark worked over by industrious woodpeckers, and frequently local outbreaks are completely checked. Hall (*208*) reported woodpeckers as one of the most important single factors in the control of the locust borer.

Small Mammals

The meadow mouse, the white-footed mouse, moles, shrews, voles, chipmunks, and squirrels play important roles in the destruction of forest insects hibernating in the duff or soil. These small mammals often consume a large percentage of the cocoons formed in the leaf litter and have been reported as practically controlling outbreaks of some of the sawflies. These mammals are also important in destroying broods of bark beetles exposed during the peeling operation of control projects. Rust (*366*) and Graham (*191*) have discussed predatory mammals as control factors.

Nematodes

Certain species of parasitic nematodes attack bark beetles, wood-boring insects, soil-inhabiting grubs, and lepidopterous larvae, causing sterility or death of the host. Little is known of the real importance of such parasitic animals.

Insects

Many species of insects and related forms, such as mites, belonging to several orders and families, are distinctly beneficial in that they prey on the harmful species. These beneficial forms may be divided into two groups—parasites and predators. The line of demarcation between a parasite and a predator is not a rigid one, as both live at the expense of their host. A parasite is usually considered as one capable of completing its life history in or on the body of one host, whereas a predator feeds upon a succession of individuals.

Most of the parasites belong to a few families of wasps (Hymenoptera) and flies (Diptera). The parasitic wasps oviposit on, in, or near the host, and the parasite larvae feed either externally or internally until they reach maturity. Parasitic wasps may develop singly or gregariously, and in the case of those that develop polyembryonically as many as 100 or more individuals may be produced from a single egg. The parasitic flies either oviposit or larviposit on, in, or near the host, although there are some species that deposit their eggs on the foliage and these eggs must be devoured by the host insect to be effective. The larvae of parasitic flies, called maggots, usually develop within the body of the host, whereas the larvae of parasitic wasps may be either internal or external feeders. After the wasp larva or fly maggot becomes full grown the host usually dies. The parasite then pupates in a cocoon, or puparium, or as a naked pupa either within the remains of the host, or without, if the larva is an external feeder or if it leaves the host before it pupates.

Most native forest insects, with the exception of borers and some forms that feed inside the host plant, are attacked by an abundance of parasites which often include a great many species. All stages of the host from egg to adult may be attacked, although, generally speaking, the larvae and pupae are most heavily parasitized. Parasites range in size from minute forms that attack insect eggs to some with ovipositors several inches long, which parasitize wood borers in their tunnels.

Unfortunately many of the parasites that attack forest insects are themselves preyed upon by other parasites, called hyperparasites. Hyperparasitism may be occasionally carried to the second or third degree, thus making the host-parasite relationship quite complex.

Some of the more important predaceous enemies of forest insects are beetles belonging to the families Cleridae, Ostomatidae, Carabidae, and Coccinellidae, lacewing flies of the family Chrysopidae, several families of true bugs of the order Hemiptera, and the dipterous family Syrphidae. Often both the immature and adult forms of predaceous insects feed directly upon all stages of their hosts. Ants of several species are voracious feeders, often devouring not only large numbers of defoliating larvae as they come to the ground to pupate, but also pupae in the duff, and newly emerged adults. They likewise destroy the broods of borers and bark beetles exposed during peeling operations on control projects.

The effectiveness of parasites and predators is very difficult to measure accurately, but it is safe to say that these natural enemies play a very important role in keeping forest insects in check. Their effectiveness is dependent on many factors, such as the character and habits of the host insect, density of population of the host, presence of alternate hosts, degree of hyperparasitism, conditions affecting hibernation, and artificial control measures.

The larvae of some of the roundheaded borers are voracious feeders and are often indirectly beneficial in that they devour the inner bark so rapidly that they rob the more primary bark beetles infesting the same tree of their food. This is a case of competition between two species of insects, one of which is capable of killing trees, the harmless species putting the destructive one to a disadvantage. Such larvae are often referred to as robbers.

Diseases

Insects are subject to many fatal diseases, which sometimes are potent factors in suppressing an outbreak of a harmful pest. These diseases are caused by many different micro-organisms, including filterable viruses, bacteria, and fungi. Few of these have been adequately studied. One of the most common examples is a wilt disease which spreads rapidly during outbreaks of various caterpillars. The caterpillars suddenly sicken and die, and are seen hanging from leaves and twigs. At first, they are filled with liquid but later present a blackened shriveled appearance.

RÉSUMÉ OF NATURAL CONTROL FACTORS

Under normal conditions, the operation of these physical, nutritional, and biological forces counteracts the enormous reproductive capacity of insects and tends to keep the destructive and beneficial ones more or less in balance. The few survivors of harmful species, which at such times escape their enemies, continue to live and feed on their hosts without doing conspicuous injury. Thus, defoliating insects usually feed on a few leaves or needles, but the damage is so small as to escape notice. The bark beetles kill an occasional tree or breed in down logs and broken tops. The aggregate damage is negligible, and the annual growth in the forest exceeds this small drain, so that there is a net accretion in the volume of wood in the stand. Infestations which exist under these conditions are termed normal or endemic, and it is a hopeless and unwise undertaking to try to exterminate the insects by control measures.

Under certain conditions, however, the natural balance may be broken by any one of a number of factors. The beneficial insects or other enemies of harmful species become reduced in numbers; the resistance of the trees is lowered through defoliation, drought, fire, overmaturity or stagnation; large quantities of slash or other breeding material become available; or climatic factors become especially favorable; and the injurious species breed rapidly and in excessive numbers, and a destructive outbreak soon develops.

Within a few seasons a high percentage of a timber stand may be killed by bark beetles, and the destruction may continue for years and spread over large areas. Defoliators may suddenly increase within an area, and after destroying the foliage of valuable timber over large acreages, disappear with equal swiftness. There are many factors which come into play in bringing about these sudden changes, and it is often difficult to isolate the responsible causes. Outbreaks of such a character are called epidemic infestations and require immediate attention and drastic control measures.

SILVICULTURAL CONTROL OF FOREST INSECTS

There are many types of second-growth stands in the East where it is quite possible, through silvicultural practices applied to the growing stands, to bring about conditions unfavorable for the development of outbreaks of certain insects or to maintain the stand in sufficient vigor to avoid serious losses. Some examples of the general principles involved in the application of forest practices to insect control are here discussed under several different conditions of growth, and further information is available from the following sources: United States Bureau of Entomology (*416*, *417*), Munns (*313*), Munns and Coville (*314*), and Craighead (*115*).

IN MATURE TIMBER

It is common knowledge that overmature timber is difficult to protect. In a way, insects are one of nature's agencies for harvesting mature timber, thus clearing the way for new growth. With shorter rotations in the future, losses in mature timber should be greatly reduced. Systems of selective cutting have been devised for ponderosa pine in the West, based on the greater susceptibility of certain types of trees to bark beetles. Recently it has been found necessary to cut overmature stands of spruce in Vermont to avoid losses by the spruce bark beetle.

IN SECOND GROWTH

In contrast to the susceptibility of overmature stands, second-growth stands, particularly those of good vigor, are more able to resist insect invasion and are seldom totally destroyed. The production of pulpwood in New England, the Lake States, and the adjacent provinces of Canada is largely dependent on the control of the spruce budworm. The mortality in spruce and fir stands when attacked by this insect is lessened if the trees are in vigorous growth at the time of defoliation.

FOREST COMPOSITION

The composition of the forest is of prime importance in inviting or avoiding disaster. Recent destructive outbreaks of the spruce budworm in Minnesota, New England, and Canada are attributed to the great proportion of balsam fir in the stands, due to a hundred years of selective cutting of pine and spruce and to natural forest succession.

The gypsy moth is a pest that must be reckoned with in the management of the hardwood forests in New England. Fortunately serious defoliation is restricted to areas having a high percentage of certain favored species, and the management of the forest to hold these favored hosts in the minority will prevent damage by this insect. Groupwise stands of white pine and hardwood are rarely badly injured by the white-pine weevil, whereas adjacent pure pine stands are often so heavily attacked that their future value for clear lumber is destroyed.

Outbreaks of the southern-pine beetle are notably less severe where hardwoods form a considerable percentage of the stand. This calls for practices favoring the increase of hardwood species in those stands under management. In general, the planting or the encouragement of great blocks of a single species is to be avoided except where the climax type is such as is found in the pineries of the coastal plains of the South, which are notably free from serious insect outbreaks. Such mixtures of species as those that nature tends to work toward in the climax types of an area should be the goal. The transition types of trees should be utilized early, before insect outbreaks take their toll.

THINNINGS

Sudden drastic changes affect trees unfavorably and make them susceptible to attack. For this reason the opening of the stand through logging favors the subsequent attack on certain trees by such insects as the bronze birch borer in birch, the hemlock borer in hemlock, and bark beetles in pine. Either the thinning should be less drastic or the entire stand should be removed. This subject was covered in 1933 by Hall (*207*).

TURPENTINING

The woods practices of a decade ago in the naval stores industry in the South resulted in extravagant losses from dry facing and windthrow. Such a high percentage of the stand was blown down that turpentining frequently had to be abandoned. This was in a large measure the result of the weakening of the main stem of the boxed pines by mines of the turpentine borer in the heartwood. This insect gained entrance through exposed wood on the turpentined faces. Such loss is almost entirely preventable through the adoption of better practices designed to increase the ultimate yield of gum and greatly to prolong the period of operation on a given area. The work of this borer has been discussed by Beal (*25*).

CHOICE OF SITE

Northern white pine, a most desirable and fast-growing tree, has been more extensively used for replanting in the New England States and New York than any other species and has also reseeded naturally on much abandoned farm land. With the enormous increases in the acreage of susceptible material, the white-pine weevil has become a serious menace. Recent study of the problem indicates that if plantations are confined to the better sites, the trees spaced not more than 6 by 6 feet apart, or managed groupwise in a mixture with hardwoods, a profitable crop can be obtained. Even in the pure stands or plantations that have been very severely injured, if the spacing is no more than 6 by 6 feet, it is possible to carry out certain reclamation practices that will insure a good yield where otherwise there would be a total loss. Cline and MacAloney (*95*, *96*) and MacAloney (*278*, *279*) have published information on this weevil.

It is apparent that there are great possibilities for avoiding insect damage as forest management becomes more intensive in our eastern forests. Fortunately, in most places, measures for avoiding insect damage will be found to fit in well with silvicultural practices for producing the crop best adapted to those areas or sites.

INSECTS ATTACKING SHADE AND ORNAMENTAL TREES

The care and treatment of shade and ornamental trees has developed so rapidly in recent years that it has resulted in a specialized commercial field. In many localities reliable commercial concerns will care for and spray, or otherwise treat, affected trees. Many of the States have specialists in this field, and numerous bulletins covering the subject are available. For present purposes only a brief résumé is necessary, and readers desiring more complete information are referred to the following sources: Kotinsky (*269*), De Gryse (*128*), Felt and Rankin (*155*), Herrick (*223*), Houser (*239*), Felt (*147*), and Pirone (*353*).

Proper selection, planting, and general care of ornamental trees are generally the best guarantee against damage by insects. The importance of selecting the most suitable species of trees for certain sections of the country, and even for a particular site or location, cannot be overemphasized. Some factors to take into consideration are adaptability to climate, rate of growth, size, form, longevity, soil requirements, root characteristics, and susceptibility to insects or diseases. Many trees are so weakened by improper planting that they succumb readily to attack by borers. The usual planting instructions for various types of plants should be rigidly followed. In the care of trees consideration must be given to such factors as pruning, effect of light, care of wounds, tree surgery, bracing, fertilizing, watering, and grading. Thorough consideration of these features can be obtained by consulting State or local authorities or by referring to Collins (*101*), Houser (*239*), Mulford (*311*), Marshall (*291*), and Pirone (*353*).

MUNICIPAL CONTROL OF INSECTS

It is becoming the practice in most large cities to employ a force of trained experts to take care of the city trees. With such an organization it is possible to keep on hand the expensive equipment needed for spraying, transplanting, pruning, tree surgery, and other necessary activities in prolonging the life and improving the appearance of the trees. Even in towns with populations as small as 10,000 it would probably be economical in the long run to provide for competent care of the trees and to purchase the necessary equipment.

SELECTION OF TREES FOR ORNAMENTAL PURPOSES

The old adage "an ounce of prevention is worth a pound of cure" is particularly applicable in the case of shade trees for ornamental plantings. It is usually possible to select species well adapted to any particular locality or site and least subject to insect attack. In general, the conditions under which particular species of trees grow best in nature should be given consideration when transplanting them for ornamental purposes. For example, the American elm usually grows on low ground, or at least where there is an adequate moisture supply, and does poorly on dry ridges or poor soils. In general, conifers, particularly pines, will do better on poor soils that are lacking in humus than will the hardwoods. Many States employ specialists who can give advice on the best trees for a particular locality, and such authorities should be consulted.

GRADING AND FILLING

Changing the soil level about trees is a frequent source of injury leading to borer attack and the ultimate death of the tree. Scraping off the topsoil increases the temperature of the soil about the roots and actually kills many of them. Filling in with earth prevents passage of air to the rootlets and suffocates the plant. Where it is necessary to lower the grade about a tree, applications of manure or fertilizer should be made, particularly a mulch, when the topsoil is removed. If filling is necessary, a well should be built around the trunk of the tree with a diameter at least 3 feet larger than the diameter of the tree.

FERTILIZERS

The thriftier the tree, the less likely it is to be seriously injured by insects. Thrifty, healthy trees fully recover from attack by defoliators more often than do poorly growing trees. Unhealthy trees or those showing indication of borer attack in the branches can often be saved by adequate watering and by applying a fertilizer such as nitrate of soda or stable manure. This treatment, together with severe pruning of infested parts and adequate cultivation, will often result in marked improvement. An excellent way of providing better absorption of water by the soil and at the same time of applying commercial fertilizer is to make holes in the soil by driving a crowbar or pickax 10 to 12 inches deep at intervals of a foot or less. The treatment should extend as far out as the spread of the branches, each hole should be filled with fertilizer, and the soil about the tree should be frequently watered if rainfall is lacking.

WATERING

The effect of drought on trees and its bearing on insect attack has been mentioned frequently on previous pages. Experience has shown that lack of moisture is one of the most important predisposing factors inducing attack by insects, particularly borers and bark beetles. Consequently, adequate watering of the trees during dry periods will offset this threatened injury.

Experimental work with some of the wood borers and bark beetles has indicated that, if done in time, watering is one of the most effective methods of preventing attack. Thorough watering should be started just as soon as there is a deficiency of 1 inch or more of rainfall during the growing season. On hard, poor soils, or in places where the soil around the tree is subject to a great deal of tramping or packing, it is well to water frequently during summer and fall.

CARE OF TREES ON CAMP GROUNDS

The use of groves for camp grounds, parks, or other purposes where people congregate presents a difficult problem in keeping these trees in good condition. In such locations the soil litter providing humus is usually raked off each year, and frequent tramping of the ground packs the soil, interfering with aeration and drainage, and even exposes some of the roots. It is practically impossible to keep the trees in healthy condition, and they frequently succumb to the attacks of bark beetles and other borers. Where the damage becomes very noticeable and severe, the only remedy seems to be to avoid the use of the area for several years and apply humus or fertilizer to improve the soil and increase the vigor of the trees. In recreational areas and public parks, it is advisable to plan the campgrounds or other areas frequented by large numbers of people so that different sites can be used alternately every few years.

MECHANICAL BARRIERS

Mechanical barriers for preventing the access of insects to portions of the trees on which they would feed are often very successful in preventing damage, particularly to roadside or other ornamental trees.

Transplanted hardwood stock is frequently attacked by secondary wood borers that mine beneath the bark, girdling the stems of the trees before the plants become firmly established. Wrapping the trunks with heavy paper, wire gauze, burlap, or other material that will prevent oviposition has been very helpful in protecting the trees the first year or two, or until they are well established.

Mechanical barriers placed around the trunk of the tree are very effective in preventing the ascent of leaf-eating caterpillars. A number of materials have been successfully used for this purpose, including burlap, cotton batting, fine-mesh screen, and sticky substances. Some sticky materials are on the market and, although more expensive than some other materials, are easily obtained and simple to apply. A good formula for a sticky banding material and its preparation for use against the gypsy moth are described by Collins and Hood (*102*).

To apply burlap or cotton batting, the bark should be smoothed, the material placed around the trunk and held firmly with a wire or string, and then the upper portion of the material turned down, so as to form a loose flange all the way around the tree. Johnson and Fenton (*258*) describe a method with paper bands. For some insects DDT sprayed around the lower trunk has been very effective.[8]

TWIG OR STEM GIRDLERS

Twigs or stems girdled by any of several species of insects causing this type of damage usually contain the borer in the severed portion of the twig. In some cases, however, the borers work toward the trunk, cutting off the portion of the twig behind them. In the former case gathering and burning of the girdled twigs is the most satisfactory means of preventing further damage, provided it is thoroughly done and extended some distance in the surrounding area. This form of control, however, is of very little value if the trees are growing adjacent to wood lots where these girdlers are abundant.

For those forms that girdle the twig behind them and bore down into the stem, prompt action in cutting the twig ahead of the borer and destroying it is the best remedy. The injection of a few drops of carbon disulfide into the hole, followed by plugging the stem, will also kill the borer.

Carbon disulfide is inflammable and explosive when mixed with air in certain proportions, and is poisonous. The liquid should be handled with great care and never be exposed near fire in any form. Even hot steam pipes may ignite the gas. The fumes are poisonous and should not be inhaled. When applying the chlorinated benzenes the hands should be protected with rubberized gloves, since the chemical might irritate the skin. Care should be taken to keep the vapor from the nose and eyes.

ROOT BORERS

Root borers are notoriously difficult to handle, but fortunately are not frequently encountered. Those attacking a tree at the ground line can often be destroyed by fumigating with paradichlorobenzene. (See p. 25.) True soil-inhabiting insects that attack the roots of plants are treated in the discussion of insects affecting nursery plants (p. 28).

GALL MAKERS

Certain gall-forming insects can be controlled by sprays as mentioned, but for many forms the only known method of control is to cut and destroy the galls at that period of the year when they contain the living broods and thus prevent the adults from emerging and attacking the same or other trees.

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[8] For a full discussion of spraying and dusting, see pp. 51–57.

BORERS IN LIVING TREES

The control of borers in living trees is well known to be a difficult matter. Many species of borers attack only weakened or dying trees, and after the attack the larvae are well protected by a thick layer of impervious bark. In the forest, it is impractical to attempt control except through the sacrifice of the infested tree; and often in shade and ornamental trees, the condition is discovered too late to apply a remedy.

There are two distinct types of borers causing damage to living trees. The first attacks sparingly over the stem, boring individual galleries under the bark and into the wood of apparently healthy trees. This group includes the species of *Goes* and *Romaleum*, and some species of *Saperda*, the carpenter worm, pitch moths, the maple borer, locust borer, and others. In the early stages, while the borers are in or under the bark, their work causes an exudation of sap and boring dust. Later, large excavations are extended into the wood. These holes weaken small trees, and often result in the breaking off of the affected part, and in larger trees they serve as points of entrance for decay.

In valuable trees the simplest method of treatment is to drop a small quantity of some fumigant into the borer tunnel. Carbon disulfide or carbon tetrachloride are recommended. The holes should then be plugged with moist soil or putty. Where the borers are numerous, painting or spraying with orthodichlorobenzene emulsions or with 1 pound of paradichlorobenzene dissolved in 2 quarts of cottonseed oil is often effective. For formulas and details of application, see pp. 25–26.)

The second class of borers, those that attack in great numbers over a considerable portion of the tree and extend the larval mines under the bark of the larger branches or the entire trunk, are represented by such genera as *Agrilus*, *Melanophila*, *Tylonotus*, *Chrysobothris*, and by some species of *Saperda*. These borers are dependent on a lowered vitality of the tree for successful attack. There is really no effective means of controlling them after the borers are well established in the tree. As they bore beneath the bark and have no exit holes to the outside, it is impossible to reach them with sprays. Usually by the time the tree is attacked throughout, it is too late to apply effective measures.

Recent work with DDT indicates that it may be effective in preventing attack of many borers if the trees are sprayed at the time the adults are active. A concentration of 2 to 5 percent, applied either as an emulsion or a wettable powder, is effective.

DDT is poisonous and should be handled with care. It should be stored in clearly labeled packages and kept away from food products. The use of DDT on ornamental plants growing close to fish ponds or streams should be avoided, since there is danger of killing fish and other aquatic life. DDT in oil solutions and emulsions may be absorbed through the skin of man and animals. Persons using it in these forms should take special precautions to avoid repeated or prolonged exposures to the material.

General care of shade trees, such as avoidance of injury from lack of water, filling in of earth, or grading over the roots; care in transplanting; and thinning and pruning where possible, will help to prevent attack. In the early stages of attack by some species, while only the upper branches are infested and before the tree is completely girdled, it is helpful to improve the vigor of the tree by watering, fertilizing, and spraying for sucking or defoliating insects, as explained elsewhere (pp. 20–23). In transplanted stock, mechanical barriers are often effective.

FUMIGATING TREATMENTS

One of the most effective treatments for many borers is a spray carrying one of the common fumigants. Such sprays will not penetrate green bark, but they are absorbed by any dead bark around the insect and enter the exudation holes maintained through the bark by certain species of borers, thus bringing the active ingredient in contact with the larvae.

Probably the best of these fumigant sprays is orthodichlorobenzene emulsion. The stock emulsion is made as follows:

Orthodichlorobenzene	12 parts.
Liquid potash soap, fish-oil soap, or common laundry soap	1 part.
Soft water	3 parts.

When laundry soap is used, the soap should be dissolved in boiling water and after it has cooled somewhat the orthodichlorobenzene should be added and the ingredients thoroughly mixed.

If the water is hard, 1 teaspoonful of washing soda should be added to each gallon.

Pumping the mixture through a coarse nozzle back into the same container will aid in insuring a good emulsion that will stand up for several months. To make the spray solution, 1 part of this stock emulsion is mixed with 6 parts of water. The emulsion should be thoroughly stirred both before diluting it with water and before applying it to the trees, to be sure that the chemical has not separated out. *The emulsion should not be applied to the foliage or tender branches, as it will cause burning.*

A simpler mixture consists of orthodichlorobenzene in a miscible oil. Naphthalene in a nontoxic carrier, such as an emulsion, has proved effective.

Where only a few lightly infested trees are to be treated on the lower part of the trunk, it is often advantageous to paint the infested places on the bark with an emulsion rather than to spray. An effective emulsion for this purpose is made up by dissolving 2 pounds of paradichlorobenzene in 1 gallon of crude cottonseed oil and emulsifying the mixture with a good grade of potash soap or fish-oil soap. This stock solution should then be diluted with 2 to 4 parts of water and applied to the infested areas of the bark with a paint brush. The crystals can also be used in a mineral-oil emulsion. Chandler (*83*) in 1939 discussed the method.

Paradichlorobenzene is a good fumigant for borers at the base of the tree. From ¼ to 1 ounce of the crystals (depending on size and age of tree) should be placed on the loosened soil around and about

2 inches from the trunk so as not to touch the bark, and then covered with a mound of earth. The earth mound and any remaining crystals should be removed in from 10 to 14 days. This treatment is not very effective in cold weather.

Preliminary work with some of the newer insecticides, such as benzene hexachloride, indicate that they may be very useful in borer control.

SPECIAL TREATMENTS FOR CERTAIN BORERS

The Locust Borer

Control of the locust borer (*Megacyllene robiniae*) through silvicultural practices is discussed on page 244. Occasionally it is desirable to utilize a spray on small plantations or individual trees for the control of this insect. The most effective insecticide for this purpose is one of the fumigant sprays described in preceding paragraphs.

The spray must be applied early in the spring when the leaves are unfolding, before the borers go into the wood. The trunk of the tree should be given a complete covering, especially from the ground line to a height of 5 or 6 feet. The spray should not be applied to the young branches or foliage, as there is danger of burning.

The Ash Borer and the Elm Borer

Injury to ash plantations by *Tylonotus bimaculatus*, the roundheaded ash borer, and the elm borer (*Saperda tridentata* Oliv.) can be somewhat lessened by sanitation cuttings to remove heavily infested trees during the fall and winter. The stumps should be cut at least to the level of the ground, and preferably an inch or two below the ground line, since the base of the tree is frequently heavily infested. The infested material should be burned before the beetles emerge in the spring. In areas where green ash is especially susceptible to attack by this borer and by the carpenter worm, the ash trees should be planted only on the more favorable sites.

The Poplar Borer

Fast-growing trees are less attractive to the beetles than slow-growing ones, and the tendency for the poplar borer (*Saperda calcarata* Say) to concentrate its attacks upon trees already infested or weakened can be used to advantage to protect surrounding trees, by cutting and burning these so-called brood trees or by splitting the infested logs and exposing them to the direct rays of the sun. Coal-tar creosote painted over the egg scars soon after oviposition is recommended for killing the eggs. Fumigating sprays (p. 25) can also be used. **Caution should be exercised in handling coal-tar creosote, as it irritates the skin and eyes.**

The Carpenter Worm

The carpenter worm is controlled in much the same manner as the poplar borer, or a few drops of carbon disulfide squirted into the galleries, followed by plugging the entrance with wet mud or putty, is effective against this insect.

Timber Beetles

Several species of insects representing different orders have a common habit of attacking wounds or catfaces on living trees and, from this point of access, riddling the sapwood and heartwood for considerable distances. Such injuries are caused by the chestnut and the oak timberworms. Also certain ambrosia beetles attack directly through the bark. Control of these borers is difficult. It is good practice to remove brood trees and to prevent fires or other causes of lesions. Under exceptional conditions, as for individual trees, fumigating sprays would be practical and effective.

Pitch Moths

Pitch moths reinfest the same trees year after year, and it is from these trees that most of the moths are produced. The cutting during the winter of these heavily infested brood trees, which are frequently deformed or broken, may reduce an infestation. Trees not over 7 or 8 inches in diameter will dry out sufficiently by early summer, if cut and left in the open, to prevent the maturing of the small overwintered larvae. When the insects are in individual trees of high value the larvae may be cut out with a knife at the time the pitch masses appear on the bark late in the spring. No effective sprays are known.

Borers in Wounds and Callouses

There are several species of borers that attack the heartwood of living trees, gradually extending their mines until there is nothing left but a shell of sapwood. The attack starts from points of injury, such as fire scars or wounds exposing the wood surface. *Parandra* and *Malladon* in hardwoods and *Buprestis apricans* in pine are the most destructive borers of this type and cause much wind breakage of ornamental trees. In the forest, this injury results in defective butt logs. Prevention of fire scars or other wounds which expose the wood will prevent infestation. All wounds on ornamental trees should be painted or covered with a waterproof dressing until they are healed. Tree surgery must be relied upon in advanced cases of damage to valuable trees.

The borers that live in the callouses of wounds and thus prevent healing are difficult to control by any other means than cutting them out or by covering the wound edges with a protective coating to prevent oviposition.

INSECTS IN NURSERIES AND YOUNG PLANTATIONS

The control of many of the insects injurious to seedlings and young trees in plantations, such as the common sucking insects and defoliators, can be obtained through the application of insecticides as recommended on pp. 51–57. On the other hand, certain kinds of insects require specialized control methods. This is particularly true with those that live in the soil, as cutworms, wireworms, white grubs, and leaf-cutting ants, which find conditions favorable for development accompanying the specialized practices in forest nurseries. In both nurseries and young plantations, more expensive methods of protection are justified than can be practiced in the forests or natural stands of reproduction. Under certain circumstances the use of insecticides and special tools or appliances are feasible, as is a considerable amount of hand labor. Soraci (*395*) in 1937 published a circular on control of insects in the nursery.

INSECTS FEEDING ON ROOTS

Some of the most serious nursery pests, and the most difficult to control, are insects that feed on the roots. White grubs, certain weevils, and termites are among the worst offenders, with minor damage by wireworms and borers. Soil poisons or fumigants offer the best possibilities for control, but in their use there is always danger of injuring the seedlings. Experiments by St. George (*370*) indicated that *it is dangerous to use crude white arsenic or lead arsenate as a soil poison in seedling nurseries, since the arsenic will remain in the soil and continue to cause injury for a number of years.*

White Grubs

The best control of white grubs has been obtained with commercial carbon disulfide injected into the seedbeds, but flooding the infested area with 50-percent miscible carbon disulfide has given some success on small areas. In the use of either form of the chemical, the results vary in different soils and under different soil temperatures and moisture conditions. Since the grubs go deep during the winter and soil temperatures are too low for successful control, these methods can be used only during warm summer weather when soil temperatures are high and when the larvae are feeding within a few inches of the surface. Young seedlings are more susceptible to chemical injury than older ones, but under certain conditions older stock may be damaged. *It is therefore advisable to test the chemicals on a small area of the same soil before large-scale control is undertaken.*

Straight carbon disulfide injected into the seedbeds at the rate of 1 pint per 100 square feet is, under many nursery conditions, an effective control and causes negligible chemical injury to pine seedlings. The depth of penetration of the chemical depends somewhat on the nature of the soil.

In addition to being extremely poisonous, the vapors of carbon disulfide are highly inflammable and explosive and will ignite at temperatures as low as 212° F.

To obtain maximum grub control and minimum chemical damage to the seedlings in sandy soil or sandy loam, the following conditions must be complied with: (1) The soil should be moist, loose, and friable (conditions suitable for cultivation) with a moisture content of not more than 15 percent. Do not water within 1 hour after treating and do not treat immediately before or after rains, as such conditions result in severe chemical injury to the seedlings, (2) the temperature of the upper 6 inches of soil must be 78° F. or above for successful control of the larvae, (3) the chemical should be injected into holes 3 to 4 inches deep, spaced 6 by 6 inches apart, at the rate of 1.2 cc. per hole.

Fill the holes with soil and pack it in firmly immediately after the chemical has been applied. If possible, the holes should be placed between the seed drills in order to keep the chemical as far away from the plants as possible. The chemical may be injected with a hypodermic syringe with the needle removed or with an automatic injector.

Flooding the infested areas with 50-percent miscible carbon disulfide, consisting of equal parts of carbon disulfide and soap solution, may be used with some success on seedbeds of even topography. This method, however, is not practical on rolling seedbeds since puddles will result in uneven distribution of the chemical and severe plant injury. The treatment is made by diluting the 50-percent stock emulsion in the proportions of 1 quart to 50 gallons of water and applying it at the rate of 3 pints per 100 square feet of soil surface. Six or eight holes (made with a broomstick) per square yard, will aid in the penetration of the chemical into the soil.

Recent work with DDT for soil-inhabiting insects suggests that it will be effective on white grubs in nurseries and plantings.

Numerous cultural practices have been tried as control measures. In the Lake States, making the furrows of various depths and widths has not prevented grub injury and has been generally unsatisfactory from the standpoint of control. Seedbed screens made of ¼-inch hardware cloth have been recommended for nursery use, but these are expensive and inconvenient, and do not prevent the migration of grubs except when placed around the seedbeds below the ground level. The mechanical destruction of larvae by piercing the soil with many-tined wire brushes has likewise proved unsatisfactory. Large nurseries are using a tractor-drawn rotary tiller for general nursery cultivation, and this machine is proving an effective means of mechanical control. It may not, however, be successful in all localities or under all cultural conditions. Its use is restricted to soil relatively free from rocks, roots, and heavy debris, but it can be used in mulch and litter.

In long-established nurseries damage results through oviposition by adult beetles attracted into the nursery for feeding on the foliage of certain trees, and these preferred trees should be removed from near the nursery. New ground should not be planted to tree seed until it has been clean-cultivated for at least 2 years.

Little control of grubs may be expected from parasites, predators, or diseases. Parasites may become an important control factor of the Japanese beetle, however, owing to the importation and establishment of Asiatic parasites. The native parasites of grubs appear to be ineffective against white grubs.

The possibilities of control, based on a knowledge of the food preferences and other ecological relationships of the various species of white grubs, is beginning to be recognized. Since female beetles generally oviposit in the vicinity of their food plants, and as the larvae are probably not capable of long migrations, it is obvious that the density of infestation is in direct proportion to the proximity of adult food. An illustrative instance showed an average of 0.1 grub per square foot at about 200 feet and 1.562 grubs at 25 feet from an oak-aspen-maple stand on the Huron National Forest, Mich. A similar distribution has been found to hold in numerous instances on the Huron Forest and elsewhere.

From this viewpoint, the problem of control becomes one of determining the injurious species of grubs, and for each, its distribution, food choices in the adult and larval stages, the ovipositing habits of the females, and the distance that females may fly to oviposit. The jack pine areas of the Huron National Forest, especially those relatively free of hardwood brush, invariably show light grub injury, whereas seedbed underplanting on the oak-aspen sites generally shows a loss of from 10 to 20 percent because of grub injury. Luginbill (*277*) in 1938 discussed the control of white grubs and Travis and Decker (*413*) in 1933, the control of adults.

Seed-Corn Maggot

The seed-corn maggot (*Hylemyia cilicrura* (Rond.)) furnishes another instance in which an agricultural crop insect has become a pest of forest nurseries. The maggots attack and devour, or tunnel into, the underground stem of seedling red cedars during spring and early summer, causing the plants to wilt and die. The flies prefer to oviposit in soil rich in organic matter; consequently injury is usually most severe in such soils. Since the flies are attracted to decaying organic material, it appears advisable to avoid the use of organic fertilizers in seedbeds. Completely covering the beds on all sides with cheesecloth or other suitable material during the spring when the flies are ovipositing should aid in preventing an attack. The larvae feed near the surface, and indications are that they can be controlled in seedbeds with 50-percent miscible carbon disulfide, as recommended for use in the control of white grubs.

Termites

In regions where termites are common, nursery soil should be kept free of all decaying wood and of as much other organic matter as possible, since such material harbors termite colonies. Where termites are known to occur in large numbers, it is advisable to clean up any debris, such as wood, stalks, or stubble, let the land lie idle for a year, and thereafter use only well-rotted manure, or preferably commercial fertilizers, to stimulate tree growth. Where these protective measures cannot be undertaken, treatment of the soil with heavy dosages of carbon disulfide prior to seeding, although costly, can probably be relied upon to free the area of termites. Where trees are growing in an infested block, considerable precaution in treating is necessary so as not to injure the trees.

The use of carbon disulfide emulsion as suggested for the control of white grubs would probably also be effective against termites. Paradichlorobenzene crystals worked into the soil to a depth of 3 to 4 inches with a hoe or other implement, at the rate of 3½ pounds per 100 square feet, has given indications of good control against root-feeding termites. Care should be taken to keep the crystals at least 2 inches from the seedlings.

In recent experiments 1 percent of DDT, either in the form of a wettable powder or an emulsion, has given effective control in seedbeds.

Wireworms

Wireworms are likely to be numerous in soil that has been in sod for several years, and may occasionally cause some damage in nurseries that have been under cultivation. Control is very difficult in soil where nursery stock is being grown, because treatments severe enough to affect the insects will probably destroy the seedlings also.

Root Borers

Occasionally where nurseries are planted on newly cleared land considerable damage is done by borers. The larvae of a species of long-horned beetle of the genus *Prionus*, which usually work in the roots of larger trees, may remain temporarily in the soil and feed on the roots of seedlings. To avoid such damage, stump land, or land containing trees or brush, should be cultivated for a year or two before it is used for a nursery site.

FLATHEADED BORERS

In hardwood seedlings held more than one season in the nursery, especially when they become crowded and in poor condition, serious damage may be caused by the flatheaded apple tree borer (*Chrysobothris femorata* F.). To avoid this injury trees should be kept in good growing condition and, if possible, should be moved from the nursery each season and planted out.

Frequently young trees are injured by this borer during the first few years after their planting. The use of such protectors as thin veneer, paper matrix, or wire screen, placed around the base of the trees up to the first large branches, will prevent oviposition on the lower bole. The wrapping should be maintained in good condition from May to September for 2 years after planting. Results obtained from recent limited tests indicate that attack may be prevented by spraying the trunk with 5-percent DDT emulsion. Little dependence can be placed on repellents, poisoned washes, or chemicals to kill the eggs and larvae. Since normal and vigorous trees are rarely injured by this borer, it is important to keep the trees healthy by good cultural methods. Burke (*75*), Chandler (*83*), and Johnson and Fenton (*258*) have discussed the control of these borers.

COTTONWOOD BORERS

Oviposition by the cottonwood borer (*Plectrodera scalator*) is best prevented by barriers made of such material as burlap, wire screen, or tar paper, placed around the bases of the young cottonwood trees. Such barriers are needed for several years, or until the trees become large enough to resist or withstand attack. Later any borers can be cut out with a pocket knife if this is done by early September of the season of attack. After this time the borers may be too deep in the wood to be reached. Fumigants, such as the orthodichlorobenzene emulsion described on page 25 can be used to advantage. The emulsion should be poured or sprayed around the base of the tree between July 15 and August 1 in quantities sufficient to saturate the bark around the egg scars. If too much of the emulsion is used it is apt to injure the roots. Milliken (*304*) has written on the control of the cottonwood borer.

OTHER BORERS

Several species of *Melanophila* and *Agrilus* likewise attack green trees weakened from various causes. Fumigant sprays have been tested against both these insects, but with indifferent success.

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Locust seedlings are often damaged by the twig borer (*Ecdytolopha* sp.). Close inspection and pruning, together with control of young sprouts on adjacent areas that serve as breeding grounds are about the only remedies.

DDT sprays may prevent oviposition of these species.

INSECTS GIRDLING THE STEMS AND TWIGS

Cutworms, the lesser cornstalk borer, and grasshoppers often girdle the stems although they are not always true stem girdlers and may feed also on the buds and foliage.

Cutworms

The worst damage by cutworms is likely to occur when the plants are coming up. During a single warm night a great many seedlings may be cut off. Early discovery of the larvae will prevent much damage. Cutworms can be controlled by scattering poisoned-bran mash over the nursery in the evening. The bait should be made up as follows:

Materials:	*Large quantities*	*Small quantities*
Coarse wheat bran	100 pounds	5 pounds (1 peck).
Sodium fluosilicate	4 pounds	3½ ounces.
Water	10 to 12 gallons	2 to 3 quarts.

All fluorine compounds are poisonous and should be handled with care and kept away from food. If the bait is prepared and applied properly, its use will not endanger domestic animals or wildlife.

The poison and most of the water should be combined and then poured evenly into the bran, with constant stirring to prevent the poison from settling out. Enough water should then be added to make a crumbly mixture that will just stick together when tightly squeezed in the hand.

The bait should be thinly scattered over the nursery at the rate of 20 to 40 pounds (wet weight) per acre. Since the cutworms feed at night, and the bait is not attractive after it has dried out, it is necessary to spread it during a warm evening or late in the afternoon. Frequently serious losses occur before the injury is noticed and before treatment can be applied; therefore, where damage was serious the previous spring and cutworms have again been found in the soil, it is advisable to make a scattering of the bait some warm evening just before the seedlings are due to come up, to prevent heavy damage later.

Several species of army cutworms, which occur in the Plains States, may become very abundant, and large numbers of the larvae will travel together over the ground, destroying vegetation as they advance. Different species occur at different times in the season. Poisoned baits, sprays, or dusts can be used to stop their progress. To protect the nursery, a deep furrow with vertical sides can be plowed at a right angle to the line of march. The larvae that fall into this furrow can be killed by dragging a log through it, or shallow holes can be dug at intervals in the furrows and the worms that collect in them crushed or destroyed with kerosene. Stanley (*396*) published on the control of cutworms in Tennessee in 1936.

Grasshoppers

When grasshoppers are nursery pests the infestation usually comes from sod areas adjacent to the nurseries, since the grasshopper eggs are seldom laid in cultivated land. During their early nymphal stages the young hoppers feed near the place where they have hatched, and can readily be poisoned at this time. In the later stages they move about in search of food and, if numerous, may infest the nurseries. Considerable migration may occur following the cutting of adjacent hay and small-grain fields. The nurseries can be protected from such migrations by spreading poisoned-bran mash in a barrier strip 100 feet or more wide around the nursery. Several applications at intervals of 4 or 5 days will usually be necessary. A couple of deep furrows with vertical sides can also be used around the edge of the nursery to trap young grasshoppers. As they collect in these furrows they can be killed by daily applications of poisoned bait. After the insects have developed to the flying stage, these barriers will be of no value.

The poisoned bait is prepared as follows:

Materials:	*Quantity*
Mill-run bran, mixed feed, or shorts	25 pounds.
Sawdust (3 times bulk of mill-run bran)	3½ bushels.
Chlordane, 50 percent wettable powder	1 pound.
or toxaphene	2 pounds.
Water	10 to 12 gallons.

The millfeeds in the above formula contain considerable flourlike material which covers the sawdust particles. The grasshoppers chew this coating off the sawdust particles or entirely consume the bran and are killed by the poison it contains. Standard bran, 50 pounds, and sawdust, 2¼ bushels, can be substituted for the first two ingredients in the above formula. Standard bran does not contain as much flourlike material as do the millfeeds and therefore does not coat the sawdust particles. The sawdust in this case acts mainly as a diluent and prevents lumping. Where sawdust is not available, 100 pounds of bran can be substituted for the first two ingredients in the formula.

Spread the sawdust out on a tight floor or in a wagon box or similar container to a depth of 6 to 8 inches. Scatter the millfeed uniformly over the sawdust and mix the two ingredients thoroughly by turning with shovels. Then thoroughly mix the arsenic preparation with the required amount of water. If crude arsenic or paris green is used it should be continually stirred to prevent its settling. Gradually splash the solution over the bran and work it into a mash with a shovel or rake until it contains no lumps and is moist throughout.

All arsenical compounds, including lead arsenate, calcium arsenate, and paris green, are poisonous to man and higher animals and should be clearly labeled "POISON." They should be kept away from food products, and stored in a place inaccessible to children and animals. The arsenicals, except paris green, are usually colored pink to denote their poisonous nature.

This bait should be spread thinly and evenly at the rate of 10 to 15 pounds (wet weight) per acre. It should fall into flakes when scattered with the hand, and in this form will be safe for use.

If the bait is left on the ground in lumps, there is danger that livestock will pick up the poison.

As the mash dries, it becomes less attractive, so it is necessary to apply it when the grasshoppers are beginning their first feeding of the day, usually early in the morning. During migrations the hoppers may feed at almost any time where food is found. In such case the bait should be spread on a clear day, when the temperature is between 70° and 85° F. An easy way to determine whether conditions are right for bait spreading is to scatter a few handfuls where the grasshoppers are thick. If feeding begins at once, spreading should be continued.

Most sawdusts if fairly fine and a year or more old are suitable, although fresher sawdust from cottonwood can be used; fresh pine sawdust is not suitable. A bulletin by Parker (*329*) gives detailed discussions of control methods.

According to Snyder (*392*), the lesser cornstalk borer (*Elasmopalpus lignosellus* (Zell.)) can be controlled with the bran mash recommended for grasshoppers.

LEAF-CHEWING INSECTS

A great many species of insects feed on the foliage of nursery plants, but these can be discussed in a few broad groups, as the control measures for the species within a given group are very similar. The common method of control is to spray a poison, or contact spray on the infested foliage, so that the poison will be eaten with the food of the insect.

Caterpillars and Slugs

Caterpillars and slugs can be readily controlled by applying contact sprays as described on pages 52–53.

Tip Moths

Tip moths boring in the ends of branches are not so destructive in the nursery, but the danger lies in carrying the infestations to plantations with infested nursery stock. Infested stock should be dipped in a miscible-oil insecticide. See page 54, formula 10.

For more information on the tip moths the reader is referred to Graham and Baumhofer (*195*, *196*), and Friend and West (*171*).

Blister Beetles

Spraying the foliage with 1½ pounds of lead arsenate to 50 gallons of water will usually protect the seedlings, largely by repelling the beetles, although some of the beetles will be poisoned. Bordeaux mixture, a common fungicide, is also repellent to these beetles. Combining the lead arsenate with bordeaux mixture should give better protection than the arsenical alone where the beetles are numerous. As the new growth comes out, beetles will return to feed on this unprotected foliage, and it will be necessary to spray several times to give good protection. The use of a sticker in the spray is not advisable where these repeated applications are made.

Bordeaux mixture may cause gastric disturbances if taken internally. It is also somewhat irritating to the eyes and skin.

Flea Beetles

Flea beetles were difficult to control before DDT became available, because the arsenicals apparently were distasteful and repelled them. Excellent protection results from DDT sprays when they are thoroughly applied to all parts of the foliage. Several applications at about 10-day intervals will be required to take care of new growth. Bordeaux mixture is also repellent, but will give protection against some species of flea beetles.

Leaf-Cutting Ants

Atta texana Buckley, the leaf-cutting ant, can be controlled by injecting methyl bromide into the nest by means of a funnel and a long tube inserted deep in a few of the main entrance holes. Such control work must be done before the trees are planted or after the latter part of November. Control work during the summer when the ants are more active and scattered over a wider area is ineffective. It requires about 1 pound to treat the average colony. **Reasonable care should be exercised when methyl bromide is used.**

The Florida harvester ant (*Pogonomyrmex badius* (Latr.)), which carries off seeds and cotyledons of young pine trees in nurseries in the Gulf States, makes a small mound nest in the nursery, not extending very deep into the soil. It can be controlled by using carbon disulfide in the same manner as for the control of white grubs, or, if skilled labor is employed, by injecting into the nest 1 ounce of powdered calcium cyanide.

Calcium cyanide liberates a gas which is deadly to all forms of animal life, and this material must be used only by experienced operators. Containers of the cyanide should never be opened indoors, and the gas or fumes must not be inhaled.

Walter, Seaton, and Mathewson (*424*) and Johnston (*259*) have published papers on the leaf-cutting ants.

SAP-SUCKING INSECTS

Sap-feeding insects cannot be controlled by stomach poisons, such as the arsenicals, because the plant parts on which the poison would be sprayed are not eaten. They feed by inserting their beaklike mouth parts into the plant tissues and drawing out the juices. Contact insecticides, that kill by coming in contact with the body, must be used. Recent work with DDT on many insects in this group indicates that it offers promise as a control for this type of insect, owing to its long residual effect. Prior to its discovery it was impracticable to attempt control of many of these insects on a forest-wide basis.

Aphids

A number of generations of aphids are produced during a single season, and the population builds up rapidly under favorable conditions. Infestation should, therefore, be treated early. The usual recommendation for control is a spray made up as follows:

Materials:	*For large quantities*	*For small quantities*
Nicotine sulfate (40 percent)	1 pint	1 teaspoonful.
Water	100 gallons	1 gallon.
Laundry soap or fish-oil soap	3–4 pounds	1 tablespoonful.

If directions for aphid control are given on the container of the nicotine solution as purchased, these should be followed. Pyrethrum and derris compounds have also been used successfully against aphids. Dormant sprays, either oil emulsions or lime-sulfur, applied before growth starts in the spring give best control. See formulas for these on pages 53–54.

Nicotine and its compounds are violent poisons, and care should be exercised in their use. Exposure to fumes and sprays for any length of time causes acute nausea in some persons. Susceptible persons should protect themselves with a respirator provided with pads saturated with a solution of citric acid. If concentrated solutions of nicotine are spilled on the skin they should be washed off with water immediately. The operator should not continue working in outer clothing which has become wet with nicotine-containing sprays, as the body will take up the nicotine from the clothing. In mixing the dust avoid inhaling much of it, as it may irritate the nose and throat.

Scale Insects

Although scale insects are not likely to cause serious damage to seedlings that are left in the nursery for only 1 to 3 years, the stock should be kept free from scales, since there is danger of transporting the pests to the field. The most common control measure is to spray with a dormant-strength miscible oil, oil emulsion, or lime-sulfur during the dormant period of the trees, preferably in the spring just before the buds open. Such sprays are on the market under different proprietary names and should be used according to the directions of the manufacturers. With the dormant strengths of the heavy oils there is a possibility of injury to some of the thin-barked seedlings. During the growing season a summer white-oil emulsion or a summer strength of lime-sulfur may be used, but these usually are not so effective as the dormant sprays.

Usually none of these treatments will give complete control in one season, and consequently, if only a small part of the nursery stock is infested, that part should be destroyed and not sent to the field. Under more serious conditions it is possible that fumigation might be needed for some of these scale insects at the time of shipment.

When using sulfur, especially as a dust, care should be taken to avoid getting it into the eyes. If the eyes are affected, do not rub them. It is well to wear goggles and a respirator.

Spittle Bugs

Often a strong stream of water will effectively control spittle bugs by dislodging them from their protective covering of spittle. Contact sprays under strong pressure can also be used.

Recent tests indicate that a 1-percent DDT emulsion or wettable powder will control the nymphs of *Aphrophora parallela* Say and *A. saratogensis* in spittle masses on pines. Promising results have also been obtained by applying DDT from the air at the rate of 1 pound per gallon of fuel oil per acre, provided it is done when the adults are active.

Mites

One of the simplest means for controlling spider mites is to wash the plants several times with a stream of water under considerable pressure. Infestations on ornamentals and nursery stock can usually be kept down by this method. A derris spray with sulfonated castor oil (turkey red oil) as a spreading agent has been found very effective when used in the following proportions:

Materials:	*For large quantities*	*For small quantities*
Derris powder (4 percent rotenone)	1 pound	½ ounce.
Sulfonated castor oil	1 quart	1 ounce.
Water	100 gallons	3 gallons.

First add the oil to the water; then with a small amount of this mixture make a paste of the powder and stir it into the rest of the oil and water.

Derris and other rotenone insecticides are comparatively nonpoisonous to man and other warm-blooded animals, although they do irritate the tender skin and mucous membranes.

The summer white oils (p. 54, formula 10) give good control of both the mites and the eggs. They may cause injury to spruce, but can be used safely on pine and juniper, as well as on most broad-leaved species.

Sprays made of glue or billposter's paste have been reported as giving good control, especially on conifers. Use 1 pound of cabinetmaker's glue in 10 gallons of water, dissolving the glue in a small amount of warm water and straining it before adding it to the full quantity. Billposter's paste is used at 1 pound to 25 gallons of water, preferably with a wetting agent added. If some of the tips stick together, this can be remedied by an application of water.

Several new chemicals, such as tetraethyl pyrophosphate and parathion, now being developed by private industry, are proving to be exceedingly effective for the control of spider mites.

Dusting sulfur or the wettable sulfurs are also effective against spider mites, especially when temperatures are above 80° F. When temperatures are extremely high there may be some danger of injuring tender foliage with the sulfur materials.

It is usually necessary to make two or more applications, a week or 10 days apart, with such materials as derris or sulfur. The other materials should not be applied so frequently.

INSECTS ATTACKING FOREST PRODUCTS

Insect damage to such forest products as logs, green or seasoned lumber, posts, poles, or lumber and furniture in buildings can be classed in two broad groups: (1) Defects caused in the wood of living trees, and (2) injury caused to wood after the tree is felled. The former damage occurs in the forest and is difficult to control, whereas the latter, involving materials and finished articles of a much higher value than that of the standing tree, may be justifiably handled by much more expensive and more elaborate methods of control.

Theoretically speaking, there is little excuse for the enormous bill annually paid as the result of insect attack on forest products. Conditions occasionally arise, however, over which man has little or no control, such as fires, tornadoes, floods, droughts, and even business depressions, and then extensive losses are unavoidable. For the reduction of insect losses to forest products, prevention of damage, rather than control, should be the aim. In most cases this may be accomplished by efficient management of logging and milling operations, by the proper inspection and handling of stored materials, by the use of preservatives in protecting wood in contact with the ground, and by the proper designing and sound construction of buildings.

PREVENTING DEFECTS IN LIVING WOOD

Defects in the wood of living trees, such at pitch pockets, pinholes, worm and grub holes, pith flecks, gum streaks, ring distortions, and black check are not readily preventable. However, with more intensive forest practices, such as selective cuttings and thinnings, in operation, it should be possible to remove from the forest the trees that serve as brood trees for the injurious insects and thus hold down the infestation to a low degree. Pitch pockets resulting from the attack of the turpentine borer can be largely prevented, as explained under discussion of that insect (p. 193). Control of forest fires, thus preventing fire scars at the bases of trees, helps to prevent pinholes caused by ambrosia beetles. Grub holes and worm holes caused by such wood borers as *Prionoxystus*, *Parandra*, *Goes*, and *Romaleum*, and pinholes caused by the Columbian timber beetles, the true timber worms, and certain ambrosia beetles, can be avoided only by removing the brood trees from the forest.

These defects lower the grade and render the material useless for certain purposes, but frequently it is possible to use damaged material for purposes that do not call for perfect lumber. For example, in localities where damage by timber beetles is prevalent, white oak that could have been used for barrel staves may be cut into lumber or dimension stock. Often wood containing an abundance of defects like knots, ring distortions, gum streaks, and pith flecks, can be used for specialities where the defects become a character of added value, as for rustic slabbing or interior finish (Snyder, *389*).

PROTECTING GREEN LOGS

Green logs are very attractive to ambrosia beetles and wood borers, and under optimum conditions beetles may be found boring into the wood within a few hours after a tree is felled. The surest means of preventing damage by these insects is by keeping the logs moving promptly from the woods to the saw; and if it does become necessary to store the logs for any length of time, they should be placed in a stream or millpond, preferably where direct sunlight can strike the tops of the floating logs. The old adage "a stitch in time saves nine" is a key to the prevention of borer and ambrosia beetle attack on sawlogs and lumber.

Depending on the season, temperature, and moisture conditions, and the species of insects involved, there is usually an interval of a week to a month or more between the felling and the time when green logs must be sawed if they are to be safe from insect attack. In many instances it takes the young borers some time to penetrate the bark and enter the wood before damage occurs. Recently some effective sprays have been developed which will prevent the attack of ambrosia beetles and borers for at least 2 to 4 months. Where it does become necessary to use such methods, a fuel-oil solution of benzene hexachloride containing a 0.4 percent concentration of gamma isomer by weight is by far the most efficient material known, but the logs must be very thoroughly covered with it. Barking the logs will prevent borer but not ambrosia beetle attack, but this is frequently impractical because of the rapid drying and checking which results. It can, however, be used to advantage where special circumstances permit, as for protecting pulpwood.

Benzene hexachloride is poisonous and should be handled with care. It should be stored in clearly labeled packages and kept away from food products.

Floating the freshly cut logs in fresh-water millponds or streams until they can be put through the sawmill is effective in materially lessening the attacks of nearly all wood borers and ambrosia beetles. In the Southern States high-floating logs will be attacked on the top sides by ambrosia beetles and by some borers. It is best, therefore, to hold the logs or rafts in open water where they will receive the full effects of the sun. They will be further protected if sprayed with benzene hexachloride in fuel oil. Many logs can be stored for indefinite periods in water without any deterioration, but some hardwoods, such as hickory, will be darkened if submerged.

In addition to the defects made by the insects tunneling through the bark and wood of green logs, there often results a further depreciation due to blue stain, which is carried into the wood by bark and ambrosia beetles as they make their tunnels. The sapwood of green logs and lumber may be blued within 2 to 3 weeks from the time of felling, unless care is taken to prevent it.

PROTECTING GREEN LUMBER

Green lumber is frequently attacked by ambrosia beetles and wood borers, particularly if the bark is not removed from the edges or if a rainy period occurs after the sawing, which retards the drying of the stock. To prevent pinhole defects caused by ambrosia beetle attack, green lumber should be piled so that it will season as rapidly as possible without checking. Valuable hardwood lumber should be end-racked for 10 days or 2 weeks, or until the moisture content is reduced to 50 percent or less. It should then be transferred to storage piles well provided with stickers. Spacing between piles should be adequate to allow for free circulation of air. Another effective means of preventing or checking ambrosia beetle attack is to kiln-dry the lumber. Christian (*89*) indicated that a few chemical sprays have proved effective in preventing ambrosia beetle attack in piled lumber, and that sap stain was prevented in experimental work. More recent tests have proved that an aqueous suspension containing 0.2-percent gamma isomer of benzene hexachloride is the most effective spray.

The attack of wood borers is readily prevented by the removal of the wane from the edges of the boards, and this should be done before the spring and summer months—that is, before the flight period of the adult beetles.

PROTECTING SEASONED LUMBER

Well-seasoned lumber and other rough unmanufactured products in the yard, as well as finished manufactured products in storage under cover, are subject to attack by various powder-post beetles. Damage resulting from the attacks of these insects is most prevalent during periods of business depression, when stored materials move very slowly. Frequently material held for future use in large bases of supply, such as army and navy storage depots, is ruined.

Present knowledge of the habits of powder-post beetles indicates that attack by many of these species is dependent on certain requisites. Before the wood is susceptible an adequate supply of starch or other food materials must be present in the wood or sapwood, or a definite degree of seasoning must have been reached. In attack by *Lyctus* beetles only the sapwood of hardwoods containing larger pores capable of receiving the eggs is infested. With *Xestobium*, and probably other genera, the presence of certain fungi is essential.

Methods of management, manufacture, and storage or utilization of wood products, so as to eliminate conditions favorable to these species will aid in preventing attack. Several of the more effective means of prevention and control are outlined briefly in the sections immediately following. For more detailed methods, see Snyder (*388*) and Christian (*88*, *90*).

Inspection and Treatment of Stored Stock

Seasoning of lumber in the yard or shed can safely be carried out without fear of *Lyctus* powder-post attack for 3 to 9 months in the Southern States and 9 months or longer in the North. After that time the wood is susceptible and must be carefully watched for evidences of attack. Thin-dimensioned air-seasoned lumber, and all kiln-dried hardwood stock is subject to *Lyctus* attack in less than 3 to 9 months. Periodic inspection for the presence of boring dust is of prime importance. Stock that must be held for 1 to 3 years should be treated as follows to avoid *Lyctus* damage:

1. Classify as far as possible all dry or seasoned hardwood stock (a) by species or kinds, as hickory, ash, oak; (b) by quality, as heartwood, pure sapwood, part sapwood; and (c) according to the number of years it has been seasoned. If the stock is thus classified, only the sapwood and part-sapwood piles need be handled and repiled in case of infestation, thereby saving labor, time, and worry. The heartwood is not attacked and need not be inspected.
2. Inspect susceptible material at least once a year and remove for destruction or treatment all wood showing evidence of powder-post attack.
3. Burn all useless sapwood material and prevent the accumulation of refuse in which the insects can breed.
4. Utilize or sell the oldest stock first.
5. Where possible avoid the prejudice against heartwood material, which is just as strong and suitable as sapwood and is not attacked by *Lyctus* powder-post beetles.

Chemical Treatment

For valuable uninfested stock that is to be held for some years, such as ax handles, gun stock, or lumber, painting or spraying with linseed oil or other oils or paraffins that will fill the pores of the wood and thus prevent the laying of eggs by the beetles will prevent damage to the wood indefinitely. Dipping the green wood in a 5-percent water solution of borax is also an effective preventive if the solution is hot (180° F.), or a cold 1- or 2-percent water suspension of finely divided sulfur (Christian (*88, 90*). A 5-percent solution of pentachlorophenol in a fuel oil will also prevent attack to seasoned wood. These treatments must be repeated if the coating is removed.

For flooring that is already infested and for heavy dimension stock in use in structures, one or two applications by spraying or saturating the wood with orthodichlorobenzene, paradichlorobenzene dissolved in kerosene or light fuel oil, or a 5-percent solution of pentachlorophenol in fuel oil will generally destroy the insects.

For infested stored wooden products, dipping in a 5-percent solution of pentachlorophenol in fuel oil will kill the borers. Heavy-dimension material will require longer submergence than thinner stock.

Kiln Drying

Where facilities are available, bringing infested stock to a temperature of 125° F., or higher, and, after this temperature has been reached within the wood, holding it there for an hour or more will kill all the insects. The exact time required depends upon the temperature, humidity of the kiln, and the thickness of the stock being treated. This treatment destroys all insects present but does not prevent subsequent attack. For further information on lethal temperatures see Snyder (*388*), Snyder and St. George (*394*), and St. George (*368*).

Water or Steam Treatments

Stream driving of hardwood logs to the mill or holding them in a millpond for several months, so reduces or affects the food content of the wood that it is no longer susceptible to attack by *Lyctus* and related powder-post beetles. Steaming, as commercially practiced in some industries, also produces the same result and brings about immunity to any subsequent attack.

PROTECTING POLES AND SLABS FOR RUSTIC WORK

The construction of cabins, bridges, and rustic furniture has given rise to a growing demand for logs, poles, and slabs with the bark left on. In some industries, such as the manufacture of shuttle blocks, mallets, and mauls, it is the usual practice to store small-dimension material with the bark on, for seasoning. Such material is peculiarly subject to insect attack because most wood-boring insects require the soft, inner bark for the early stages of their development. The types of insects affecting this class of material are pinhole borers, roundheaded and flatheaded borers, powder-post beetles, and carpenter ants.

Insects of each of these types require somewhat different and rather exacting conditions for their attack, and a knowledge of their life habits will help to prevent a great deal of injury.

Fall Cutting

Bark beetles, pinhole borers, and wood borers require a moist or green inner bark, and much damage can be prevented by cutting the material early in the fall and seasoning it well through the winter under cover and off the ground, so as to have it dry by the time the beetles appear in the spring. Early fall is the time to cut wood if it is desired that the bark remain tight. Sometimes girdling in the fall, especially with conifers, permits effective drying through the winter, and the logs can be felled and utilized in the spring without danger of insect attack.

A few borers and many powder-post beetles attack round material in the process of seasoning, especially hickory and persimmon to be used for manufactured articles. To prevent this, the wood should be cut in the fall and seasoned through the period of inactivity of the insect, or if cut during the active season, it should be stored under insectproof conditions or else utilized promptly. A spray containing 5 percent of DDT in fuel oil will prevent attack for some time, but is recommended only where other methods are not available or where the wood must be cut green and held during the period of insect activity (St. George *368*).

Introducing Chemicals Into the Sap Stream

One of the most effective treatments for the preservation of material for rustic work is obtained by introducing chemicals into the sap stream of the living or freshly cut tree. Several methods of accomplishing this have been devised. One of the simplest, suitable for small timber, is to cut the tree off at the base, and, with the top lodged against or fastened to another tree, lower the base into a container holding the chemical solution.

A method for larger trees consists of removing a 4-inch ring of bark at the base of the tree. Then by using a sharp, wide-set saw or a sharp chisel, cut a notch or groove completely around the tree in the middle of the strip from which the bark was removed. This notch should be from ½ to 1 inch deep. A piece of suitable waterproof material, such as rubberized cloth, oilcloth, or old inner tubing is put around the tree in the form of a collar open at the top, but carefully tacked or tied at the bottom immediately below the groove. A ring of asphalt cement or heavy cup grease beneath the tacked edge of the collar helps to make it watertight. The joint where the ends of the collar meet is likewise tacked against the tree or pleated in such a manner as to make it watertight. A chemical solution is then poured into this collar.

A third but less reliable method consists in felling the tree, leaving the crown intact, and removing the bark from 6 to 8 inches of the butt and stretching over this a length of inner tube with the other end turned up and supported to form a container. The chemical solution is then poured into the open end of the tube. Conifers can be treated at any time of year when the solutions will not freeze, but best results are obtained during the active growing season. Hardwoods can be treated satisfactorily only while in leaf.

Many different kinds of wood-preservative chemicals can be used, but the most satisfactory of those tested are chromated zinc chloride, zinc chloride, and copper sulfate, used at concentrations of ½ to ¾ pound per cubic foot of sapwood to be treated. For details of this method of treating green timber see Craighead and St. George (*119*).

Chemical Sprays

Although prevention of insect attack is far more desirable than treatment later, material already infested can be treated with any of several chemicals to kill the insects and thus prevent complete loosening of the bark or annoyance caused by rasping noises and the exudation of sawdust. Effective chemical sprays are (1) 5 percent of pentachlorophenol in fuel oil, and (2) crude orthodichlorobenzene. The latter can be applied full strength or diluted up to 5 parts of fuel oil, and the bark or wood should be saturated with the chemical. Liberal applications are recommended. One gallon of the chemical should be sufficient to treat 5 logs, 10 feet long, and 5 inches in diameter, or approximately 65 square feet of bark surface. These chemicals may be obtained from a number of large manufacturing concerns, and they are frequently stocked by chemical supply houses. **Care should be taken in handling these sprays as they are extremely irritating to the eyes.**

Frequently rustic cabins are constructed of peeled logs. This procedure, of course, prevents practically all insect attack, the most objectionable feature of which is the checking of the wood.

PROTECTING WOOD IN CONTACT WITH THE GROUND

All kinds of wood in contact with the ground, as poles, posts, mine props, and cross ties are subject to attack by termites, carpenter ants, and wood-boring beetles. The use of a good wood preservative will greatly increase the life of most woods; and nondurable woods, if properly treated, can be made to last as long as the most durable species. Coal-tar creosote applied by an approved, standard pressure process is the most satisfactory all-round preservative. Methods of using creosote were described by Hunt (*248*) and by Hunt and Garratt (*249*).

Other wood preservatives are 5 percent of pentachlorophenol and copper naphthenate having a 2-percent metallic content. These are sold on the market under various trade names. Wood preservatives are of value only in proportion to the amount of effective ingredients they contain. Both chromated zinc chloride and zinc chloride are useful preservatives where the wood is not subject to much dampness or leaching, or where it can be protected by an adequate covering of paint or varnish.

Materials in use, as poles or posts of considerable importance, can be made to last longer, even after they have been infested by wood borers, carpenter ants, or termites, by poisoning the soil about them with such chemicals as orthodichlorobenzene, a mixture composed of 1 part of coal-tar creosote (grade 1 oil) to 2 parts of a light petroleum oil or kerosene, or a 5-percent solution of pentachlorophenol. A 5-gallon treatment will protect a pole 15 inches in diameter for about 5 years. In heavy soils the necessary procedure consists of digging a trench to a depth of 30 inches, if the pole is set deeply, and then wetting the soil evenly with the preservative as it is being replaced.

In light soils penetration can be obtained by punching holes 12 inches apart and 30 inches deep with a heavy pointed iron rod and filling them with orthodichlorobenzene or 5-percent pentachlorophenol. The holes should be filled (or plugged) with earth. Creosote alone does not penetrate very well in the soil, and in fact, it has a tendency to cake, especially when the soil is dry and of heavy texture.

PROTECTING FINISHED ARTICLES AND WOODWORK

Seasoned wood products such as furniture and wooden parts of buildings are subject to the attack of a wide variety of insects, such as roundheaded and flatheaded beetles, weevils, powder-post beetles, wood-nesting carpenter ants, carpenter bees, wood-boring wasps, and termites.

CONTROL OF WOOD-NESTING ANTS

Several species of wood-nesting ants, such as the small "acrobatic" and large "carpenter" ant, cause considerable damage by boring holes in poles, posts, and the woodwork of buildings as places for rearing their broods. They usually attack wood that is somewhat decayed or already open to the interior through knotholes or deep cracks, although occasionally sound wood is infested.

For the most satisfactory control it is necessary to find the insect nest, which is usually in a partly decayed porch column, sill, or joist. Replacement of this infested wood is desirable, but often good results can be obtained by injecting such chemicals as 2-percent chlordane, 5-percent pentachlorophenol, orthodichlorobenzene, carbon disulfide, or creosote diluted with kerosene or gasoline into the nests. Friend and Carlson (*170*) discussed the methods of controlling the ants in telephone poles.

Caution, of course, is necessary in the use of inflammable chemicals.

Often it is difficult to locate the nest, as the ants are seen coming from cracks in the building, at the junction of the floor and walls, and not right at the nest. Good control can frequently be obtained by dusting sodium fluoride, 10-percent DDT powder, or powdered derris containing 4 percent of rotenone into these cracks. The material should be left there for some time. If other broods develop and worker ants appear again, the treatment should be repeated as often as is necessary.

SUBTERRANEAN TERMITE CONTROL

Except in coastal regions of the South, the Gulf States, and parts of California, termite infestation in the United States is restricted to the subterranean forms; that is, the insects must have communication with the ground for nesting and in order to maintain an adequate moisture supply. Upon this fact is based the principal means of prevention or control, namely, isolation of all untreated woodwork from contact with the ground by use of some materials impervious or toxic to the termites. The reader is referred to U. S. Bureau of Entomology (*418*) for a complete treatment of the subject of termites.

Good Construction

Termite control should begin when the plan for the building is under consideration. Generally speaking, the same practices acceptable as good construction methods among builders are well adapted to the prevention of termite attack. Every town or city should have specifications in the mandatory sections of its building codes, calling for termite-proof construction. Specifications can be obtained from the Bureau of Entomology and Plant Quarantine, United States Department of Agriculture, Washington 25, D. C.

A strong, impervious, moisture-proofed foundation and avoidance of any untreated woodwork within 18 inches of the ground on the inside and 6 to 8 inches on the outside will practically prevent termite damage.

The foundation of a building is the most important link in the chain of termite movement between the soil and the woodwork. The walls should be constructed of the best materials available, with ample footings on firm subsoil to make them impervious to termites through subsequent settling and cracking. All surfaces of masonry units composed of hollow tile or cement blocks in contact with the ground should be well plastered with cement mortar and the top capped with a 4-inch layer of poured concrete, reinforced to prevent cracking. The mortar used in walls of unit-block construction should contain Portland cement.

Termite Shields

Metal shields should be considered only as a supplement to good construction and not as a substitute for it. Where termite injury is very serious as in the Southern States and in the Tropics, it may be desirable to use shields as an additional precaution. They must be very carefully designed and installed, otherwise they will be ineffective.

Under certain conditions termites will build earthlike tubes over the surface of a wall to reach woodwork without exposing themselves to the light. They build these tubes in protected places or along the inside walls of moist cellars, or under dirt-filled porches where poor ventilation or none exists. A simple metal sheet of noncorrosive material such as 16-ounce copper or 26-gage galvanized iron, placed on top of the foundation, posts, or pillars, and around pipes, is helpful in preventing termites from gaining access to the woodwork above. The shield should form a cap over the foundation and should project 2 inches horizontally and then downward at an angle of about 45° for 2 more inches. Care must be exercised to have tight joints between shield pieces. The shield method is the most efficient and one of the cheapest methods of preventing termites from gaining entrance. The work of placing the shields must be done thoroughly to obtain the desired results. Where the outside wall is exposed for easy inspection, the exterior projection of the shield may be omitted if its appearance would be undesirable.

Basement Floors

Special care should be taken in constructing the basement floor. Too frequently the builder leaves wooden supports to stairs, coal bins, or doorframes in contact with the earth and pours the concrete floor by puddling the cement around them. Again, many builders fail to realize the danger of a termite attack and place sleepers or floors on a cinder, slag, or thin rough-grout base, and cracks develop through which termites can penetrate to the wood. After termites have entered in this manner, or directly through the cinder base, it is only a short while before the flooring, paneling, and uprights are attacked.

Termite-Resistant Woods

A few tropical woods are more resistant to termite attack than any grown in this country. The untreated heartwood of a few species of native woods has been found fairly resistant to termites under most conditions. These native species are close-grained heartwood of redwood, tidewater red bald-cypress, certain species of juniper, and the dense heartwood of longleaf pine, which contains a high percentage of resin.

Wood Preservatives

When wood must be used in direct contact with the ground, it should be thoroughly impregnated by a standard pressure process with coal-tar creosote or some equivalent preservative. Whenever possible, timber should be cut to proper dimensions before treatment, but when cutting after treatment is unavoidable, the cut surface should be thoroughly treated with two or three brush coats of the hot preservative. For further discussion see pages 41–44.

Owing to the ramifications of the termite galleries in a building which has been infested for some little time and the protection which they have in their burrows concealed in the wood, control by fumigation, by spraying, or by injecting chemicals into the infested wood has not proved satisfactory.

Soil Poisons

Protection over a period of several years may be obtained by applying chemicals to the soil adjacent to the foundations of buildings. (See pp. 43–44.) In a building having a full basement these chemicals should be thoroughly worked deep into the soil.

A good method of obtaining a thorough distribution of the chemical along a foundation wall is to dig a trench and replace the soil gradually, using alternate layers of soil and chemical. Where it is not possible to dig a trench, protection may be obtained in light soils by digging post holes or punching holes with a bar about 12 inches apart. These holes, like the trench, should be deep where there is a full basement.

Where 10-percent of sodium arsenite, orthodichlorobenzene, trichlorobenzene, or a 5-percent solution of pentachlorophenol is used, 1–1½ gallons per linear foot should be applied. Where creosote and petroleum oil is used, the proportion should be 1 to 2 parts, respectively. Such treatment is most effective when combined with necessary structural repairs or alterations. Chemical treatments alone are not recommended as a permanent cure. **Caution must be exercised in using these soil poisons, as they may kill shrubbery if they come in contact with the roots. Soil poisons may contaminate wells.**

Frequent Inspections

Termite damage frequently can be prevented by careful inspection of the premises twice a year, in order to detect the first evidences of damage. Merely breaking down any earthlike shelter tubes and removing any pieces of wood in contact with the ground will prevent damage in certain types of buildings.

DRY-WOOD TERMITES

In a narrow strip close to the coast from Norfolk, Va., southward, and along the southern coastal areas of the United States and in California south of San Francisco, dry-wood termites damage the woodwork of buildings. As a rule this damage is not serious, except in southern California and the southern tip of Florida.

To control dry-wood termites, drench the infested wood with orthodichlorobenzene, using a saturated rag or mop, or inject the chemical into holes bored 18 inches apart in the eaten wood. Several applications may be necessary. If the termites are too deep within the wood, or if the wood is structurally weakened, it should be replaced with timbers that have been preimpregnated with wood preservatives. **It is advisable to open up the house while treatments are being made, since the chemical has an odor that might prove disagreeable in a closed room. When orthodichlorobenzene is used for treating furniture in buildings where food is dispersed or stored, it is well to remove the infested material and make the treatments out of doors.**

The next best remedy is to dust dry paris green, the less dangerous 50-percent DDT, or sodium fluosilicate, into holes bored with an auger into the infested wood, penetrating to the galleries of the termites. If the powder becomes caked because of moisture the treatment should be repeated.

Fumigation with heavy dosages of toxic gases after tightly sealing structures exteriorly with heavy paper has recently proved effective in killing drywood termites in isolated buildings. **Such work must be performed by a professional fumigator.**

BARK BEETLE CONTROL

It has been mentioned before that in the Eastern States bark beetle control is less important than in the Western States, where there are great areas of mature timber. In the West the methods of bark beetle control have been perfected and greatly elaborated to fit special conditions In Insect Enemies of Western Forests (Keen, *262*), these methods are discussed in detail, and that work should be consulted for a fuller treatment of the subject. In the present publication only a brief résumé of methods will be attempted.

No means are known to save a tree that has been successfully attacked by bark beetles. The blue stains (see Insects and Diseases p. 10) introduced at the time of attack by pine beetles, quickly penetrate the sapwood, blocking the conduction of water to the crown, and death results in 5 to 10 days. Experimentally a few trees have been saved after such attack by use of chemicals applied on the bark or introduced into the sap stream, but this method is still a matter of laboratory experiment.

In the East, bark beetle control methods have been applied to only a few species of the tree-killing beetles—the southern pine beetle, the spruce bark beetle, the hickory bark beetle, and several species of *Ips*. Outbreaks of these species are sporadic and short-lived, and control to be effective must be applied quickly and thoroughly.

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The application of measures for the control of bark beetles may be justified by such factors as the value and merchantability of the timber, the preservation of the forest cover as a watershed-protection measure, the elimination of fire hazards, and the prevention of the spread of the beetles into adjacent stands of timber. The results to be obtained must be balanced against the cost of the operation to determine whether the project is economically justified.

Successful bark-beetle control depends primarily on early detection of the outbreaks and prompt application of effective control measures. This is particularly important in the East because of the quick rise and decline of the outbreaks of the eastern bark beetles. Almost without exception, outbreaks of these insects occur during a period of deficient rainfall. Usually a deficiency of an inch or more for 2 months or longer during the active season is sufficient to bring about conditions favorable for outbreaks, and those charged with the protection of timber should make systematic observations of susceptible areas whenever such deficiencies in rainfall occur. This is particularly true of the southern pine beetle, the hickory bark beetle, and species of *Ips*.

The relationship between deficient rainfall and spruce bark beetle occurrence has not been so clearly demonstrated, although the first signs of an outbreak are usually to be noticed on exposed ridges or poor sites, where the effects of the drought are most extreme.

BARK BEETLE SURVEYS

Upon the first evidences of fading foliage, a survey of the entire susceptible area should be undertaken in order that the extent and character of the infestation may be determined and sound plans be formulated for any control operations found necessary. Several methods of making surveys are available, each of which has certain advantages.

The simplest and least expensive type of survey is made by viewing the country from lookout points and making counts of the infested trees from roads or trails. Observation from airplanes for evidences of fading foliage is also an excellent means of early detection. Sample strips run at intervals back and forth across infested areas give a very comprehensive estimate of the amount and distribution of infestation, and where time and money are available they unquestionably furnish the most satisfactory basis for an estimate of costs.

The cruising of sample plots has its place as a supplement to topographic viewing, and with small units it is often possible actually to survey a rather large percentage of the area in this way. Where large areas of diverse topography include a number of different forest types, several different methods or combinations of methods of estimating may be used. Too often there is a tendency to examine too small an area and consequently to obtain an incomplete picture of the magnitude of the infestation.

THE CONTROL UNIT

The size of the area in which control operations should be carried out depends on the extent of the infestation. It is often entirely futile for one owner to do control work on his land if no work is done on adjacent infested properties. Every effort should be made to clean up all the infestation over a considerable area. In the East the mixed character of the stands and the consequent more spotted distribution of the susceptible host trees make it possible to handle smaller units more successfully than in the western forests. As far as possible, control units should be bounded by natural barriers, such as high ridges, open valleys, or broad strips of timber of a different type.

SPOTTING

The first step in connection with any control project is to locate and mark every infested tree requiring treatment. Good spotting is absolutely essential to the success of the control work and must be carried out by competent entomologists or men trained particularly for this purpose. Ordinarily the laborers of a control unit cannot be relied on to find and mark all the trees needing attention.

BARK BEETLE CONTROL METHODS

Methods of bark beetle control must take into consideration the diverse habits of the insect species, the types of trees affected, and the topography and other conditions of the area. Since most of the destructive bark beetles confine their attacks to a few species of trees, control can be carried out by treating only the affected host trees. Methods satisfactorily used with one beetle in one location may not be applicable to another insect or to the same species under other conditions. For example, with species that breed under the bark, it is only necessary to remove the bark, whereas in dealing with those that pupate and transform within the bark proper, it is necessary to destroy the bark in order to kill the broods.

Logging or Utilization of Infested Timber

It is becoming more and more practical in recent years to salvage infested trees because of the opening up of forested areas with passable roads. Salvaging has been especially useful in woodlots or in regions where the timber stands are broken. In two outbreaks (1931, 1936) in Virginia it was used effectively. Salvaging serves the dual purpose of destroying the bark beetles and utilizing for lumber or fuel the material that otherwise would be of no value within a short time. Frequently it can be carried out with a profit to the operator. Where a millpond or similar facilities are at hand, storing the infested logs in water for several weeks is very effective and simple. It is also inexpensive.

Solar-Heat Method

The solar-heat, or "sun-curing," method is particularly applicable to the control of bark beetles that attack thin-barked trees of small diameter, such as second-growth shortleaf pine, especially trees growing in open stands and in areas where the burning method is objectionable. With this method, trees are felled in a north-and-south direction parallel to one another. They are completely limbed and the brush is cleared away, so that the logs will receive direct sunlight. After a few days exposure with clear skies and with air temperatures of 80° F., or higher, all the bark beetles on the top half of the logs will have been killed. Then the men return and with peavies turn the logs completely over, so that the other side will be exposed. Craighead (*109*) reported that this method had been tested on the southern pine beetle and on several species of *Ips* with good results.

Penetrating Oils

Recent experiments have demonstrated that certain chemicals, when dissolved in oils and sprayed on the surface of the bark will penetrate the bark and kill the bark beetle broods beneath. The most effective formula tested to date is 1 part of orthodichlorobenzene to 4 to 6 parts of kerosene or light fuel oil. This solution when applied to infested pine bark at the rate of about 4 ounces per square foot will give effective control. Oils of this type, however, are effective only when temperatures are above 60° F. during the day and are easier to use when the bark is dry. This method of control has possibilities in treating infested trees during the summer months, when the fire hazard is too great to permit burning. It is best adapted to thin-barked trees, where the bark is of such a texture as to absorb the oil readily. It has not been tried for the control of the hickory bark beetle, but has proved effective against the southern pine beetle and elm bark beetles. This treatment does not save the tree.

The Peeling Method

The peeling method of control can be used against the immature stages of bark beetles that develop between the bark and the wood. When the bark is removed they die of exposure or are destroyed by ants, birds, and voles and other mammals. The method is especially applicable to moderately thick-barked trees that are easily peeled. It has been used extensively for the control of several western bark beetles and the spruce bark beetle in the Northeast. It is a relatively cheap method if the trees are treated after the bark has been loosened by the insects, and it does not involve any fire risk. Furthermore, no specialized technique is necessary and ordinary woodsmen can do the work very effectively. Occasionally when the infestation is massed at the base of the tree, as it often is with the spruce bark beetle, long-handled bark spuds can be used and the felling of the tree avoided.

The Trap-Tree Method

The control of bark beetles by trapping them in logs felled for that particular purpose has been recommended repeatedly in European literature, but extensive tests in this country have proved this method of control to be of little value for our insects and for conditions encountered here. The method can be used in special cases. Often, however, trap logs attract great numbers of beetles from the surrounding areas and cause them to attack the green standing timber nearby rather than the trap logs.

For further details on the use of these methods consult Keen (*262*); for the eastern spruce beetle, see Swain (*402*); for the southern pine beetle, see St. George and Beal (*371*); and for the hickory bark beetle, see Hopkins (*235*).

INSECTICIDAL CONTROL OF INSECTS IN THE FOREST

By S. F. Potts

The control of insects in the forest is a different problem from the control of those same insects attacking shade trees. In the forest, where relatively low values are at stake, the basic aim is prevention of unusual losses or of the spread of outbreaks; whereas in shade or park trees, where individual trees are readily reached and represent relatively high values, direct control to check immediate damage is desirable. Consequently, a distinction between forest and shade trees is maintained throughout the following discussion.

In the forest there is recognized a normal or endemic type of infestation by many insects that feed on trees and shrubs, causing only slight damage and against which the cost of artificial control would be unwarranted. Control is therefore confined to the prevention of threatened outbreaks and the suppression of those that have attained destructive proportions.

Many artificial control methods that have proved to be effective are discussed in the following pages.

SPRAYING AND DUSTING

CAUTION

It should be clearly kept in mind that most of the substances under consideration are poisonous. If they were not, they would probably be useless against the insects for which they are recommended. Therefore the recommendations for the proper use of these substances should be followed. Careless, unnecessary exposure and misuse is fraught with hazard. Splashing of liquid on the skin or inhalation of dust while handling dry powders should be avoided. Containers that have been used for mixing or applying chemicals should be stored in a safe place, if they are to be used again, or destroyed. Any excess liquid left after treatment is completed should be disposed of by digging a pit into which the chemicals can be poured and covered with soil. Such liquids should never be poured into streams or ponds where they will endanger humans, livestock, or fish.

Chemical sprays or dusts may be applied for the direct control of defoliating, sucking, and certain other insects, such as twig-infesting forms that pass a part of their life cycle on the surface of the plant. Although spraying and dusting are important methods of control where valuable shade and ornamental trees are involved, they have not had wide application in the forest, except where insect eradication was the objective or in serious outbreaks in recreational areas, watersheds of reservoirs, or areas where the timber was especially valuable.

So many different factors affect the cost of spraying that no definite cost figures can be given. The total cost of treatment depends on the size of the trees and the density of the stands, the accessibility of the area to be treated, the availability of suitable equipment, and the cost of labor and materials. Usually where the trees are being grown for a timber crop, their value will not warrant much expense for spraying. With the improvement of distributing apparatus for some of the larger airplanes for spraying extensive forests and with the development of newer types of slow-moving aircraft, such as the helicopter, for smaller areas and for forest plantations, it is being found practical to utilize more generally direct measures of control.

The manufacture of cheaper and more effective insecticides and the use of concentrated spray mixtures would stimulate the practice of direct control. One of the newer products, DDT, offers much promise, since it is extremely toxic to most insects, both as a stomach poison and as a contact insecticide. Because of its residual properties, it is effective over a considerable period of time. Before treating large areas with dosages of more than 1 pound per acre it is necessary to consider its effect on beneficial insects, fish, and wildlife in forested areas.

Since hundreds of compounds are used as insecticides, the choice of any one depends on a number of considerations, such as the type of insect to be controlled and the purpose and allowable cost of the application. For convenience, these compounds may be divided into two classes, stomach insecticides and contact insecticides. Some are most effective when applied as sprays and some give better results when used as dusts. Sometimes combinations or mixtures of insecticides and fungicides are used.

STOMACH INSECTICIDES

Stomach insecticides are taken through the mouth into the stomach. Leaf-feeding Lepidoptera, Coleoptera, and Hymenoptera are insect types for which stomach insecticides are used. In applying stomach poisons the material is sprayed or dusted on the parts of the plant that the insect eats. The most important inorganic stomach insecticides are the arsenicals, particularly lead arsenate, but a number of new materials are coming into general use. The dosages or concentrations vary with the insecticide and with the insect and its stage of development, the intensity of infestation, and many other factors.

Organic substances, such as the toxic principles of derris root, cube root, tobacco, and hellebore, are sometimes used as stomach insecticides. Derris root and cube root are relatively nontoxic to warm-blooded animals and may be used with safety where there is danger of poisoning such animals. Some of the newer organic insecticides, such as DDT, benzene hexachloride, and chlordane, are very effective as stomach insecticides and also as contact insecticides.

CONTACT INSECTICIDES

Contact insecticides kill by penetrating into the breathing pores or sensory pores, or directly through the body wall of the insect. They are used for controlling sucking insects more often than for chewing insects. In applying certain contact insecticides it is necessary for the material to hit the body of the insect, but with others, like DDT, it suffices to hit only the parts of the plant on which the insect is active. Examples of contact insecticides are DDT, benzene hexachloride, chlordane, nicotine sulfate, free nicotine, pyrethrum powder and extract, derris compounds, oil emulsions and miscible oils for dormant spraying, thin, miscible, white oils with unsaturated hydrocarbons removed for summer application, lime-sulfur, and sulfur dust.

Nicotine sulfate and pyrethrum sprays are particularly useful for the control of aphids. Pyrethrum and DDT are more effective in killing certain insects, such as rose chafers, loopers, and small cankerworm larvae than is nicotine sulfate. Wetting and spreading agents increase the efficiency of low concentrations of pyrethrum. Recent experiments indicate that derris is more effective than nicotine or pyrethrum against spider mites. DDT, benzene hexachloride, and chlordane are among the newer insecticides that are very effective in controlling leaf-eating insects. Although DDT is no cure-all and does not kill certain aphids and mites, it is the most effective contact insecticide known at present. Oil emulsions and miscible oils are used principally in dormant spraying, and for the control of scale insects, spider mite and aphid eggs, and other stages of insects that pass the winter on dormant trees. Thin, miscible, white oils of about 50 seconds (Saybolt) viscosity are better than nicotine or derris for controlling the summer stages of scale insects, certain woolly aphids, mealybugs, and spider mites. Lime-sulfur is used as a dormant spray for the control of certain scale insects, casebearers, and other pests. It may also be used as a summer spray.

FORMULAS

Although no attempt will be made to list all the different insecticides that have been developed, a few of the most important will be given with formulas for the preparation of concentrations commonly employed in controlling forest and shade-tree pests. Recent development and improvement of spraying apparatus, which include mist blowers, airplanes, and helicopters, make it practical to apply insecticides and fungicides in the form of concentrated sprays at a low dosage and gallonage per acre. **Some of these formulas are not safe to use in the conventional types of power and knapsack sprayers because of the danger of burning foliage** and, therefore, formulas for the conventional types of sprayers are given separately from those for distribution from aircraft or by mist blowers.

Amounts of insecticides required to prepare 100-gallon and 1-gallon quantities are given. It will be noted that the amounts of insecticides required to prepare 1-gallon lots are given in metric units, as well as in more practical units, such as teaspoonfuls. If lead arsenate and nicotine sulfate are used in combination, soap should be omitted.

The following formulas are for use in controlling forest and shade-tree pests:

For large quantity		*For small quantities*	
Insecticides:			
(1) Lead arsenate (powdered)	4 lb.	18.2 gm.	9 teaspoonfuls.
Water	100 gal.	1.0 gal.	1 gal.
Fish oil or linseed oil	1 pt.	4.7 cc.	1 teaspoonful.
(2) Derris or cube powder (4 percent rotenone).	4 lb.	18.2 gm.	13 teaspoonfuls.
Water	100 gal.	1.0 gal.	1 gal.
Fish oil or linseed oil	2 qt.	18.9 cc.	4 teaspoonfuls.
(3) DDT wettable powder (50 percent DDT).	0.5 to 1.5 lb.	2.27 to 6.8 gm.	1 to 3 teaspoonfuls.
Water	100 gal.	1.0 gal.	1 gal.
(4) DDT emulsion. (Dilute according to manufacturer's directions.)			
(5) Nicotine sulfate (40 percent nicotine)	1 pt.	4.7 cc.	1 teaspoonful.
Water	100 gal.	1.0 gal.	1 gal.
Soap (solid)	3 lb.	14.0 gm.	Piece size of yeast cake.
or			
Liquid soap	6 pt.	28.0 cc.	6 teaspoonfuls.
(6) Pyrethrum powder or extract (1 percent total pyrethrins).	1.66 lb.	7.6 gm.	5 teaspoonfuls.
Water	100 gal.	1.0 gal.	1 gal.
Soap (solid)	3 lb.	14.0 gm.	Piece size of yeast cake.
or			
Liquid soap	6 pt.	28.0 cc.	6 teaspoonfuls.

	For large quantity	For small quantities			
Insecticides—Continued					
(7) Derris or cube powder or extract (4 percent rotenone).	1 lb.	4.8 gm.	3 teaspoonfuls.		
Water	100 gal.	1 gal.	1 gal.		
Soap (solid)	3 lb.	14 gm.	Piece size of yeast cake.		
or					
Liquid soap	6 pt.	28 cc.	6 teaspoonfuls.		
or					
Soap powder	6 lb.	28 cc.	6 teaspoonfuls.		
(8) Dormant spray:					
Oil emulsion	5 gal.	189 cc.	6.4 fluid oz.		
Water	95 gal.	3,634 cc.	7.75 pt.		
(9) Dormant spray:					
Miscible oil	4 gal.	151.4 cc.	5 fluid oz.		
Water	96 gal.	3,634 cc.	7.7 pt.		
(10) Summer spray:					
Miscible oil	1 gal.	37.86 cc.	1.3 fluid oz.		
Water	99 gal.	1 gal.	1 gal.		
(11) Dormant spray:		*Dry*		*Liquid*	
Lime-sulfur (liquid or dry)	33 lb.	150 gm.	5 oz. (avoir.)	10 gal.	378 cc.
Water	100 gal.	1 gal.	1 gal.	90 gal.	0.8 pt.
(12) Lime-sulfur	8.25 lb.	37.5 gm.	1.25 oz.	2.5 gal.	95 cc.
Water	100 gal.	1 gal.	1 gal.	97 gal.	3690 cc.

The following formulas are for distribution by aircraft, mist blowers, and hand atomizers:

(Apply at rate of 0.5 to 2 lb. in 1 to 2 gal. per acre)

(1) DDT (technical)	6 oz.	8 oz.	1 lb. dissolved in 1 qt. xylene.
Solvent	1 gal. kerosene	1 gal. fuel oil	Enough fuel oil to make 1 gal. of solution.

(2) DDT (technical): 1 lb. dissolved in 1 qt. of xylene.
Emulsifying agent: 1.5 oz.
Water: Enough to make 1 gal.

(3) DDT (50 percent wettable powder): 2 lb. in enough water (7.5 pt.) to make 1 gal.

(4) Benzene hexachloride (10 percent gamma): 1 lb.
Water: Enough to make 1 gal.
Sticker: 3 oz. oil (1 oz. motor oil and 2 oz. linseed oil).

SPREADERS AND ADHESIVES

Spreaders added to spray mixtures tend to distribute or spread the insecticide more evenly over the plant or insect, as the case may be, by diminishing the forces of surface and interfacial tension. Unfortunately, spreaders reduce materially the deposit of insecticide, as well as its adherence. Some alkaline spreaders tend to decompose such insecticides as arsenicals and this may cause plant injury or result in ineffective control. Examples of spreaders are: Butylhydroxypheny=benzene sulfonate, alkylpheny=benzene sulfonic acid, sodium lauryl sulfate, various sulfonated alcohols, sulfonated castor oil, calcium caseinate, and soaps. Except for the soaps, most spreaders in the powdered form are used in the proportion of about 1 pound to 100 gallons of water.

Certain oils added to spray mixtures increase the adherence of the insecticide. Raw, unemulsified linseed oil and fish oil are most commonly used with ordinary sprays on shade and forest trees.

When dusts are applied as stomach poisons, their adherence may be increased by adding 10 to 20 percent of oil (one-half fish oil or linseed oil and one-half paraffin oil) by weight, depending on the amount of oil the dust will absorb without affecting its application by a dusting machine.

SPRAYING AND DUSTING EQUIPMENT

Recent advances have been made by the Division of Forest Insect Investigations in the development of spray mixtures of high concentrations (Potts *357*). In these sprays the amount of water or other liquid used as a carrier ranges from 1 to 10 gallons per acre, whereas in the older, conventional spray concentrations, 400 to 700 gallons of water were used per acre. It has been fully demonstrated that concentrated sprays distributed from aircraft or by mist blowers (fig. 1) are usually more effective and far less expensive than the coarsely atomized dilute sprays applied from the conventional type of spraying machines. Ordinary dusting of insecticides, in some cases, may be less troublesome, but is effective against fewer pests and results in poor adherence and wastage of materials.

A small power sprayer or a mist blower mounted on a wheelbarrow or on a garden tractor may be used for treating small groups of trees not over 35 feet high. To insure satisfactory coverage of the taller trees, small power sprayers should be equipped with an extension spray rod to which is attached a disk or vermorel type of nozzle. Power sprayers capable of maintaining 300 to 400 pounds' pressure at the nozzle have been used for many years for spraying large shade and roadside trees and extensive woodland areas. The Worthley type of spray nozzle has been in general use on such sprayers. This method of spraying woodlands and shade trees, using large quantities of coarsely atomized dilute sprays is at best a slow, laborious, and expensive operation.

Prior to recent improvements in spraying apparatus for use in aircraft, and before the development of power mist blowers, the high-pressure sprayers mounted on trucks were the most practical and effective means of spraying large areas. The development of new insecticides, most of which can be used effectively in concentrated forms of solutions, emulsions, and suspensions, and also the improvement of distributing apparatus for installation in aircraft, makes it more economical to spray large areas from the air. Power mist blowers recently developed by the Division of Forest Insect Investigations have proved most efficient for spraying large shade and roadside trees, forest plantations, and woodland areas that are in small blocks or have roads or passable fire lanes at intervals of about 500 feet.

AERIAL DUSTING AND SPRAYING

Prior to 1940 airplanes had been used in forest-insect control, mainly for dusting insecticides over large inaccessible woodlands. Although large areas could be covered quickly by this method, it was difficult to control the dust cloud. In general, adherence of the dust to the foliage was poor.

During World War II, a number of new insecticides appeared on the market, many of which can be used effectively as concentrated sprays. Because of these new materials and the recent improvements in distributing apparatus for use in airplanes and helicopters, aerial application of insecticides is now becoming a general practice for large woodland infestations. Helicopters have the advantage over airplanes in that they can land and take off from very small open areas. They have greater maneuverability and can be flown more slowly and nearer the treetops with safety. However, an airplane can carry a much larger pay load than a helicopter, can spray a wider swath, and can cover an area much faster.

To obtain the maximum efficiency in distribution and coverage, the application of insecticides from either type of aircraft should be made when the wind velocity is not much more than 5 miles per hour, and

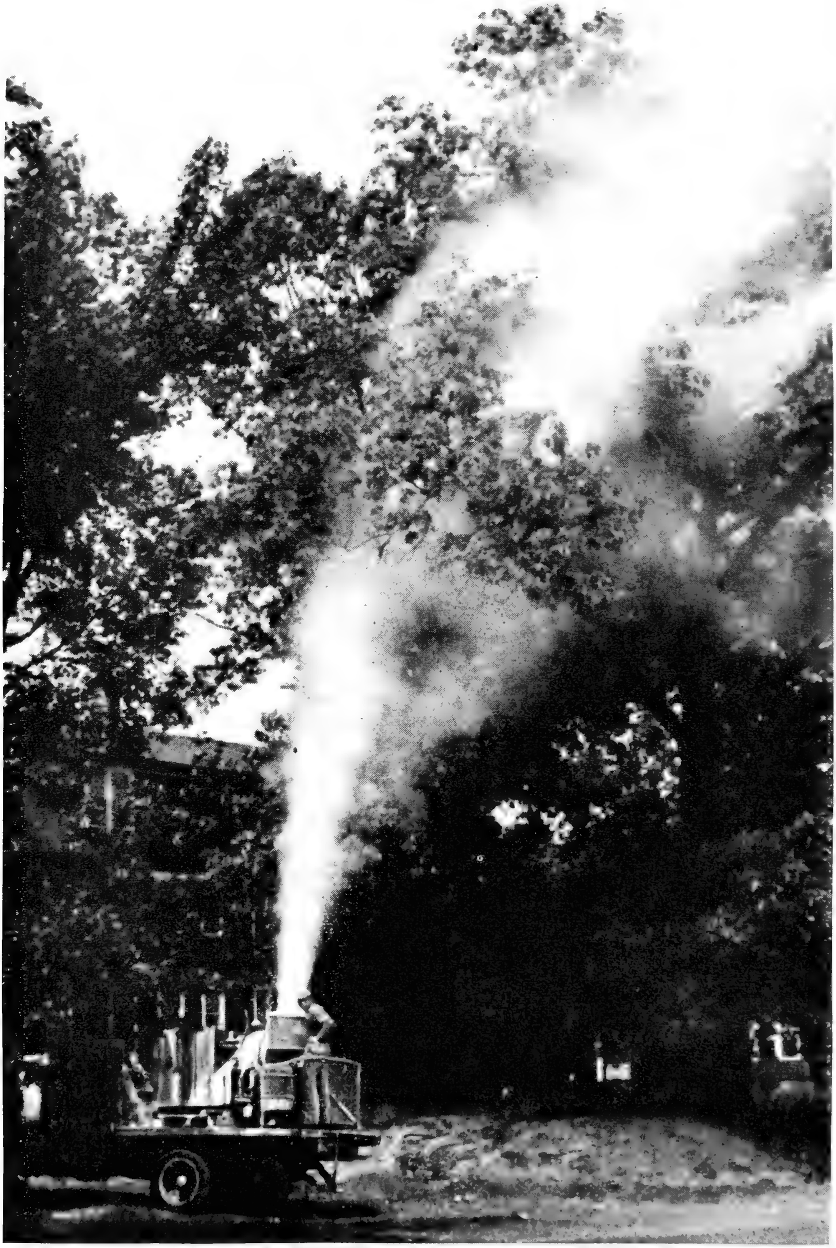

FIGURE 1.—Treating an 80-foot red oak with a 25-horsepower mist blower.

when there are no convection currents of air. Except on cloudy days, the most suitable period for aerial spraying is just after dawn.

When properly applied, the concentrated spray mixtures have a distinct advantage over dusts. The loss from drift is less, the deposit is heavier, and adherence is better. This method of using the concentrated sprays has been more fully treated by Potts (*356, 357*).

USE OF BENEFICIAL INSECTS IN THE CONTROL OF FOREST-TREE PESTS

By R. C. Brown

It has already been pointed out that practically all forest insects are attacked by numbers of parasitic and predaceous insects that normally exert a very definite influence in keeping the forest insects in check. The forest entomologist is therefore interested in the use of these beneficial insects, whenever possible, as a control measure. Obviously those types of control in which nature itself will lend a helping hand should be utilized to the fullest extent. It may seem presumptuous on the part of man to attempt natural control. Man is, however, continually upsetting the balance of nature, and the purpose of biological control is to restore to equilibrium, as far as possible, the normal balance between a host and its natural enemies.

CONTROL OF INTRODUCED FOREIGN INSECTS

When a forest insect is accidentally introduced into a new favorable environment without its native parasites and predators, and finds an abundance of favored food, it is likely to develop into a serious pest. Many important forest insects have been accidentally introduced into North America from Europe. Most of these imported insects have gained entrance into the Northeastern States or Canada and present some of the most serious problems confronting forest entomologists in these regions. The gypsy moth, the brown-tail moth, the satin moth, the European pine shoot moth, the larch casebearer, the larch sawfly, the European spruce sawfly, several species of pine sawflies, the smaller European elm bark beetle, the elm leaf beetle, the beech scale, the fir bark louse, and two birch leaf-mining sawflies are all native European species, which have been introduced and are now firmly established in the Northeast. Several of these have become serious pests in natural woodlands and forest plantations.

The gypsy moth alone has already cost State and Federal Governments many millions of dollars in attempts to control it and prevent its westward spread Other introduced forest insects have already spread over rather large areas in the United States and Canada, and in the aggregate thousands of acres of forests and plantations are affected annually. The presence of these insects was not detected until they had spread over such large areas that it was too late to attempt eradication. It appears that the absence of their natural enemies was one of the main reasons for their tremendous increase.

Generally speaking, insect parasites are fairly specific in their host relationships; therefore it is a rare occurrence to find a native parasite that has become an effective enemy of an introduced pest.

IMPORTATION OF PARASITES AND PREDATORS

In 1892 A. D. Hopkins introduced *Thanasimus formicarius* (L.) from Germany into West Virginia, in an attempt to control the southern pine beetle (*Dendroctonus frontalis* Zimm.). This marked the beginning of the importing of natural enemies of forest insects into this country. Gypsy moth parasites and predators were imported from foreign countries from 1905 to 1930. This project was perhaps the most extensive of its kind in history. Information on methods and technique of rearing and shipping parasites obtained from this extensive experiment has been largely the basis for work with the parasites of a great many insects in later years. This pioneer undertaking has demonstrated in many ways the obstacles, as well as some of the achievements, of this type of endeavor.

Parasites of eggs, larvae, and pupae of the gypsy moth were introduced into the United States from Europe, Africa, and the Orient. Some of the predators of larvae and pupae of this moth also were imported from Europe. A number of natural enemies have become established, and several are now present throughout the gypsy moth area in this country. Their aggregate effectiveness in certain areas approaches that obtained in central Europe. The gypsy moth represents a type of forest defoliator that will probably never be completely controlled by natural enemies. Even in Europe, where it is apparently an indigenous species, outbreaks occur from time to time when conditions for increase are favorable. There are, however, certain areas in Europe, and in this country as well, where outbreaks of the gypsy moth are rare, and some of the parasitic species may be responsible for such conditions.

Parasite introduction is more or less a trial-and-error project. This makes it necessary to import and liberate a large number of species in the hope that some may find conditions favorable for increase. Of course this does not mean that an analysis of the factors of environment is unimportant, for sometimes there is some very obvious reason why a given species could not become an effective enemy of its host when introduced into a new region, such as the absence of an alternate host, the lack of some climatic requirements, or the lack of synchronism with the seasonal development of the host.

Some natural enemies of nearly all our important introduced forest insects have been imported and released. Usually several years are required to obtain and colonize successfully a complete series of natural enemies which attack the different stages of the host. When a parasite has become firmly established in a given area its further dispersal can often be aided by recolonization in other areas of infestation of the same host.

Because of the effect of the various factors of an environment on a given organism, it is difficult to place a quantitative value on the effectiveness of a parasite or group of parasites in controlling a given host. Obviously, in order to evaluate properly, the effect of any one factor of control it is necessary to know the effect of the other controlling agents.

The conventional method of expressing parasite abundance is in percentages of hosts attacked by the parasites. The percentage of parasitization, however, simply indicates the relative abundance of host and parasite. Unless an absolute measure of host abundance is given, therefore, this percentage means very little. If the host population is suddenly reduced by lack of food or by some climatic factor, the percentage of parasitization will show a marked increase because of a concentration of parasites among the remaining host population. Thus, over a series of years the host may increase or decrease in actual abundance and the percentage of parasitization may show a coincident decrease or increase without any actual change in the parasite population. Parasites are therefore often erroneously credited with checking outbreaks, when, as a matter of fact, some other factor was primarily responsible.

In some instances parasites may prolong outbreaks. In connection with an outbreak of the forest tent caterpillar in the Chippewa and Superior National Forests of Minnesota from 1935 to 1937, L. W. Orr found that had it not been for the retarding effects of parasites this outbreak might have died out quickly because of starvation of the larvae, before serious damage was done to the host trees by repeated annual defoliation. It should not, however, be inferred that over a long period of years the parasites of the forest tent caterpillar are detrimental, for they may play a major role in holding the host in check during long periods between outbreaks.

The Governments of the United States and Canada have carried out a combined attack on the European spruce sawfly by the introduction of its natural enemies from Europe. This sawfly threatened the destruction of large areas of spruce in eastern Canada and the northeastern part of the United States.

Some parasites attack a great variety of hosts. A striking example of this is *Compsilura concinnata* Meig., a parasitic fly introduced originally into New England from Europe as a parasite of the gypsy moth. Since its establishment some 40 years ago it has been found to attack over 140 species of native caterpillars. A species of such polyphagous habits offers excellent possibilities for utilization as a natural enemy of forest insects in other regions of the United States. On several occasions during the past 30 years *C. concinnata* has been reared by the Division of Forest Insect Investigations from the gypsy moth in New England and shipped to other parts of the United States for release against injurious insects. It is known to be established in the State of Washington as an enemy of the satin moth, and subsequent rearings may reveal its presence elsewhere.

Parasites of two species of western sawflies have been reared at the New Haven, Conn., laboratory of this Division and have been tried out as possible parasites of the European spruce sawfly. A native sawfly attacking red pine in New England was also subjected to attack by the western parasites. These species of western parasites attacked the red pine sawfly and developed readily on it and one attacked and developed on the European spruce sawfly. The red pine sawfly was definitely preferred to the European spruce sawfly probably because it was more closely related generically to the western host species from which the parasites were obtained. These cases illustrate the possibilities of biological control within continental North America through transfer of parasites from one region to another. Certain species of spruce budworm parasites are now being transferred from the Rocky Mountain region to budworm infestations in the Northeast.

Although complete control of forest insects seldom results from the activities of parasites alone, the host population is often greatly reduced, and it is believed that natural enemies contribute materially in alleviating conditions during an outbreak of the host and especially in lengthening the period between outbreaks.

Generally speaking, the type of management that encourages the development of a forest composed of a mixture of tree species is also advantageous to the parasitic insect fauna existing there. Both forest management and the utilization of natural enemies offer permanent types of control.

THE ZOOLOGICAL POSITION OF INSECTS AND SOME OF THEIR COMMON RELATIVES

It is of interest to most technical workers inquiring into the name and habits of an animal or plant to have it oriented in the generally recognized classifications. Its position in relation to other known forms helps materially in knowing it.

Insects and some of their relatives, such as the spiders, mites, scorpions, and pseudoscorpions, some of which are briefly treated here because of their common association with the forest or forest products and forest wildlife, all belong to the phylum of invertebrates known as Arthropoda, which have bodies composed of several segments, some of which carry jointed appendages. Here also belong the crawfish, millipedes, crabs, and many other abundant forms of life that do not come into the classification of forest fauna.

The relationships of the pertinent forms are shown in the following outline:

Arthropoda	
Classes:	
Crustacea	Crawfish, shrimp, wood lice[1] or gribble.
Diplopoda	Millipedes.
Chilopoda	Centipedes.
Arachnida	Spiders, etc.
Orders:	
Scorpionida	Scorpions.
Pseudoscorpionida	Pseudoscorpions.
Araneida	Spiders.
Phalangida	Daddy-long-legs, or harvestmen.
Acarina	Mites, redbugs, red spiders, ticks.
Hexapoda	Insects.[2]
Mollusca	
Class:	
Pelecypoda	Shipworms.

[1] Wood lice and shipworms are treated together in the discussion under the heading of marine borers.

[2] Subdivided at length in later discussion.

CRAWFISH AND SHRIMPS

CLASS CRUSTACEA

The members of the class Crustacea, represented by crawfish, crabs, and shrimps, and also sowbugs and wood lice, are almost entirely aquatic and breathe by means of gills. As a group, they are of utmost importance as a source of fish food in our streams. These, together with aquatic insects, form the bulk of the food of many species of fish.

A few marine forms injure woodwork in salt water and are discussed on pages 66–69.

The consideration of these forms in relation to fish in our streams was very adequately treated by Needham (*319*).

MILLIPEDES

CLASS DIPLOPODA

and

CENTIPEDES

CLASS CHILOPODA

Both the millipedes and the centipedes are very common arthropods and are worth brief mention, as they are found in the same associations as insects. Both forms are primarily outdoor creatures found under

FIGURE 2.—A large millipede, *Spirobolus marginatus.* About twice natural size.

bark, stones, old boards, or damp rubbish. Many fears and superstitions are built around these creatures. The millipedes are elongate slow-moving forms with two pairs of legs on each segment, and when disturbed they curl up as for protection (fig. 2). Under certain conditions some species of millipedes will swarm into camps, old buildings, and residences. They feed on decaying vegetation.

In contrast, the centipedes are elongate flattened forms, with one pair of strong legs on each segment, and are capable of very rapid locomotion. One species, **the house centipede** (*Scutigera forceps* Raf.) (fig. 3), is common around buildings, particularly in damp cellars and bathrooms. It feeds on insects and other small animals, and is provided with poison glands on the claws of the first pair of leglike appendages. The bite of this species is not severe on man, but that of some of the larger species is more painful.

Millipedes in buildings can be readily controlled by poison baits, such as slices of raw potatoes or apples dusted with paris green. They

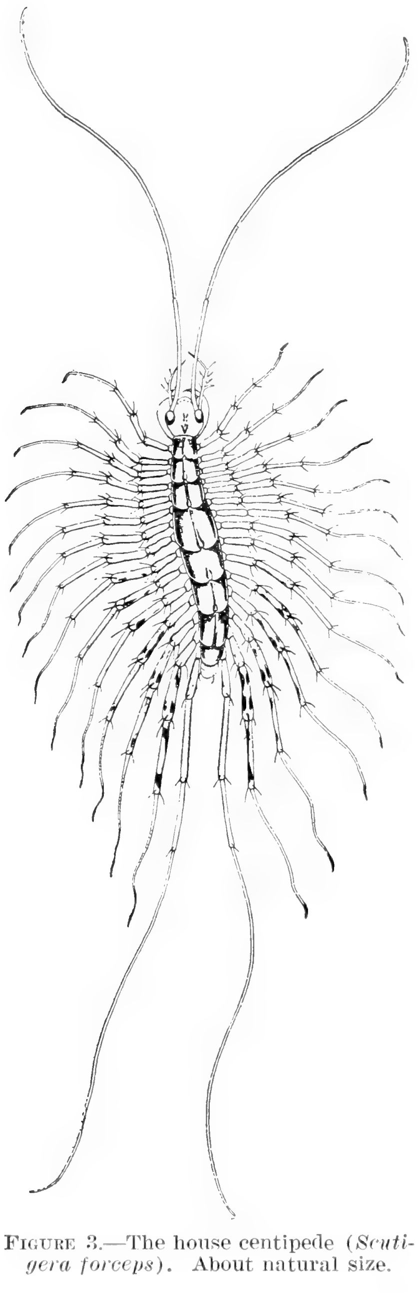

FIGURE 3.—The house centipede (*Scutigera forceps*). About natural size.

cannot live under dry conditions. Centipedes are more difficult to control. Any debris which offers concealment should be removed. For further information on centipedes and millipedes in houses see Back (*10*).

SCORPIONS

ORDER SCORPIONIDA

The scorpions, which are illustrated in literature so frequently that there is hardly any need to describe them, are residents of warm climates. A few species occur in the Southern States and are common in the Southwest. Scorpions are nocturnal, lying concealed under bark or stones during the day and feeding at night, chiefly on insects or spiders. They kill their prey by means of a poison sting located on the tail and can inflict an injury very painful to man. The young are born alive and are carried by the mother for some time clinging to her body by means of their well-developed pincers.

THE PSEUDOSCORPIONS

ORDER PSEUDOSCORPIONIDA

The pseudoscorpions resemble their larger relatives, but have a wide, short abdomen instead of the slender tail-like abdomen, and they do not have the terminal poison gland. Their flattened bodies adapt them to a life in crevices under bark of dead trees, or in ants' nests, where large numbers can often be observed in all parts of the country. Unlike the scorpions, the female lays eggs, and these are attached to her body in a mass. Both sexes have silk organs and spin weblike cocoons. The pseudoscorpions are predaceous on small animal life, such as mites and insects, and are probably destructive to the earlier stages of bark beetles.

THE SPIDERS

Order ARACHNIDA

The spiders are merely mentioned here to show their relationship to insects in the general scheme of classification. Their predatory habits, chiefly on insects, cause them to rank as highly beneficial and useful. The black widow spider and the tarantulas, which are provided with poison sacs, occasionally bite men, causing painful, though rarely fatal, wounds. The spiders and their relatives are adequately treated by Comstock (*104*).

THE HARVESTMEN

Order PHALANGIDA

The harvestmen, or daddy-long-legs, are fairly well characterized by the latter name. They have a small, compact, nearly globular body supported by eight long angular legs on which they awkwardly totter about. They are of no economic importance, as they feed on dead insects and vegetable matter, but they frequently attract attention around houses and camps.

THE MITES, TICKS, AND RED SPIDERS

Order ACARINA

The acarinids are of considerable economic importance in the forest to plants, wild game, and to man, as well as in their relation to agriculture. For a very good general treatment of western forms see Essig (*145*). Several families will be discussed separately to better bring out their importance. Several species of mites representing different families are very abundant under the bark of trees that have been killed by bark beetles. These are predaceous and reasonably beneficial in destroying bark beetle eggs.

THE ITCH MITES

Family SARCOPTIDAE

One of the representatives of the itch mite group is the common **itch mite** (*Sarcoptes scabiei* Deg.), which attacks man and causes the skin disease known as itch or scabies. Related species cause mange of domesticated animals. Sulfur ointments; tar oil; nicotine solutions; and, in persistent cases on dogs, a 10-percent silver nitrate solution, have been used effectively. Derris or cube used as an ointment or wash is especially effective.

A related form, the chicken mite (*Dermanyssus gallinae* (Deg.)), is a serious pest of poultry and attacks game birds as well, particularly while they are in confinement at breeding stations. This pest can be controlled by spraying the pens with kerosene. If the birds can be kept out of the pens for 24 hours anthracene oil may be used. This latter material is very effective and persistent.

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THE GALL MITES

Family ERIOPHYIDAE

Gall mites produce galls on the twigs and leaves of plants. They are usually open galls with hairy surfaces, and 4-legged, elongate mites inhabit these cavities in great numbers. Certain bright-colored patches, known as "erineum," on leaves, are caused by these mites. A related form infests the sebaceous glands and hair follicles of man.

THE TICKS

Superfamily IXODOIDEA

Several species of ticks are not only annoying pests of man but transmit fatal diseases, such as Rocky Mountain spotted fever, tick paralysis, tularemia, and typhus fever. In certain localities, as the Bitterroot Valley and the surrounding mountains in Montana, where particularly fatal strains of the spotted fever occur, stringent precautions must be taken by forest workers to avoid being bitten by ticks.

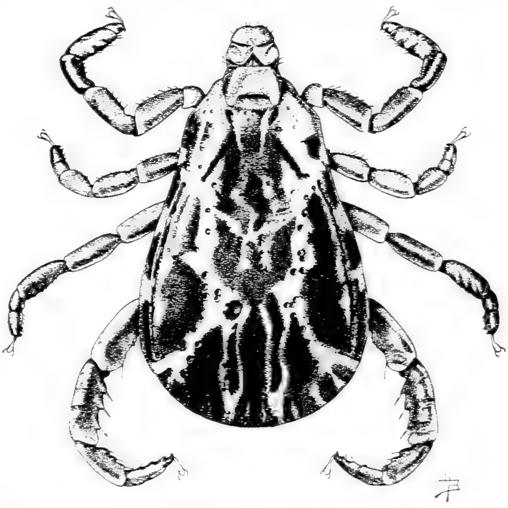

Figure 4.—The American dog tick (*Dermacentor variabilis*) (female). About 13 times natural size.

The life history of the more common ticks is carried through four stages—eggs, larvae, nymphs, and adults. The larvae are six-legged, active creatures which attach themselves to animals and, after obtaining a meal of blood, transform into the eight-legged (four pairs), or nymphal stage. These feed again before transforming into adults. It is this adult stage, or wood tick, that attaches itself to man and other large animals. The earlier stages usually feed on small animals, such as rodents. Ticks attach themselves to animals by working into the skin a sucking beak provided with recurved barbs. A pair of jaws serve to cut a hole for the entrance of the beak. After the adult female tick is fully engorged, it drops off and lays several thousand eggs.

Occasionally ticks become so abundant on large game animals as to cause anemia and finally starvation and death. The body surface of host animals such as deer, elk, and moose may be literally covered with engorging ticks.

The American dog tick (*Dermacentor variabilis* (Say)) (fig. 4) is prevalent throughout the eastern part of the United States and, like its western relative (*Dermacentor andersoni* Stiles), commonly transmits Rocky Mountain spotted fever. Splenetic, or Texas fever, of cattle is transmitted by the tick *Boophilus annulatus* Say. Other species attack birds, especially those that live on the ground, such as quail, and others attack domestic animals, causing considerable economic loss.

Control and preventive measures for the common dog tick which transmits Rocky Mountain spotted fever were discussed by Bishopp (*30*). More recently DDT sprays have been used effectively. Daily removal of the ticks from dogs, which bring them into houses, is important. Ticks can be prevented from attaching to dogs by dusting a little derris powder into the hair. When a person walks in the woods during tick season, suitable clothing should be worn to keep the ticks from reaching the skin, and one's body should be carefully inspected at least twice a day. A preventive vaccine for the fever virus has been developed by the United States Public Health Service.

THE RED SPIDERS

Family TETRANYCHIDAE

Several species of red spiders are important pests of plants. They are minute (0.5 mm.), oval, eight-legged animals, covered with long hairs and having sucking mouth parts. They are scarcely visible to the naked eye except as they move about. Most species are of a reddish color, tinged with green or yellow. They are more readily recognized by their injury, which for the more common forms consists of a mottled brownish or rusty discoloration of the leaves (fig. 5, *A*), the surfaces of which are usually covered with a very fine matting of silk threads, and spotted with tiny spherical eggs or broken eggshells (fig. 5, *B*.) They become abundant during hot weather and are particularly damaging during periods of drought, as discussed by Gar-

FIGURE 5.—The southern red mite (*Paratetranychus ilicis* McG.): *A*, Damage to hemlock leaves by red spiders; *B*, eggs, greatly enlarged.

man (*182*). Severe infestations may build up after spraying with DDT.

Tetranychus telarius L. is a species of nearly world-wide distribution, attacking many species of hardwoods and evergreens. It is our most common and injurious species.

The European red mite (*Paratetranychus pilosus* C. & F.), a European species now established in this country, is injurious to shade trees, particularly basswood or linden, maple, elm, and willow, often causing the leaves to fall.

Oligonychus americanus Ewing has been abundant on pine seedlings in the nurseries of the Middle West.

Control of the red spiders is discussed on pages 37–38.

THE HARVEST MITES AND CHIGGERS

Family TROMBIDIIDAE

The harvest mites resemble the red spiders, but are much larger, particularly a bright red species commonly found moving slowly about on the moist leaf litter or on logs in woodlands.

Red bugs or **chiggers** need no description, because the annoying itching sores produced by these minute animals after they attach themselves to the skin are well known to all foresters in the Central and Southern States, along the seaboard into New Jersey, and occasionally in Pennsylvania. Heavy attack on man may cause fever, and secondary infections can be very serious. Red bugs are the first instars of a rather large mite. Normally they feed on such animals as snakes, lizards, birds, and rodents. Certain local areas, such as briar patches and sunny exposures, are more heavily infested than other sites and can, with experience, be avoided to some extent.

Prevention of attack by chiggers is better than cure. Clothing that will prevent access of the larvae to the skin is recommended. High boots and closely woven cotton trousers are excellent protection, and flowers of sulfur dusted into the clothing is effective. The mosquito repellents mentioned on page 527 are effective in repelling chiggers. Derris powder is also effective and less irritating than sulfur. A thorough hot bath with a soapy lather immediately after returning to camp is simple and effective. The clothes that were removed should not be worn again until the following morning. Ammonia water, soda, cooling ointments, or colloidin help to allay itching.

MARINE BORERS

By R. A. St. George

Serious damage to the submerged portions of marine piling, wharves, or other wooden members, fixed or floating in salt (and occasionally brackish) waters, is caused by certain molluscs and crustaceans.

Extensive damage occurs on the Atlantic, Gulf, and Pacific coasts, chiefly in warm southern waters, but also to some extent in New England, Nova Scotia, and even in Newfoundland, where the waters are cold during much of the year. Under certain conditions these animals are capable of completely destroying untreated timbers in less than a year. Although no reliable estimates are available, it is believed that the annual damage caused by marine borers runs into several million dollars. Recent information indicates that attack is restricted to the breeding season, which lasts from 8 to 10 weeks.

Infestation is dependent on such factors in the water as salinity, temperature, pollution, hydrogen-ion values, dissolved oxygen, and sulfureted hydrogen. Infestation is increased in warm waters, where marine life develops luxuriantly. It is retarded where streams are polluted, resulting in a lack of dissolved oxygen and a concentration of hydrogen sulfide. With the molluscs, activity ceases when the water temperatures drop to just above the freezing point, when the borers remain dormant, according to Clapp (*93*). This condition is not so evident with the crustaceans.

The two groups of marine borers are distinct in structure and method of attack. The molluscs are relatives of the clams, whereas the crustaceans are related to the lobsters. The former embed themselves in the wood and do greater damage than the latter, which are superficial borers. Their attacks are limited to areas near the wood surface, principally between the low-tide and mid-tide levels of piling, where they are aided by the eroding action of water and debris in hastening the destruction of timbers. It is reported that under favorable conditions, a 14-inch pile can be destroyed in a few months by the molluscan shipworms, whereas it requires at least a year for the crustacean borers to do this.

THE SHIPWORMS

The molluscan borers are represented by three important genera, the wormlike *Teredo* and *Bankia* (commonly known as shipworms) and the clamlike *Martesia* (Hunt and Garratt, *249*). The free-swimming young shipworms usually attack timbers near the mud line, using their rasplike shells to penetrate the outer wood at right angles to the grain, and later bore longitudinally throughout the submerged portion of the timber (fig. 6, *A*.). As they bore, the body elongates and the burrows are lined with a calcareous deposit. The small opening to the surface enables the shipworm to extrude two siphons, one to admit the water and much of the food, the other to expel it. It is believed that in addition to small aquatic organisms, wood itself is partly digested and serves as food for these worms. The opening to the exterior can be closed by means of a pair of plates to exclude unfavorable water or harmful organisms. In heavy attacks the burrows are often from ⅛ to ¼ inch in diameter and a few inches long. Under favorable conditions they may attain a diameter up to 1 inch and a length of 1 to 4 feet. Because their entrance holes are usually located near the mud line and are only ⅛ inch or less in diameter, the extensive destruction within the piling often is not realized until the timber gives way under stress.

The clamlike-appearing molluscs, the *Martesia*, like the shipworms, have free-swimming young which attack the timbers, making entrance holes up to ⅛ inch in diameter. Once embedded in the wood, they excavate it sufficiently to accommodate their bodies, which are usually not over 2½ inches long and 1 inch in diameter when mature. They are capable of causing considerable damage to untreated timbers.

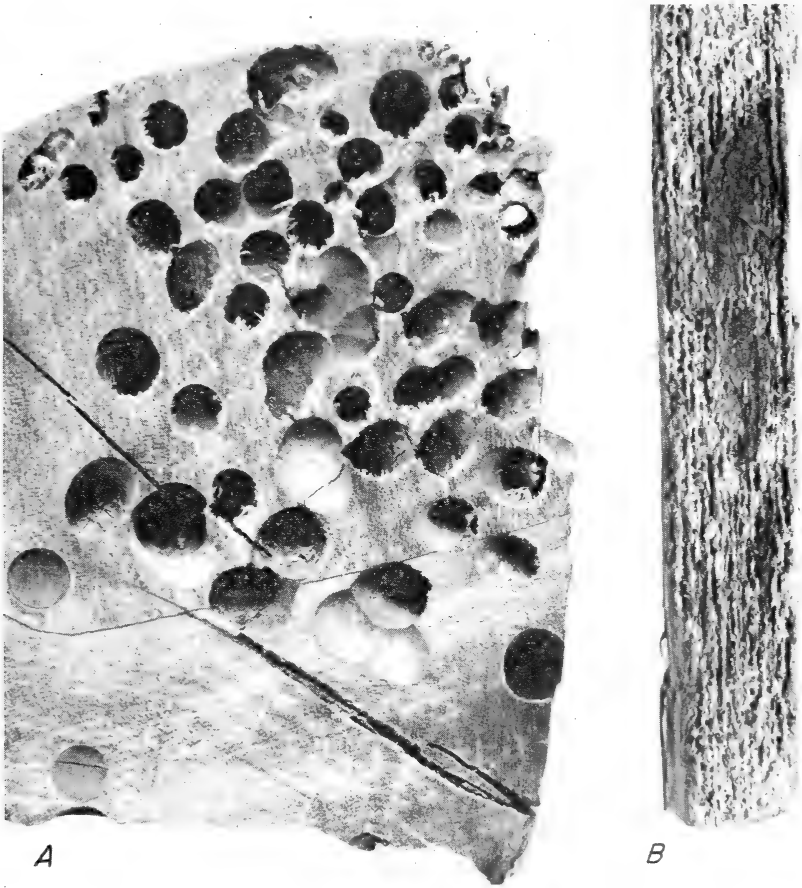

FIGURE 6.—Wood damaged by marine borers: *A*, Work of the miraflora shipworm *Teredo miraflora*, in cross section; *B*, work of a gribble, *Sphaeroma* sp.

Their distribution is believed to be limited to the shores of the Gulf of Mexico.

THE WOOD LICE

The crustacean borers are quite distinct from the molluscs in general structure, appearance, and method of attacking and destroying marine timbers. Both young and old burrow into the surface wood of timbers, but are never imprisoned for life within the wood, as are the molluscs. Their attacks are confined mostly between low- and half-tide levels, where the wood becomes eroded by water and debris coming against it, giving that portion of the piling an hourglass shape.

The crustaceans are also represented by three genera, which are found along the Atlantic coast. They are *Limnoria* and *Sphaeroma*, often called gribbles, or "wood lice" (fig. 6, *B*), because they are related to and closely resemble the sowbugs, and *Chelura*, which belongs to the group containing the "sand fleas."

The wood louse *Limnoria* has been considered the most destructive of the three forms mentioned above, but it has lately been reported that the associated form *Chelura* is assuming greater importance in some localities.

Limnoria lignorum (Rathke), the most destructive species, is capable of reducing piling about 1 inch in diameter per year. It has seven pairs of legs, with sharp claws to hold onto wood and a pair of toothed mandibles with which to bore into the wood that serves as its food. Being poor swimmers, these animals spread slowly from a center of infestation, and are usually carried by infested driftwood. When mature, *Limnoria* are from 1/8 to 1/4 inch long. They seldom penetrate more than 1/2 inch directly into the wood. Sometimes they make oblique galleries an inch or more long.

Sphaeroma, although slightly larger (up to 1/2 inch long) is less numerous and less destructive than *Limnoria*, although its burrow is relatively wider and penetrates to a depth of 3 to 4 inches. It is a southern species, and is sometimes found working in fresh water.

CONTROL OF MARINE BORERS

Although it is possible to control marine borers by the use of mechanical barriers and paints, the standard pressure treatments of southern pine and Douglas-fir with coal-tar creosote, or creosote-coal-tar solution, have been found to be most practical. Such timbers, when thoroughly impregnated with dosages of at least 20 pounds per cubic foot, respectively, for Douglas-fir and southern yellow pine in accordance with recommendations in Federal specifications (*419*) should give long service under average conditions, whereas untreated piling along the Atlantic and Gulf coasts may be destroyed within a year or less.

THE FOREST INSECTS [9]

PRACTICAL KEYS TO THE ORDERS, FAMILIES, AND GENERA OF FOREST INSECTS, BASED ON TYPES OF INJURY

The keys that follow are designed to aid those who are not familiar enough with the orders of insects to recognize and place the insect immediately under the correct order, from which they may work down to a particular insect or specimen of injury.[10] In keys of this kind, it is

[9] An effort has been made to refer to each insect, wherever possible, by a common name in general use by forest workers or woodsmen. These common names are printed in **bold-faced type.** Many little-known insects or species not easily distinguished from similar forms, except by entomologists, are designated by the scientific names alone. An approved name, as given in a list of approved common names of insects, published by the American Association of Economic Entomologists, is placed before the scientific name and the latter is set off by parentheses. Other names not so established, but used locally or perhaps generally, are placed after the respective scientific names and set off by commas, in accordance with the style used in Department of Agriculture publications. It is suggested in the interest of a definite nomenclature that the approved names be used regularly in preference to the various local names of insects.

[10] For those who are able to recognize the order to which an insect belongs the simplest procedure is to turn to the key preceding that order in a later section of this publication and seek its specific determination in that place.

impractical to make a very fine distinction in the insects or in overlapping types of injury, and some judgment and patience must be exercised in looking for the name of a specimen under a slightly different heading, if the first attempt does not seem to answer the problem. For example, to separate the leaf miners of the beetles, moths, and sawflies would require almost the entire replication of the respective keys under these orders; consequently, it seems more simple to refer to all three groups.

The three main divisions used as a primary breakdown aim to group the insects according to well-marked fields in the forestry profession; namely, nursery practice, the forest, and the lumbering industry. Beneficial forest insects, including predators and parasites, and insects serving as fish and game food or attacking wildlife are not considered in these keys, even though they are discussed to some extent in the text. These principal divisions are as follows:

Insects injurious to seeds, seedlings, young plantations, and small reproduction	Division A.
Insects injurious to larger reproduction, forest trees, and shade trees	Division B.
Insects injurious to forest products	Division C.

These main divisions are again subdivided to other groups or subdivisions as shown in the next outline of headings.

PRIMARY DIVISIONS OF KEY

A. Insects injurious to seeds, seedlings, young plantations, and small reproduction	
To seeds, cones, and fruits	[11] 1–6
To seedlings and small reproduction	7–11
B. Insects injurious to large reproduction, forest trees, and shade trees	
Acarina (red spiders)	1
Defoliators, leaf miners, etc.	2–6
Twig and tip damage, etc.	7–14
Borers in wood and bark	15–23
Galls, swellings, etc.	24–31
Sucking insects	32–35
C. Insects injurious to forest products	
Defects in green timber	1–5
Insects in round logs	6
Insects in lumber	7–10
Insects in material in ground	11
Defects in wood in salt and brackish water, marine borers	12

DIVISION A

INSECTS INJURIOUS TO SEEDS, SEEDLINGS, YOUNG PLANTATIONS, AND SMALL REPRODUCTION

This group includes the insects that attack the fruit and seeds of forest trees and the young plants in the nursery or forest. After the plants have become 4 or 5 years old, or more or less shrubby or woody, they are considered under Division B. This distinction between A and B is artificial but convenient.

[11] The numbers given in this column refer to those to be found at the left margin in the respective keys that follow.

INSECTS ATTACKING SEEDS, CONES, AND FRUITS

1. Larvae without well-developed head capsule; relatively inactive; maggotlike:
   With a sclerotized structure like a breastbone near anterior end; in seeds of fir, cypress, birch, and also fruit of chokecherry **Diptera, Cecidomyiidae**
   Without breastbone; mouth parts well developed; in pomaceous fruits, cherry, apple, plum, hawthorn; also berries of dogwood, holly, and others; and also walnut husks **Diptera, Trypetidae**
   Larvae with distinct head capsule ____ 2
2. Larvae rather active; body extended; abdominal prolegs present ____ 3
   Larvae relatively inactive; no abdominal prolegs; body curved ____ 4
3. In the shucks of pecans, hickories, and walnuts and in acorns **Lepidoptera, Blastobasidae, Olethreutidae**
   In the cones of conifers ____ **Lepidoptera, Phycitidae**
   In the fruits of wild cranberries and blueberries **Lepidoptera, Phycitidae**
4. In acorns, walnuts, chestnuts, hickory nuts, and filberts ____ 5
   In leguminous seeds ____ **Coleoptera, Bruchidae**
   In cones of coniferous trees ____ 6
5. First abdominal spiracle vestigial; body spindle-shaped **Hymenoptera, Cynipidae**
   First abdominal spiracle normal; body curved, like a closed finger **Coleoptera, Curculionidae,** *Curculio*
6. Cones not developing normally and dropping prematurely **Coleoptera, Scolytidae,** *Conopthorus*
   Cones maturing; damage to seeds alone
   Larvae legless ____ **Hymenoptera, Chalcididae**
   Larvae with true legs ____ **Coleoptera, Anobiidae**

INSECTS ATTACKING SEEDLINGS AND SMALL REPRODUCTION

7. Plants cut off near ground line or stems lacerated and shriveled ____ 8
   Plants wilting or fading, easily plucked from ground because of severed stem or roots below ground ____ 9
   Gall-like swellings on the stems ____ 10
   Bark gnawed in patches along the stem of conifers ____ 11
   Foliage off color, yellowish or rusty, and often covered with very fine cobweblike threads or matting ____ Red spiders, **Acarina**
   Roots showing small cottony or globular objects at time of transplanting ____ Root aphids, **Homoptera, Aphidae**
   Leaves or cotyledons cut off and carried away; Southern States Ants, **Hymenoptera, Formicidae**
   Other types of damage. See Division B.
8. Small, tender plants:
   Small, maggotlike larvae causing injury Seedcorn maggot, **Diptera, Muscidae**
   Large, smooth, dark-colored caterpillars present Cutworms, **Lepidoptera Phalaenidae**
   Larger plants, hardwoods, with woody part tunneled:
   Tunnels longitudinal ____ **Coleoptera, Cerambycidae**
   Tunnels across the grain, wood stained **Coleoptera, Scolytidae, Corthylus**
   Tunnels irregular, chiefly underground. Termites, **Isoptera**
9. Curved, grublike larvae in the soil White grubs, **Coleoptera, Scarabaeidae**
   Elongate, cylindrical, hard-shelled larvae Wireworms, **Coleoptera, Elateridae**
   Small, molelike tunnels near the surface of the soil or deeper ____ Mole crickets, **Orthoptera, Gryllotalpinae**
10. Bark swollen and gnarled at or just below ground line ____ Lesser cornstalk borer, **Lepidoptera, Phycitidae,** *Elasmopalpus*
   Southern States ____ Treehoppers, **Homoptera, Fulgoridae**
   Northern States ____ Mount-building ant, **Hymenoptera, Formicidae**

INSECTS ATTACKING SEEDLINGS AND SMALL REPRODUCTION—Continued

11. Northern and Lake States, Pales weevil, **Coleoptera, Curculionidae**
More southern and western States and Lake States Grasshoppers, **Orthoptera, Acrididae**

DIVISION B

INSECTS INJURIOUS TO LARGER REPRODUCTION, FOREST TREES, AND SHADE TREES

This group includes the insects and mites which commonly attack living forest and shade trees other than those insects confined primarily to small plants (Division A), but not those primarily inhabiting dead trees or those attacking forest products (Division C).

1. Foliage discolored, yellowish, rusty, or mottled and usually covered with very fine cobweblike threads or matting. Red spiders, **Acarina**
Injury consisting of defoliation, leaf rolling, leaf tying, or bagworms, leaf or petiole miners, and bast or epidermis miners on green-barked stems ... 2
Injury occurring on new growth, twigs, branches, or small trees, parts mined, pruned, withered, or flagged ... 7
Injury caused by larvae or beetles boring in the bark, under the bark, or in the wood ... 15
Injury consisting of a gall or swelling on the stem, branch, or leaf ... 24
Injury resulting from the feeding of sucking insects on leaves, twigs, or bark surfaces, usually the softer tissues of the plant— hard-bodied, fixed scales; soft-bodied aphids; or actively moving tree hoppers or leafhoppers, etc ... 32

DEFOLIATION AND OTHER INJURY

2. Injury caused by beetles ... 3
Injury caused by larvae ... 5
Injury caused by other forms or insect not present ... 6
3. Adults and larvae associated on the leaves **Coleoptera, Chrysomelidae**
Adults only present ... 4
4. Rather hard-shelled beetles, usually feeding at night **Coleoptera, Scarabaeidae**
Small bright-colored, jumping beetles Flea beetles, **Coleoptera, Chrysomelidae**
Dull black, purplish, or gray, soft-bodied beetles Blister beetles, **Coleoptera, Meloidae**
Small snout beetles ... **Coleoptera, Curculionidae**
5. Prolegs, usually 2 or 5 pairs ... **Lepidoptera**
Prolegs, usually 6 or more pairs or none Sawflies, **Hymenoptera, Tenthredinidae**
Prolegs, inconspicuous; leaf- or bast-mining forms ... ([12])
6. Circular holes cut in the leaves .. Bees, **Hymenoptera, Megachilidae**
Leaves rolled into a small compact bundle Leaf rollers, **Coleoptera, Attelabidae**
Grasshoppers associated with injury ... **Orthoptera, Acrididae**
Walkingsticks associated with injury ... **Orthoptera, Phasmatidae**

[12] There seems to be no simple and practical method of separating the leaf miners of the four orders that have species with this habit. Those found in conifers are probably either Lepidoptera or Hymenoptera; and those on hardwoods may be Lepidoptera or Hymenoptera, or of the families Curculionidae, Chrysomelidae, or Buprestidae of the Coleoptera; or they may be Diptera of the families Agromyzidae or Cecidomyiidae.

TWIG PRUNING AND OTHER INJURY

7. Injured portion hollowed or mined; injury caused by larvae or bark beetles, which are usually present........ 8
Injury caused by external feeding or ovipositing, which removes a portion of the bark or causes a definite mechanical injury or a resin-infiltrated scar........ 14
Cottony masses on tips of twigs concealing the insects; conifers
Homoptera {**Coccidae**, **Chermidae**}

8. Injury on two or more whorls of the terminal of conifers; inactive, curved larvae under bark or in pupal cells in wood
Coleoptera, Curculionidae, *Pissodes*
Twigs or branches of hardwoods or conifers containing bark beetles or powder-post beetles or a cylindrical shotlike hole, usually darkly stained, directly entering injured portion
Coleoptera, Scolytidae, Bostrichidae
Injury otherwise........ 9

9. Twigs not mined below fading portion........ 10
Twigs mined far below fading portion, tunnel often extending to the ground........**Coleoptera, Cerambycidae**

10. Conifers........ 11
Hardwoods........ 12

11. Larvae with prolegs; often pitch masses at point of injury
Tip moths, **Lepidoptera, Olethreutidae,** *Petrova*
Larvae without conspicuous prolegs; usually a spine on last segment........Sawflies, **Hymenoptera, Tenthredinidae**

12. Larvae with well-developed prolegs; usually colored; usually in more tender parts of twigs
Lepidoptera, Olethreutidae, Nepticulidae, Aegeriidae, Cossidae
Larvae otherwise; in woody portions of twigs........ 13

13. Elongate, flat larvae; mines filled
Coleoptera, Buprestidae, *Agrilus*
Cylindrical larvae; mines open........**Coleoptera, Cerambycidae**

14. Obvious scar and pitching of wood at base of injury or along twigs; conifers:
  Scale bodies present on twig
  Homoptera, Coccidae, *Matsucoccus*
  Scale bodies absent
  Coleoptera, Cerambycidae, *Monochamus*
  Numerous phloem scars on twigs; spittle masses may or may not be present........Spittle bugs, **Homoptera, Cercopidae**
  (Hail injury is similar except that the scars are always on top side of branch)
Twigs slit with a lacerated wound at base of injury or at point of breaking........Cicada, tree hoppers, tree crickets
Homoptera {**Cicadidae**, **Membracidae**}
Orthoptera, Gryllidae

BORERS IN WOOD AND BARK

15. Borers in the phloem and outer corky bark of living trees rarely scarring the wood........ 16
Borers in callous tissue around wounds
  On various hardwoods
  Coleoptera, Curculionidae, *Conotrachelus*
  On maples
  Maple callous borer, **Lepidoptera, Aegeridae,** *Conopia*
  On conifers
  Clear-wing moths, **Lepidoptera, Aegeridae,** *P. pini*
  Phycitidae, *D. zimmermani*
Borers in the dead wood beneath fire scars, turpentined faces, blazes, cavities, and such wounds........ 17
Borers (larvae) under the bark or in the wood (other than beneath scars or catfaces) of living trees........ 18
Bark beetles associated with their larvae under the bark
Coleoptera, Scolytidae
Root borers or mining at base of tree........ 23

BORERS IN WOOD AND BARK—Continued

16. White, unpigmented larvae............**Coleoptera, Cerambycidae**
Highly pigmented larvae............**Hymenoptera Tenthredinidae**
Serpentine mines just under the epidermis of chestnut and oak **Lepidoptera, Nepiculidae**
17. Ambrosia beetles (pinhole borers); wood stained around holes **Coleoptera, Scolytidae, Platypodidae**
White fleshy cylindrical larvae in hardwoods **Coleoptera, Cerambycidae, Brentidae**
White fleshy flat-headed larvae in turpentined faces in fire scars on conifers..................**Coleoptera, Buprestidae,** *Buprestis*
Larvae with heavy chitinous armature on last segment; chestnut, oak, maple...............**Coleoptera,** *Melittomma, Strongylium*
18. Larval mines extended under the bark and also deep into the wood in later stages.. 19
Larval mines entirely under the bark or only in wood of current annual ring.. 22
19. Pitch exuding from larval mines; larvae with prolegs present; conifers..............................Pitch moths, **Lepidoptera**
No pitch, but often water and frass exuding.................... 20
20. Head of larvae globular, protuberant........................ 21
Head of larvae somewhat flattened and embedded in prothorax **Coleoptera, Cerambycidae**
21. Prolegs absent; last segment often heavily armed **Coleoptera, Tenebrionidae**
Prolegs absent; larvae curved, grublike; in willow, poplar, and palmetto............................**Coleoptera, Curculionidae**
Prolegs present; last segment not heavily armed **Lepidoptera, Hepialidae, Aegeriidae**
22. Larvae depressed, flat-headed or pestle-shaped **Coleoptera, Buprestidae**
Larvae curved grublike................**Coleoptera, Curculionidae**
Larvae slender; thoracic segments not noticeably enlarged; causing pitch flecks in wood, birch, etc............**Diptera, Agromyzidae**
23. Larvae with prolegs; poplar, willow, alder, ash, persimmon **Lepidoptera, Hepialidae, Aegeriidae**
Larvae without prolegs
In hardwoods..................**Coleoptera, Cerambycidae**
In conifers; associated with pitch mass **Coleoptera, Curculionidae, Scolytidae** (*D. valens*)

GALLS[13]

24. Galls of more or less open, exposed, simple structure, or when enclosed the insects maintain permanent openings or the gall is dehiscent to permit the escape of the numerous insects inhabiting them.. 25
Gall usually completely enclosing the inhabitant; one or rarely several insects to a cavity; occasionally a permanent opening is maintained by the feeding larva.................................. 28
25. Mites present having 2 pairs of legs; galls of various shapes but always provided with an opening to the exterior and lined on the inside with hairy or fuzzy growths....................**Acarina**
Galls otherwise.. 26
26. Insects not fitted for jumping................................ 27
Insects with hind legs developed for jumping **Homoptera, Psyllidae**
27. Leaf galls on hardwoods, chiefly elm, poplar, hickory, ash, sumac, and witchhazel..........................**Homoptera, Aphidae**
Conelike galls on tips of spruce twigs..........**Homoptera,** *Adelges*
Pitlike galls on twigs of hard pines.......**Homoptera,** *Matsucoccus*
Pitlike galls on twigs of white oak.....**Homoptera,** *Asterolecanium*

[13] It seems impossible to devise a key that will separate all the varied types of galls into family or order groups. On the other hand many groups are fairly true to type, and if considered with the larvae or other stages of the insect inhabiting them, it is possible to make a fairly workable distinction.

GALLS—Continued

28. Galls inhabited by larvae with a well-developed head capsule.... 29
Larvae without well-developed head capsule, maggotlike; white to yellowish or reddish in color:
Larvae with a distinct structure like a breastbone near anterior end.................... **Diptera, Cecidomyiidae**
Larvae without breastbone; mouth parts well developed **Diptera, Agromyzidae**
29. Larvae legless or with only minute legs.......................... 30
Legs well developed, also prolegs present.......................... 31
30. Woody galls containing plain evidences of mining activity of the larvae; larvae with a well-developed head capsule and mandibles **Coleoptera, Buprestidae, Cerambycidae, Curculionidae**
Larval mines not obvious; white larvae, curved or grublike in form, legless, and with distinct head capsule, each contained in a specialized cell............. **Hymenoptera, Cynipidae, Chalcidae**
31. On willow...................... **Hymenoptera, Tenthredinidae**
On locust, poplar, maple............. **Lepidoptera, Olethreutidae**

SUCKING INSECTS

32. Injury or insects present on leaves [14]......................... 33
Injury primarily confined to twigs.......................... 34
Injury primarily confined to branches and main stem............ 35
33. Leaves off color, yellowish or spotted from feeding punctures of active, jumping insects:
Leafhoppers, **Homoptera, Cicadellidae**
Lacewing bugs, **Hemiptera, Tingitidae**
Leaves bearing galls or abnormal spots:
On hackberry, infested with jumping lice **Homoptera, Psyllidae**
On elm, poplar, willow, witchhazel, hickory, oak, chestnut, etc., infested with plant lice **Homoptera, Aphidae; Homoptera, Phylloxeridae**
On conifers infested with adelgids **Homoptera, Phylloxeridae**
Exposed insects on the leaves:
Scalelike, gall-like, or soft grublike insects covered with wax in the form of powder or tufts
Scale insects, **Homoptera, Coccidae**
Fringed scalelike immature forms associated on the leaves with white 4-winged flies
Whiteflies, **Homoptera, Aleyrodidae**
Soft-bodied insects with long conspicuous antennae
Plant lice or aphids, **Homoptera, Aphidae**
34. Insects surrounded by a conspicuous frothy mass of spittle; ends of branches and trees slowly dying in severe infestations; pines
Spittle bugs, **Homoptera, Cercopidae**
Injury consisting of ragged slits in the twigs, often breaking at incision; the tips of the branches hanging with withered leaves; hardwoods.................... Cicadas, **Homoptera, Cicadidae**
Treehoppers, **Homoptera, Membracidae**
Injury consisting of gall-like or gouty swellings on limbs and twigs of fir............... Fir bark louse, **Homoptera, Phylloxeridae**
Tips of hard pines flagged (needles yellowing); scales embedded in pits in bark................ **Homoptera, Coccidae,** *Matsucoccus*
Branches and twigs infested with scalelike, gall-like, or soft-bodied insects covered with waxy powder or tufts; twigs often dying **Homoptera, Coccidae**
Tips of branches swollen forming pineapplelike galls; conifers **Homoptera, Phylloxeridae,** *Adelges*
Tips of new growth withering, infested with numerous soft-bodied insects with prominent antennae Aphids, **Homoptera, Aphidae**

[14] The sucking insects are treated here as a group and some repetition of habits occurs in other parts of the key as they appear as gall makers, twig killers, etc. This seems advisable as these insects are easily recognized as a group by their mouth structure, and it is therefore convenient to turn immediately to this section of the key.

SUCKING INSECTS—Continued

35. Fir trees unhealthy and dying; trunks infested with masses of soft-bodied insects appearing as a whitish wool
Fir bark louse, p. 137

Beech trees unhealthy and slowly dying, with dead areas of bark on stems covered with whitish masses of soft-bodied insects
Beech scale, p. 140

Trees infested with scalelike, gall-like, or soft grublike insects, and covered with wax in the form of powder or tufts
Homoptera, Coccidae

DIVISION C

INSECTS INJURIOUS TO FOREST PRODUCTS

This division or group includes insects causing the type of injury met with in the handling of forest products, i. e., logs and lumber, poles, posts, piling, and manufactured materials, as handles, gun stocks, stored wood, and wood in buildings. Certain types of damage found in green logs or freshly sawed lumber are the result of insects boring in the phloem or wood of the living tree. These are treated here for convenience. They are usually distinguishable by the more or less stained condition of the surrounding wood, pitch infiltration, or the presence of scar (callous) tissue. These injurious insects may be classified as follows:

Defects occurring in the wood of green logs or lumber, which are revealed as the logs are sawed; usually as darkly stained, pitch-infiltrated wood, or scar (callous) tissue ---------- 1

Injury occurring to material having the bark present (lumber excepted), such as round logs after the trees are felled and left either in the woods or at the mill, or utilized for rustic work, etc ---------- 6

Injury to freshly sawed lumber, seasoned lumber, stored and manufactured materials, or wood in buildings ---------- 7

Injury to material in contact with the ground, such as cross ties, posts, poles, foundation materials, piling above water, etc ---------- 11

Injury occurring to the submerged portions of piling or woodwork in brackish or salt water ------- Marine borers (Shipworms and wood lice) 12

DEFECTS IN GREEN TIMBER

1. In hardwoods ---------- 2
In conifers ---------- 5

2. Holes small, "pinholes," ¼ inch or less in cross section; circular, open, i. e., never filled with boring dust ---------- 3
Holes larger, "grub holes," up to ¾ inch in diameter, usually oval in cross section, usually open, not filled with boring dust ------- 4
Pith flecks in wood, birch, maple, etc.
Diptera, Agromyzidae, *Agromyza*

3. Pinholes, about ⅛ inch in size, of uniform diameter throughout, wood stained in streaks, in oaks and yellow poplar
Coleoptera, Scolytidae, *Corthylus*
Holes tapering, several sizes grouped together and originating in a wound:
Holes up to ¼ inch in diameter, in chestnut and chinquapin
Coleoptera, *Melittomma*
Holes up to ⅛ inch in diameter, in oak and other woods
Coleoptera, *Arrhenodes*

DEFECTS IN GREEN TIMBER—Continued

4. Variable-sized holes grouped and radiating from wounds or cavities
Coleoptera, Cerambycidae, *Parandra;* **Tenebrionidae,** *Strongylium;* **Brentidae,** *Arrhenodes*

Still larger grub holes, up to 1 inch in diameter, usually appearing singly and not associated with wounds.

In hickory
Coleoptera, Cerambycidae, *Goes;* **Lepidoptera, Cossidae,** *Cossula*

In poplar and cottonwood
Coleoptera, Cerambycidae, *Saperda, Plectrodera;* **Lepidoptera, Cossidae,** *Prionoxystus;* **Lepidoptera, Aegeriidae,** *Aegeria*

In maple
Coleoptera, Cerambycidae, *Glycobius;* **Coleoptera, Tenebrionidae,** *Strongylium;* **Lepidoptera, Cossidae,** *Zeuzera, Prionoxystus;* **Aegeriidae,** *Conopia*

In ash................ **Lepidoptera, Aegeriidae,** *Podosesia*

In persimmon.......... **Lepidoptera, Aegeriidae,** *Sannina*

In locust............. **Lepidoptera, Cossidae** {*Prionoxystus*, *Zeuzera*, *Cossula*}
Coleoptera, Cerambycidae, *Cyllene*

5. Pitch pockets in the wood...... Pitch moths, **Lepidoptera, Aegeriidae,** *Parharmonia;* **Phycitidae,** *Dioryctria;* **Coleoptera, Scolytidae,** *Dendroctonus*

Holes filled with boring dust, associated with turpentine faces or fire scars

In the South, pines.... **Coleoptera, Buprestidae,** *Buprestis*

In the North, pines or other conifers
Coleoptera, Cerambycidae, Buprestidae

INSECTS IN ROUND LOGS

6. Sawdust excuding from small round "pinholes" (1/10 inch or less in diameter) on the surface of the bark; wood usually stained around the holes.......Ambrosia beetles, **Coleoptera, Scolytidae**

Sawdust exuding from larger holes; larvae present under the bark or in wood
Coleoptera, Cerambycidae *Cyllene, Chion, Callidium, Monochamus, Elaphidion*

Sawdust not exuded; the only evidence of work is the presence of larvae or galleries under bark or in the wood

Larvae elongate, cylindrical......**Coleoptera, Cerambycidae**

Larvae flat-headed...............**Coleoptera, Buprestidae**

Larvae curved, legless; only one larva to a burrow
Coleoptera, Curculionidae

Larvae curved, legless; several larvae in a burrow, each usually separated by a pith or clay partition across the gallery..**Hymenoptera, Sphecidae, Vespidae, Xylocopidae**

Larvae and bark beetles associated...**Coleoptera, Scolytidae**

INSECTS IN LUMBER

7. Fine sawdust exuding from small "pinholes" (less than 1/10 inch in diameter) in green lumber; holes usually darkly stained
Ambrosia beetles, **Coleoptera, Scolytidae**

Sawdust, if exuding, coming from larger holes in drier lumber, cut a month or more.. 8

8. Damage to lumber with the bark present:

Larvae elongate.................**Coleoptera, Cerambycidae**

Larvae curved...................**Coleoptera, Bostrichidae**

Damage not associated with presence of bark on material......... 9

INSECTS IN LUMBER—Continued

9. Fine sawdust exuding from circular or oval holes:
Small curved larvae __________ **Coleoptera, Lyctidae**
Elongate larvae __________ **Coleoptera, Cerambycidae**
Large black ants associated with damage; sawdust accumulating in large piles from damp wood
Carpenter ants, **Hymenoptera, Formicidae**
Damage concealed and sawdust usually not falling from holes _____ **10**

10. Larval tunnels packed with sawdust:
Larvae elongate, cylindrical ______ **Coleoptera, Cerambycidae**
Larvae elongate, flatheaded ________ **Coleoptera, Buprestidae**
Tunnels open:
Irregular cavities following the grain of the wood loosely filled with fine impressed pellets
Dry-wood termites, **Isoptera**
Round holes ½ inch or less in diameter, often with cross partitions or cells
Carpenter bee, **p., 635, Hymenoptera, Xylocopidae, Vespidae, Sphecidae**

INSECTS IN MATERIALS IN GROUND

11. Large, elongate larvae associated with damage consisting of grub holes extending through the wood
Coleoptera, Cerambycidae, *Parandra, Orthosoma, Prionus*
Oedemeridae, *Nacerdes*
Large irregular cavities eaten in the wood, representing spring wood; usually extending with the grain of the wood; sides of cavities plastered with claylike excrement
"White ants," **Isoptera,** p. 85
Large irregular cavities eaten into wood, usually cutting across the grain, surfaces smooth, no excrement, large piles of sawdust accumulating outside; large black ants associated with injury in moist or damp wood
Carpenter ants, **Hymenoptera, Formicidae,** p. 622

DEFECTS IN WOOD IN SALT OR BRACKISH WATER

12. Submerged portions of piling or woodwork channeled by burrows of varying diameters and often lined with a calcareous deposit
Marine borers (shipworms and wood lice, or gribble), **p. 66.**

IMPORTANT ORDERS OF INSECTS

The listing and brief treatment of the more important, injurious forest insects, is the primary purpose of this publication. There are, however, several orders of insects that are abundant in forests or streams, but not destructive to forest growth. As some of these are frequently brought to the attention of the forester, particularly now that wildlife and game in the forest have become recognized as an important resource, it is proper to discuss them briefly before turning to the major forest pests.

Several of the orders of insects, such as the fish flies (Neuroptera), the mayflies (Ephemeroptera), the dragonflies (Odonata), the stone flies (Plecoptera), and certain true bugs (Hemiptera) are primarily aquatic and furnish the most of the food of some fishes. Often they are the determining factor between abundance and scarcity of the game fishes. Other orders, such as the fleas (Siphonaptera), the bird lice (Mallophaga), and true lice (Anoplura) have representatives that are pests of warm-blooded animals living in the forests.

Again, as pointed out by Metcalf (*296*) and Metcalf and Flint (*298*), insects or their relatives annoying to man are the subject of frequent inquiries in recent years, because of the great increase in visitors to the forests as their recreational values are becoming appreciated. Among these insects are the mosquitoes, blackflies, and punkies (Diptera), and ticks and mites (Acarina).

For further information on insects the reader should consult general references, such as Comstock (*103*); Essig (*145*); Metcalf and Flint (*298*); Herrick (*223*); Graham (*194*); Doane et al. (*133*); Packard (*323*); and Imms (*251*).

THE TRUE LICE

Order ANOPLURA

The true lice are wingless insects with sucking mouth parts, and are parasitic on mammals. **The head louse, the body louse,** and **the crab louse** are common representatives of this order that infest man. Other species attack domesticated and wild animals. The eggs are glued to the hairs of the host. DDT (10 percent) powder is effective in control.[15]

THE BIRD LICE

Order MALLOPHAGA

The bird lice resemble the true lice in being parasitic on warm-blooded animals, but they have chewing mouth parts instead of the sucking type. They chiefly infest birds and are often troublesome on domestic stock, but some forms are found on mammals. The eggs are attached to the feathers or hairs. Derris powders, sodium fluoride, and DDT are effective in control.

THE FLEAS

Order SIPHONAPTERA

The fleas are small, hard-bodied, compressed, wingless insects, having piercing and sucking mouth parts and undergoing a complete metamorphosis. The larvae lie in the litter in cracks in the floors of houses, under porches, about the kennels or stables of animals, or in the nests of animals or birds in hollow logs and trees, and are seldom seen. The adults suck the blood of mammals and some birds and are often annoying to man, especially in the home and in camps. One species, **the human flea** (*Pulex irritans* L.), naturally lives on man but also infests other animals. The fleas transmit several diseases, including bubonic plague, which is now endemic in rodents in our Western States.

The fleas leave the body of their host almost immediately after it is killed. Hunters are often severely bitten by fleas that leave the bodies of the game carried in their coats. A simple precaution is to wait a few minutes until the animal has cooled before placing it in one's coat, or to carry it by a string until the fleas have jumped off. The

[15] Eddy, G. W., and Bushland, R. C. control of human lice. U. S. Bur. Ent. and Plant Quar. E-675, 5 pp. 1946. [Processed.]

rat fleas and those on some ground-inhabiting rodents are especially to be avoided because of the danger of their transmitting bubonic plague. Bishopp (*31*) discussed these insects and methods of control.

Fleas are easily controlled about premises by preventing their breeding. This is done by treating the floors and bedding, or other places frequented by animals, with DDT dust. Inside the house, liberal applications of DDT or pyrethrum sprays or dusts are effective. Domestic animals should be kept free of adult fleas by weekly or bi-weekly applications of derris powder·

DDT powder is also effective and can be safely used on dogs but not on cats.

THE BRISTLETAILS

ORDER THYSANURA

and

THE SPRINGTAILS

ORDER COLLEMBOLA

Certain small and often very active insects are frequently found in great numbers congregated under stones or bark of dead trees and stumps or in old damp buildings around lumber camps. They are bristletails and springtails. They are very primitive insects without wings and with chewing mouth parts. In the springtails the third and fourth abdominal segments are provided with a springing apparatus. On warm days during the winter some species often appear in enormous numbers on the surface of the snow.

Although often abundant, these two orders do not cause any damage, but they are of economic importance to the forester in that they play an important role in the reduction of leaf litter on the forest floor and aid in the formation of humus. More detailed information on these insects may be found in Jacot (*253*) and in Back (*8*).

THE THRIPS

ORDER THYSANOPTERA

The thrips are minute insects, often of active movements, either wingless or with four slender wings fringed with hairs. They have mouth parts fitted for sucking, and legs ending in a bladderlike tip.

These tiny insects are extremely abundant at times on all kinds of flowers, and some species do considerable damage to cultivated plants, causing characteristic malformation or unhealthy appearance of the parts affected, and at times transmitting certain virus diseases of plants. They are rarely injurious in the forest, although *Liothrips umbripennis* Hood caused extensive curling of chestnut oak leaves in northern New Jersey in 1937, and some occasionally are injurious in the nursery. Some forms are abundant on the pollen-bearing flowers and attract the attention of those collecting pollens. *Gnophothrips piniphilus* Cwfd. occasionally causes much injury to pine seedlings in nurseries. Other forms are so abundant in midsummer that they become a nuisance by crawling over the skin and occasionally biting man. For control measures see page 53, formula 4.

THE PSOCIDS AND BOOKLICE

Order CORRODENTIA

To the order Corrodentia belong several species of small insects with chewing mouth parts and four membranous wings, which when present, are held rooflike over the body.

The psocids (fig. 7) are often seen in great numbers on the trunks of trees where they feed on lichens and the surface of the bark, or among the leaf litter on the ground. A species, *Archipsocus nomas* Gurney, is often abundant on the trunks of shade trees in New Orleans. It completely covers the bark with a matlike cobweb.

The booklice are wingless, whitish, or grayish-white forms, about 1 mm. long, found in damp corners of buildings, musty bulletin cases, and bookshelves. They feed on molds and other vegetable or animal matter. Back (*9*) stated that when they become annoying they can be controlled by sprinkling the infested locations with powdered sodium fluoride, or better by spraying with DDT. (See caution on p. 24.)

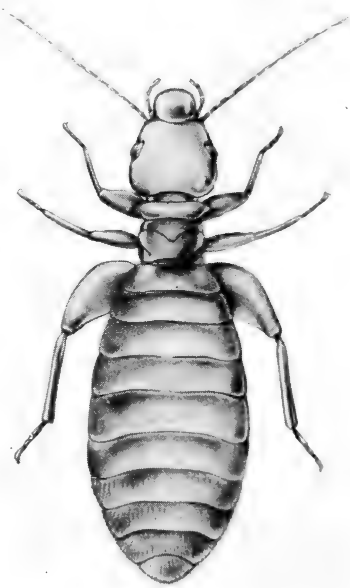

Figure 7.—Adult book louse (*Liposcelis divinitorius* (Müll.)), common in dwellings. About 55 × natural size.

LACEWING FLIES, FISH FLIES, ANT LIONS, AND RELATED FORMS

Order NEUROPTERA

The order Neuroptera includes a variety of aquatic and terrestrial insects representing a wide range of forms, but all have four membranous wings (fig. 8) with numerous cross veins, mouth parts fitted for chewing, and five-jointed tarsi. They have a complete metamorphosis.

THE DOBSON FLY AND OTHER FISH FLIES

Family SIALIDAE

The best known representative of the family Sialidae is **the Dobsonfly** (*Corydalus cornutus* (L.)) and its larval stage, **the hellgrammite** (fig. 9). The adult is a large conspicuous insect, sometimes nearly 100 mm. in length, with large membranous wings, and a conspicuous rectangular head and thorax, the former provided with long pincers (mandibles) in the male. The larva is equally large, grayish black, depressed, with a prominent, rectangular prothorax and head, and well-developed legs; the abdominal segments are each provided with a pair of lateral appendages, those on the ninth acting as graspers.

The eggs are laid on overhanging trees, stones, or walls, in blotch-like white masses from 12 to 25 mm. in diameter and containing 2,000 or more eggs. The larva of a small beetle is often found predaceous in these egg masses. The larvae, on hatching, fall into the water.

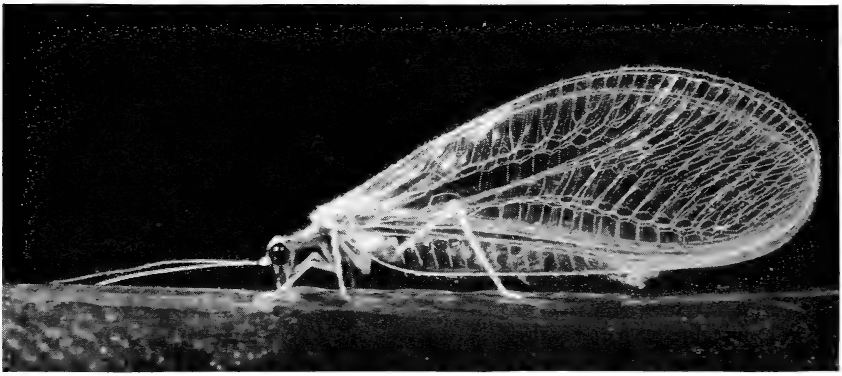

FIGURE 8.—The golden-eye lacewing (*Chrysopa oculata* Say).

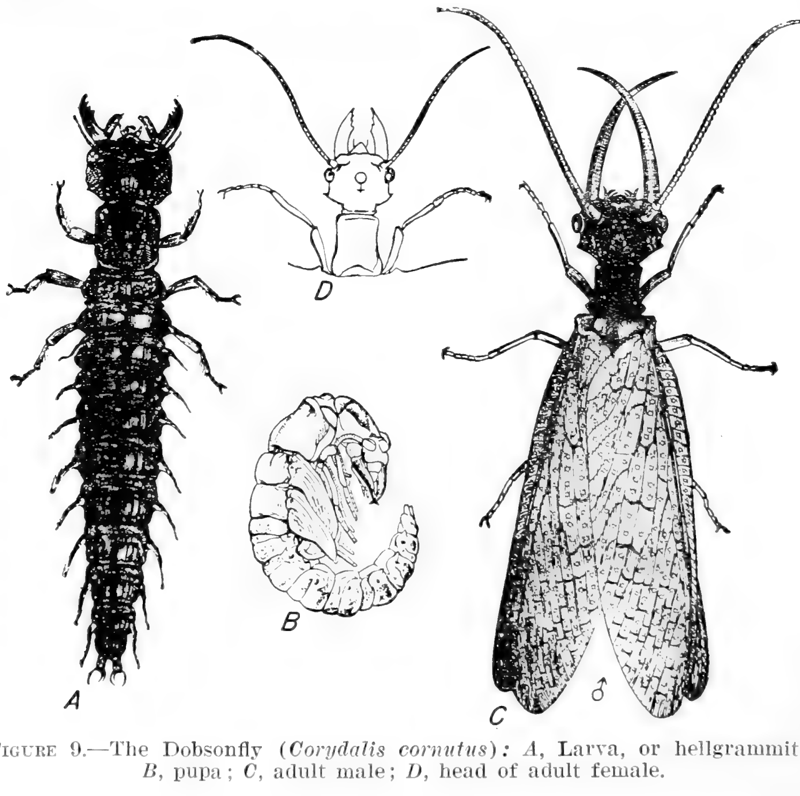

FIGURE 9.—The Dobsonfly (*Corydalis cornutus*): *A*, Larva, or hellgrammite; *B*, pupa; *C*, adult male; *D*, head of adult female.

The larvae, like those of most other species in the family, live under stones in rapidly flowing water where they feed on other aquatic life. They live for nearly 3 years in the water and then crawl up on the bank to pupate in earthen cells under stones or logs.

The hellgrammite is one of the finest fish baits found in fresh-water streams. It ranks on a par with the large angleworms, "night-crawlers," and can always be depended on if there are any fish biting. The white blotches of the egg masses which persist for several years unfailingly indicate the presence of these insects in the stream, and a search under flat stones in the most rapid water will not likely prove futile. The larvae are readily taken by placing a landing net downstream and lifting or turning the flat stones under which they live. Early in the summer large numbers can be collected on the shore opposite rapids by turning over logs and stones, under which the full-grown larvae have crawled to pupate and transform to the adult stage.

THE APHIS LIONS, OR LACEWINGS

Family CHRYSOPIDAE

Aphis lions, or lacewing flies, are common insects found on the foliage of trees where they feed on aphids. They are the larvae and adults, respectively, of the same insect. The mature insect has a conspicuous yellowish-green color and delicate and prominent lacelike wings which are arched over its body when at rest. The larvae are spindle-shaped, flattened, slow-moving forms with long mandibles. The eggs are laid at the tips of tall threadlike stalks attached to the leaves.

THE ANT LIONS

Family MYRMELEONTIDAE

Tiny, conical pits, or craters, in dry, dusty, or sandy spots along the sides of houses, under overhanging cliffs, or other protected places furnish the best evidence of the presence of these insects. At the bottom of each pit is a small, robust, fusiform larva with a pair of strong, projecting mandibles waiting to grasp an unlucky ant that may stumble into the pitlike trap. In case the ant lion does not grasp the ant on the first attempt, it throws a shower of sand over the victim which carries it to the vortex of the pit, where it is finally seized and devoured. The adult is a slender insect with large, delicate wings, and with a slow, apparently aimless flight.

THE MAYFLIES

Order EPHEMEROPTERA

The Mayflies are frail, delicate insects, with four (rarely two) triangular, many-veined wings, the hind ones quite small. Many have two or three long, frail caudal setae. Some have a peculiar divided eye, one part with large facets adapted to use at night, the other with small facets for daylight vision. They have an incomplete metamorphosis. As the Latin name of the order indicates, they live only a few hours as adults, although the naiads may live for from several weeks to 2 or 3 years.

The larvae, or naiads, have chewing mouth parts, whereas those of the adult are vestigial. All the larvae are aquatic, often extremely abundant, especially in cool streams. They are provided with gills and live under stones or among the debris on the stream bottom where they eat decaying vegetable matter.

The peculiar dipping flight of the adults of some species, as they hover over the water surface, is quite distinctive. Another peculiarity is that many of the adults molt after attaining full development. During the mass emergence or flights of the adults, the naiads can be seen emerging on the surface of the water in great numbers, where they cast off their skins and rise into the air. Any experienced trout fisherman has learned to watch for the so-called flights of Mayflies on a warm, calm evening, and to take advantage of the coincident voracious feeding of the fish. These insects form a very substantial food item for many fish.

THE STONE FLIES

Order PLECOPTERA

The stone flies have four wings with numerous cross veins; the rear wings are folded in pleats (as the technical name of the order implies) when at rest, and are usually the larger (fig. 10). They have chewing mouth parts, and many-jointed cerci. The metamorphosis is incomplete.

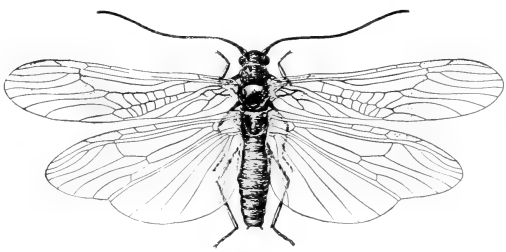

Figure 10.—A stone fly, *Taeniopteryx pacifica*, × 3.

The flat-bodied, immature stages (naiads) of stone flies are all aquatic and can be found abundant under stones in the swift water of streams. They are an important source of fish food, and can always be depended on by the angler when other forms of bait fail, or when the trout are reluctant to take a fly. A few luscious naiads of these insects will often fill the creel.

Some species, like the Mayflies of the preceding order, appear in flights of enormous numbers. Many are rather cool-weather insects, and on the first warm, sunny day of spring, even though ice is still floating in the water, the smaller species of stone flies may be observed crawling out of the water's edge to shed their skins and listlessly take to flight, and may annoy the angler by crawling up his trouser leg.

THE DRAGONFLIES AND DAMSEL FLIES

Order ODONATA

The dragonflies and damsel flies are characterized by two pairs of membranous wings of about equal size and abundantly net-veined. They have chewing mouth parts and go through an incomplete metamorphosis. The larvae, or naiads, are aquatic.

Dragonflies and damsel flies are abundant and characteristic insects around slow streams and ponds. The former are active, strong fliers that pursue, catch, and devour other insects. When at rest the wings are outspread (fig. 11). The damsel flies rest with the wings folded above the abdomen and are poorer fliers. The eggs are laid in the water or on the stems of plants, logs, etc. The larvae are predaceous on other aquatic life. Those of the dragonflies breathe by drawing water into a pocket located at the posterior end of the abdomen and provided with tracheal gills. This water can be forcibly expelled thus moving the larvae through the water. The damsel fly larvae have external gills at the tip of the abdomen. The larvae of both insects when fully developed crawl up the stems of plants, and the adults emerge. The cast skins are common objects on vegetation along streams. The naiads are frequently found in the stomachs of fish.

FIGURE 11.—An adult dragonfly, *Libellula pulchella* Drury.

THE TERMITES

ORDER ISOPTERA

By T. E. SNYDER

GENERAL DESCRIPTION

Termites are primitive insects related to the cockroaches and, while superficially antlike, are not related to the ants. The termites have thick waists and the fore and hind wings are similar, whereas the ants are narrow-waisted and the forewings are markedly different and larger than the hind wings. Both termites and ants are social insects, that is, they live in large colonies and have a caste system and a more or less closely adhered-to division of labor. Ants run about in the open above ground, but termites are concealed in wood, earth, or earthlike shelter tubes.

Termites vary greatly in color, form, size, habits, and life history, and in the different castes present in the colony. Usually, winged adults, soldiers, and workers (fig. 12) constitute the chief castes, but in certain kinds of termites in specified localities any one of these forms may be lacking. Unlike the ants, termites have no pupal or resting stage, but are always active, except for short periods when they are shedding their skins.

The workers and large-jawed soldiers are wingless, blind, and sterile (although potentially males and females) and are, respectively, the castes for labor and defense, although workers also defend the colony and young soldiers perform the duties of workers, as do also the young reproductive forms. The workers are the forms that damage

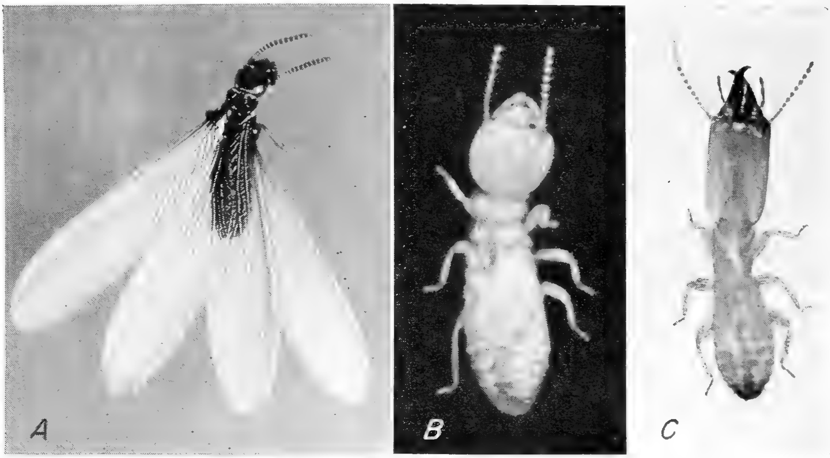

FIGURE 12.—*Reticulitermes flavipes: A*, Winged adult; *B*, worker; *C*, soldier.

wood. The mature soldiers cannot eat wood and are fed by the workers.

The sexual winged adults (macropterous, or large-winged adults), the only form with true eyes, engage in a short dispersal flight at certain seasons of the year, the subterranean termites during the day, and the nonsubterranean termites at night. After the colonizing flight and the loss of wings, the dealated sexual adults become the monogamous reproductive forms. Other reproductive forms of two main types—the form with wing pads (brachypterous adults) and the apterous (wingless) form, both of which have simple eyes—are also present in colonies, as is a series of intermediate forms, all of which are polygamous (Snyder, *387*, *390*).

GENERAL HABITS

The sexual winged adults fly in a colonizing flight at seasons of the year varying with the species and the locality. Of the dry-wood termites, as a rule, only a few individuals fly from the parent colony at the same time, whereas from colonies of the subterranean termites the flights consist of very large numbers.

After a short flight the wings are broken off at points of weakness, and a pair of dealated adults excavate a new abode, either in wood or in the earth, depending on the type of termite; only then does mating occur. The male termite continues to live with and fertilize the female or females, and both excavate the first home and rear the first brood. After the colony is well established, the workers care for and feed the female reproductive forms which, though becoming enlarged (physogastric), are not confined in a special cell, as are those of some tropical termites. Even the queens never lose their power of locomotion. They move about with seasonal changes. The rate of egg laying in our native termites, which have relatively small queens, never approaches that of tropical species. The first brood of young of subterranean termites consists mostly of workers and a few soldiers, which mature in a year; the winged adults do not appear in the colony until after 2 years. Nonsubterranean termites have no workers.

In well-established colonies, in addition to the first form of winged, or macropterous adults, workers, and soldiers, young of a second form, brachypterous (provided only with wing pads), and a third form, apterous (wingless reproductive adults) also appear. These forms, however, never become parent adults in their original colony unless there is an accident to the functioning first reproductive forms. A small number of males are associated with a large number of females, and, although the queens of this type are smaller, in the aggregate their egg-laying powers are greater than that of queens developing from the winged adults.

Termites are scavengers in the forest and are beneficial in converting fallen logs and stumps into humus. Man, by placing suitable woodwork at their disposal, has invited termites to seek shelter and food in his structures. There has been no sudden invasion across this country by termites, but rather termites are widely distributed and attack any suitable wood material when favorable conditions permit. Termites inhabit temperate as well as tropical regions.

The food of termites is principally the cellulose of wood, primarily dead wood, although living vegetation is occasionally attacked in this country. Termites will attack all kinds of wood, but certain chemical extractives in the close-grained heartwood of California redwood, tidewater red baldcypress, and pitchy pine render these woods resistant to termite attack when they are used above ground, where they do not leach out. Hardness is no deterrent. Most woodboring termites contain low forms of life, especially protozoa, in their intestines. By means of enzymes they digest the cellulose for the termites. This is not true of many of the higher, specialized termites. No native termites construct large, conspicuous, concentrated nests, but all species in the East lead concealed lives in colonies of more or less disconnected ramifications and constantly changing site.

There are three types of termites in the Eastern States, the nonsubterranean, or damp-wood, the dry-wood (including powder-post termites), and the subterranean. So far as damage to the woodwork of buildings is concerned, damage by the damp-wood termites is confined entirely to southern Florida. Except for preferring moist wood, the habits of the damp-wood termites are similar to those of the dry-wood type. Damage by dry-wood termites is also limited, but can be locally serious. The subterranean termites make up the group that does practically all the serious damage to buildings and their contents.

The dry-wood termites fly directly to the woodwork of buildings and attack the wood through crevices or bore directly into it. They do not live in the earth and do not attack wood indirectly from the earth, nor do they require the presence of moisture. Their galleries are longitudinal chambers cut across the grain of the wood, and the excrement is in small impressed pellets. No worker caste is present, and the nymphs, or young, perform the duties of workers.

Subterranean termites are ground-living forms that attack wood indirectly from the earth and require much moisture. They attain this moisture from the earth, to and from which they constantly come and go in galleries through wood or through earthlike shelter tubes. Their galleries are, so-to-speak, "air-conditioned," and subterranean termites will plug up holes in wood and construct earthlike shelter tubes mainly to maintain constant humidity. If subterranean termites have a humid condition, they will not necessarily shun light. Their galleries follow the grain of the wood and are spotted with the dark excrement.

LISTS, KEYS, DISTRIBUTIONS, AND HABITS OF SPECIES OF TERMITES

The following species list (systematically arranged), keys to habits of genera or groups, keys to species, and discussion of individual species covers only the States east of Texas. In these States no species of the family Termitidae occur. The Termitidae are the higher, more specialized, termites which cause comparatively little damage in the United States. In some instances both winged adults and soldiers are necessary for specific identification.

LIST OF TERMITES OF THE EASTERN STATES

Family KALOTERMITIDAE

Dry-wood termites:
- ***Kalotermes*** **(*Kalotermes*)** ***approximatus*** Sny.—dark-colored, eastern dry-wood termite.
- *Kalotermes* (*Kalotermes*) *jouteli* Banks—eastern coastal dry-wood termite.
- *Kalotermes* (*Kalotermes*) *schwarzi* Banks—southern dry-wood termite.
- *Kalotermes* (*Kalotermes*) *snyderi* Light—light-colored, eastern dry-wood termite.

Damp-wood termites:
- *Kalotermes* (*Neotermes*) *augustoculus* Sny.—narrow-eyed, southern damp-wood termite.
- *Kalotermes* (*Neotermes*) *castaneus* Burm.—large-eyed, southern damp-wood termite.

Powder-post termites:
- *Kalotermes* (*Cryptotermes*) *brevis* Wlk.—tropical rough-headed powder-post termite.
- *Kalotermes* (*Cryptotermes*) *cavifrons* Banks—cavate-headed powder-post termite.
- *Kalotermes* (*Calcaritermes*) *nearcticus* Sny.—nearctic spur-legged termite.

Family RHINOTERMITIDAE

Damp-wood termite:
- *Prorhinotermes simplex* Hag.—Florida *Prorhinotermes*.

Subterranean termites:
- *Heterotermes* sp. (Florida)—straight-mandibled subterranean termite.
- *Reticulitermes arenincola* Goellner—sand-dwelling subterranean termite.
- *Reticulitermes flavipes* Kol.—eastern subterranean termite.
- *Reticulitermes hageni* Banks—light-colored, southern subterranean termite.
- *Reticulitermes tibialis* Banks—arid-land subterranean termite.
- *Reticulitermes virginicus* Banks—southern subterranean termite.

KEY TO THE GENERA OF TERMITES OF THE EASTERN STATES BASED ON HABITS AND PROMINENT CHARACTERS

1. Wood-inhabiting termites usually not extending galleries from wood into earth ---------- 2
   Soil-inhabiting termites extending galleries from earth into wood ---------- 6
2. Wood eaten across the grain; chambered galleries; excrement in small impressed pellets ---------- 3
   Wood eaten longitudinally with the grain; excrement fluid, spotting walls of galleries; usually in moist wood --- *Prorhinotermes*, p. 91.
3. Wood moist ---------- *Neotermes*, p. 91.
   Wood dry ---------- 4

KEY TO THE GENERA OF TERMITES OF THE EASTERN STATES BASED ON HABITS AND PROMINENT CHARACTERS—Continued

4. Head of soldier short and concave in front ---------- 5
   Head of soldier elongate and flattened, light-colored ----- *Kalotermes*, pp. 90–91.
5. Dark or blackish ---------- *Cryptotermes*, p. 91.
   Castaneous and apex of tibia of foreleg with spur -- *Calcaritermes*, p. 91.
6. Soldiers with long, slender, S-shaped mandibles -- *Reticulitermes*, p. 92.
   Soldiers with long, slender, straight mandibles ---- *Heterotermes*, p. 93.

KEY TO TERMITES OF THE EASTERN STATES BASED ON WINGED ADULTS

1. Fontanelle, or head gland, absent; forewing scale usually not much longer than pronotum; branches between costal and subcostal veins ---------- 2
   Fontanelle usually present; forewing scale definitely longer than pronotum; no branches between costal veins ---------- 9
2. Median vein heavy, close to costal vein ---------- 3
   Median vein light, free from costal veins ---------- *Kalotermes* 5
   Median vein light, usually united with subcostal vein near middle of wing ---------- *Cryptotermes* 8
3. Wings smoky; coarsely punctate, small species *Calcaritermes nearcticus* Snyder, p. 91.
   Wings clear; large species ---------- *Neotermes* 4
4. Eye wide ---------- *N. castaneus* Burmeister, p. 91.
   Eye narrow ---------- *N. angustoculus* Snyder, p. 91.
5. Color blackish ---------- *K. approximatus* Snyder, p. 90.
   Color yellowish or light castaneous ---------- 6
6. Short hairs on tergites; length 10 mm ------- *K. jouteli* Banks, p. 91.
   Long erect hairs on tergites ---------- 7
7. Ocelli oblique; head yellowish; length 15 to 16 mm. *K. schwarzi* Banks, p. 90.
   Ocelli round; head yellowish; length 11 to 12 mm. *K. snyderi* Light, p. 90.
8. Length 10 mm ---------- *Cryptotermes brevis* Walker, p. 91.
   Length 8.5 mm ---------- *Cryptotermes cavifrons* Banks, p. 91.
9. Median vein absent; fontanelle very distinct; yellow-brown; length 9 mm ---------- *Prorhinotermes simplex* Hagen, p. 91.
   Median vein present ---------- 10
10. Wing membrane not reticulate; wing margins ciliate; fontanelle indistinct or absent ---------- *Heterotermes* sp., p. 93.
    Wing membrane markedly reticulate, fontanelle indistinct *Reticulitermes* 11
11. Color yellowish; length 8 mm. *R. hageni* Banks, p. 93.
    Color blackish ---------- 12
12. Tibia always more or less plainly blackened; length 10 mm. *R. tibialis* Banks, p. 92.
    Tibia usually pale ---------- 13
13. Wings whitish; ocelli much less than diameter from eye; length 8 mm ---------- *R. virginicus* Banks, p. 93.
    Wings grayish ---------- 14
14 Ocelli plainly more than diameter from eye; length 10 mm. *R. flavipes* Kollar, p. 92.
   Ocelli less than diameter from eye; tibia pale, length 9 to 10 mm. *R. arenincola* Goellner, p. 93.

KEY TO TERMITES OF THE EASTERN STATES BASED ON SOLDIERS

1. Head long, much longer than broad; light castaneous ---------- 2
   Head short; front cavate; mandibles without prominent marginal teeth ---------- 11
2. Mandibles with prominent marginal teeth ---------- 3
   Mandibles without prominent marginal teeth ---------- 6
3. Hind femora slender; third segment antennae not modified *Neotermes*, p. 91.
   Hind femora swollen; third segment antennae modified .. *Kalotermes* 4

KEY TO TERMITES OF THE EASTERN STATES BASED ON SOLDIERS—Continued

4.	Third segment antennae but little longer than fourth; eye spot black — *K. jouteli* Banks, p. 91	
	Third segment antennae does not equal fourth and fifth; anterior margin of pronotum not dentate — *K. approximatus* Snyder, p. 90	
	Third segment of antennae equal to next two	5
5.	Anterior margin of pronotum dentate	
	Length 7 to 8 mm — *K. snyderi* Light, p. 90	
	Anterior margin of pronotum not dentate — *K. schwarzi* Banks, p. 90	
6.	Labrum rounded at tip; head broader behind; fontanelle distinct — *Prorhinotermes simplex* Hagen, p. 91	
	Labrum pointed at tip; head barely broader behind; fontanelle indistinct	7
7.	Mandibles straight — *Heterotermes*, p. 93	
	Mandibles S-shaped — *Reticulitermes*	8
8.	Gula less than twice as broad in front as in middle — *R. tibialis* Banks, p. 93	
	Gula fully twice as broad in front as in middle	9
9.	Larger species	
	Head 1⅔ times as long as broad; length 6 to 7 mm. — *R. flavipes* Kollar, p. 92	
	Smaller species	
	Head fully twice as long as broad; length 4.5 to 5 mm. — *R. virginicus* Banks, p. 93	
	Head 1¾ times as long as broad (pale) — *R. hageni* Banks, p. 93	
	Head 1½ times as long as broad; length 4.6 to 4.9 mm. (Chicago area) — *R. arenincola* Goellner p. 93	
10.	Front of head blackish, light castaneous behind; head cleft (bilobed) at anterior — *Calcaritermes nearcticus* Snyder, p. 91	
	Front of head blackish to dark castaneous behind (not bilobed)	
	Anterior of head tuberculate — *Cryptotermes brevis* Wlkr., p. 91	
	Anterior of head not tuberculate — *C. cavifrons* Banks, p. 91	

DRY-WOOD AND DAMP-WOOD TERMITES

Kalotermes (*K.*) *snyderi* Light, **the light-colored, eastern, dry-wood termite,** is the most widely spread and injurious of the eastern species of dry-wood termites in the United States. It also occurs in Bermuda and in the West Indies. It has been found from South Carolina to Florida and west to Brownsville, Tex., mainly along the coast. *K. snyderi* damages not only the woodwork of buildings but also the bases and tops of utility poles and posts. In nature it is found in dead trees, logs, and branches. This termite "swarms" or engages in a colonizing flight at night, as do most other species of this genus, and the winged adults are attracted to lights. The swarm consists of but few individuals which fly usually in May and June over considerable periods. Young macropterous reproductive forms of this species have been found in colonies. They were not markedly physogastric.

Kalotermes (*K.*) *schwarzi* Banks, **the southern dry-wood termite,** is one of the commonest termites of the genus *Kalotermes* in southern Florida, Pensacola being the northern limit. This species also occurs in Cuba, Jamaica, and the Bahamas in the West Indies, and in Yucatan, Mexico. It attacks the woodwork of buildings and all wooden parts of telegraph and telephone poles. In nature it is found in dead trees, logs, and stumps. The colonizing flight occurs late in April or in May. Both macropterous and brachypterous reproductive forms have been found in colonies, but the queens were only slightly physogastric.

Kalotermes (*K.*) *approximatus* Snyder, **the dark-colored, eastern dry-wood termite,** has as yet been found only in northern Florida, in and near New Orleans, La., and in southern Virginia. It has been found in dead trees, logs, and stumps, as well as in the woodwork of buildings. Winged adults of this termite were found at Cape Henry, Va., in a dead baldcypress tree in the vicinity of the sand dunes on August 23, 1924. The adults had attained their mature pigmentation. This species flies late in July at New Orleans, La.

Kalotermes (*K.*) *jouteli* Banks, **the eastern coastal dry-wood termite,** is restricted to southern Florida, including the Keys. It has seldom been found to be injurious, except in a few instances in the moist foundation timbers of buildings. In nature it lives in dead trees and in logs and branches lying on the ground.

Kalotermes (*Neotermes*) *castaneus* Burmeister, **the southern damp-wood termite,** occurs in the United States only in southern Florida, including the Keys. This termite damages the trunks and limbs of citrus trees. In a laboratory colony supplementary reproductive forms lived for 25 years. *Kalotermes* (*Neotermes*) *angustoculus* Snyder apparently has the same distribution and habits as *K.* (*N.*) *castaneus*, under which name it was formerly included.

Prorhinotermes simplex Hagen, **the Florida Prorhinotermes,** a damp-wood termite, is confined to swampy areas in southern Florida, where it is found in moist logs. At present it is of but slight economic importance and probably never will be important; only one case is on record where the woodwork of a building has been damaged. On the Florida Keys, where the parent adults are apterous, winged adults have not been found in colonies.

POWDER-POST TERMITES

Kalotermes (*Cryptotermes*) *brevis* Wlk., the tropical rough-headed powder-post termite, is of wide distribution in the West Indies, Mexico, Central America, and South America, and of local occurrence at Durban, South Africa. In the United States it is commonly found only in southern Florida and in New Orleans, La., and recently has been discovered infesting furniture at Memphis, Tenn. This termite has never been found in nature living in logs or timbers out of doors, but only as a house pest, damaging the woodwork and furniture in large hotels in the West Indies and in southern sections, which are inhabited by people of Latin origin. This fact indicates possible introduction from farther south. *K. brevis* not only destroys furniture and woodwork, but the constant dropping of pellets from infested wood is an annoyance to the householder. Because of its destructive habits in Central America and South America, it has been given special names, "carcoma," and "polilla" in the West Indies, in contrast to that given the subterranean termites, "comejen." In the United States the colonizing flight occurs in May or June. Slightly physogastric, macropterous reproductive forms have been found in colonies.

Kalotermes (*Cryptotermes*) *cavifrons* Banks, **the cavate-headed powder-post termite,** occurs in Bermuda, the West Indies, and southern Florida. It is apparently not a species of economic importance, being found only in natural infestations in dead trees, logs, stumps, and branches.

Kalotermes (*Calcaritermes*) *nearcticus* Snyder, **the nearctic spur-legged termite,** is known only from Florida. In habits, the species of *Calcaritermes* are similar to species of *Cryptotermes* in that they reduce the wood to a fine powderlike consistency and in this respect differ somewhat from the other dry-wood termites.

SUBTERRANEAN TERMITES

Reticulitermes flavipes, **the eastern subterranean termite,** plays the role in the eastern part of the United States that *Reticulitermes tibialis* does in the West, *R. claripennis* and *R. humilis* in the Southwest, and *R. hesperus* on the Pacific coast. Its distribution overlaps that of *R. tibialis*. It also occurs in Ontario, Canada, in northern Guatemala and Mexico and in certain localities along the Mediterranean Sea in Europe, especially in southern France. This termite attacks and destroys the woodwork of buildings and materials stored therein, telegraph and telephone poles, fence posts, railroad ties, and, occasionally, living trees, shubbery, flowers, and crops. It is a very destructive termite, because it weakens the foundation timbers of buildings (U. S. Bur. Ent. *418*).

In the United States the colonizing flights of outdoor colonies of *Reticulitermes flavipes* occur in the warmer part of the day in March or April, or early in May. Swarms may also occur in September, October, or November. Swarms may appear indoors in any month. The same colony may swarm as many as four times over a period of about a month, with males and females in relatively equal numbers. The first swarm is the largest. Young and mature brachypterous supplementary reproductive forms are found in fairly large numbers, and fewer numbers of apterous (wingless) supplementary forms each year in the same colony, usually with a very much greater number of macropterous, or winged, reproductive adults. But before the colonizing flight the former two types disappear; presumably, leaving by means of subterranean tunnels to establish new colonies. Incipient colonies are founded by dealated adults which burrow under pieces of decaying wood in or on the soil. Rarely do they utilize crevices in trees or logs, probably because of the less certain moisture supply. Young colonies established by brachypterous adults are to be found in similar locations. Whether crossing occurs between dealated and brachypterous reproductive types in young colonies is doubtful, but it is certainly to be found in old, well-established colonies.

Macropterous queens reach a maximum length of 14.5 mm. and a breadth of 4 mm.; brachypterous queens, a length of 12 mm.; apterous queens, a length of 7 mm.[16] Macropterous reproductive adults probably head colonies more commonly, with brachypterous forms next in frequency, and apterous forms rarest. The last two types are polygamous, and large numbers of queens occur with small numbers of males. All these reproductive forms are long lived. In artificial colonies in the laboratory, workers sometimes kill them if the colonies are frequently disturbed and they become greatly excited.

There is no definite, permanent royal cell; queens are always active. The reproductive forms are usually found in the more protected inner wood, often near hard knots. If conditions are unfavorable in winter, they migrate from wood into the soil or in galleries in

[16] All these were the physogastric, or postadult stage, with abdomen greatly enlarged. They were measured while living. When preserved in alcohol, a maximum length of 16.5 mm. was found for macropterous queens. Termites are among the few insects that grow after becoming adult.

wood to cells below the frost line. Occasionaly, physogastric macropterous queens are found below ground during the heat in summer in the roots of trees; also both macropterous and brachypterous reproductive forms are frequently found in the wood in the base of telegraph and telephone poles below the surface of the ground. The galleries are rambling, and the colonies migrate with changing environment. Where these termites are infesting a building, it is usually impossible to locate the main colony.

The rate of egg laying is slower in recently established colonies, and from 6 to 12 eggs comprise the first batch; eggs require from 30 to 90 days to hatch. The male and female continue to live together for life unless an accident intervenes. The length of life of these macropterous reproductive forms is unknown in nature, but from their size in relation to their known rate of growth they live for many years; they have been kept alive in colonies in the laboratory for 6 years. Copulation occurs at irregular intervals, and gradually the colony increases in size. In well-established colonies tens of thousands of eggs are to be found. Large colonies, although spread out and difficult to estimate as to size, are known to contain hundreds of thousands of individuals. Very few data are available as to the relative proportions in the castes, but workers and macropterous forms usually predominate, varying according to the time of year.

Reticulitermes tibialis Banks, **the arid-land subterranean termite,** is the termite most common in the Western States, and probably the most widely distributed species of *Reticulitermes* in the United States. It lives under the most varied conditions, and its ecology presents a fascinating study.

In the Chicago area, in Nebraska, and in California it lives among sand dunes, infesting small pieces of wood partly buried in the sand, and making shelter tubes through the sand. In Colorado it occurs at high elevations on mountain sides up to 7,000 feet elevation, and in Kansas and Texas it is to be found in heavily sodded prairies and in hard-baked and often in alkali soil. It is also found in moist river-bottom lands and along streams in canyons, but essentially it is a desert or prairie species. Its distribution overlaps that of *R. flavipes* in the Eastern States. In the Southwest it has damaged or killed hardwood nursery stock in forest nurseries. Colonizing flights occur both in spring and summer. Brachypterous reproductive forms have been found in the roots of scrub oak below the ground in the Garden of the Gods, in Colorado. Apterous reproductive forms were found under a stone in the same locality.

Several other species of *Reticulitermes* and one of *Heterotermes* are known in the Eastern States. With the exception of *R. virginicus* they are of little economic importance, but as they are sometimes encountered, these species are listed as follows:

R. hageni Banks, **the light-colored termite,** and *R. virginicus* Banks, **the southern subterranean termite,** are confined to southeastern and central western parts of the United States. *R. arenincola* Goellner has been found in the vicinity of Chicago in the sand dunes. *Heterotermes* sp., **the Florida straight-mandibled subterranean termite** (soldier caste only), has been found in Florida. It may prove to be a species destructive to the woodwork of buildings as are some of the other species of this genus.

GRASSHOPPERS, KATYDIDS, WALKINGSTICKS, AND RELATED FORMS

Order ORTHOPTERA

By N. D. Wygant

The Orthoptera form an order of insects, some common representatives of which are the grasshoppers, crickets, katydids, walkingsticks, mantids, and cockroaches. For the most part they are fairly large. The front wings are leathery or parchmentlike and are called tegmina. The hind wings are thinner and membranous and are folded when the insect is at rest in fanlike pleats beneath the forewings. In many species, such as walkingsticks, the wings are rudimentary. The mouth parts are well developed for biting and chewing. The nymphs, or immature insects, especially those of wingless species, resemble the adults. In the other species the wings are not fully developed until the adult stage is reached.

With the exception of the mantids, which are carnivorous, nearly all forms are injurious to vegetation. The tree crickets and others feed on both vegetable and animal material. While this is a relatively large order of insects and of great economic importance, very few are important forest pests.

Grasshoppers, katydids, crickets, and other members of this order, which from time to time become tremendously abundant, are a very valuable source of food for game birds and many insectivorous mammals. Turkeys, grouse, and chickens are particularly fond of these insects. The grasshoppers are of interest to the sportsman as one of the most satisfactory baits for many species of fish. Their large size, great abundance, and tough bodies, which insure good lasting qualities on the hook, make them superior to many other kinds of insects. Crickets are especially liked by black bass, but their soft bodies are difficult to keep on the hook.

Entomological literature has been consulted freely in preparing the section on Orthoptera, but space limits reference to only the more important publications. Blatchley (*48*) contributed the most complete treatise of the order. Other important reports were by Fulton (*174*) on the tree crickets of New York, by Hebard (*213*, *214*, *215*, *216*) on the Orthoptera of the Midwestern States, and by Morse (*308*) on the Orthoptera of New England.

KEY TO THE FAMILIES

1.	Legs nearly equal in size, femora of hind legs not distinctly enlarged for leaping; running insects	2
	Hind legs elongate, femora enlarged for leaping; jumping insects	4
2.	Front legs fitted for grasping and holding prey — Mantidae	
	Front legs simple, not fitted for grasping prey	3
3.	Body strongly depressed, oval in dorsal aspect — Blattidae	
	Body elongate and slender — Phasmatidae	
4.	Antennae much longer than body and setaceous	5
	Antennae much shorter than body and relatively heavy	6
5.	Tarsi four segmented; ovipositor forming a strongly compressed, generally sword-shaped blade — Tettigoniidae	
	Tarsi usually three segmented; ovipositor forming a nearly cylindrical, straight needle — Gryllidae	
6.	Front legs short, stout, and fitted for digging — Mole crickets (Gryllidae)	
	Front legs not fitted for digging — Acrididae	

Family BLATTIDAE

The Cockroaches

The cockroaches can be distinguished from other families of Orthoptera by their depressed, oval form; by their nearly horizontal head which when at rest is nearly concealed by the broad pronotum; by their slender depressed legs of almost equal size; and by the absence of an ovipositor at the end of the abdomen.

Cockroaches live chiefly on animal and vegetable refuse. Some of them are found under the bark and in cavities of the wood of dead trees, but they are of no importance to forestry. Other species are serious household pests.

Family MANTIDAE

The Mantids

The mantids are medium to large-sized insects with biting mouth parts. By many writers the mantids are considered and treated as a distinct order rather than a family. They are easily recognized by their unusually long prothorax, sometimes nearly as long as the remainder of the body, and by their front legs, which are fitted for grasping their prey. The coxae of the front legs are long, and the femora and tibiae are armed with spines so that when the tibiae are folded back against the femora the spines will securely hold the prey seized by the mantids.

The head is short, much wider than long, triangular, vertical, and loosely joined to the thorax so as to be freely movable. The eyes are very large, convex, and prominent. Three ocelli are located on a triangular elevation just above the insertion of the antennae. The front pair of wings is leathery and the hind pair membranous.

All species feed on any insects which happen within their reach, usually flies, bees, or moths. They are found on the foliage of trees, shrubs, and other plants where they wait for their prey with their front legs raised (fig. 13, *A*). They are sometimes called praying mantids because of the resemblance of their raised front legs to hands uplifted in prayer. Although the mantids devour a large number of honeybees and other beneficial insects, they probably more than make up for this loss by destroying a larger number of harmful ones.

The eggs are laid in the fall of the year in large masses attached to twigs and covered with a tough gray or brown mucus (fig. 13, *B*). They hatch the following spring. The life cycle is completed in 1 year through a gradual metamorphosis.

Most of the forms are tropical, and only a few species are found in the Eastern States. Some of these were introduced from Europe or Asia.

The Carolina mantis (*Stagmomantis carolina* (Johan.)) is our most common native species and is found from the Atlantic coast to eastern New Mexico and as far north as Colorado, Missouri, Illinois, and southern Pennsylvania. The male is grayish brown with semitransparent, grayish, more or less mottled, smoky-brown outer wings. The body and legs are often in part greenish yellow. The female is either greenish yellow with bright-green outer wings or like the male.

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The outer wings of the female are notably shorter than the abdomen. The adults are approximately 2 to 3 inches long.

Stagmomantis floridensis Davis is somewhat more slender and longer than *S. carolina* and is confined to Florida.

Stagmomantis limbata (Hahn), **the bordered mantid,** is similar in appearance and habits to *S. carolina*, but is found only in Mexico, Arizona, New Mexico, and Texas.

The Chinese mantis (*Tenodera sinensis* Sauss.) was accidentally introduced near Philadelphia, Pa., about 1896 from Asia and has

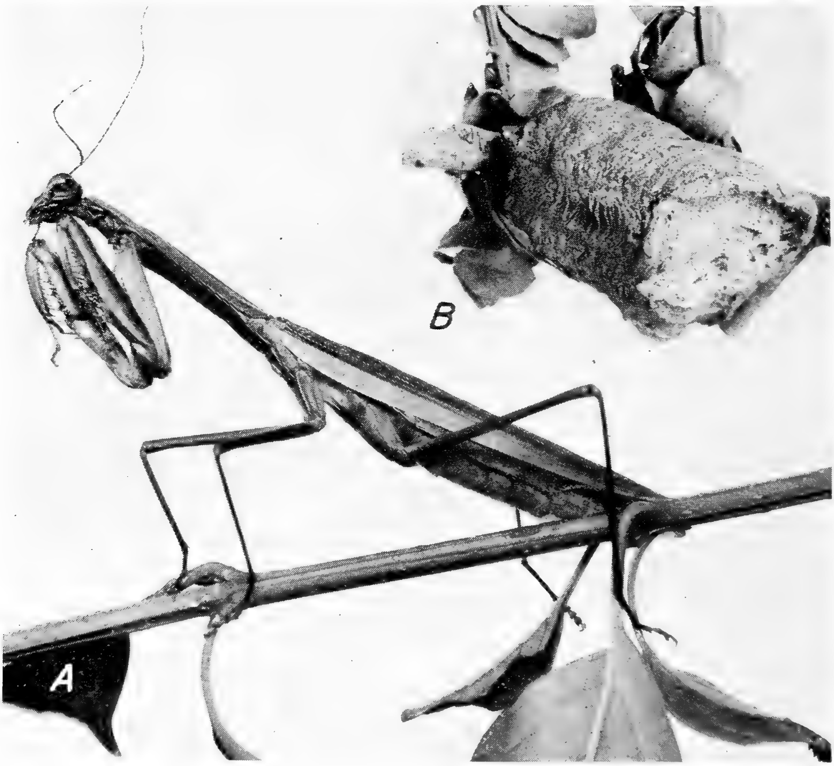

FIGURE 13.—*A*, The Chinese mantis (*Tenodera sinensis* Sauss.) : *A*, Adult, about natural size; *B*, egg mass. (Courtesy Conn. Agr. Expt. Sta.)

become quite widely distributed from that source, mainly by introduction. The eggs survive the winters along the coast of the more northern States, but inland the climate apparently is too severe. It is a very elongate and robust insect measuring approximately 4 inches in length (fig. 13). The females are green or greenish-yellow and the males are either of the same hue or wholly brown or brown with the margins of the outer wings green.

Tenodera angustipennis Sauss. is another oriental mantid, first discovered in the United States near Vandyke, Del., in 1930. It has become well established there and will no doubt spread to other localities. It is very similar to *T. sinensis* but is somewhat more slender and smaller.

The European mantis (*Mantis religiosa* L.) was first recorded from the United States at Rochester, N. Y., in 1899. It is a medium-sized, greenish-yellow species.

Litaneutria minor (Scudd.), **the minor mantis,** is much smaller than the other species discussed, being a little more than 1 inch long. It is found among rocks and short grass in the Great Plains and in Mexico.

Family PHASMATIDAE

The Walkingsticks

Our species of this family are remarkable for their resemblance to twigs, but some of the tropical forms resemble leaves. The North American species found in the East have the body elongate, very slender, and subcylindrical; the head free, nearly horizontal, usually subquadrate; antennae long; eyes small, ocelli often absent; abdomen elongate; wings rudimentary except on one in Florida; and legs very long and slender, nearly equal in size. They are slow-moving insects

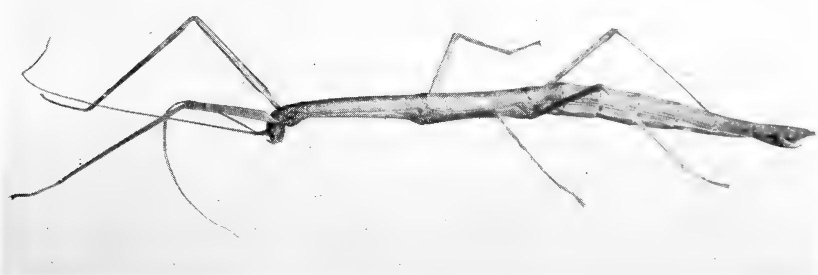

Figure 14.—Walkingstick (*Diapheromera femorata*). About one-half natural size.

and apparently depend upon their mimicry for protection. All species are plant feeders and, except for the species *Diapheromera femorata* (Say) (fig. 14), never become abundant enough to be of economic importance. The eggs are dropped promiscuously to the ground during the fall where they remain over winter and sometimes two winters before hatching. The eggshells are hard and resemble seeds or small beans.

The walkingstick (*Diapheromera femorata* (Say)) is widespread over the United States east of the Rocky Mountains and at times becomes numerous enough to defoliate the trees over large areas. The black oaks and wild cherry are preferred, but it will also feed on other species of hardwood trees and shrubs. Graham (*193*) reported that logging followed by repeated burning in Michigan has produced nearly pure oak forests, and this condition is leading to walkingstick outbreaks. Only recently have fires (which formerly destroyed the eggs) been effectively controlled in the oak hills. Ultimately the outbreaks may lead to the improvement of the stand by killing the black oaks and allowing the better species, such as white oak and red pine, to become more abundant. The spread of the walkingsticks is slow because they are wingless and are not so active as many insects.

The young walkingsticks are pale green, but as they become mature they change to dark green, gray, or brown. The adult females measure up to 3 inches in length and are stouter bodied and longer than the males. Most of them molt four or five times and a few molt six times. After the last molt, in August, mating takes place, and egg laying begins 6 to 10 days later. The eggs are approximately 2.5 mm. in length, bean-shaped, and polished black with a whitish stripe on one side. They are dropped promiscuously from the trees to the ground, where they remain in the litter to hatch the following May or a year from the following May. Under dry conditions many of the young fail to extricate themselves completely from the egg capsule and die.

Two species of tachinid parasites have been reared from the walkingstick in Wisconsin—*Biomya genalis* Coq. and *Phasmophaga antennalis* Towns. The latter species gains entrance to the host by laying its eggs on the foliage which is eaten by the walkingstick. Graham (*193*) also states that several kinds of birds, especially crows and robins, concentrate in infested areas late in the summer. For control in Michigan, Graham recommends that the favored black oak type of forest be converted to safer types made up of white oak and other nonsusceptible hardwoods and conifers. Although the use of ground fires during the time the eggs are in the litter will control this insect, it is not recommended because of other damage it may cause. An arsenical spray (p. 53) or dust applied the first part of June is effective and feasible in recreational areas. (See caution on p. 23.)

Diapheromera velii Coq., **the prairie walkingstick,** frequents tall shrubs and grasses in the Great Plains west of the Mississippi but rarely becomes abundant except in small local areas. It is very similar to *D. femorata* in size, shape, and color, but differs in having the head slightly more elongate, the middle femora of the male without the gray bands found on *D. femorata* and the seventh abdominal segment of the male no longer than the ninth.

Diapheromera blatchleyi (Caud.) occurs from the Great Plains to the Atlantic coast and is similar in habits to the preceding species.

Megaphasma dentricus (Stol), **the giant walkingstick,** is interesting because of its large size, sometimes attaining a body length of 6 inches. It is similar in habits to *Diapheromera femorata* but never has been numerous enough to be destructive.

Anisomorpha ferruginea (Beauv.) occurs from just north of the Ohio River west to southeastern Nebraska, and east through the high country of the Carolinas and Georgia. It feeds on the foliage of trees and shrubs but has never become abundant.

Family **ACRIDIDAE**

The Grasshoppers

The grasshoppers, sometimes called locusts or short-horned grasshoppers, comprise a large family which has been very destructive to agriculture. The members are of all sizes and may be characterized by having short filiform or clubbed antennae, hind legs greatly enlarged for jumping, three-jointed tarsi with a pad between the claws, a very short inconspicuous ovipositor, a pair of narrow tegmina, and a pair of membranous fanlike wings.

The life history is much the same for all species. The eggs, gummed together to form pods, are laid 1 to 3 inches deep in the soil late in the summer or in the fall, usually in grain stubble, meadows, along ditch-banks, fences, and roadsides. In the South the eggs may hatch as early as February, but in the Northern States hatching usually does not occur until May or June. The young grasshopper nymphs resemble the mature insects, except that the wings are not fully developed and functional. Although maturity is reached in 40 to 70 days, the 'hoppers may continue to feed until cold weather. There is usually only one generation a year. There are a few species, especially in the South, that overwinter in the nymphal or adult stage, but these forms never become abundant enough to be destructive. The habits are variable.

Most of the species breed and live in the same general area throughout the year and these are called nonmigratory grasshoppers. A few of the species, however, which build up in vast numbers, leave their breeding grounds when their wings are fully developed and migrate in vast swarms, settling on and devastating farm crops, orchards, shelterbelts, and shade trees. These are known as migratory grasshoppers. One species, *Dendrotettix quercus* Pack., is known to be arboreal in habit and occasionally causes some damage to oak in very local areas.

Grasshopper outbreaks in the United States are largely confined to the northern Great Plains, Rocky Mountain and Plateau States, upper Mississippi Valley, and the Great Lakes region. After crops and grasses have been destroyed they frequently eat the leaves and green bark of both deciduous and evergreen trees commonly planted for shelterbelts and shade trees. One complete defoliation of conifers is fatal. The girdling of the bark on young hardwoods is also fatal.

Although there are a great many species of grasshoppers, five species are responsible for 90 percent of all the grasshopper damage to cultivated crops. The same species kill many shelterbelts and shade trees during their epidemics. They are **the lesser migratory grasshopper** (*Melanoplus mexicanus* (Sauss.)), **the differential grasshopper** (*M. differentialis* (Thos.)) **the two-striped grasshopper** (*M. bivittatus* (Say)), **the red-legged grasshopper** (*M. femur-rubrum* (Deg.)), and **the clear-winged grasshopper** (*Camnula pellucida* (Scudd.)). For a good discussion of these grasshoppers see Parker (*329*).

The migratory grasshopper (fig. 15) is about 1 inch long, reddish brown with a distinct patch of black on the neck or collar, and is a strong flier. It is found throughout the United States, but is most abundant in the northern Great Plains. It is similar in most respects to the Rocky Mountain locust, or grasshopper, which ravaged the Western States years ago.

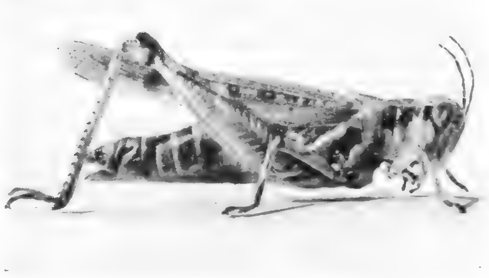

FIGURE 15.—The migratory grasshopper (*Melanoplus mexicanus*), × 2½.

The differential grasshopper is 1½ inches long, yellow with contrasting black markings, has clear glossy hind wings, and hind legs usually distinctly marked with yellow and black chevron-shaped bars on the sides of the thighs. It is seldom found farther north than the southern counties of North Dakota and Minnesota and is most injurious in the Great Plains, Mississippi Valley, and Southern States.

The two-striped grasshopper is about 1¼ inches long and slightly more robust and shorter than the preceding species. It is greenish yellow underneath, with two yellow stripes down its otherwise brown back from its head to the end of its wings. It is found from southern Canada to Mexico, except in the South Atlantic States.

The red-legged grasshopper is about ¾ inch long, reddish brown above and yellow beneath, with its hind legs tinged with bright red, and its hind wings colorless. It occurs throughout the United States.

The clear-winged grasshopper is about 1 inch long, yellow to brown, with clear or pellucid hind wings and the front wings distinctly blotched with large brown spots. It occurs in all the Northern States but is seldom found very far south. For control measures found successful against this and the other ground-feeding species, see Parker (*329*) and page 33 of this publication.

Dendrotettix quercus Pack. is strictly a forest insect, feeding on the foliage of oak. It is about 1 inch long, yellow or greenish yellow varied with piceous, and has a large head. Some individuals are low-winged and others short-winged. It was first discovered in northeastern Texas and is now known to occur as far north as Nebraska, southern Iowa, and Illinois. It also occurs in New Jersey and Long Island. The species appears in waves of devastating local abundance separated by periods of virtually complete absence. The egg pods are deposited in the soil in late summer and fall. The nymphs hatch from the eggs in the spring and climb the trees to feed. They are very active but shy in all stages of growth. The adult stage is reached during the period from June to September.

Family TETTIGONIIDAE

The Katydids, Long-Horned Grasshoppers, Meadow Grasshoppers, Cave Crickets, Camel Crickets

The Tettigoniidae are mostly large insects with long, slender, tapering many-jointed antennae which usually extend backward far beyond the tip of the abdomen. The tarsi are four-jointed. The ocelli are nearly always absent. The ovipositor is sword- or sickle-shaped. They vary a great deal in their habits and appearance (fig. 16).

The arboreal forms are usually long-winged and green, matching the foliage on which they feed. They seldom become numerous enough to be pests. The eggs of the arboreal forms are elongate-oval, flat, white, or brownish and laid overlapping end to end in rows on the leaves or twigs or inserted in the edges of the leaves. Most of the species of this family overwinter in the egg stage, and when they hatch in the spring the young resemble the adults except for the absence of wings. The stridulation, or music, of the males is well known. The familiar "katydid" sound is produced by rubbing a row of minute filelike teeth on the under side of the upper tegmen over a vein on the upper surface of the other wing.

The grass-inhabiting forms are often large, wingless, and destructive to farm crops. The ground-inhabiting forms are usually wingless and gray or brown. The most important member of the family is the well-known **Mormon cricket** (*Anabrus simplex* Hald.) which when abundant is very destructive to forage and cultivated crops in the West.

The family is a large one. Many of its members inhabit trees and shrubs but are never numerous enough to cause injury, and only a few of the more common ones will be mentioned.

The species of bush katydids treated by Blatchley (*48*) as occurring in the eastern part of the United States are typically arboreal in their habits, pale green, and of medium size. The vertex is compressed and hollowed out on both sides for the better accommodation of the eyes. The tegmina are long and narrow and only a little or slightly broader at the middle than at the apex. The females lay their eggs in the edges of the leaves between the upper and lower epidermis.

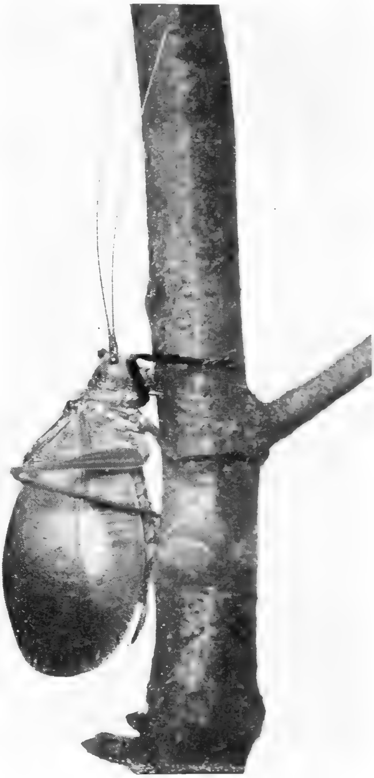

FIGURE 16.—Katydid (*Cyrtophillus perspicillatus* L.), resting on a branch. (Courtesy Conn. Agr. Expt. Sta.)

The most widely distributed and abundant species is **the forktailed bush katydid** (*Scudderia furcata* (Brun.)). It gets its name from the forked appendages at the tip of the abdomen of the male. *S. texensis* (Sauss. & Pictet) is also a common form but is less restricted to trees than are the others. *S. pistillata* (Brun.) is an arboreal form found around the edges of lakes and swampy places on bushes, tall herbs, and grasses. *S. curvicauda* (Deg.) is commonly found on oak.

Three species of round-headed katydids, listed by Blatchley (*48*) as occurring in the eastern part of the United States, differ from *Scudderia* in having the vertex rounded. They are typically pale green, but some specimens may be pink. They lay their eggs in the soil. *Amblycorpha oblongifolia* (Deg.), the most common species, occurs on shrubs and weeds along edges of thickets and on fence rows, especially in damp localities. *A. rotundifolia* (Scudd.) is more terrestrial in habits and is common except in the Southern States. *A. uhleri* Stol is mainly southern in range.

Microcentrum rhombifolium (Sauss.) is 25 to 35 mm. long, leaf green, and truly arboreal. It is widely distributed in the East. Its eggs are grayish brown, long, oval, and very flat, 5.5 mm. long and 3 mm. wide. They are laid on sides of twigs in double rows, those in one row overlapping about one-fourth their length and alternating with those of the other row. ***The angular-winged katydid*** (*M. retinerve* (Burm.)) is smaller than the above species and more southern, its range extending from New Jersey west through southern Indiana to Kansas and Nebraska and south throughout the Southern States.

Pterophylla camellifolia (F.), **the true katydid,** is a large, green, robust form. The tegmina are dark green, leaflike, very broad, concave within, longer than the wings, and wholly enclose the abdomen. The prosternum is armed with two slender tapering spines. This broad-winged katydid dwells in small colonies in dense foliage of forest and shade trees and is more commonly heard than seen. Its call is begun soon after dusk and often continues till dawn and is the loudest of any member of the family. The known range extends from New England west to northern Illinois and south and west to North Carolina, northern Georgia, and central Kansas. The eggs are thrust by means of the ovipositor into crevices of loose bark or into soft stems of woody plants. The eggs are dark slate color, about 6.5 mm. long and 2 mm. wide, very flat, pointed at each end, and with the edges beveled off.

Camponotus carolinensis (Gerst.) is not important, but it has a unique habit of rolling leaves into a nest in which it hides. It is medium sized, 12 to 15 mm. long, reddish brown above, yellowish white beneath, and wingless. The middle and hind pair of femora are mottled with dark brown. On each of three posterior dorsal segments of the abdomen is a dark-brown transverse bar. Its range extends from New Jersey west to southern Illinois and south to Tennessee, Mississippi, Georgia, and Florida.

Family GRYLLIDAE

The Crickets

The crickets are medium-sized, jumping insects usually with long filiform antennae, three-jointed tarsi, and a spear-shaped ovipositor. The tegmina lie flat on the back and are bent down abruptly at the sides of the body. The wings may be fully developed, abbreviated, or wanting. The hearing organs when present are visible on one or both sides of the fore tibia. The calling organs on the male are located near the base of the dorsal surface of the tegmina.

The crickets are nocturnal, the males being shrill and loud singers. They are variable in habits, living in or on the ground, or in bushes and trees, and feeding on vegetable or animal matter. Although they are commonly found in countless numbers, they are not so serious pests as some of the other Orthoptera. The tree crickets, which injure young branches with their oviposition scars, and the mole crickets, which occasionally cause some injury in nurseries, are the only crickets injurious to trees or shrubs.

The mole crickets are quite different in appearance from the more typical crickets. Their front legs are fitted for digging, being greatly broadened and shaped somewhat like the front foot of a mole. Their hind legs are but little enlarged and their ovipositors are not visible. They burrow in sandy soils or loose soils somewhat after the manner of moles. They feed on roots, earthworms, and on other insects. At night they feed near the surface, cutting off the plants.

The mole crickets can be controlled by scattering a poisoned bait similar to the grasshopper baits. Cottonseed meal substituted for the bran and sawdust in the grasshopper formula (p. 33) is reported to make the formula more effective against mole crickets.

The northern mole cricket (*Gryllotalpa hexadactyla* Perty) is the most common form and is found from Canada to the southern part of South America. It inhabits the moist mud and sand along the margins of the smaller streams and ponds and usually causes no damage.

Gryllotalpa gryllotalpa (L.), **the European mole cricket,** has become established at a few points along the coast in the East and may become a serious pest of nurseries. It is large, robust, approximately 1½ inches long, reddish or brownish yellow tinged with fuscus above and pale brownish yellow beneath. The front legs terminate in four strong bladelike teeth called dactyls.

FIGURE 17.—The changa (*Scapteriscus vicinus* Scudd.).

The mole crickets belonging to the genus *Scapteriscus* can be distinguished from *Gryllotalpa* by the presence of two dactyls instead of four; otherwise they are quite similar in appearance. **The changa** (*S. vicinus* Scudd.) (fig. 17) is found in the coastal plain in the Southeastern States, as well as in the West Indies and parts of South America. It attacks mainly truck crops, pastures, and lawns. This species is approximately 1¼ inches long, brown above, and light brown beneath. Thomas (*407*) records one cycle annually, the eggs being deposited in the burrows in the spring.

Scapteriscus abbreviatus Scudd. is brownish fuscus blotched with yellow. It is recorded from Florida and Georgia, and from parts of South America.

The southern mole cricket (*Scapteriscus acletus* R. & H.) is somewhat more slender and pinkish buff in color. It is recorded from Georgia, Texas, and other Southern States.

The tree crickets are an interesting group of small, delicate, pale-colored crickets that are definitely arboreal. Injury to trees and shrubs is caused by the females, which chew small pits in the bark and then drill into the holes with their ovipositors to lay their eggs. This injury causes the branches to break. Fulton (*174*) reported that tree crickets also fed on aphids and scale insects, as well as on foliage and fruit, and for that reason may be considered beneficial at times.

The tarsi are three-jointed, the second segment being small and compressed. The legs are very slender and in *Oecanthus* the hind tibiae are armed with a double row of slender spurs interspersed with toothlike spines. The tegmina of the males are very broad and flat and lie in a horizontal position over the abdomen. The tegmina of the females are narrow and wrapped closely about the body. The song of the male, which seems to attract the female, is produced by a minute rasp on the inner side of the forewing which is scraped by a structure on the inner edge of the opposite wing. On the metanotum of the male is a glandular secretion which attracts the female. They overwinter in the egg stage. One generation is produced annually.

The snowy tree cricket (*Oecanthus niveus* (Deg.)) is widely distributed throughout the United States. It is very pale greenish white with a single black spot on each of the first two antennal segments. It inhabits trees, bushes, and orchards, preferably in the open. The eggs are deposited singly in branches.

Oecanthus angustipennis Fitch is widely distributed in the eastern part of the United States. It is pale greenish white with a **J**-shaped mark on the basal segment of the antenna. The eggs are deposited singly in the branches of trees.

Oecanthus exclamationis Davis is similar in appearance, habits, and range to the preceding species but can be distinguished by the mark on the basal segment of the antenna being club-shaped instead of like a letter **J**.

The black-horned tree cricket (*Oecanthus nigricornis nigricornis* Wlkr.) is widely distributed in the United States. It is greenish-yellow with the head and pronotum either wholly black or with three more-or-less distinct, lengthwise, black stripes. The eggs are deposited in rows in canes of raspberry and blackberry and the branches of trees, and it is quite destructive in certain berry-growing regions. **The four-spotted tree cricket** (*Oecanthus nigricornis quadripunctatus* Beut.) is a subspecies that has two distinct spots on each of the two basal segments of the antennae. The ventral surface of the abdomen is pale rather than dark.

Oecanthus pini Beut., **the pine tree cricket,** has been found only in the Eastern States. The head, thorax, and antennae are reddish brown. It lays its eggs about 3 mm. apart in regular rows in pine bark.

Oecanthus latipennis Riley occurs in the eastern part of the United States. The male is greenish white and the female is pale yellowish green. The basal joints of the antennae are pinkish. It deposits from 4 to 12 eggs in a single hole in the smaller twigs of shrubs and vines.

Neoxabea bipunctata (Deg.) is widely distributed in the East but is rather rare. It differs from the species of *Oecanthus* by having the hind tibiae unarmed and the wings nearly twice as long as the tegmina. It lays its eggs singly in the bark or cambium of various trees, vines, and shrubs.

The tree crickets can be controlled by spraying with an arsenical early in the summer, when they are young.

SUCKING INSECTS

Order HEMIPTERA

By. W. L. Baker, P. W. Oman, and Thaddeus J. Parr

The order Hemiptera is generally considered as being composed of two suborders, Heteroptera and Homoptera. Many species belonging to these groups are recognized as serious pests of agricultural crops, but comparatively few have received attention as forest pests. This is probably because the injury caused by the feeding of sucking insects is rather inconspicuous and often slow in development. On many trees it does not become apparent until after the insects have disappeared; consequently, the weakened or unhealthy appearance of the trees is attributed to unfavorable growing conditions or some other factor. Much additional study is therefore needed to determine the actual importance of the many species commonly found on forest trees and to develop effective control measures for the ones that prove to be of economic significance.

The following keys are intended to facilitate recognition of economically important species. Species of little or no economic importance, but commonly encountered in forests, will usually run to family or subfamily names only.

FIELD KEY FOR APPROXIMATE DETERMINATION OF SUCKING INSECTS OF THE ORDER HEMIPTERA

I. Wings, when present, of uniform texture; usually carried rooflike over sides and dorsum of abdomen; mouth parts attached to or projecting from the posterior ventral portion of the head; head closely joined to the prothorax; legs present or absent in adult stages
Suborder Homoptera (p. 119)

II. Wings usually present, not of uniform texture; forewings carried flat over the back with the tips overlapping; mouth parts attached to the front part of the head; head generally not closely joined to the prothorax; legs always present-----Suborder Heteroptera (p. 112)

FIELD KEY TO HETEROPTERA

1.	Antennae shorter than head, generally hidden in a cavity beneath the eyes------Aquatic or semiaquatic groups (not treated)--	
	Antennae as long as or longer than head, not hidden in a cavity beneath the eyes----------------------Terrestrial groups	2
2 (1).	Antennae 5-segmented; scutellum reaching at least to the base of the membranous portion of the forewing-Pentatomidae (p. 114).	3
	Antennae 4-segmented; scutellum not reaching the base of the membranous portion of the forewing----------------------	5
3 (2).	Tarsi 3-segmented; sternum without keel--------------------	4
	Tarsi 2-segmented; sternum with a keel---------Acanthosominae	
4 (3).	Beak slender, basal joint slender and lying in a groove along under side of head (phytophagus)-------------Pentatominae	
	Beak robust, basal joint short, thick, and inserted at the apex of head; under side of head without groove. (Predaceous except in the first instars of some species.)------Asopinae (p. 114).	

KEY TO THE GENERA OF ASOPINAE

a. Front femora armed beneath at apical third or fourth with a. short spine.
  b. Scutellum broad, U-shaped ---- *Stiretrus* (p. 114).
  bb. Scutellum triangular, apex narrowed *Perillus* (p. 114).
aa. Front femora without spine.
  c. Larger, 14 or more mm. (9/16 inch); cheeks slightly longer than middle lobe --- *Apateticus* (p. 114).
  cc. Smaller, less than 12 mm. (1/2 inch); cheeks equaling middle lobe ---------------- *Podisus* (p. 114).

5 (2). Forewing with a cuneus (triangular section of forewing forming the outer apical part of the leathery portion) ---- 6
Leathery portion of forewing entire, without any transverse incision setting off a cuneus ---------------------------------- 7
6 (5). Beak 4-segmented; membranous portion of forewing with 2 small cells, rarely 1, at base ----------------- Miridae (p. 118).
Beak 3-segmented; membranous portion of forewing without cells or apparent veins --------------- Anthocoridae (p. 118).
7 (5). Beak robust, curved, apex normally resting in a groove located between and in front of the forelegs ------ Reduviidae (p. 117)
Beak slender, without evidence of a groove between and in front of the forelegs --- 8
8 (7). Tarsi 2-segmented; body flattened both above and below ------- 9
Tarsi 3-segmented; body convex at least below --------------- 10
9 (8). Forewings not lacelike (normally living under bark) Aradidae (p. 115).
Forewings lacelike, having a network of veins enclosing membranous areas ---------------------- Tingidae (p. 115).

KEY TO THE GENERA OF TINGIDAE

a. Side margins of pronotal expansions and of outer margins of the forewings usually furnished with a fringe of small spines; lateral margins of forewings when at rest parallel or slightly converging apically ----- *Corythucha* (p. 115).
aa. Side margins of pronotal expansions and outer margins of the forewings without spinules; outer margins of the forewings convexly rounded, never parallel *Stephanitis* (p. 117).

10 (8). First segment of the beak short, thick; front femora larger than middle or hind femora; front femora and tibia set beneath with numerous fine setae (predaceous) ---------- Nabidae (p. 118).
First segment of the beak slender, nearly as long as head; femora and tibia usually not adapted for grasping prey ------------- 11
11 (10). Membranous portion of forewing with many veins (more than 8) Coreidae (p. 118).
Membranous portion of forewing with not more than 4 to 6 veins Lygaeidae (p. 119).

KEY TO THE FAMILIES OF HOMOPTERA

1. Beak arising at a point between or behind the base of the front legs - 2
Beak clearly arising from the lower margin of the face --------- 5
2 (1). Tarsi 1-segmented, with 1 apical claw; females wingless and usually remaining fixed to the host plant throughout life, scalelike or covered with a scale; males usually with 1 pair of wings ----------------- Superfamily Coccoidea (scale insects).
Tarsi 2-segmented, with 2 apical claws. Wings, when present, usually 4 in number. Usually active species --------------- 3
3 (2). Hind femora enlarged for jumping Psyllidae (jumping plant lice).
Hind femora not enlarged ---------------------------------- 4
4 (3). Legs short, tarsal segments equal in size; wings usually opaque, whitish, frequently marked with bands or spots Aleyrodidae (whiteflies).
Legs long and slender, basal segment of tarsus often short; wings usually transparent; cornicles usually present Superfamily Aphoidea (plant lice).

KEY TO THE FAMILIES OF HOMOPTERA—Continued

5 (1). Intermediate coxae long, similar to the anterior coxae, and attached at a point distant from middle of body; usually a scalelike sheath over base of forewing at point of attachment Superfamily Fulgoroidea.
Intermediate coxae short, not similar to the anterior coxae, and attached near middle line of body; no scale over insertion of forewing____________________ 6
6 (5). With three ocelli arranged in a triangle______Cicadidae (cicadas)
With not more than two ocelli____________________ 7
7 (6). Pronotum greatly prolonged posteriorly, its anterior portion vertical__________________________Membracidae (treehoppers).
Pronotum not prolonged posteriorly____________________ 8
8 (7). Posterior tibia armed with a few stout spines, no setae Cercopidae (spittle bugs).
Posterior tibia armed with many stout setae arranged in rows Cicadellidae (leafhoppers).

FIELD KEY TO THE GENERA OF SCALE INSECTS BASED PRINCIPALLY ON HOST PLANTS

1. Restricted feeders on specific host plants____________________ 2
General feeders found on a variety of plant hosts______________ 4
2 (1). On conifers____________________ 3
On hardwoods (see appropriate host).
Beech branches and trunks; mature female oblong; 1 mm. or less long; color yellow, body covered with white woolly wax *Cryptococcus* (p. 140).
Celestrus or euonymus leaves and stems, female oblong, broadened posteriorly ,dirty gray to nearly black; small white male scales usually abundant and conspicuous in clusters on leaves__________________*Unaspis euonymi* (p. 149).
Elm bark, branches and stems; mature female oval; about 2 mm. long; color red brown, body with white waxy fringe about margin________________________*Gossyparia* (p. 142).
Euonymus or Celestrus leaves and stems; female oblong, broadened posteriorly, dirty gray to nearly black; small white male scales usually abundant and conspicuous in clusters on leaves________________________*Unaspis euonymi* (p. 149).
Horsechestnut twigs and branches; mature female oblong; 1 to 2 mm. long; color dark gray to black with lighter border *Aspidiotus*, in part (p. 148).
Magnolia twigs and branches; mature female round or slightly oblong; about 1 centimeter in diameter; color rich dark brown; very convex______________________*Neolecanium* (p. 144).
Maple:
a. On leaves. Mature female 4 mm. or more long.
b. Color dark purplish; large white egg sac with 2 longitudinal grooves and several transverse ridges__________________*Pulvinaria* (p. 143).
bb. Color yellow; body covered with large white cottony mass of wax thread. On sugar maple *Phenacoccus* (p. 142).
aa. On stems and branches (Southern States). Mature female round to oval; about 2 mm. long; color gray; dark nipple concentrically placed__*Chrysomphalus* (p. 149).
Oak:
a. Mature female gall or berrylike in shape; 3 to 4 mm. in diameter; color brown with mottling. On twigs and sometimes on leaves_______________*Kermes* (p. 140).
aa. Mature females nearly round; 1 to 1½ mm. in diameter; color reddish brown; body covered with translucent greenish wax "test"; causing small craterlike or pitlike galls on twigs, branches, and stems. Various species of white oak group______*Asterolecanium* (p. 143).
Pecan branches, stems and fruit in Southern States, not producing red coloration under infested bark; mature female round to oval; about 2 mm. long; color gray; dark nipple concentrically placed______________*Chrysomphalus* (p. 149).

FIELD KEY TO THE GENERA OF SCALE INSECTS BASED PRINCIPALLY ON HOST PLANTS—Continued

2 (1). On hardwoods (see appropriate host).—Continued
Tulip tree twigs and branches, sometimes on magnolia and poplar; mature female hemispherical; 5 to 8 mm. in diameter; color dark brown .... *Toumeyella*, in part (p. 144).

3 (2). On pines (five alternatives)
Hard pines at base of needles on new growth during summer; mature female oval; woolly wax covering 1 cm. or more in length; color of woolly covering white
Pseudophilippia (p. 144).
Scotch, jack, lodgepole, and other hard pines on twigs and branches; mature females oval; 5 to 7 mm. long; color reddish brown; dorsal surface very convex and pitted or irregular
Toumeyella, in part (p. 144).
Hard pines on new shoots and under bark scales; mature female long oval; 2 to 4 mm. long; color dark brown to black; producing long flat white egg sac under bark scales of branches and trunk; immature instars causing small pit galls in epidermis of new growth; new growth dying in July, August, and September .... *Matsucoccus* (p. 139).
Pine leaves, various species; mature female pear-shaped; 1½ to 3 mm. long; color dirty white to dirty gray
Phenacaspis (p. 149).
Pine, various species, and Douglas fir leaves; mature female oval; 1 to 2 mm. long; color dark gray; concentric nipple orange .... *Aspidiotus*, in part (p. 148).

On other conifers (four alternatives)
Arborvitae twigs; mature female, round to oval; 3 to 4 mm. long; color reddish or reddish brown, sometimes mottled; dorsal surface very convex ...... *Lecanium*, in part (p. 145).
Hemlock leaves and twigs; mature female oblong; 1 to 2 mm. long; color dark gray to black with lighter border
Aspidiotus, in part (p. 148).
Juniper leaves and twigs; mature female nearly circular; about 2 mm. in diameter; color light gray to white; central or concentric nipple yellow .... *Diaspis* (p. 151).
Spruce, various species, at base of buds on new growth; mature female round; 3 to 4 mm. in diameter; color light brown; dorsal surface very convex .... *Physokermes* (p. 147).

4 (1). Body of adult female covered by a "scale" made up of secreted matter plus the cast skins of the two larval stages 5
Body of adult female otherwise, as naked, covered with waxy or woolly secretion, enclosed in a secreted shell, never covered by a scale as described above 7

5 (4). Scale of adult female elongated, narrowed anteriorly with the larval cast-skins terminal, broadened posteriorly 6
Scale of adult female circular to oval with exuviae central or subcentral .... *Aspidiotus*, in part (p. 147).

6 (5). Scale of adult female white or dirty white
Chionaspis, in part (p. 149, 151).
Scale of adult female dark, usually dark brown
Lepidosaphes (p. 151).

7 (4). Body small, not exceeding 2 to 3 mm. in diameter, enclosed in a thin transparent shell with a fringe of secretion around margin
Asterolecanium, in part (p. 142–143).
Body not enclosed in a shell, mostly considerably larger, 4 mm. or more 8

8 (7). Adult female at maturity with body remaining soft, fringed at hind end with a large ovisac showing conspicuous flutings
Icerya (p. 139).
Body at maturity becoming hard and eventually brittle; ovisac, if present, loosely formed, not fluted 9

9 (8). With a short, stout posterior ovisac .... *Pulvinaria* (p. 143).
Body naked at maturity, eggs deposited beneath it
Lecanium (p. 145).

Superfamily *APHOIDEA*

FIELD KEY TO THE APHIDS, BASED PRINCIPALLY ON HOST PLANTS

1. Aphids causing galls or gall-like formations 2
   Not causing galls or gall-like formations 19

2 (1). On conifers 3
   On hardwoods 10

3 (2). On balsam fir twigs, branches, and trunks, causing "gouty" swellings at tips of twigs and stems, often causing leaves to turn red and trees to die. Insects $\frac{1}{2}$ to $1\frac{1}{2}$ mm. long: color dark brown to black, covered with white flocculence .... *Chermes piceae* Ratz. (p. 137).
   On spruce 4

4 (3). Causing only terminal galls or gall-like formations 5
   Causing galls other than terminal galls 8

5 (4). Terminal galls compact, small 6
   Terminal galls larger, composed of entire new growth with needles thickened at base, or loose and on current growth 7

6 (5). Terminal galls conelike, compact; on new growth. On black, Engelmann, red, or Sitka spruce .... *Pineus pinifoliae* (Fitch) (p. 138).
   Terminal galls small, not conelike, on current year's growth. On spruce, mostly red and black .... *Chermes strobilobius* Kalt. (p. 137).

7 (5). Terminal galls comprising entire new growth and causing thickening of needles at base. On black and red spruce .... *Pineus floccus* (Patch) (p. 138).
   Terminal gall a loose growth. On Engelmann, Norway, white, black, and red spruce .... *Pineus similis* (Gillette) (p. 138).

8 (4). Causing galls on entire new growth of spruce host. On blue, Engelmann, oriental, and Sitka spruce .... *Chermes cooleyi* Gill. (p. 135).
   Causing pineapple-shaped galls only at base of new growth of spruce 9

9 (8). Galls with very short needles. On white and Norway spruce .... *Chermes lariciatus* Patch (p. 137).
   Galls with longer needles. On white, red, and Norway spruce .... *Chermes abietis* L. (p. 134).

10 (2). On hickory or pecan, causing green, hollow, bulletlike galls on twigs or leaf stems in June .... *Phylloxera* spp. (p. 138).
   On other hardwoods 11

11 (10). On elm 12
   On other hosts 15

12 (11). Producing spindle-shaped galls up to 1 inch long. On slippery elm leaves. Insect 1 to $1\frac{1}{2}$ mm. long, color reddish .... *Gobaishia ulmifusus* W. & R. (p. 131).
   Galls not spindle-shaped. On various elms 13

13 (12). Causing leaf curl or root swellings .... *Eriosoma* (p. 129).
   Causing cockscomb or pouchlike galls on upper surface of leaves 14

14 (13). Color pale yellow, translucent, or head greenish black and abdomen and thorax dark green, covered with white waxy powder. On leaves of slippery and wych elm, producing cockscomb or pouchlike galls on upper surface .... *Tetraneura* (p. 131).
   Color olive green to dark olive brown or reddish brown; $\frac{1}{2}$ to $1\frac{1}{2}$ mm. long. On leaves, causing only cockscomb galls on upper surface .... *Colopha* (p.130)

15 (11). On apple or serviceberry, causing leaf curl and leaf swellings. About 2 mm. long; color yellowish or brown to reddish, usually with white or bluish flocculence .... *Eriosoma* (p. 129).
   On other hosts 16

16 (15). On poplar 17
   On witchhazel 18

17 (16). Causing convolute galls at tips of branches. Insects 1 to 4 mm. long; head and thorax black, abdomen pale; oviparous female with head, thorax, and abdomen golden yellow. *Mordwilkoja* (p. 133).
   Occurring on leaves and petioles, causing galls at base of leaf, juncture of leaf and petiole, or on petiole. Insects 1 to 3 mm. long; color greenish or yellowish green to greenish white, head and thorax usually dark; body often pruinose .... *Pemphigus* (p. 133)

FIELD KEY TO THE APHIDS, BASED PRINCIPALLY ON HOST PLANTS—Continued

18 (16). Causing conical galls on upper surface of leaves. Insects 1 to 2 mm. long, color pale yellowish to greenish *Hormaphis* (p. 133).
Causing spiny galls from buds on stems. Insects 1 to 2 mm. long, color pale yellowish to greenish *Hamamelistes* (p. 133).
19 (1). On conifers 20
On hardwoods 29
20 (19). On pine 21
On other conifers 24
21 (20). Small, dark insects covered with white flocculence. Occurring on trunks and branches of Austrian, Scotch, and white pine. *Pineus strobi* (Hartig) (p. 138).
Insects not covered with white flocculence, at most pruinose. Occurring on twigs, branches, or leaves 22
22 (21). Color shining black with white powdery spots on sides and white median dorsal line; legs black; body hairy, hairs long and stiff. On branches and twigs of white pine *Cinara strobi* (Fitch) (p.128)
Not as above 23
23 (22). Color olive brown, body hairs sparse and spinelike. On leaves of Scotch, ponderosa, shortleaf, and white pine. *Eulachnus rileyi* Wms. (p. 127).
Color pale green with white pruinosity. On leaves and twigs. *Mindarus abietinus* Koch (p. 133).
24 (20). On larch 25
On other conifers 26
25 (24). Color dark brown to black with brown spots on abdomen, legs mostly black; about 3 mm. long. On twigs and around base of leaves *Cinara laricis* (Wlkr.) (p. 127).
Appearing as white woolly masses on the needles, as dark individuals on the underside of twigs, or as clusters of dark individuals at the base of the leaves *Chermes strobilobius* Kalt. (p. 137).
26 (24). Nymphs dark green in color. On Douglas-fir, often causing abnormal foliage drop *Chermes cooleyi* Gill. (p. 135).
Not as above 27
27 (26). Color cinnamon brown with 4 rows of black spots on abdomen; length about 3 mm.; many specimens covered with fluffy white wax above; body hairs long and fine. On black spruce branches and twigs *Cinara abietis* (Fitch) (p. 127).
Not as above 28
28 (27). Color brownish black with a slight pruinosity, legs brown to black, antennae pale; length about 5 mm. On branches, twigs, stems, and roots of fir and Atlas cedar *Cinara curvipes* Patch (p. 127).
Color pale green with pruinosity, or with white flocculent covering when on balsam fir; length about 2 mm. On fir and spruce twigs and leaves, causing curling and roughening of twigs *Mindarus abietinus* Koch (p. 133).
29 (19). Large species, about 6 mm. long; color ash gray with triangular spots on pronotum; body covered with bluish-white bloom.
On various hosts; common on hickory and sycamore *Longistigma* (p. 127).
Smaller species, usually 5 mm. or less in length. See appropriate host.
Alder: Causing mottling or dropping of leaves. Insects 1½ to 2 mm. long; color green or greenish yellow, abdomen uniformly colored or dusky-spotted *Myzocallis* (p. 129).
On underside of leaves or on stems. Insects 2 to 4 mm. long; color brownish, covered with white flocculence *Prociphilus* (p. 132).
Beech: On underside of leaves. Insects 2 to 3 mm. long; color bluish white to greenish yellow, covered with white flocculence *Phyllaphis* (p. 129).
On underside of branches or on trunk. Insects 2 to 4 mm. long; color brownish, covered with white flocculence *Prociphilus* (p. 132).

FIELD KEY TO THE APHIDS, BASED PRINCIPALLY ON HOST PLANTS—Continued

29 (19). Large species, etc.—Continued

Birch: On twigs and leaves; 3 to 4 mm. long; color whitish to yellow, with or without black stripes on head and thorax and dark bands on dorsum of abdomen------- *Calaphis* (p. 129).

On twigs and leaves: 2 to 3 mm. long; color light green, with or without dark patch on abdomen; hind tibiae pale with distal part and tarsi black or with dark brown stripe-------------------------- *Euceraphis* (p. 129).

Boxelder: On leaves and twigs; 2 to 2½ mm. long; color yellowish green marked with brown on thorax and abdomen or with head, antennae, thoracic lobes, sternal plates, and cornicles black or yellowish to apple green; antennae rather hairy *Periphyllus* (p. 129).

Butternut: On leaves; 1½ to 2 mm. long; color pale yellow, costal vein yellow or brown, or a brown band extending beyond stigma; antennae ringed with brown-- *Monellia* (p. 129).

Dogwood: On leaves and twigs except during summer; about 1½ mm. long; head and thorax black, abdomen greenish with a pink tinge and a row of black spots on each side----- *Anoecia* (p. 127).

Elm: Causing mottling or dropping of leaves; 1½ to 2 mm. long; color green or greenish yellow, abdomen uniformly colored or spotted dusky-------------- *Myzocallis* (p. 129).

Hawthorn: On branches and twigs in winter, leaves in spring; 3 to 4 mm. long; abdomen green with black dots on each side, head and thorax black----------- *Anuraphis* (p. 129).

Hickory:

a. Large species, about 6 mm. long; mostly on branches and twigs; color ash gray with triangular spots on pronotum covered with bluish-white pruinosity *Longistigma* (p. 127).

aa. Smaller species, 1½ to 2 mm. long; occurring on leaves

b. Causing mottling or dropping of leaves; color green or greenish yellow, abdomen uniformly colored or spotted dusky--- *Myzocallis* (p. 129).

bb. Color pale yellow, costal vein yellow or brown or a brown band extending beyond stigma; antennae ringed with brown---- *Monellia* (p. 129).

Linden: On underside of leaves; 2 to 3 mm. long; color yellow; antennae uniformly yellow or ringed with brown *Therioaphis* (p. 129).

Maple:

a. Color brownish, often covered with white flocculence.

b. Without white flocculence; egg-laying females with 7th and 8th abdominal segments prolonged into ovipositor--- *Drepanaphis* (p. 129).

bb. Usually with white flocculence

c. Fourth antennal segment about one-half or less as long as third segment; length 2 to 4 mm.; always with white flocculence on underside of leaves or on trunks *Prociphilus* (p. 132).

cc. Fourth antennal segment at least two-thirds as long as third segment; length about 3 mm.; usually with white flocculence. On leaves and twigs of sugar maple--------- *Neoprociphilus* (p. 132).

aa. Color not brownish; either yellowish, reddish, or shading ing to green

d. Four alternatives:

On soft maple leaves and twigs; 3 to 4 mm. long; color dusky reddish to dark yellowish green------------------ *Clavigerus* (p. 129).

FIELD KEY TO THE APHIDS, BASED PRINCIPALLY ON HOST PLANTS—Continued

29 (19). Large species, etc.—Continued

aa. Color not brownish; either yellowish, reddish, or shading to green—Continued

d. Four alternatives—Continued

On Norway and sugar maple, on underside of leaves; 2 to 2½ mm. long; color yellowish green marked with brown on thorax and abdomen, or with head, antennae, thoracic lobes, sternal plates, and cornicles black or yellowish to apple green; antennae rather hairy ---------- *Periphyllus* (p. 129).

On Norway, sycamore, or English maple, on underside of leaves; 2½ to 3 mm. long; color yellow or reddish to green, with black markings or bands, legs and cornicles yellow to dark orange ---------- *Drepanosiphum* (p. 129).

On underside of leaves; 2½ mm. long; color olive green or pale sordid green *Drepanaphis* (p. 129).

Oak (three alternatives):

Causing mottling or dropping of leaves; 1½ to 2 mm. long; color green or greenish yellow, abdomen uniformly colored or spotted dusky ---------- *Myzocallis* (p. 129).

On leaves; 1½ to 2 mm. long; color pale yellow; costal vein yellow or brown or brown band extending beyond stigma, antennae ringed with brown ---------- *Monellia* (p. 129).

On underside of leaves; 2 to 3 mm. long; color yellow, antennae uniformly yellow or ringed with brown *Therioaphis* (p. 129).

Poplar (three alternatives):

On sprouts or tender growth; 2 to 2½ mm. long; color yellowish or greenish, with brown mottling, head brown *Neothomasia* (p. 129).

On leaves and twigs; 3 to 4 mm. long; color dusky reddish to dark yellowish green ---------- *Clavigerus* (p. 129).

On leaves and twigs; about 5 mm. long; color ash gray due to white pruinosity over base color of brown, abdomen marked with black spots; large black tubercle on 4th abdominal segment ---------- *Lachnus* (p. 127).

Sycamore: Length about 6 mm.; body covered with bluish-white pruinosity ---------- *Longistigma* (p. 127).

Length 2 to 4 mm.; covered with white flocculence *Prociphilus* (p. 132).

Walnut: On leaves; 1½ to 2 mm. long; color pale yellow or brown, or brown band extending beyond stigma; antennae ringed with brown ---------- *Monellia* (p. 129).

Willow: Length 3 to 4 mm.; color dusky reddish to dark yellowish green ---------- *Clavigerus* (p. 129).

Length about 5 mm.; color ash gray due to pruinosity over base color of brown, abdomen marked with dark spots *Lachnus* (p. 127).

Suborder HETEROPTERA

The suborder Heteroptera comprises a group of sucking insects, some of which are aquatic or subaquatic, while others are terrestrial. They range in size from certain tropical species of the family Belostomatidae, which attain a length of 3 to 4 inches, to species of Microphysidae and Cryptostemmatidae, which may be less than a millimeter long. Of the fifty-odd known families of this suborder, only 9 or 10 are of much importance and most of these do little actual damage to forest growth.

The antennae of the land forms are usually rather long, the prothorax is large and free, and the mesothorax and metathorax are fused together. All species in this group that attack forest and shade trees are winged in the adult stage, with the forewings, or elytra, thickened for about the basal one-half and the distal ends membranous (except in the Tingidae, where the elytra are membranous over the entire surface). The wings lie flat over the back when folded, and the membranous tips overlap.

In the Heteroptera the mouth parts usually are located near the front of the head. The mandibles and maxillae, drawn out to form piercing stylets, are adapted for sucking. The maxillae lie with the two inner faces pressed together, and the inner surfaces are grooved, forming tubes. The mandibles form a sheath around the maxillae, which strengthens and holds them in place.

The feeding habits of this group vary greatly, even within a species. Some species are entirely phytophagous, some feed now and then on either plants or insects, some are phytophagous in the early instars and predaceous later, and others are entirely predaceous.

In their feeding on plant growth these insects may produce injury of various types. Secretions of the salivary glands, injected into the plant while the insects are feeding, may prove to be more harmful than is the withdrawal of plant juices. The toxic effect of these secretions often causes the plant tissue around feeding punctures to turn brown, to become distorted, and eventually to die. Large numbers of such punctures may even kill entire plants. Feeding by insects in this group may also cause a stoppage in the conductive tissues of plants, and a comparatively few insects may kill a twig or branch, and heavy infestations may kill a tree. In their feeding on plants, these insects may also transmit diseases, although known instances of such transmission are uncommon.

The biology of many species of Heteroptera remains undetermined. The number of generations each year varies widely among species, and within any species, according to the length of the season and the altitude and latitude. The winter may be passed in either the adult or the egg stage. All species undergo gradual metamorphosis, in which newly hatched nymphs, as well as those in successive stages or instars, bear a striking resemblance to the mature insects. In the immature stages color changes may develop from molt to molt, and fully developed wings are not present until the adult emerges. In some pentatomids the first-instar nymphs do not feed, but all other stages feed during their development.

Eggs of the different groups vary greatly in appearance. Those of the Pentatomidae are usually barrel-shaped and are cemented in compact clusters on the surfaces of leaves or branches, many species having beautiful iridescent colors and bearing a fringe of processes around a dorsally located cap. Eggs of the Coreidae are generally cylindrical and cemented flat in loose clusters or rows on plant surfaces. The Miridae, Anthocoridae, and Nabidae insert elongate cylindrical eggs into plant tissues. The eggs of the Tingidae appear as black, volcano-shaped structures on the under side of leaves, usually along the veins. One thing in common among eggs of most heteropterous insects is the presence of a removable cap at one end, which has a diameter approximately the same as that of the egg.

Most species of Heteroptera are equipped with a fluid or gas, which they expel when disturbed. This material may be highly disagreeable and is assumed to have a protective value.

A general work by Blatchley (*50*), treating the Heteroptera of eastern North America, will be found of value in identifying species and providing information as to habits and distribution.

Family PENTATOMIDAE

Insects in this family are generally referred to as "stinkbugs," because all of them emit a characteristic disagreeable odor when disturbed. They are fairly large bugs, ranging in length from 5 to 18 mm., and look short, broad, and slightly convex. In the Northern States and Canada they pass the winter in the adult stage under debris, loose bark, logs, and similar material. They usually deposit their eggs in spring or early in the summer. In the South almost any stage in the life cycle may be found throughout the year.

Several species of pentatomids may be encountered on forest growth at one time or another, but probably none are ever so injurious as to warrant alarm or the application of artificial control measures.

The subfamily *Asopinae* includes several species of predators which are of importance in our forests because they aid in controlling injurious insect species.

Subfamily ASOPINAE

The pentatomids in this subfamily vary in size, form, and general appearance. In all species, however, the head extends forward almost horizontally, the beak is stout, and the tarsi are three-jointed. In the United States they are considered beneficial, because most of the species are predaceous on various destructive insects, at least during a part of their lives.

The bordered soldier bug (*Stiretrus anchorago* (F.)), a shiny, dark metallic insect sometimes tinged with bronze, measures from 8 to 11 mm. in length and feeds on gypsy moth larvae and tent caterpillars.

The spined soldier bug (*Podisus maculiventris* (Say)), is one of the most beneficial of our predaceous pentatomids, as more than 30 species of destructive insects have been listed as being attacked by it. It is a fairly large bug, from 10 to 13.5 mm. long. It is dull yellow above, marked with numerous fuscous punctures, which produce a dull-brown effect. It has two generations in the North and more in the South.

Podisus serieventris Uhler, a species that attacks the larvae of many destructive insects, is from 9.5 to 11.5 mm. long. It has from one to three generations annually.

Podisus modestus (Dallas) and *P. placidus* Uhler, the first a pale reddish-brown bug from 9 to 10.6 mm. long, and the second a brown bug with darker punctations and 7.5 to 11 mm. long, are sometimes important as predators.

Apateticus cynicus (Say), *A. bracteatus* (Fitch), and *Perillus circumcinctus* Stal. comprise the rest of the species in this subfamily that may be important as aids in controlling other insects. *A. cynicus* is rather large, from 15 to 20 mm. long, and is dull yellow to pale brown, with dark reddish punctures. *A. bracteatus* is from 13 to 17 mm. long, is dull yellow thickly marked with reddish or greenish punctures, and has the cheeks edged with a narrow green line. *P. circumcinctus* is somewhat smaller than *P. bioculatus* (F.), **the double-eyed soldier bug.** It is brown, sometimes tinged with reddish, and the pronotum and scutellum are marked with pale-yellow-to-ivory marginal stripes.

Family ARADIDAE

The aradids are known as flatbugs. They may be recognized by their strongly flattened oval form. Most species are small brown or blackish bugs seldom more than 10 mm. in length. They are usually found beneath closely fitting bark or in narrow crevices in the wood of trees that have recently died or have been felled but a year or two. They tend to be gregarious, living in small colonies comprised of both adults and nymphs. It is believed that they feed principally on fungi. Most species, at least in the Northern States, hibernate in both the adult and nymphal stages.

Family TINGIDAE

The tingids, with their broad gauzelike or lacelike wing covers, their prothoracic expansions, and the reticulations of their hoods, are easily recognized. There are a great many species in this family, all of which live and feed on the under surfaces of leaves. The upper surface of the infested leaf usually changes color, becoming either whitened or brownish and dead in appearance. The under side of an infested leaf becomes conspicuously speckled with eggs, excrement, and cast skins of the developing nymphs. The winter is passed either as adults under bark scales or other cover on the host trees, as eggs cemented to the under surface of leaves and covered with a gluelike substance, or embedded in leaf tissue and covered with a brown crusty material. Most species have 2 generations each year. In the Eastern States over 70 species, all belonging to the subfamily Tinginae, are recognized, and most of these are confined either to a single host species or to very closely related host species.

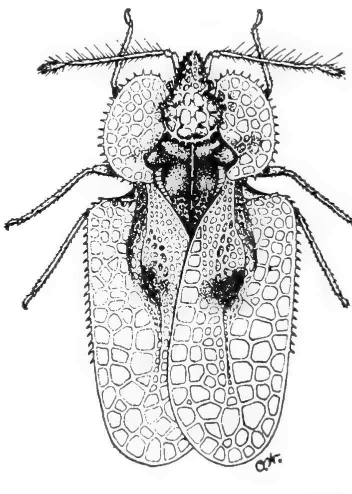

FIGURE 18.—Adult of the sycamore lacebug (*Corythucha ciliata*). Greatly enlarged.

The sycamore lacebug (*Corythucha ciliata* (Say)) (fig. 18), feeds principally on sycamore, although it has been recorded on ash, hickory, and mulberry. It is fairly common over the entire Eastern States (Wade, *423*).

Corythucha ciliata lays its eggs along the ribs of the undersurface of leaves early in the spring. The eggs hatch in 2 to 3 weeks and the nymphs mature in another 5 to 6 weeks. In the North there are two generations each year, and even more in the South and Southwest. This lacebug passes the winter in the adult stage.

Injury may be rather severe on important street and shade trees. Heavily infested trees may drop most of their leaves, and when this happens in conjunction with drought the trees may be seriously affected.

A contact insecticide (p. 52) directed against the under side of the leaves and applied twice, at 2-week intervals, as soon as the young have hatched in the spring, should give adequate control.

FIGURE 19.—Spotting of oak leaves caused by a lacebug, *Corythucha* sp.

The oak lacebug (*Corythucha arcuata* (Say)) feeds on various species of oak throughout the Eastern States north of the Carolinas and Alabama.

This species may overwinter as either adults or eggs, but otherwise its life history is similar to that of the sycamore lacebug. Feeding by large numbers causes curling and whitening, then browning of foliage. Severe infestations may cause premature defoliation of the tree (fig. 19). Measures recommended for control of the sycamore lacebug are applicable for the control of this insect.

A variety, *Corythucha arcuata mali* Gibson, closely resembles *C. arcuata* and is often found in association with it on oak. It, however, has also been recorded at times on hard and soft maples.

Corythucha mollicula O. & D. (=*Salicis* O. & D.) (=*canadensis* Parsh.), **the willow lacebug,** occurs throughout the Eastern States and when present in large number may seriously injure willow, its only known host. It is easily recognized by the lack of spines on the margin of the elytra, and may be controlled by measures recommended for the sycamore lacebug.

The elm lacebug (*Corythucha ulmi* O. & D.) has been recorded in many Eastern States and probably will be found wherever American elm, its only known host, grows. Little is known of the life history of this species; however, heavy infestations may cause serious foliage discoloration, and this may happen as early as mid-June. The species can be controlled by the application of a contact insecticide (p. 52).

The genus *Corythucha* contains several other species that may become so numerous as to be noticeable at times. They are listed, along with their hosts, as follows: *C. pergandei* Heidemann, **the alder lace bug,** principally alder, but occasionally hazel, elm, and birch; *C. pruni* O. & D. (=*pyriformis* Parsh.), **the cherry lacebug,** Wild cherry: *C. juglandis* (Fitch), **the walnut lacebug,** black walnut, butternut, and linden; *C. pallipes* Parsh. (=*betula* Drake=*cyrta* Parsh.), **the birch lacebug,** principally yellow birch, but also on white birch, beech, eastern hophornbeam, willow spp., mountain-ash, and maple; *C. elegans* Drake, **the willow and poplar lacebug,** willow, balsam poplar, quaking aspen, and bigtooth aspen; *C. aesculi* O. & D., **the buckeye lacebug,** various species of buckeye; *C. associata* O. & D., wild cherry; *C. cydoniae* (Fitch), hawthorn, and *C. celtidis* O. &. D., hackberry.

The rhododendron lacebug (*Stephanitis rhododendri* Horv.), which feeds on rhododendron, mountain-laurel, and azalea, is a peculiar-looking insect, with elytra nearly twice the length of the body and rounded at the apex, with a small triangular hood, and with long and slender antennae. It is nearly 4 mm. long. The nymphs are almost transparent, except for their bright red eyes.

The rhododendron lacebug is of European origin and is now present in the United States from New England west to Ohio and south to North Carolina. It passes the winter in the egg stage and has two generations each year in the northern part of its range. Its feeding causes the upper surface of the leaves to become mottled or covered with small whitish blotches; and the underside of the leaves shows a brownish mottling from the excrement. This species can be controlled by methods recommended for other lacebugs. Two spray applications, one in June and one about mid-August, should control it effectively.

Family **REDUVIIDAE**

The family Reduviidae is commonly referred to as the **assassin bugs** and comprises a large group of predaceous species. They vary greatly in size and shape, the species of most interest in this country ranging from 15 to 36 mm. in length. They are characterized by a cylindrical head bearing a stout, rigid, 3-jointed beak which is usually curved in the form of a semiloop beneath the head, with the tip resting in a stridulatory groove located between and in front of the forelegs. The front legs are more or less fitted for grasping, although the femora are seldom much stouter than those of the middle and hind legs.

Most species are beneficial, since they prey on small plant-feeding insects. In the forest *Zelus exsanguis* (Stål.) is commonly encountered on low herbage, foliage of shrubs, ,and scrub growth. *Arilus cristatus* (L.), known as **the wheel bug** because of the peculiar semicircular crest on the pronotum, is perhaps of most importance, since it lives in trees preying upon caterpillars and other insects. This species is common throughout the Eastern States as far north as New York. It overwinters in the egg stage. The bottle-shaped eggs are closely cemented together in a more or less rectangular or hexagonal mass.

Family NABIDAE

The nabids are elongate-oval to rather slender oblong species of medium size, usually between 7 and 9 mm. long, and pale brown to straw-colored. The beak is 4-segmented; however, the first segment is short and easily overlooked. The forelegs are fitted for grasping prey, having the tibiae armed with minute spines, and the fore femora are somewhat enlarged. The nabids may be considered as beneficial, since they appear to be entirely predaceous on the soft-bodied larvae and nymphs of plant-feeding insects. *Nabis sordidus* Reuter is probably the species most frequently encountered in eastern forests. Here it is often found in considerable numbers on rank undergrowth. This species overwinters in the adult stage, and may have as many as four generations a year.

Family ANTHOCORIDAE

There are several species in this family of small bugs, some of which are predaceous on other insects. Altogether they are probably of little importance in checking infestations of injurious species. One species, *Anthocoris musculus* (Say) (=*borealis* Dallas), occurring in the United States from Indiana northward, is predaceous on soft-bodied, leaf-feeding insects, principally the tingids on deciduous trees. It is most common on willow. It has a single generation yearly, and passes the winter under dead bark or leaves.

Family MIRIDAE

This is the largest family in the order Hemiptera, and more than 500 species have been described from America north of Mexico. Although many of the species are found on trees and shrubs, very few are of economic importance. Many species are predaceous on soft-bodied or young insects, but most of them are probably plant feeders (Britton *59, pp. 422–658*). A more complete discussion of this family, together with descriptions of many of its species, may be found in Knight (*267*).

Three species that may be numerous enough to cause noticeable injury are as follows: *Neoborus amoenus* (Reuter) on species of ash, *Neolygus invitus* (Say) on young succulent growth of elm, and **the tarnished plant bug** (*Lygus oblineatus* (Say)), a pest of nursery stock and ornamental plants.

Family COREIDAE

The boxelder bug (*Leptocoris trivittatus* (Say)) becomes a pest at times where boxelder is grown as a shade tree. It is principally a source of annoyance because of its habit of congregating in large numbers in or on houses in the fall, when it is seeking hibernation quarters. It feeds on the leaves and seed of boxelder during the summer and, when abundant, on ash and maple.

This bug is elongate, somewhat flattened, and almost one-half inch long. Mature insects are blackish on top with three red longitudinal stripes on the thorax and with red margins on the basal half of the wings. Under the wings the abdomen is bright red. Eggs are deposited on boxelder leaves in the spring by female bugs that have survived the winter. There is one generation each year.

The boxelder bug may be controlled early in the spring by spraying infested trees with a contact spray containing pyrethrum, used at the strength recommended by the manufacturer for other plant bugs. When adults are congregating on or in houses large numbers may be destroyed simply by sweeping them up and burning them. Masses of bugs may also be destroyed by spraying or dusting them with an insecticide containing pyrethrum. Indoors, an ordinary fly spray containing pyrethrum will probably prove effective.

Family LYGAEIDAE

The lygaeids are commonly referred to as **chinch bugs.** This group varies greatly in size and habits. They are small to medium-sized, oblong or narrowly oval in shape, and range from 2 to 18 mm. in length. Most species are dull colored although some are contrastingly marked with red and black. All species are characterized by the presence of 4 to 6 veins in the membrane of the forewing. Many of the species are plant feeders, but the members of the large subfamily Rhyparochrominae are thought to be mainly predatory. The forelegs of this group have the femora swollen and armed beneath with spines. Species belonging to this predaceous group are frequently encountered in the duff covering of the forest floor. Some plant-feeding species may be numerous on herbaceous undergrowth.

Suborder HOMOPTERA

The suborder Homoptera includes many divergent groups, differing in both size and appearance. Some of these, such as the males of certain species of scale insects, are almost microscopic in size, whereas others, such as certain cicadas, may have a wing expanse of over 4 inches. All are sucking insects, however, and all undergo a gradual metamorphosis. Some of these insects are winged, others are wingless; some are motile, others are legless; some lay eggs, some give birth to living young, and still others may lay eggs at one period of their life cycle and give birth to living young at another. Some require the presence of males for the production of fertile eggs or living young, whereas others are parthenogenetic; some are relatively naked, and some are covered with wax in the form of threads, powder, plates, or scales.

In the feeding by members of this group, the degree of injury to plants ranges from comparatively little to the death of the host plant. Some species are injurious simply through their withdrawal of sap from plants; some cause injury by slitting twigs for the insertion of eggs; some cause the development of galls or other distortions; and others are indirectly injurious in serving as vectors of various destructive diseases. Species in the group may be found at one time or another on almost any part of plants, both above and below ground. The length of the life cycle in the group ranges from a few days (for aphids) to several years (for cicadas).

Family FULGORIDAE

This family is mainly tropical in distribution, although certain species may be encountered frequently in the forests of the Eastern States.

Many of these are interesting because of the peculiarity of form so characteristic of the group. Yet, considered economically, few if any species are ever so injurious to forest growth as to cause alarm (Osborn, *322;* Van Duzee, *420*).

Family CICADELLIDAE

The leafhopper family is represented in the United States and Canada by over 2,200 species, many of which are injurious to various forms of vegetation. A great many species feed on forest or shade trees, but the members of this family are most distructive to cultivated plants and grains.

The species are rather small, being 3 to 15 mm. in length. The antennae are located in front of and between the eyes. The hind tibia are about as long as the abdomen and are armed with a row of spines on each margin. As may be inferred from the common name, the hind legs are formed for jumping.

Injury by leafhoppers may be caused by feeding, in which case the leaves become brown and withered or curled, or fruit may be blasted. The eggs are often deposited in slits in leaves, stems, or twigs of host plants. This may cause definite injury. Leafhoppers are frequently the means of inoculating the host with destructive viruses. This type of injury is, so far as is known, more prevalent on cultivated plants than on trees.

Some of the more common leafhoppers on forest and shade trees are listed with their hosts, as follows: **The Japanese maple leafhopper,** [*Platymetopius*] *Japananus hyalinus* (Osb.), on Japanese and Norway maples; *Idiocerus* spp., on willow, poplar, and hawthorn; *Macropsis* spp. on willows and poplars; *Oncopsis* spp., on birch, hazel, alder, and walnut; [*Cicadella*] *Neokolla gothica* (Sign.), on many shrubs and trees, particularly willow; also species of *Alebra*, *Empoasca*, *Typhlocyba* and *Erythroneura* on maples, elms, poplars, willows, alder, hazel, eastern white pine, oak, birch, and dogwood. Many others could be listed. However, where any one species becomes so abundant as to require the application of control measures a contact insecticide may be used. Insecticides applied while the insects are in the nymphal stage will give the best control (De Long, *132*).

Family MEMBRACIDAE

In number of species and in diversified and grotesque forms the family Membracidae reaches its greatest development in the tropical and subtropical regions. The pronotum usually extends backward for a considerable distance, and may completely cover the abdomen. Pronotal development, prominent on many exotic species (fig. 20, *A*), becomes less so in the United States, although there are some rather extraordinary species in this country (fig. 20, *B*). Insects in this family have only two ocelli. The antennae are hairlike, poorly developed, and situated below and in front of the eyes. The wings are usually membranous (Funkhouser, *175*).

Although the insects in this family are interesting in many respects, they are of little consequence in our forest- and shade-tree economy. They may be encountered in the woods, and most frequently in open stands. A type of injury which is usually of slight importance, but which may be serious, that can be attributed to insects in this family is the slitting of twigs by ovipositing females for the placement of eggs. Both *Ceresa bubalus* (F.) and *Stictocephala inermis* (F.) are responsible. **The three-cornered leafhopper** (*S. festina* (Say), is reported to be injurious to black locust seedlings in nurseries. Injury to the seedlings results from feeding. A callus forms and a point of weakness develops that may either kill the seedling outright or cause it to break off when being pulled for planting.

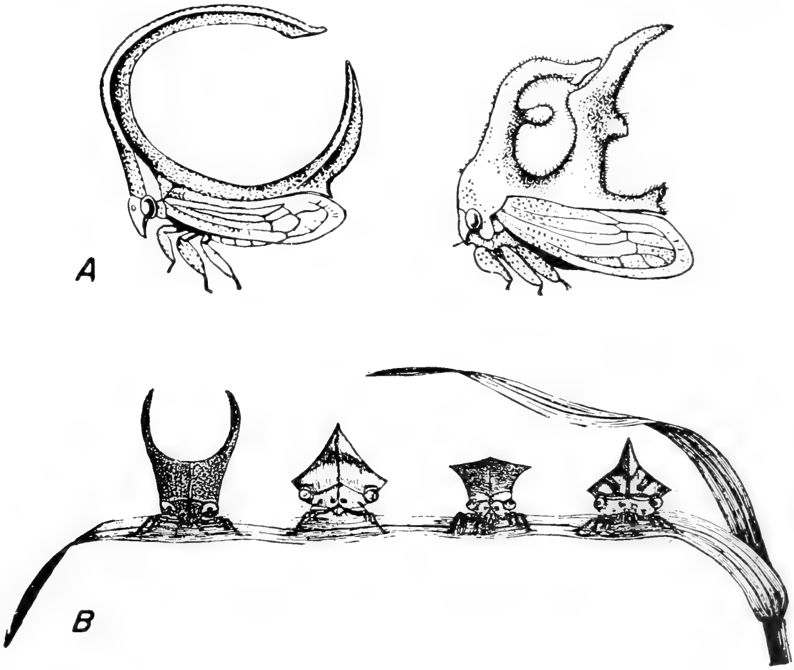

FIGURE 20.—Treehoppers: A, Unusual and fantastic development of the prothorax of exotic species; *B*, front view of four species of treehoppers. All × 3. (From Comstock.)

FAMILY CERCOPIDAE

The bodies of the spittle bugs are stout, oval, or elongate-oval (fig. 21, *A*). There are two ocelli situated in the vertex between the eyes. The antennae are short and inserted between the eyes and below the margin of the vertex. The various species produce quantities of white froth or "spittle" (fig. 21, *B*), from which the family derives its common name, "spittle bugs."

Nearly all the species in the United States belong to the subfamily Aphrophorinae. They are rather dull colored, and feed on a variety of trees, shrubs, grasses, and cultivated plants. Most important from the standpoint of the forest entomologist is the genus *Aphrophora* (Stearns, *397*).

The pine spittle bug (*Aphrophora parallela* (Say)), a native of North America, is distributed from southern Canada and New England west to the Lake States and southwest to Missouri and Arkansas.

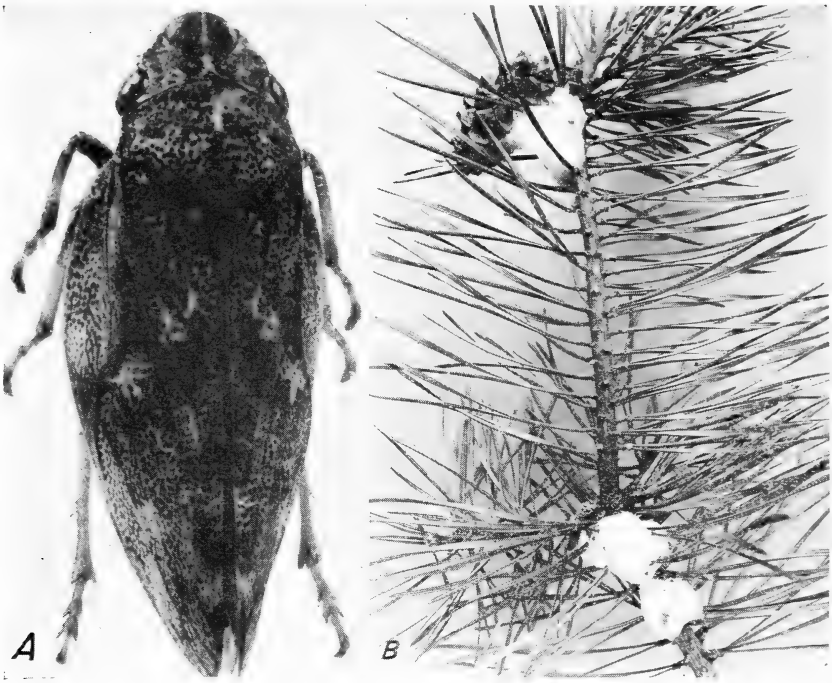

FIGURE 21.—Aphrophora parallela: *A*, Adult; *B*, masses of spittle produced by nymphs on Scotch pine. (Courtesy Conn. Agr. Expt. Sta.) *A*, About 15 times natural size.

Although most injurious to Scotch pine, it also attacks pitch pine, eastern white pine, jack pine, Virginia pine, red pine, Japanese red pine, and Norway spruce. Brown [17] reported that in Canada in 1939 the insect was most commonly found on white pine. Adults are about 10 mm. long, light brown on top, and dotted with pale and dark spots, which appear as obscure transverse bands.

The eggs are deposited at the bases of the terminal buds of the host tree in July and August. They hatch the following spring, usually in May, and the young nymphs at once begin feeding on the twigs. The nymphs soon become covered with the spittle. During development they may move to new locations on the twigs and form new masses of froth. By the time they are full grown in July, they will have migrated to the main trunk of the tree, where a large number may occupy the same spittle mass. When ready to transform to adults, the nymphs leave the masses of froth, migrate to the needles of the tree, and shed the last nymphal skin, emerging as winged adults. The adults continue to feed during July and August, but produce no froth masses (Henry, *220*).

In a heavy infestation of *Aphrophora parallela* there is a constant drip from the frothy masses, and also a flow of the liquid along the twigs and branches. The adult insects eject undigested sap in the form of a fine mist, which continually drops from heavily infested trees

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[17] BROWN, A. W. A. ANNUAL REPORT OF THE FOREST INSECT SURVEY 1939. Canada Dept. Agr. Ann. Rpt. Forest Insects Survey 1939, 37 pp. 1940. [Processed.]

like the falling of very light rain. After the nymphs have moved to a new location, the spots on the bark where they have fed are invaded by a black, sooty mold. Needles of heavily infested branches turn brown, and the twigs die. As the infestation continues, the branches die progressively from the tip toward the main trunk. Lower branches are generally killed first, the infestation moving upward in the crown until the whole tree is killed. In severe infestations Scotch pine may be killed in 2 or 3 years.

Henry (*220, pp. 3, 4*) stated that a parasitic fungus, *Entomophthora aphrophora* E. Rastr., is the most important natural-control factor operating on this insect. The relationship between the two, however, is such that periodic outbreaks of the spittle bug may be expected about every 9 years. Artificial control on ornamentals may be obtained by spraying about the middle of June with pyrethrum extract at the strength of 1 pint in 50 gallons of water (p. 53).

The Saratoga spittle bug (*Aphrophora saratogensis* (Fitch)) is known from New England west to the Lake States and south to Florida, and has caused serious damage in jack and red pine plantations and in young open-grown natural stands of these pines in the Lake States, especially in Wisconsin. In its immature or nymphal stage it feeds on sweet fern and many other plants, usually just above the root collar but below the surface of the litter. Adults migrate from these hosts late in June or early in July and attack pine, where they may be found feeding until October.

These insects, while feeding, may extract large quantities of sap from pines. Their feeding also causes numerous small pinholes to appear in the bark tissues, and some of these holes become infiltrated with pitch. Scar tissue forms around these wounds, and this tissue may coalesce and girdle branches. The first indication of injury to pines by this insect is an almost imperceptible yellowing of the foliage in September. The following spring this foliage turns brown. Damage is heaviest on poor sites, sandy barren soil, and burned areas, where pine is found in association with sweetfern (*Comptonia peregrina* (L.)).

Newly hatched nymphs probably cannot survive exposure to temperatures of 16° to 18° F. in May, especially when such low temperatures follow a much warmer period. It also appears that not only stands of mixed pine and hardwoods, but also well-stocked and closed stands of pine, suffer little or no injury by the species. Probably damage can be prevented or overcome by selecting good sites for planting and by encouraging the better hardwoods to help in crowding out sweetfern and building up the soil.

In New England the European species *Aphrophora salicis* (Deg.) is frequently abundant on willow.

Family CICADIDAE

The large size of the forest-inhabiting insects in this family distinguishes them from all other Homoptera in the Eastern States. They appear rather short and are heavy, the wings are membranous, and the compound eyes are large. In so-called "song" the male produces a high, shrill sound that can be heard long distances. Although the length of the life cycle of many species remains unknown, that of the well-known periodical cicada occupies 17 years (Davis, *127*).

The periodical or **17-year cicadas** (*Magicicada septendecim* (L.) and *M. cassinii* (Fish.)), one or the other of which occurs from New England west to Iowa and south to Florida and Texas, are about 1½ inches long from the tip of the head to the tip of the folded wings. The eyes and legs are red. In the female the dorsum of the abdomen is black, and the sides and ventral surface are banded with orange brown. In the male the dorsal surface of four or five of the abdominal segments is orange brown, rather than black, as in the female, and there is a pair of orange-colored covers to the sound-producing membranes beneath the bases of the wings.

The female makes slits in the twigs of various trees and shrubs where she places her eggs late in the spring or early in the summer (fig. 22). These eggs hatch in 6 to 8 weeks and the young nymphs drop to the ground, burrow into it, and attach themselves to the roots of plants by inserting their beaks. Here in small moist chambers they remain, feeding and growing, until time to emerge as adults (Marlatt, *290*).

The periodical cicada has two races in the United States. One race ranges from New England west to Iowa and central Kansas, and south to Georgia, and requires 17 years for full development. The other race ranges from Virginia west to Missouri and eastern Texas, and south to Florida, and requires only 13 years to complete its development. Different broods of the two races emerge in different years in various places, and this results in the emergence of one or more broods every year in one place or another throughout the range of the species.

Artificial control measures against this species have not been considered practical, since to be effective contact insecticides would need to be applied constantly during the period of adult emergence. However, such extreme methods might be practicable in nurseries, where damage to seedlings by the ovipositing females is sometimes rather severe.

Family PSYLLIDAE

These are rather small insects, from 2 to 5 mm. long. The hind legs are formed for jumping, and the adults of both sexes are winged. When examined under magnification, the adult insects bear a striking resemblance to the enormously larger cicadas. They are very active, jumping and flying when disturbed.

Forest and shade trees are attacked by several species in this group of insects. Hackberry is the host of four gall-producing species in the genus *Pachypsylla*. These are *P. celtidis-gemma* Riley, *P. celtidis-mamma* (Fletcher), *P. celtidis-vesicula* Crawf., and *P. venusta* (Osten-Sacken) (fig. 23), all of which cause galls on leaves or leaf petioles. In the genus *Psylla*, the nymphs of *Psylla annulata* Fitch feed on paper birch and maple, *P. carpinicola* Crawf. on birch, *P. floccosa* Patch on alder, *P. galeaformis* Patch on alder, *P. negundinis* Mally on boxelder, *P. stirata* Patch on birch, and *P. trimaculata* Crawf. on wild cherry. Members of the genus *Psylla* produce quantities of honeydew on their hosts, giving them an unhealthy appearance because of the black mold that grows in the honeydew. For control of these insects, use a delayed dormant spray, followed by a contact insecticide, such as nicotine sulfate.

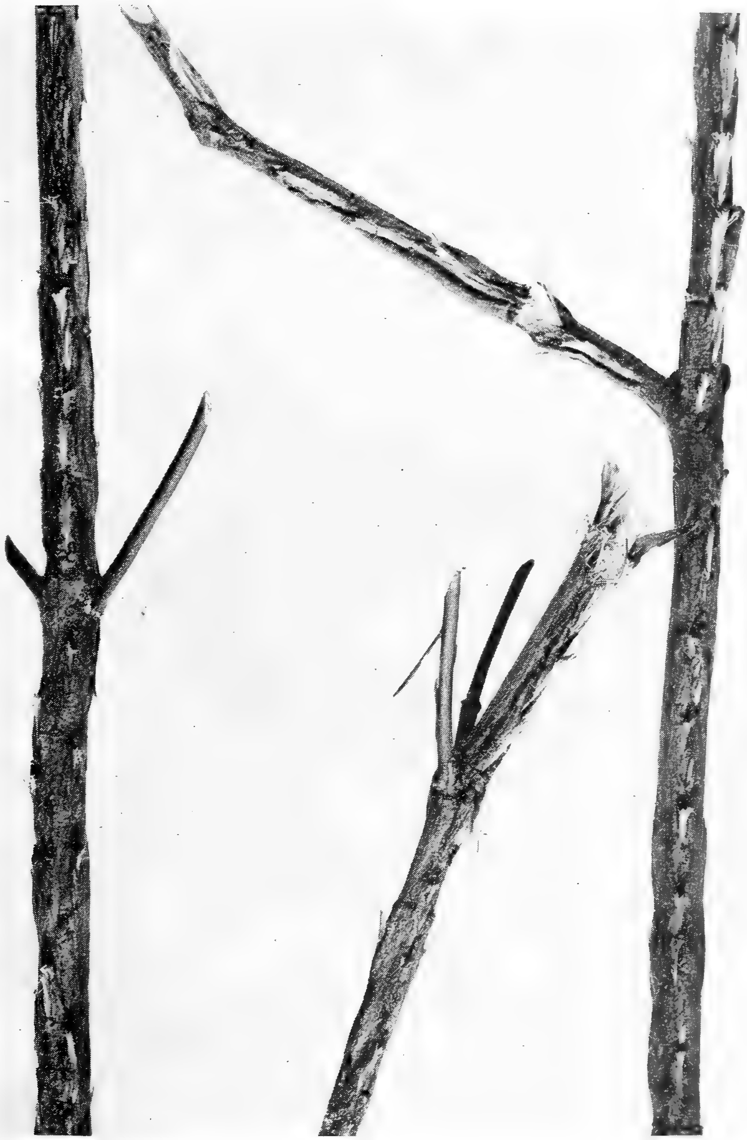

FIGURE 22.—Injury to twigs by females of the periodical cicada (*Magicicada septendecim*).

FIGURE 23.—Galls caused by *Pachypsylla venusta* on hackberry.

FAMILY APHIDAE

In the aphid family only the sexually perfect females lay eggs, and the parthenogenetic females give birth to developed young, which may in same cases be enclosed in a pellicle. The wing venation differs from that in the Chermidae, the next family to be discussed, by having the radius of the forewings branched and the outer part of the stigma bounded by R_1.

One of the characteristics of the Aphidae is that of cyclic reproduction, in which a series of parthenogenetic generations is alternated with a sexual generation, and there may be an alternation of winged and wingless forms within the series of parthenogenetic generations. Also, the life history may be further complicated by having part of it occur on one species of plant (the primary host), and the remainder on an entirely different species or genus (the secondary host). In such cases the life history may be somewhat as follows: From an overwintering egg on the primary host, the stem mother hatches in the spring. This stem mother gives birth to living young, all females, and these in turn give birth to more living young, also all females. This goes on until a variable number of generations have been produced on the primary host, when the next form appears. This is a winged form, which migrates to the secondary host. These are also parthenogenetic females, which give birth to living young. After becoming established upon a secondary host, wingless females are again produced for a variable number of generations until winged forms are born which migrate back to the primary host, where they give birth to true sexual forms, males and females.

After mating, the females deposit from one to several eggs, depending on the species. In some tribes of aphids the egg-laying females are winged, the males are commonly winged, and both sexes have beaks and feed as do the asexual females. In other forms the males and females are small, wingless, and beakless, and each female deposits only one egg. Sometimes the egg is not even deposited but remains inside the shriveled body of the dead female over winter, to hatch in the spring or whenever favorable weather permits. The change from one form to another may be brought about not only by the season of the year but by lack of moisture or too much of it, overcrowding of the population, or change in food conditions. The following papers discuss these habits more fully; Baker (*13*), Balch (*16*), Gahan (*177*), Gillette and Palmer (*185*), Hottes and Frison (*238*), Johannsen and Patch (*255b*). Patch (*337*, *338*, *339*, *340*, *341*, *343*, *344*).

Subfamily APHINAE

Included in the subfamily Aphinae are most of the free-living aphids that ordinarily feed on the foliage of plants. Some of these may cause curling or distortion of the leaves, but such deformations are not true galls. Other species in the group also feed on the stems or roots of plants. Both males and females have functional mouth parts. Winged males are common and in some species the egg-laying females are winged and lay several eggs each. On conifers the eggs are laid in rows on the needles and generally are black, although sometimes they are covered with a white powder, which gives them a grayish appearance.

Tribe *LACHNINI*

In this tribe the species *Longistigma caryae* (Harr.) and *Cinara strobi* (Fitch) may cause real injury to forest trees. In addition, the following species are sometimes encountered: *Anoecia querci* (Fitch) on dogwood; *Cinara abietis* (Fitch) on black spruce; *C. curvipes* (Patch) on balsam, white, alpine, noble, and Spanish firs and on Atlas cedar; *C. laricis* (Wlkr.) on various species of larch; *Eulachnus rileyi* Williams on Scotch, shortleaf, eastern white, and ponderosa pines; and *Lachnus salignus* Gmel. on willow and poplar. These aphids range in size from 1.5 mm. in *A. querci* to 6 mm. in *L. caryae.*

Longistigma caryae is one of our largest aphids, its body being about 6 mm. long. It attacks a wide variety of trees, both in the forest and when used as ornamentals, as follows: Hickory, pecan, elm, sycamore, oaks, maples, lindens, chestnut, birch, beech, black walnut, and willow. It occurs over most of the eastern half of the United States, ranging from New England to Minnesota on the west and to Arkansas and Florida on the south. There are several generations annually, depending on the locality. All forms feed on the twigs and small branches of the hosts and, when abundant, may cause serious injury or death of the affected parts.

This species includes both wingless and winged viviparous females. The entire body is covered with a bluish-white bloom. In the winged female the head and thorax are dull black; the abdomen bears the same markings as that of the wingless form. Its general color is ash gray. The egg-laying female is wingless and lays several eggs (fig. 24). The male is winged.

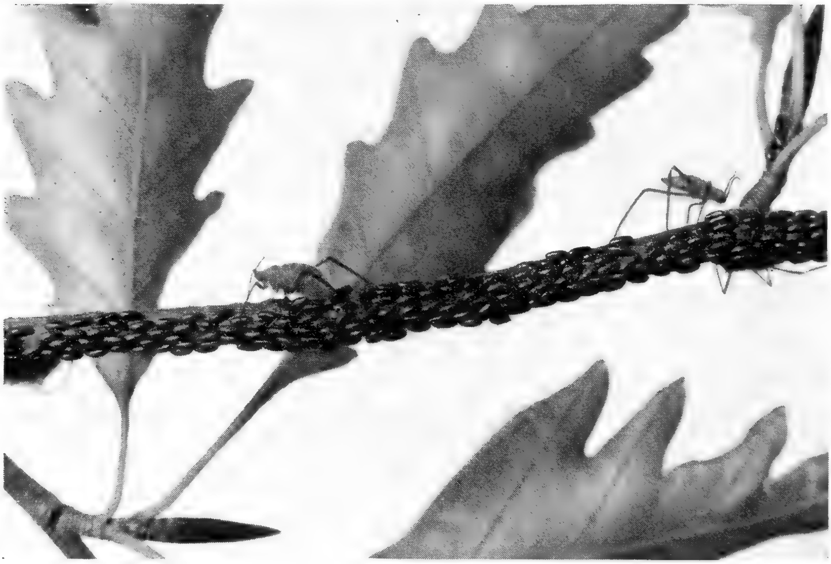

FIGURE 24.—Females of *Longistigma caryae* laying eggs on an oak twig.

The white pine aphid (*Cinara strobi*) is from 3 to 5 mm. long and is found from New England west to Illinois and south to the Carolinas. It feeds on the twigs and branches of eastern white pine, and small trees, when heavily attacked, may be seriously injured or killed. While feeding, the aphids produce quantities of honeydew in which a sooty mold develops, giving the attacked portions a blackened appearance.

Females of this species are viviparous and include both winged and wingless forms. The female deposits her eggs in lines of five or six on the needles in the fall. When first laid, they are yellow but soon turn jet black. They hatch about the middle of May in Maine and earlier southward. Infestations on ornamentals may be controlled easily by washing the aphids off the trees with a direct stream of water from a garden hose, or by spraying as suggested on page 36.

TRIBE *CALLIPTERINI*

Numerous species in this tribe are found on forest and shade trees in the eastern half of the United States. Few, however, appear to be of much importance economically. Some species may be found wherever their hosts grow in the United States, though most of them appear to be confined to the eastern half of the country as far south as the Carolinas.

A list of these species with their hosts is as follows: *Calaphis betulella* Walsh, various species of birch; *Calaphis betulaecolens* (Fitch), various species of birch; *Euceraphis betulae* (Koch), various species of birch and Japanese maple; *Monellia caryella* (Fitch) and *Monellia costalis* (Fitch), hickory, walnut, butternut, and oaks; *Myzocallis alnifoliae* (Fitch), various species of alder; *Myzocallis discolor* (Mon.), oak and hickory; *Myzocallis ulmifolii* (Mon.), American, winged, slippery, and English elms; *Therioaphis bellus* (Walsh), oak; *Therioaphis tiliae* (L.), native and introduced lindens; *Chaitophorus populifoliae* Oest., various species of poplar; *Neothomasia populicola* (Thos.), various species of poplar; *Periphyllus lyropictus* (Kess.), Norway and sugar maples; *Periphyllus americanus* Baker, sugar and vine maples; *Periphyllus negundinis* (Thos.), boxelder; *Drepanaphis acerifoliae* (Thos.), various species of maple; *Drepanosiphum platanoides* (Schrank), Norway, English, and sycamore maples; *Phyllaphis fagi* (L.), practically all species of beech; *Clavigerus smithiae* (Mon.), various species of poplar and willow; *Clavigerus populifoliae* (Fitch), various species of poplar; and *Clavigerus salicis* (L.), on various species of willow.

Tribe *APHIDINI*

One species, *Anuraphis crataegifoliae* Fitch, occurs on hawthorn from New England to Illinois, but is of little importance.

Tribe *ERIOSOMATINI*

Only three species belonging to this tribe are of sufficient importance as pests of forest and shade trees to warrant discussion in this manual. They are *Eriosoma americanum* (Riley) and *E. rileyi* Thos., found on American elm; and **the woolly apple aphid** (*E. lanigerum* (Hausm.)), found on American, wych, smooth-leaved, and slippery elms.

Eriosoma lanigerum is one of our commonest elm aphids. It is also a pest of apple, which is important, because this tree is directly involved in the biology of the aphid. A discussion of the morphological characteristics of the species seems unnecessary, since it may be recognized easily by the type of injury it causes. It probably is to be found in this country wherever apples are grown.

The life history of *Eriosoma lanigerum* is interesting and complicated. The egg-laying female generally deposits her egg in a crevice of elm bark. Occasionally she lays it on another species of tree. In the spring the egg hatches and the stem mother migrates to the base of a bud. As soon as the leaves appear she begins to feed, and the affected leaf curls or forms a rosette about her. In this curled leaf she produces her young—the second, or spring generation, which consists of wingless viviparae that also live in and feed on the curled leaf. This generation matures about a month after the stem mother has emerged from the egg, and it produces the third generation, which is winged and is known as the spring migrant.

The third generation flies from the elms to apple or related plants and settles on the leaves, twigs, or water sprouts. Here it produces the fourth generation, which is wingless and is the first generation of the woolly aphid on apple. In July this generation produces another, the fifth, which is exactly like the fourth. Some individuals of this generation migrate to the roots of the host plant, while others remain on the twigs. Those that remain above ground produce the sixth generation, which is winged and matures in September.

These fall migrants may remain on the apple or related trees until late in the fall, but most of them return to elms, where they settle on the bark and produce the sexual forms, which are small and wingless and do not have functional mouth parts. The female, after mating, deposits her solitary egg in a crevice of the bark, where it remains until spring, when the stem mother hatches from it.

The part of the fifth generation which migrated to apple roots may remain there over winter.

Injury to elm by *Eriosoma lanigerum* consists of the forming of rosettes at twig terminals and the curling of leaves. Rosettes are formed early in the spring. Leaf curling is most pronounced early in the spring, but may be observed until midsummer. The species may be controlled by applying the measures recommended for other aphids.

The woolly elm aphid (*Eriosoma americanum*) has much the same appearance and life cycle as *E. lanigerum*. It differs, however, in that it is known to attack only American elm and to have as its alternate host the roots of *Amelanchier* sp. Injury to elm consists of leaf curling. For further discussion of the species see Patch (*340*, *341*) and Maxson (*292, pp. 251–271*).

The woolly elm bark aphid (*Eriosoma rileyi*) is a brown, flocculent species, about 2 mm. in length, frequently found on elms during the summer from New England and southern Canada west to Illinois and Wisconsin, in the East as far south as Pennsylvania, and in the Southwest to New Mexico. It apparently has no alternate host and feeds only on American and slippery elms. Its feeding causes knotty growths on the branches similar to the growths caused on apple branches and roots by the woolly apple aphid. For further information on this species see Patch (*340, pp. 260–262*) and Hottes and Frison (*238, p. 354*).

Tribe *TETRANEURINI*

These aphids live in true galls on their winter hosts, and are separated into three genera—*Colopha*, *Tetraneura*, and *Gobiashia*.

Probably the only species in this whole tribe that can be considered of economic importance in our eastern forests is **the elm cockscomb gall aphid** (*Colopha ulmicola* (Fitch)). It is found over most of America north of Mexico, wherever its host trees, American, rock, and slippery elms, grow. This aphid has six generations annually. The first, second, and third generations are passed on elm. The fourth generation migrates to grass and the species feeds there through the fifth generation. Sixth-generation females migrate back to elm, where each deposits one egg, which represents the overwintering stage.

The appearance of unsightly galls on the leaves, especially on young trees and ornamentals, is more important than the actual injury to the tree. Full-grown galls range from 0.5 to 1 inch long and may project upwards to a height of 0.75 inch above the leaf surface. These galls are toothed along the top, this characteristic accounting for the common name of cockscomb gall (fig. 25, *A*). To control this aphid, apply a spray (see p. 36) as soon as the leaves appear in the spring, while the aphids are feeding on the leaf surface and before they become enclosed in the galls soon to be produced.

The genus *Tetraneura* includes two species, *T. graminis* (Mon.) and *T. ulmisaccula* Patch (fig. 25, *B*), which are sometimes encountered on elm. The former attacks American and slippery elms from New Eng-

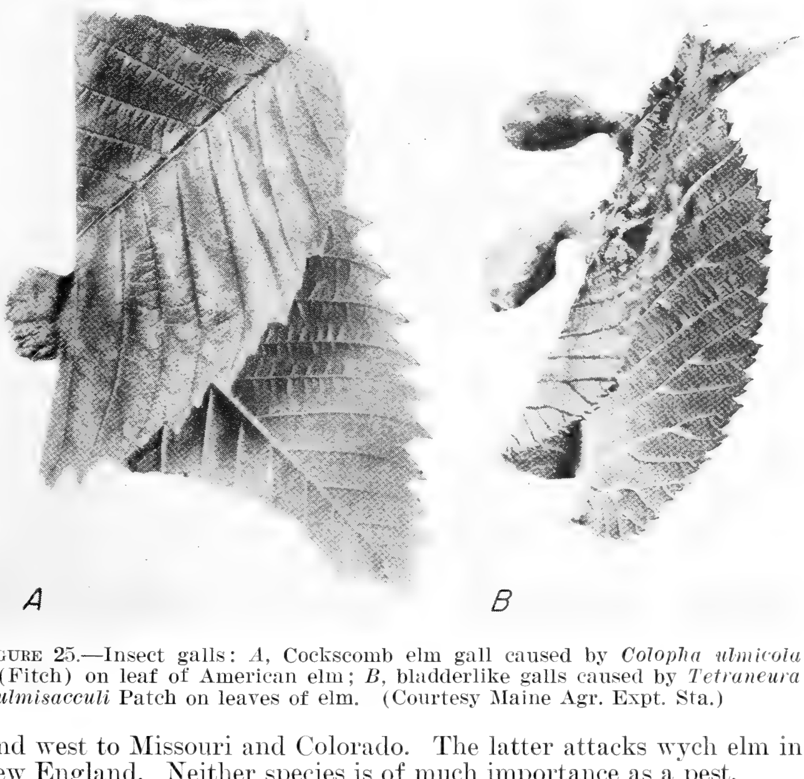

FIGURE 25.—Insect galls: *A*, Cockscomb elm gall caused by *Colopha ulmicola* (Fitch) on leaf of American elm; *B*, bladderlike galls caused by *Tetraneura ulmisacculi* Patch on leaves of elm. (Courtesy Maine Agr. Expt. Sta.)

land west to Missouri and Colorado. The latter attacks wych elm in New England. Neither species is of much importance as a pest.

Gobiashia ulmifusus Walsh and Riley, the red elm gall aphid, is found from New England and southern Canada to Colorado on the west. It is probably present in all other parts of the country where its only known host, slippery elm, grows. Galls produced by the species are spindle-shaped and sacklike, and may be 1 inch long.

TRIBE *PEMPHIGINI*

The species included in the tribe Pemphigini live exposed on the twigs of the host or within curled leaves or true galls on leaves or young wood of the winter host. Summer generations are generally produced on roots of grasses, herbs, or trees. The stem mothers have four- or five-jointed antennae, the young of the stem mother are winged, or apterous, and wax production is highly developed. A discussion of this tribe was given by Maxson (*292, pp. 319–328*).

These aphids are seldom of any importance as pests of forest and shade trees. Nevertheless, some species are sometimes so numerous as to occasion alarm.

The beech blight aphid (*Prociphilus imbricator* (Fitch)), a large, downy-woolly species, infests the under sides of branches and sometimes the trunks of beech. Moreover, there are records of its having infested sycamore (Fitch, *158, p. 68;* Hottes and Frison, *238, pp. 372–*

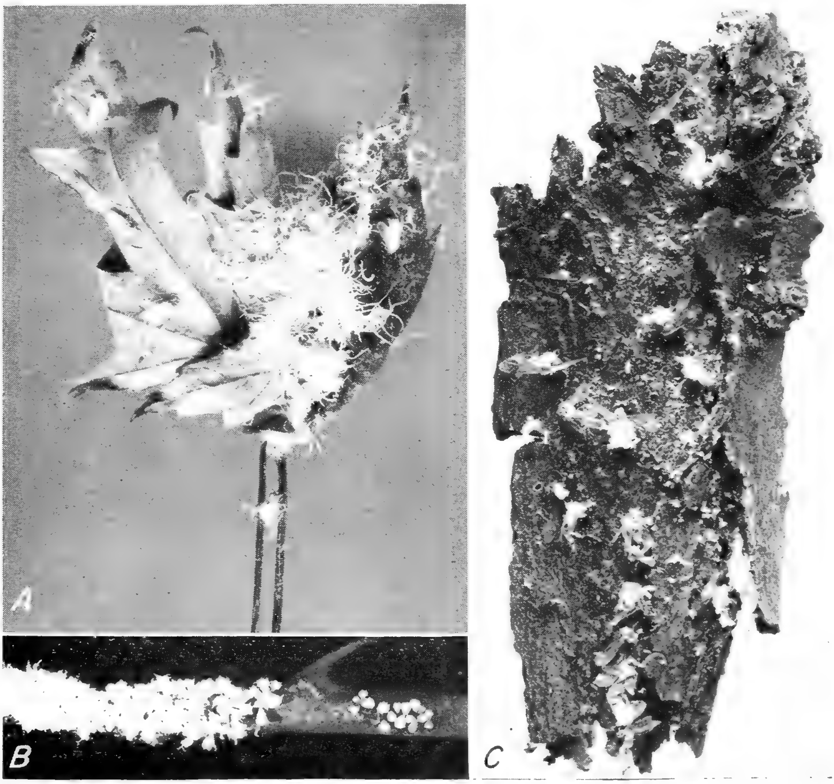

FIGURE 26.—Females of *Prociphilus tessellatus: A*, On leaves of soft maple; *B*, on alder stem; *C*, on bark of maple.

373). It occurs from New England west to Illinois and south to Georgia and Tennessee. **The woolly alder aphid** (*P. tessellatus* (Fitch)) is sometimes locally important on alder and maple. It is distributed throughout the Eastern States (fig. 26). *Prociphilus bumeliae* (Schrank) is reported as the cause of root mortality of young white pine trees in Michigan.

The genus *Neoprociphilus* is another group of aphids in this tribe that infests trees. *N. aceris* (Mon.), a flocculent species, is reported on sugar maple from New England west to Illinois and south to North Carolina (Hottes and Frison, *238, pp. 361–363*). Owing to lack of information on the complete life cycle of this species, it is considered to be possibly a form in the life cycle of *N. attenuatus* O. & S., a species infesting *Smilax* sp.

The poplar vagabond aphid (*Mordwilkoja vagabundus* (Walsh)) infests various species of poplars from New England to Montana and southwest to California, causing peculiar convoluted galls at the tips of twigs. The complete life cycle of this species has not been determined. Only part of the year is spent on poplar, for in the summer these aphids migrate to some as yet unknown host. In the fall they return to poplar and reenter the galls from which they migrated in the spring. This habit accounts for the fact that certain trees are infested year after year, while nearby trees of the same species remain uninfested (Gillette and Palmer, *185, pp. 220–221*).

In the genus *Pemphigus* the three species considered are named for the galls they produce. *P. populicaulis* Fitch infests various species of poplar and produces semiglobular galls normally located at the base of the leaf where the blade and petiole unite. These galls may be one-half inch or more in diameter (Maxson and Knowlton, *293, p. 258*). *P. populi-globuli* Fitch infests various species of poplar and forms semiglobular galls, sometimes more or less cone-shaped at the bases of leaves, on the under side. According to Maxson and Knowlton (*293, p. 263*), the galls are composed of a much enlarged and thickened portion of the leaf blade. The third species considered in this genus, *P. populi-transversus* Riley is known as the poplar stem gall aphid and may be found on various poplars, where it overwinters. Injury consists of galls produced on leaf petioles (fig. 27).

FIGURE 27.—Gall caused by *Pemphigus populi-transversus* on petiole of poplar.

The balsam twig aphid (*Mindarus abietinus* Koch) attacks both balsam fir and spruce. Injury consists of a curling and roughening of balsam and spruce twigs. On balsam fir a great deal of flocculence and honeydew are sometimes produced. Winged migrants may be encountered on pine. This species is distributed from New England to the Pacific coast.

SUBFAMILY HORMAPHIDINAE

Only two species in this subfamily are considered here. Both species, **the witch-hazel leaf gall aphid** (*Hormaphis hamamelidis* Fitch) and **the spiny witch-hazel gall aphid** (*Hamamelistes spinosus* Shimer), infest witch-hazel and birch. The former species is found from New England to North Carolina on the south and to Illinois on the west. *H. spinosus* covers the same range, plus an extension of the western area to Colorado. Neither species is of great economic importance.

Hormaphis hamamelidis forms conical galls on the upper surface of witch-hazel leaves in spring. *Hamamelistes spinosus* produces galls on stem buds of witch-hazel by the feeding of stem mothers in the spring.

Family CHERMIDAE

The genera included in this family differ in their biology from the more typical aphids in that both the sexually perfect and imperfect females lay eggs. The sexually perfect forms, both male and female and with and without wings, are dwarfed. There are also certain differences in the venation of the wings of the imperfect forms that set them apart from the usual aphid types. Two subfamilies are included in the family.

Subfamily CHERMINAE

The species in the subfamily Cherminae, known as spruce gall aphids, are all found on conifers, the primary host being spruce, where the entire life cycle is known. The secondary host may be spruce, larch, pine, or fir.

Comstock (*103, p. 429*) stated that the life cycle is complex and frequently includes the developing of two parallel series of forms. In one series the life cycle is completed on spruce in a single year, but in the other series it requires 2 years and is passed partly on spruce and partly on pine, larch, or fir. The number of generations needed to complete the cycle may vary considerably, and there may be a series of generations of one form. As many as seven parallel series of forms have been found to exist in one species. As with many other gall-forming insects, the galls are typical and the species concerned may be recognized by them. Annand (*3*) has brought together information on the life history and habits of many forest-inhabiting species.

The eastern spruce gall aphid (*Chermes abietis* L.), a species introduced into this country from Europe early in the nineteenth century, feeds principally on Norway and white spruces, although it has been recorded from other conifers (Friend, *167*, *169;* Patch, *335*, *336*).

Stem mothers of *Chermes abietis* deposit their eggs at the bases of buds in May. Nymphs hatch in about a week, crawl to the needles at the base of the new shoots, and settle on those that have become swollen by the feeding of the stem mother. These needles continue to swell until a gall is formed (fig. 28, *A*), each pocket of which may cover a dozen nymphs. Late in the summer the galls open and allow winged female adults to emerge. These, in turn, deposit their eggs on the needles of the host (fig. 28, *B*) and die immediately thereafter. Their dead bodies remain as coverings for the egg masses. The eggs hatch in 2 weeks and the nymphs crawl to the current year's growth, where they begin to feed. Only the nymphs that have fixed themselves to the bases of buds survive the winter. The overwintering nymphs mature in April and May, giving rise to the stem mothers, which are covered with white, waxy threads (fig. 28, *C*).

Injury to the host tree is caused by the formation of pineapple-shaped galls at the bases of the twigs. Not all the twigs so infested die, but Friend (*169, pp. 1–4*) reports that on heavily infested trees up to 85 percent of the gall-infested twigs die. Individual trees vary greatly in their susceptibility to attack. In southern New England approximately one-third are entirely immune, and the overwintering females that attempt to feed on them die. Wilford (*432, pp. 30, 31*) also reported that many trees are apparently immune to attack.

Stands on good sites suffer less than do more slowly growing forest trees and ornamentals. In fully stocked stands the affected trees will generally be removed in thinnings. It seems highly probable that much of the injury now caused to ornamentals by *Chermes abietis* can be eliminated by using cuttings from immune trees in grafting of nursery stock.

The Cooley spruce gall aphid (*Chermes cooleyi* Gill.) attacks Engelmann, Sitka, oriental, and Colorado spruces and Douglas-fir,

FIGURE 28.—*Chermes abietis: A*, Pineapple-shaped galls on spruce; *B*, egg mass broken open to show eggs, × 10; *C*, cottony wax covering of females at time of oviposition, × 10. (Courtesy Conn. Agr. Expt. Sta.)

and is common on ornamentals in the Eastern States. These aphids overwinter on spruce as immature stem mothers. They mature early in the spring and lay large numbers of eggs in masses of white cottony wax. When the eggs hatch the young nymphs migrate to new growth, where they begin to feed at the bases of needles. This feeding produces galls, which soon envelop the young aphids (fig. 29). When the nymphs are full grown the galls open and the aphids move to the spruce needles, where they cast their nymphal skins and emerge as winged adults, which migrate to Douglas-fir, if this tree is present. Eventually there is produced on Douglas-fir a winged generation which migrates back to spruce. Complete cycles may also continue on either spruce or Douglas-fir almost indefinitely. Chrystal (*91, pp. 10–18*) has described the biology of this species very fully.

FIGURE 29.—Galls of *Chermes cooleyi* on blue spruce.

The injury caused by this aphid on spruce may be serious if the galls are numerous. Young trees may be killed, or growth may be so retarded as to invite attack by other destructive insects. On Douglas-fir, feeding by the aphid may cause an abnormal drop of foliage.

Chermes laricíatus Patch attacks larch, also white and Norway spruces. It is closely related to the woolly larch aphid (*C. strobilobius* Kalt.) and the galls it produces on spruce closely resemble those caused by the eastern spruce gall aphid (*C. abietis*). However, galls formed by this species have very short needles and are even more pineapple-shaped than those produced by *C. abietis*. This aphid causes little injury.

Chermes strobilobius Kalt., **the woolly larch aphid,** an introduced European species, attacks larch as well as various species of spruce, principally red and black. On spruce it produces small galls at the end of the current growth. On larch it appears as white woolly masses on the needles, as dark individuals on the underside of twigs, and as clusters of dark individuals at the base of the leaves. It may be encountered from New England west to Wisconsin and south to Washington , D. C.

The fir bark louse, or balsam woolly aphid (*Chermes piceae* Ratz.), an introduced European insect, attacks various species of fir, principally balsam fir, and is found in Nova Scotia, southern New Brunswick, New England, New York, and New Jersey. Infestations are characterized by white flocculence on the trunk and branches of balsam fir, a gouty, swollen condition of the tips of twigs, or as an abnormal growth of brittle, brown sapwood on the main trunks of trees.

The fir bark louse overwinters in the nymphal stage in bark crevices, generally at the base of buds, on branches, or on the main stem. These nymphs resume growth in the spring when tree growth begins, and they rapidly develop into females, which deposit egg masses beneath the flocculent wax covering them, then die. Nymphs developing from these eggs crawl about for a time before beginning to feed. Eventually they develop into another generation of females, which lay eggs and give rise to the nymphs that hibernate.

The fir bark louse spreads chiefly in the crawler or nymphal stage, when the wind and air currents may aid in dissemination. Generally a single tree, or a small group of trees in a stand, is first infested. As the intensity of infestation increases there is a gradual spread to surrounding trees. All sizes of trees on any site may be attacked. A heavy infestation on the main stem may kill a tree in a single season, such trees being conspicuous because of red foliage. Large trees with gouty, swollen branches and twigs die slowly, but young stock bearing these swellings may die quickly. Injury has been particularly severe in localities in New Brunswick and eastern Maine.

After a severe winter, only those nymphs that were protected below the snow line survived. According to Balch (*16*), a temperature of $-30°$ F. is fatal to unprotected nymphs; however, it is probable that many die at even higher temperatures. Artificial-control measures consist of cutting and burning infested trees in isolated infestations and applying contact insecticides to infested ornamentals (pp. 52–54). Balch (*16*) and MacAloney (*280*) have published on this insect.

The genus *Pineus* includes four species that may be encountered on conifers in the Eastern States. **The pine leaf aphid** (*Pineus pinifoliae* (Fitch)) is one of the most important and may infest any of the following trees: Eastern white pine, western white pine, lodgepole pine, and red, Engelmann, black, and Sitka spruces. It occurs from southern Canada and New England west to Montana and Idaho, and south to North Carolina and Tennessee.

The pine leaf aphid overwinters as nymphs on white pine. In the spring the nymphs molt into winged individuals and migrate to spruce. Feeding on spruce, they produce terminal compact galls that have the appearance of true cones and bear in each chamber a single aphid. In Maine these galls open about the middle of June, and the nymphs emerge, molt, and migrate to the needles of the old growth of white pine. There they attach themselves, with their heads pointing toward the base of the needles. In this position the females give birth to a new generation of nymphs, which migrate to the new growth, feed, become covered with a white flocculence, and pass the winter.

Heavy overwintering populations on pine may cause the needles to turn yellow and the new growth to appear sickly. On ornamental spruce, galls sometimes become so numerous as to require attention. The species has been on the increase in Massachusetts, and heavy infestations have been reported in spruce stands in that State and in northwestern Connecticut.

The pine bark aphid (*Pineus strobi* (Htg.)), accidentally introduced from Europe, is a small dark aphid, covered with flocculent wax, that frequently covers the trunk and branches or appears in small clusters at the bases of needles on white pine. Hosts of this aphid are white, Scotch, and Austrian pines. It is found over most of the United States wherever these trees grow.

Trees in parks and picnic areas, ornamentals, and small nursery stock may be seriously affected by heavy infestations of *Pineus strobi*; however, serious injury seldom results from such infestations on large forest trees. Large trees heavily infested appear to have been whitewashed. Such infestations may be controlled by applying a forceful stream of water to them. On small pines a contact insecticide should be used.

Two other species of *Pineus* are *P. floccus* (Patch), a pest of spruce and white pine; and *P. similis* (Gillette), which attacks spruce alone. *P. floccus* produces terminal galls on spruce which comprise the entire new growth and cause a thickening of needle bases. The distal part of the needle may retain its green color, although the gall itself may be purplish. *P. similis* produces loose terminal galls on the current year's growth of spruce. It may be encountered anywhere from New England west to Minnesota. Patch (*335*, *336*), published on her studies of these insects. Neither of these species is of much importance.

Subfamily PHYLLOXERINAE

In this subfamily there are two genera, *Phylloxera* and *Phylloxerina*.. Most of the species encountered in our forests are found on hickory, and none of them appear to be important economically. Species of *Phylloxerina* are sometimes found on willow, poplar, and tupelo.

Family ALEYRODIDAE

THE WHITEFLIES

These very small, four-winged insects, are almost entirely leaf feeders. As forest insect pests they are of little concern. Two species that might be mentioned are *Aleurochiton forbesii* (Ashm.), which feeds on maples, and *Tetraleurodes mori* (Quaint.), the mulberry whitefly, which sometimes infests maples, mountain-laurel, ash, mulberry, and dogwood.

Superfamily *COCCOIDEA*

Scale insects are among our most destructive agents of ornamental or shade trees, and at times may cause extensive damage to forest growth. Injury may be caused either by the mere withdrawal of plant juices from the host by large numbers of insects or by their production of galls while feeding.

Male insects in this group are usually winged, but the females are entirely wingless. During metamorphosis many adult females lose their appendages; and, even when they do not, the appendages are atrophied. As a result, the females of many species never change position after once inserting their beaks or stylets into the host plant. The female body is scalelike, or gall-like, and is covered with wax, either in the form of powder, tufts, plates, or a thin layer covering the insect and beneath which it lives. Although the insect is not formless, it is often difficult to separate the body into head, thorax, and abdomen. In many species the mouth parts appear to emerge from about the center of the body.

Some species in this group are highly specific in host selection; others are more generalized and feed on a wide variety of hosts. Through their habit of feeding on many different parts of plants, many species have become nearly world-wide in their distribution, having been transported with nursery stock or cuttings (McDaniel, *285;* Marlatt, *289;* Morrison, *306;* Sanders, *373;* and Trimble *414*).

Family MARGARODIDAE

The individuals of some species in this family are quite large. The cottony-cushion scale (*Icerya purchasi* Mask.), which sometimes infests shrubbery, measures from 4 to 8 mm. in length (fig. 30).

Several species in the genus *Matsucoccus* have received considerable attention in recent years as pests of forest trees. So far as known, members of the genus live only on species of pine. **The pine twig gall scale** (*Matsucoccus gallicola* Morrison), is one of the more important species in this group. It attacks pitch, shortleaf, table-mountain, Virginia, ponderosa, loblolly, and spruce pines, and is distributed from New England west to Ohio and Missouri and south to Florida and Georgia.

Mature females of the pine twig gall scale are generally much flattened and are from 2 to 5 mm. long. They deposit their eggs under bark scales on the larger branches and trunks of infested trees, and these hatch early in the spring, about the time the host tree begins to grow.

FIGURE 30.—Adult females and young scales of *Icerya purchasi* on acacia. (Courtesy Conn. Agr. Expt. Sta.)

When present in large numbers, this scale may cause considerable injury, especially to small, immature trees. In New England heavily infested trees are characterized in mid-July by a fading, or "flagging," of new growth. Trees that have borne heavy infestations for several years may be either killed or badly deformed through the loss of leaders and branches. This scale may be controlled by applying a contact insecticide, such as lime-sulfur (1 to 40), immediately after all eggs have hatched in the spring (Parr, *331*).

Species of the genus *Kermes*, especially *galliformis* Riley, *kingii* Ckll., *pettiti* Ehrh., *pubescens* Bogue, and *trinotatus* Bogue, are fairly common on oaks over much of the eastern part of the United States (fig. 31), but are seldom of any importance.

The beech scale (*Cryptococcus fagi* (Baer.)), a European species, attacks both American and European beeches and varieties of each. Infestations occur throughout the hardwood areas of the Canadian Maritime Provinces and Maine, the eastern slope of the White Mountains in New Hampshire, some localities in Essex, Middlesex, and Suffolk Counties, Mass., at Hartford, Conn., and in some localities in Nassau, Westchester, and Sullivan Counties, N. Y.

In the Maritime Provinces and locally in Maine this scale has been associated with considerable mortality of beech in forested areas. However, since the killed trees have invariably been attacked by the fungus *Nectria*, the exact relation of the scale to this widespread killing of trees has not been completely established.

The beech scale has but one generation each year. In the southern part of the infested region, eggs are laid early in the summer and hatch by midsummer. The winter is passed in the nymphal stage.

Although this scale is fairly hardy, it is susceptible to winter temperatures below −35° F. Populations are affected to some extent by

FIGURE 31.—Female scales of *Kermes* sp. on white oak twigs and leaves.

a coccinellid predator, *Chilocorus stigma* (Say). There are indications that heaviest infestations develop in dense stands of beech, in stands occupying steep ridges, and in mixed stands containing high percentages of beech (Ehrlich *142*).

The beech scale can be controlled by the application of a dormant spray of lime-sulfur. However, such measures are probably applicable only to ornamental plantings. In the forest a degree of control is possible by thinning dense stands and lowering the percentage of overmature beech in mixed stands.

The European elm scale (*Gossyparia spuria* (Mod.)), accidentally introduced into the United States from Europe in the 1880's, sometimes becomes very destructive, especially to ornamental and street elms. It is found over most of southern Canada and the United States wherever its hosts, most of the native and European elms, grow. The adult female is oval, reddish brown, and has a waxy fringe along the body margin. Eggs are deposited from spring to midsummer. Upon hatching, the nymphs seek places of attachment, and most of them make their way to the leaves, while some settle down and feed on twigs or small branches. This scale passes the winter in the nymphal stage.

When present in large numbers, this scale causes yellowing and a premature drop of foliage. Although young elms may be killed outright, large trees seldom succumb unless they are so weakened that they fall prey to the attacks of bark beetles, fungi, or drought (Herbert *221*). During the egg-laying period the females excrete honeydew which, dropping and sticking to the foliage, may become covered with a sooty mold, and produce unsightly conditions.

Family PSEUDOCOCCIDAE

Only one species in this family, **the maple phenacoccus** (*Phenacoccus acericola* King) is of any importance as a forest or shade-tree pest. It is a rather large scale, about 5 mm. long, and is covered with a mass of cottony wax, which may be one-half inch in diameter. Its principal host is sugar maple (*Acer saccharum* Marsh), and it is found throughout the Northeastern States.

Family ASTEROLECANIIDAE

In this family of scale insects three or four species belonging to the genus *Asterolecanium* may be destructive to forest or ornamental growth. These scales are small, ranging from about 1 to 3 mm. in diameter. Most species in the genus produce pits or ringlike galls on their host, and often this injury may be used as a means of identifying the insect. Males have never been found in most of the American species. Females are smooth and shiny, light yellowish to brownish in color, legless and wingless, and possess microscopic antennae. Nymphs are so small as to be hardly visible to the naked eye. Russell (*365*) published a classification of the genus *Asterolecanium*, and Morrison and Morrison (*307*) published on the subfamily Asterolecaniinae.

The yellow oak scale (*Asterolecanium luteolum* Russell) is a very small scale that feeds in slight pits on the undersurface of leaves, in pits on smooth bark, and in crevices of rough bark. In the United States it has been found only on oak in Pennsylvania. Another species also found only in Pennsylvania on oak is *A. minus* Lindinger. It lives in pits in the bark. **The holly scale** (*A. puteanum* Russell) feeds on the bark of twigs and produces both shallow and deep pits. It feeds on holly (*Ilex vomitoria* Ait. and *I opaca* Ait.) and on *Bumelia* sp., and is found from Delaware and Maryland south to Alabama and Florida. The species *A. quercicola* (Bouché) occurs in the Eastern States, from New York to North Carolina, and feeds on the following oaks: White, swamp white, red, chestnut, English, and *Quercus robur pedunculata* A. DC. It feeds in pits in the barks of twigs, branches and trunks of trees, and may be a serious pest, causing death of twigs, branches, and sometimes entire trees. This species has been confused in the literature with *A. variolosum.*

The pit-making oak scale (*Asterolecanium variolosum* (Ratz.)) is found wherever its hosts occur in this country. It is known to attack English, chestnut, and white oaks. Other oaks probably attacked are bear, swamp white, holm, bur, red, and scarlet. This species may be distributed on nursery stock, and many countries now are quarantined to prevent the introduction of infested plants. Injury to oaks is caused by the production of galls or swellings while the scale is feeding. Heavily infested reproduction may be killed, and when heavy infestations are followed by drought even mature trees may be seriously injured or killed. Injury to chestnut oak, the species most susceptible to severe scale attack, is characterized by the dying of branches, or even entire tops of trees (Parr. *330, pp. 51–58; 332, pp. 1–49*).

Asterolecanium variolosum has a single generation annually. It passes the winter as mature or nearly mature insects, and in the Northeastern States the larvae hatch late in June and in July.

Since chestnut oak is a highly favored host, some control in forests may be brought about by eliminating that species and encouraging less favored hosts. In nurseries and on ornamentals, artificial control is possible through the use of a contact insecticide (p. 52). In heavy infestations some natural control may be effected by the feeding of birds, particularly the chickadee, and by a hymenopterous parasite, *Habrolepis dalmani* Westw.

The English ivy scale (*Asterolecanium arabidis* (Sign.)) has been reported on green ash and on privet, in addition to English ivy and several species of herbaceous vegetation. It is found from Massachusetts to New Jersey, Pennsylvania, West Virginia, and Ohio, but probably is of little importance.

The oleander scale (*Asterolecanium pustulans* (Ckll.)) has been reported on *Acacia* spp., the marmalade tree, magnolia, mulberry, and many other trees. This scale may be very destructive on the trees it attacks.

Control measures for these scales are discussed on page 36.

Family COCCIDAE

The bodies of adult female coccids are either bare or encased in waxy or cottony secretions.

The maple leaf scale (*Pulvinaria acericola* Walsh and Riley) may become numerous enough at times to cause early dropping of leaves and even the death of twigs and branches of its host trees, soft and sugar maples. It is found over most of the eastern half of the United States and southern Canada. The adult female is about 5 mm. long, 3 to 4 mm. wide, and 1.5 mm. high. It is dark purple with a median brown stripe, and bears a long cottony egg sac at the posterior end.

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Eggs are laid on the leaves in May and June. After two molts the young nymphs migrate in the fall from the leaves to twigs and branches, and hibernate there throughout the year. (For control measures, see p. 36.)

The cottony maple scale (*Pulvinaria vitis* L.) is larger than the maple leaf scale, being from 5 to 7 mm. long and about 4 mm. wide. It is brown in color and elongate-oval in shape. It is conspicuous in summer, owing to the large, white, cottony egg sac extruding from the posterior end of the body. The species is widespread over the United States and southern Canada and attacks many species of trees, including most of the maples, boxelder, white ash, black locust, sycamore, red mulberry, and the Japanese angelica tree (*Aralia elata* Seem.).

Eggs are laid from April to June and hatching takes place throughout the summer. Upon hatching, most of the nymphs migrate to the undersurface of leaves, where they feed on the principal veins. Some migrate to the upper surface of leaves; others remain on the twigs. Nymphs complete their development by fall, and after fertilization the adult females migrate to the twigs, where they overwinter and remain in the spring to produce their characteristic egg masses (fig. 32). There is one generation annually.

Heavy populations of this scale seldom occur on the same trees for two successive years, owing to the numerous predaceous and parasitic insects that attack it when it is numerous. However, it sometimes becomes so abundant in 1 year, especially on shade trees, as to require the application of control measures (p. 36.)

The woolly pine scale (*Pseudophilippia quaintancii* Ckll.), characterized by the presence of heavy white woolly masses at the bases of new-growth needles, may be found on loblolly, mugho, pitch, and longleaf pines from New England and New York to Florida and Louisiana. Apparently only young trees below 14 feet in height are attacked (Felt, *147, pp. 689–690*).

The magnolia scale (*Neolecanium cornuparvum* (Thro)) is the largest scale insect found in the United States, the adult female measuring about ½ inch across. It is a rich dark brown and nearly round, when uncrowded (fig. 33). It attacks several species of magnolia. Herrick (*222*) mentioned that excessive infestations cause serious injury to its host.

The tuliptree scale (*Toumeyella liriodendri* (Gmel.)), only a little smaller than the magnolia scale, occurs over the eastern half of the United States and attacks yellow poplar, magnolia, bay, and capejasmine. Females are dark brown, hemispherical, and are frequently found in crowded masses on twigs and branches of the host (fig. 34). Houser (*239, pp. 301–302*) discussed this insect and the damage caused by it.

In the northern part of the United States **the pine tortoise scale** (*Toumeyella numismaticum* (Pettit and McD.)) is found on Scotch, Austrian, and jack pines. Females of the species are reddish brown, oval, very convex, and from 5 to 7 mm. long. The species hibernates as immature females and has one generation a year.

Pines heavily infested with the scale become covered with a black sooty mold, the foliage drop is unusually heavy, and the needles on the trees are much shorter than normal. Whole trees may die within a few years. Young trees are preferred hosts apparently, and the

FIGURE 32.—The cottony maple scale (*Pulvinaria vitis*) on twigs of soft maple.

scale has caused mortality in young pine stands and plantations in the Lake States and in Nebraska.

Another species in this genus, *Toumeyella pini* (King), attacks mugho, lodgepole, Scotch, and cluster pines and has been recorded from Connecticut, Pennsylvania, Michigan, and Florida.

The European fruit lecanium (*Lecanium corni* Bouché) also called **the brown elm scale** is widely distributed over the entire United

FIGURE 33.—Females of the magnolia scale (*Neolecanium cornuparvum* on magnolia tree.

States and southern Canada. It has a wide range of forest- and shade-tree hosts, having been reported on sassafras, mulberry, elm, oak, maple, beech, ash, hackberry, Osage-orange, locust, Chinaberry, hawthorn, hickory, black walnut, butternut, redbud, magnolia, poplar, willow, boxwood, and arborvitae.

Females of this scale are dark brown to reddish, more or less oval, and very convex. When full grown, they are from 1.5 to 3 mm. long, and are often covered with a whitish pulverescence. They deposit their eggs early in the summer. At first the young nymphs occur anywhere over the undersurface of leaves, but after the first molt they may be found along the veins. Before leaf drop in the fall the nymphs migrate to the bark of twigs and small branches, where they overwinter. There is a single generation a year.

According to Fenton (*156*) this scale is especially destructive on elm in Oklahoma, killing branches, stunting tree growth, and in general making infested trees susceptible to attack by other insects and diseases.

The **terrapin scale** (*Lecanium nigrofasciatum* Perg.), also known as the black-banded scale, is widely distributed over the Eastern States and southern Canada and attacks sycamore, maple, boxelder, and hawthorn. A full-grown female is from 3 to 4 mm. long, slightly narrower, and very convex. In general the color is reddish to reddish brown, with black banding and mottling. Sometimes the mottling is missing and the scale is entirely reddish brown or black.

In the Northern States *Lecanium nigrofasciatum* overwinters as nearly mature females. Eggs are laid in June and hatch soon thereafter. There is only one generation a year. Heavily infested trees may be severely injured through a lowering of their vigor from feeding by the scales. The insects excrete copious quantities of honeydew, in which a sooty mold develops, giving infested trees a very unhealthy appearance. Several species of hymenopterous parasites, as well as the ladybird beetle *Chilocorus stigma* (Say), are reported as serving to hold this scale in check.

The oak lecanium (*Lecanium quercifex* Fitch) is similar to the other scales discussed in this genus. It attacks many oaks throughout the Eastern States.

The spruce bud scale (*Physokermes piceae* Schr.) attacks various species of spruce and is distributed over the Northeastern States and southern Canada to Minnesota on the west and Maryland on the south. It overwinters in an immature stage on twigs, around terminal buds. Eggs hatch in June in Michigan, according to McDaniel (*284, p. 22*), and in July in New York, according to Felt (*149, p. 165*). The pres-

FIGURE 34.—The tuliptree scale (*Toumeyella liriodendri*) on twigs.

ence of the scale is most easily determined after it matures, when it produces large quantities of honeydew.

According to McDaniel (*284, pp. 21-22*), attacks by this species are mostly confined to the terminals of the lower branches. Heavy attacks may kill branches and cause plantations to assume an unhealthy appearance. It is also reported that the black mold, which develops in the honeydew, reduces the vigor of the trees.

FAMILY DIASPIDIDAE

The members of this family live under scales composed of the cast skins of the previous stages, together with an excretion of the insects. The terminal segments of the insect are fused, forming a pygidium. The legs and antennae are present in the first-instar nymph, or crawling stage, but become atrophied when the nymph settles and feeds.

The genus *Aspidiotus* contains several species of scale insects that attack forest and shade trees, one of the most important being **the San**

Jose scale (*Aspidiotus perniciosus* Comst.). At one time this species was one of the most important shade-tree pests in the United States. It is an introduced species, having been imported on fruit-tree stock from China. From the point of original establishment in the San Jose Valley of California, it has now spread over all of the United States and Southern Canada. Although known chiefly as a pest of fruit trees, it attacks and seriously affects a considerable number of species of shade trees and ornamental shrubs, including elm, mountain laurel, redbud, magnolia, and firethorn (*Cotoneaster pyracantha*).

The covering of a full-grown female is approximately 1 mm. in diameter, is gray, and bears a dark, central, nipplelike projection. The covering of the male is smaller and more elongate.

There are two to four generations of this species in the Northern States, and probably still more in the South. Each female gives birth to about 600 living young. If allowed to develop unmolested for 2 to 3 years on forest and shade trees, it may kill twigs and branches, and even entire trees. Infestations on shade trees may be controlled by the application of contact sprays (p. 52) (Painter, *325*).

Hemlock, pine, spruce, and fir in the Eastern States are sometimes attacked by a small, dark-gray or nearly black, oblong scale known as **the hemlock scale** (*Aspidiotus ithacae* (Ferris)). It is found attached to the under side of needles of the host trees, and in heavy infestations even on twigs and branches. Injury to trees results from a heavy foliage drop.

The Putnam scale (*Aspidiotus ancylus* (Putn.)) is a small, circular scale about 1 mm. in diameter. It is found over most of the United States and attacks several species of trees and shrubs. Females differ from those of the San Jose scale in that they are a little darker and the nipple, which protrudes slightly from the dorsum, is off center and is brick red. Forest trees most susceptible to the Putnam scale are basswood, soft maple, poplar, ash, beech, black locust, and hackberry, the first two being the most susceptible. Limbs, branches, and at times the trunks of these trees are attacked. Injury is seldom great, although twigs and branches may be killed.

There are several other species of *Aspidiotus* to be found on forest and shade trees and they may be listed with their hosts, as follows: *A. aesculi* Johns, horsechestnut; *A. comstocki* Johns, maple; *A. forbesi* Johns, cherry; *A. juglans-regiae* Comst., **the walnut scale**, on a wide variety of trees and shrubs; *A. osborni* Newell & Ckll., oak; *A. ostreaeformis* Curt., the European fruit scale, on willow and poplar; *A. townsendi* Ckll., yellow poplar; *A. ulmi* Johns, elm, hackberry, locust, and yellow poplar; *A. californicus* Coleman, the black pine leaf scale, on various species of pine (fig. 35) and Douglas-fir. The last-named species was sufficiently injurious in the Lake States in 1943 to make it

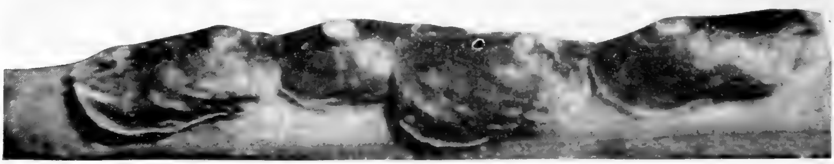

FIGURE 35.—Female scales of *Aspidiotus californicus* on pine needle. About 20 × natural size.

necessary to dip in a 1-to-12 mixture of lime-sulfur all pine stock shipped during the year from the Forest Service Cass Lake Nursery in Minnesota.

There are two species of scales in the genus *Chrysomphalus* that attack forest and shade trees sufficiently to be considered here. Probably the most injurious of the two is **the gloomy scale** (*C. tenebricosus* (Comst.)), which is particularly destructive to soft maples in the South and also attacks sugar maple, hackberry, elm, and boxelder. It is southern in distribution, being recorded from Washington, D. C., west to Ohio and south and southwest to Georgia, Tennessee, and Texas.

The gloomy scale somewhat resembles the San Jose scale. Adults are gray, but the protruding nipple on the dorsum is usually more concentrically placed than in *Aspidiotus perniciosus*. Moreover, the inner bark of trees infested with this species does not show the red coloration that occurs in trees infested with *A. perniciosus*. *Chrysomphalus tenebricosus* was reported by Kotinsky (*269, p. 78*) as especially abundant in the South.

The obscure scale (*Chrysomphalus obscurus* (Comst.)) attacks pecan, oaks, elm, hickory, and hackberry, and is found over much the same territory as the gloomy scale. Heavy attacks may cause small limbs to die. It has one generation a year (Baker, *14*).

The elm scurfy scale (*Chionaspis americana* Johns.) attacks elm and hackberry from New England west to Illinois, southwest to Oklahoma and Texas, and south to Georgia and Florida. Adult females of this species are covered with a dirty-white, oystershell-shaped scale about 3 mm. long, the front part of which is frequently covered with a grayish or blackish secretion. In the Northern States there are two generations a year. Farther south there probably are more. Injury consists of the dying of twigs, branches, and small trees in heavy infestations; and, although large trees are not known to be killed, they may be so weakened as to be susceptible to injury by other insects.

The scurfy scale (*Chionaspis furfura* (Fitch)) is frequently found on elm, ash, aspen, cherry, hickory, maple, black walnut, and willow, and is distributed widely over southern Canada and the United States. Females of the species are somewhat pear-shaped, about 2 mm. long, and under ordinary city conditions are dirty gray. This scale attacks the leaves, branches, and main trunk of its hosts. *C. lintneri* Comst., a closely related species, is found on willow, birch, dogwood, and various other trees and shrubs in the Northeastern States and southeastern Canada.

The euonymus scale (*Unaspis euonymi* (Comst.)) attacks euonymus, as well as certain other species of plants, and may be found over most of the United States wherever its hosts occur. This scale is oblong, broadened posteriorly, and varies in color from dirty gray through brown to nearly black. In the North there are two generations each year. Heavy infestations (fig. 36) may kill twigs, branches, and even entire trees within a few years.

The pine-needle scale (*Phenacaspis pinifoliae* (Fitch)), although common throughout the United States and in southern Canada, and potentially destructive in ornamental plantings throughout this extensive area, is apparently most prevalent east of the Mississippi River. It attacks, in addition to the various spruces, the following pines: East-

FIGURE 36.—*Unaspis euonymi*, mostly males, on leaves and twigs of *Euonymus*.

ern white, red, Scotch, lodgepole, ponderosa, Austrian, and mugho. This scale is about 3 mm. long, elongate, and nearly white (fig. 37). Male scales are pure white, narrow, and about one-third as long as the females.

Uncontrolled infestations of this scale gradually kill branches and entire trees. Earlier effects are a yellowing or spotting of needles from the insects' feeding, resulting in a whitish appearance of infested plants. For control, see p. 36. In the Eastern States a closely allied species, *Phenacaspis heterophyllae* (Cooley), may be found associated with *P. pinifoliae* on pine, although it apparently is not found on spruce.

The willow scurfy scale (*Chionaspis salicis-nigrae* (Walsh)) large and pear-shaped, may be encountered on willow and on dogwood, serviceberry, yellow poplar, and Cascara buckthorn in the Northern States. However, even though it may kill twigs and branches when abundant, it seldom kills trees.

Throughout the United States and southern Canada, in parks or other ornamental plantings, **the juniper scale** (*Diaspis carueli* Targ.) may be found on various species of juniper, arborvitae, and cypress. It is about 2 mm. in diameter, nearly circular, and in color ranges from light gray to white. Although it may become important in parks and ornamental plantings it seldom injures forest stands.

One of the commonest scale insects on ornamentals and hardwood-forest growth is **the oystershell scale** (*Lepidosaphes ulmi* (L.)). The mature female is rather small, 2 to 3 mm. long, narrow anteriorly, and broad and rounded posteriorly. Ordinarily the scale is strongly curved, but when crowded it may be considerably distorted. In color the female ranges from dark brown in summer to grayish in winter (Quaintance and Sasscer, *359*).

This species occurs throughout the United States, although it is most prevalent and injurious in New England and the Lake States. The forest trees most commonly injured are white ash, black ash, beech, eastern cottonwood, willow, elm, birch, and maple. The overwintering eggs hatch from late in May until late in June, depending on the season. This generation matures and lays its eggs in August or September in the Northern States, where there usually is one generation each year.

Since *Lepidosaphes ulmi* is so small and its coloring is such as to cause it to blend well with the bark, infestations often pass unnoticed until a retardation of branch and twig growth causes an early yellowing of foliage, and sometimes the death of such growth. It often happens that large branches of ash, poplar, and maple trees are killed back from the tips by this insect. Ash reproduction is often seriously affected, and entire stands of ash have been killed in Ohio.

The oysterhell scale spreads slowly from tree to tree, since spread must take place during the time when first-instar nymphs are crawling. This occupies but a few days; and therefore most of the scales do not escape to other hosts and heavy infestations are permitted to build up on a tree. This insect is subject to parasitization by several species of hymenopterons and to predatism by birds, mites, and certain insects. These controlling influences aid in holding infestations within bounds. Where it is thought necessary to apply artificial-control measures, good results can be obtained by applying a contact insecticide (p. 53, formula 5) just after the eggs hatch.

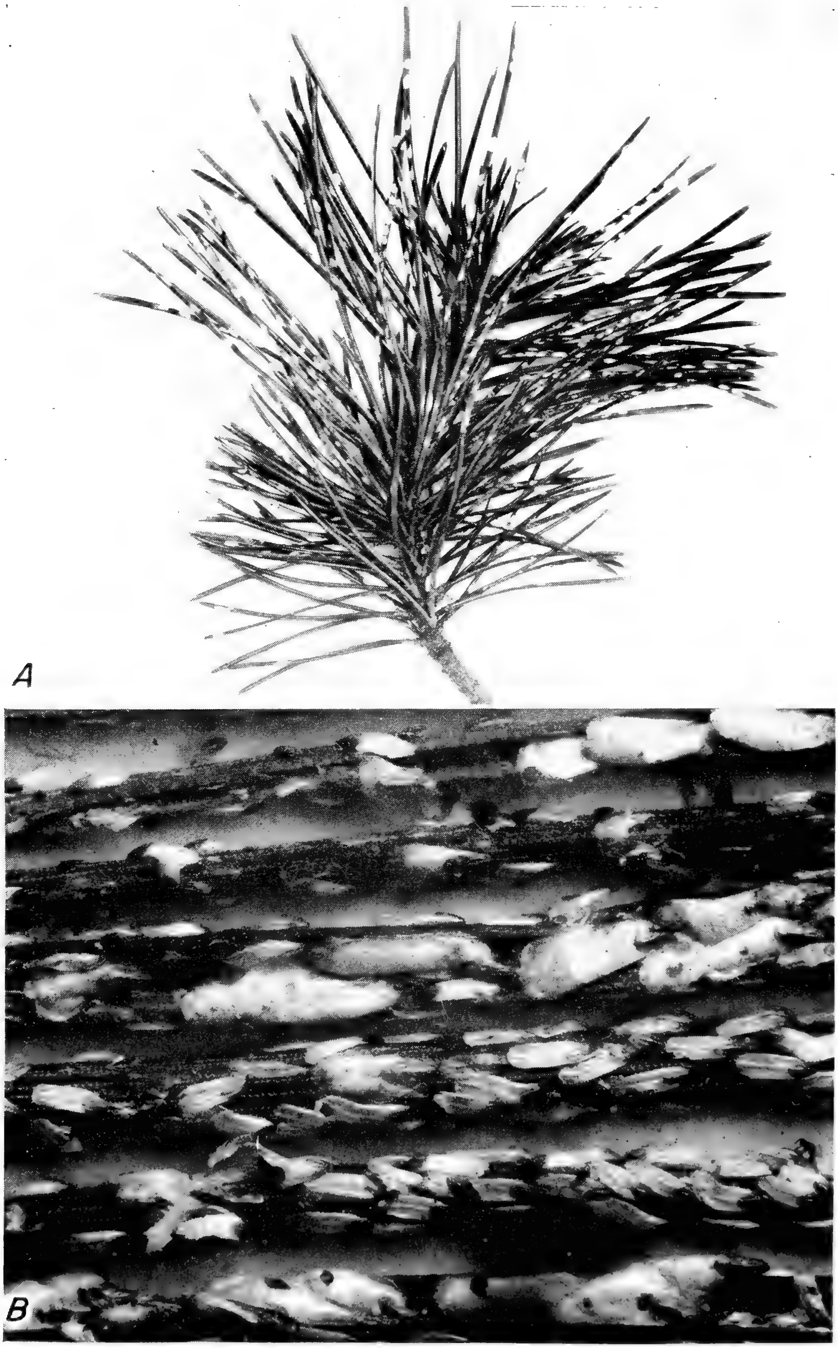

FIGURE 37.—*Phenacaspis pinifoliae* on leaves of pine: *A*, Natural size; *B*, same, magnified, showing males and females, and holes in female scales from which parasites have emerged.

THE BEETLES

Order COLEOPTERA [18]

The beetles are distinguished from other insects by having a complete metamorphosis, biting mouth parts, and hardened forewings, or elytra, which cover the folded and membranous hind, or second pair of wings, when the latter are present.

The larvae of these forms cannot be thus briefly characterized to set them off from those of other insects. The modification and complexity of form which occurs in this order is extremely varied, duplicating the aquatic adaptation of the Neuroptera, the leaf-feeding and wood-boring habits of the Lepidoptera, and the parasitic habits of the Hymenoptera, each with paralleled modifications of structure. Consequently, for present purposes no attempt will be made to give a combination of characters that will define the larvae of this order and set them off from the others.

As previously stated, the diversity of habits in this order is extremely marked. Whole families are fitted for aquatic life, both as larvae and adults; some are active predaceous swimmers; others live sedentary lives under stones and are provided either with gills or with special mechanisms to store air; some families are primarily parasitic with a complicated metamorphosis and highly modified adaptation to varied existences in their development; many are active predators or scavengers on the surface of the ground; and many of those with which we are chiefly concerned are phytophagous. Of these plant-feeding forms certain modifications are found which fit the larvae or the adults to feed on different portions of the plant—roots, stem, twigs, buds, leaves, or seeds. Some attack only living tissue, others recently dead or dying plant tissue, and again there are those that feed only on decaying vegetation or the fungi associated with decay.

The beetles are probably the most important order of forest insects from an economic standpoint. The widespread destruction of mature timber caused by the bark beetles, and the injury to forest products from the attack of roundheaded and flatheaded borers and powder-post beetles are notable instances of their destructive powers.

Many adults of this order cause extensive defoliation, other beetles kill living timber by introducing blue stain fungi, but the larval stage is generally the most destructive. For this reason it seems desirable in a discussion of this kind to give emphasis to the description and recognition of the larval stages. At present the larvae are very inadequately treated in economic literature. For simplicity and practicability the keys used to distinguish the coleopterous larvae combine anatomical and biological characters. Those characters mentioned in the keys are frequently not repeated under the family or species descriptions and must be taken into consideration for an adequate characterization of the forms. For more extended treatment of this order the reader is referred to the following works: Blatchley (*47*), Böving and Craighead (*52*), Bradley (*53*), Leng (*273*), and Leng and Mutchler, (*274*, *275*).

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[18] The information on this order has been compiled by the following authorities: The Lamellicornia by L. E. Yeager; the Chrysomelidae and Rhynchophora by H. J. MacAloney (except larval discussion); the Tenebrionidae and a few related forms by R. A. St. George; the Scolytidae and Platypodidae by M. W. Blackman; the Buprestidae by J. N. Knull; and the remainder by F. C. Craighead.

KEY TO THE FAMILIES OF MORE IMPORTANT BEETLE LARVAE

1.	Legs apparently 6-jointed, the fifth bearing 1 or 2 distinct movable claws	2
	Legs either 5-jointed with tarsus and claw fused into a single claw-shaped terminal joint, or less than 5-jointed or absent	6
2.	Hypopharynx and ligula strongly chitinized; soft-bodied wood-boring forms	3
	Hypopharynx soft; ligula soft or vestigial; mandibles falciform, fitted for grasping	5
3.	Ninth abdominal segment armed with 1 or 2 chitinous processes; mandibles with large grinding molar structure	4
	Ninth abdominal segment unarmed; mandibles of grasping type	Rhysodidae
4.	Ninth abdominal segment dorsally produced into a straight process	Cupesidae
	Ninth abdominal segment bearing a dorsal and ventral process, curved toward each other	Micromalthidae
5.	Body fusiform usually developed for active motion, no abdominal hooks	Carabidae
	Body fleshy digitate; dorsal surface of fifth abdominal segment bearing 2 or 3 pairs of hooks; larvae living in earthen burrows in the soil	Cicindelidae
6.	Ninth abdominal segment bearing 1- or 2-jointed, movable appendages or cerci	7
	Cerci rigid or wanting	9
7.	Mandibles of the grasping type without a grinding or molar structure at base; gula reduced or represented by a line, the sides of the head meeting ventrally	8
	Mandibles of the biting type; gula present	Silphidae
8.	Spiracles bifore; cardo and stipites fused	Histeridae
	Spiracles annular; stipites articulate on cardo	Staphylinidae
9.	Curved, grublike larvae with strong well-developed legs; mandible with a large grinding structure; lacinia and galea usually distinctly divided; spiracles usually cribriform; no cerci	10
	Form variable and not having the above combination of characters	11
10.	Gula present separating submentum from prothoracic skin; lacinia 2-jointed	Byrrhidae
	Gula absent; submentum and prothorax continues in a soft skinlike connection	Lamellicornia
11.	Gular region or a median gular suture present	12
	Gular region fleshy, i. e., submentum and presternum of prothorax continuous in a skinlike connection	40
12.	Parasitic; soft-bodied, swollen larvae with head and body white; mandible without molar structure	13
	Not parasitic; head and body normally chitinized	14
13.	Mouth parts protracted	Catogenidae
	Mouth parts retracted	Bothrideridae
14.	Labrum absent or fused with clypeus into a nasale	15
	Labrum distinct	17
15.	Head structures reduced and specialized; body usually much depressed; wood borers, the larvae cutting galleries across the grain of the wood	16
	Head structures not so modified	Elateridae
16.	Legs short, 5-jointed	Throscidae
	Legs absent or vestigial	Melasidae
17.	Maxillary articulating area indistinct	18
	Maxillary articulating area large and distinct	24
18.	Ninth abdominal segment operculate, terminal; body cylindrical, heavily chitinized	Rhipiceridae
	Body otherwise	19
19.	Prothorax enlarged and flattened, marked with a distinct circular or oval area above and below; legs vestigial or wanting	Buprestidae
	Prothorax not specialized; legs well developed	20
20.	Body fleshy; curved, inactive larvae feeding in fungi	Ciidae
	Body digitate or active; predaceous forms or scavengers	21

KEY TO THE FAMILIES OF MORE IMPORTANT BEETLE LARVAE—Continued

21.	Ventral mouth parts retracted considerably behind a line between the ventral mandibular articulations	22
	Ventral mouth parts not retracted; predaceous forms—Cleridae	
22.	Lacinia armed with spurs; body hairy—Dermestidae	
	Lacinia without spurs	23
23.	Epicranial suture well developed—Melyridae	
	Epicranial suture nearly absent—Ostomidae	
24.	Ventral mouth parts retracted considerably behind a line between the ventral mandibular articulations; molar or grinding structure of the mandible usually present	25
	Ventral mouth parts not retracted; larvae soft skinned, fleshy; wood borers; molar structure absent—Cerambycidae	
25.	Spiracles on tubular process; sap feeders—Nitidulidae	
	Spiracles not noticeably projecting	26
26.	Free living predaceous forms crawling about on bark or foliage; three ocelli present on each side of head—Coccinellidae	
	Concealed forms under bark or in wood or fungi	27
27.	Form very depressed, about twice as wide as thick; adapted to living between bark and wood; clypeus and front often fused	28
	Form more robust	31
28.	Cardo not composed of two pieces; mala falciform; hypopharynx without a chitinization—Cucujidae	
	Cardo of two pieces; mala obtuse; hypopharynx chitinized	29
29.	Eighth and ninth abdominal segments nearly equal; a single pit present between terminal spines; asperities on venter of ninth abdominal segment arranged in a broken arch—Pythidae	
	Eighth abdominal segment at least twice as long as ninth (terminal spines excluded); a pair of pits present between spines	30
30.	Ninth abdominal segment with asperities on venter arranged in a single arch—Pyrochroidae	
	Ninth abdominal segment bearing a series of small chitinized plates in place of asperities—Boridae	
31.	Mandibles with a reduced, smooth molar structure; somewhat resembling the mandibles of the Cerambycidae—Melandryidae	
	Mandibles with normal molar structure	32
32.	Cardo of a single piece	33
	Cardo of two pieces	37
33.	Ninth abdominal segment bearing spines, latter with pit between margins	34
	Ninth abdominal segment with or without spines, when present pit wanting between margins	35
34.	Terminal spines bifurcate—Othniidae	
	Terminal spines simple—Colydiidae	
35.	Antenna inserted close to mouth frame; apices of prothoracic coxae usually contiguous	36
	Antenna inserted some distance from mouth frame; apices of prothoracic coxae separated—Lagriidae	
36.	Back of mandibles opposite cutting edge, sharp; body cylindrical; terminal segment without spines and usually bluntly rounded—Alleculidae	
	Back of mandibles rounded; body rarely cylindrical; terminal segment often armed—Tenebrionidae	
37.	Second to fifth abdominal segments with venter bearing asperate ampullae—Oedemeridae	
	Abdominal segments normal, without ampullae	38
38.	Ninth abdominal venter bearing a pair of conical points—Synchroidae	
	Ninth abdominal venter simple, without such points	39
39.	Submentum and gula fleshy; terminal segment with well-chitinized spines—Zopheridae	
	Submentum and gula fused and heavily chitinized; terminal segment with soft, white spines—Cephaloidae	
40.	Hypopharynx chitinized; mandibles with a molar or grinding structure	41
	Hypopharynx fleshy; mandibles without a grinding structure	42

KEY TO THE FAMILIES OF MORE IMPORTANT BEETLE LARVAE—Continued

41. Legs well developed, 5-jointed: ninth abdominal segment armed: body elongate ---- Lymexylonidae
Legs weak: ninth abdominal segment unarmed: body curved: larvae in bark or wood beneath the sporophores of woody fungi ---- Anthribidae
42. Ninth abdominal segment ending in a single truncate spine or in paired spines ---- Mordellidae
Ninth abdominal segment unarmed, except some first-instar larvae ---- 43
43. Tenth abdominal segment provided with a pair of cushioned lobes (not anal lobes) separated by a median suture: fleshy, curved hairy forms, usually with slender 4- or 5-jointed legs: wood-boring forms ---- Bostrichidae, Ptinidae
Tenth abdominal segment normal ---- 44
44. Elongate, buprestid-like larvae in the roots of hickory trees ---- Disteniinae (Cerambycidae)
Form otherwise ---- 45
45. Legs vestigial, 2-jointed: cylindrical, fleshy, wood-boring form, with chitinous asperities on prothorax and abdominal terga ---- Brentidae
Legs 4- or 5-jointed except occasionally wanting in some leaf-mining forms: maxillary mala often divided: hypopharyngeal bracon absent ---- 46
Legs wanting: mala always simple: bracon present ---- 47
46. Mentum bearing a shieldlike plate: labial palpi absent or rudimentary: feeding in the seeds of plants ---- Bruchidae
Mentum without such plate: labial palpi rarely wanting ---- Chrysomelidae
47. Adults usually associated with the larvae and boring characteristic galleries in the wood or under the bark of shrubs, trees, or lumber ---- Platypodidae, Scolytidae
Larvae and adults not so associated ---- 48
48. Abdominal segments with two transverse folds: larvae often found in a compacted roll cut from a leaf ---- Curculionidae, Attelabinae
Abdominal segments with 3 or 4 transverse folds ---- 49
49. Larvae boring in the moist sapwood of dead trees or occasionally in beams of buildings, powder-posting the material ---- Curculionidae, Cossoninae
Habits of larvae variable: not working like powder-post beetles ---- Curculionidae

Family CARABIDAE

The Ground Beetles

The ground beetles make up a large family of beetles of interest to the forester chiefly because of their beneficial or predatory habits. Several larger species of *Calosoma* are also expert climbers and are voracious feeders on caterpillars, destroying great numbers of these destructive defoliators. Others stay on the ground, hunting living insects in the leaf litter and under logs or stones, while some forms live under the bark of dead trees or logs. Nearly every habitat of the forest is occupied by some form or forms of this family, and each form is specially adapted to living or procuring food under special circumstances. One interesting adaptation of this kind is represented by the old genus *Cychrus*, now *Scaphinotus*, the members of which frequent cool, damp ravines, where the beetles feed on snails. These large beetles are provided with an elongate head and mandibles well fitted for removing the snail's body from its shell.

The carabid larvae are elongate, fusiform, usually active species with darkly chitinized integument in the free-living forms, but white and thin textured in ground or bark-inhabiting forms. The mandibles are sickle-shaped and pointed for grasping prey, and the legs five-jointed, with the fifth joint bearing a distinct movable claw or a pair of claws; this character readily distinguishes these larvae and the few related families from all other Coleoptera. They usually have jointed appendages, cerci, on the ninth abdominal segment.

Calosoma sycophanta (L.) is a large very conspicuous bluish-black beetle, 24 to 30 mm. in length, with golden-green elytra. It has been introduced from Europe to feed on the gypsy moth. It has become well adapted to conditions here and has spread widely in the Northeast and is now probably the most useful species of the genus. Both the adults and larvae climb trees and are voracious feeders on caterpillars and their pupae. They are wanton marauders, biting and destroying many individuals that they cannot consume. The adults may live 4 years, sometimes hibernating over one complete season. The larva is dark colored, large, and fusiform, with the thoracic and abdominal segments bearing strongly chitinized brownish-black plates, and the ninth segment conical jointed cerci.

Calosoma reticulatum (F.) and *C. inquisitor* (L.) have been introduced from Europe and colonized in the New England States, and *C. chinense* Kirby has been brought in from Asia, but there is no evidence that they have become established. *C. frigidum* Kirby, *C. willcoxi Lec.*, *C. scrutator* (F.), and *C. calidum* (F.), are widely distributed native species in the Central and Eastern States. All these feed on caterpillars and pupae of Lepidoptera, sawflies, and other insects. The calosoma beetles were discussed by Burgess and Collins (*71*) in 1917.

The records of the Division of Forest Insect Investigations contain references to over 30 genera of Carabidae associated with trees or with insects attacking trees, yet the group as a whole has received little study from an economic standpoint, and its role in the forest is imperfectly known. One of the commonest habitats for carabid larvae is under the bark of various trees where they are associated with bark beetles and are often predators on the immature stages. *Chlaenius erythropus* Germ., *Dicaelus purpuratus* Bon., *Agonum* spp., and *Tachys* spp., are frequently collected in such places.

Geopinus incrassatus Dej., *Harpalus* spp., and *Scarites subterraneus* F. are frequently met with in seedbeds, where they injure the young seedlings.

Galerita janus F. and *G. bicolor* Drury are conspicuous carabids, frequently met with under stones in the forest and under loose bark of logs. They average about 20 mm. in length. The thorax is red and the elytra bluish black, and they have long, red legs.

Several species of *Bembidion* are common under the bark of trees and logs, where they are probably predaceous on small insect life.

Family CICINDELIDAE

The Tiger Beetles

The tiger beetles are mentioned (if an apology be needed) primarily to satisfy the curiosity of the more observant woodsman. On bright, sunny, summer days brilliant green or bluish-gray beetles of the genus *Cicindela* can be seen running actively along the sandy beaches of streams, woodland roads, and trails, or flying with surprising speed a few steps ahead of the intruder, only to alight suddenly in an open spot and turn to face him in an aggressive posture. These so-called tiger beetles are well named, for like their cousins, the ground beetles, they live by preying on other insect life. Their method of suddenly pouncing on their prey still further carries out the metaphor.

In striking contrast to the active habits of these adult beetles, their early life as larvae is spent in cylindrical burrows in the hard-packed ground. In these holes the larvae patiently wait with their heavily chitinized heads and long, upward-turned and toothed mandibles projecting to grasp the unlucky insect that may wander by. In order to prop themselves in the top of these burrows and possibly to prevent larger prey which they may grasp from pulling their bodies out of the holes, the fifth abdominal segment is provided with a hump and two or three pairs of recurved hooks.

Family CUPESIDAE

A single species of the family Cupesidae, *Cupes concolor* Westw., is mentioned here, not so much because of its economic importance, as it feeds only in moist rotting wood, but because of its peculiar larva. This is an elongate, fleshy, soft-skinned larva, 20 to 25 mm. in length when full grown, adapted to wood boring. The head is somewhat embedded in the prothorax, and the ninth abdominal segment ends in a short truncate spine. The legs are fleshy, five-jointed, and provided with a movable claw, a character common also to the families Rhysodidae and Micromalthidae, and a feature characteristic of the suborder Adephaga, in which this form has been placed. These characters will distinguish the larva from any other Coleoptera, but in addition, the mandible is provided with a molar structure which grinds against a strong hypopharyngeal chitinization.

The adult is slender, somewhat depressed, 7 to 11 mm. in length, grayish brown and covered with small scales, and has brownish blotches forming three indistinct bands on the elytra. The head is tuberculate and constricted into a neck; the antennae are slender and about as long as the body.

The larvae feed in decaying, moist wood and are often found in the basement timbers of old houses. Usually the wood is so permeated by decay that the insects cannot be considered as injurious. They have been found in pine, chestnut, and oak, and probably attack many other woods.

Family MICROMALTHIDAE

Micromalthus debilis Lec., a minute, black shining beetle, 2 to 3 mm. in length, related to *Cupes* and *Clinidium*, is mentioned because of its remarkable larva and complicated biology. The larva is thin-skinned and soft, with five-jointed legs, each leg provided with two claws, and the ninth abdominal segment carries a pair of recurved terminal spines, one ventral and one dorsal. The ligula and hypopharynx are chitinized, and the mandible has a well-developed molar structure. Several distinct larval forms have been described by Barber (*21*) and by Pringle (*358*), such as caraboid, cerambycoid, and curculioid, which appear during the complex metamorphosis of this species. The most unusual characteristic, however, is that certain stages of the larva give birth to living young of the caraboid type of larvae.

The larvae feed in moist, decaying wood and are reported as causing damage to buildings, railroad ties, and poles, and to mine props in South Africa, where, according to Pringle (*358*), this species may have been introduced with lumber from North America.

Family RHYSODIDAE

Clinidium sculptile Newm. is a small, elongate, depressed beetle, from 5 to 8 mm. in length, reddish brown, with the thorax and elytra deeply grooved. The head is globular on a distinct neck, and the antennae are made up of slender beadlike joints. The larvae are soft-bodied and fleshy, with rows of tiny asperities on the dorsum of two thoracic and six abdominal segments. The legs are short and five-jointed, the fifth segment bearing a single movable claw, as in *Cupes*. Although related to this form, they lack the terminal armature and molar structure on the mandible, and the labial palpi are lacking. They breed in moist, decaying logs and are of no economic importance, but are of interest because their larvae are peculiar and similar to those of *Cupes*.

Family STAPHYLINIDAE

The Short-Winged, or Rove, Beetles

The rove beetles constitute a large group of insects easily recognized because the wing covers are decidedly shortened so that the flexible abdomen is exposed. The abdomen is often turned back over the body as the insects run about with considerable speed. They are usually elongate, slender, medium-sized beetles with prominent sickle-shaped mandibles.

The larvae are much more difficult to characterize, as they can easily be confused with several other families inhabiting similar situations. In addition, they represent several radically different types. In general, they are elongate, slender, tapering forms, of whitish appearance, having the head prominent and projecting, well-developed legs of five joints, and usually jointed movable cerci on the ninth abdominal segment. The mandible is of the grasping type without grinding structure, the cardo and stipes are distinct, and the spiracles annular.

These beetles are of extremely variable habits. They are adapted to living under many conditions in the forests, such as in the soil litter, under stones and logs, in all sorts of decaying vegetable and animal matter, and in nests of birds, mammals, and insects. The records of the forest-insect collections contain references to over 50 genera of the family Staphylinidae found on forest trees or associated with insects feeding on them. The forms most frequently met by the forester occur under the bark of trees infested by bark beetles. These are primarily scavengers, but a number are predaceous on eggs and larvae of bark beetles and other bark-inhabiting insects. Several of the more common forms in this habitat are *Homoeotarsus bicolor* (Grav.), *Eumalus nigrellus* (Lec.), *Homalota* spp., *Omalium* spp., *Placusa* spp., *Quedius* spp., *Siagonium* spp., and *Xantholinus* spp. Several species of *Tachinus* are common on woody fungi on logs.

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Family SILPHIDAE

The Carrion Beetles

The carrion beetles, as their name implies, are most commonly met with around the bodies of dead animals or on animal excrement in the forests. The larger more conspicuous forms in these associations, such as *Silpha* or *Necrodes*, are frequently observed, yet are probably of less direct interest to the forest entomologist than a group of very small forms acting as scavengers, or possibly predators, under the bark of dead logs and trees.

The larvae of these latter forms resemble small staphylinids in having jointed cerci, but the mandibles have a well-developed grinding structure or mola. One of the most common forms is *Agathidium oniscoides* Beauv., found associated with the galleries of bark beetles in hardwoods.

Family PSELAPHIDAE

The Ant-Loving Beetles

The ant-loving beetles are very small brownish or black compact beetles, not over a few millimeters in length, closely related to the rove beetles, and like them, having short wing covers. They are mentioned only because they are frequently met with in ant and termite nests in logs or damp woodwork. They are supposed to be cared for by the ants because they furnish certain secretions on which the ants feed.

One of the most common eastern forms is *Batrisodes virginiae* Casey, found in decaying logs and frequently associated with termite colonies.

Family HISTERIDAE

The Hister Beetles

The hister beetles, met with under bark or associated with wood-boring insects, are often very flat, roundly rectangular, black, shining forms with shortened wing covers, usually marked with deeply impressed striae. They are sluggish and slow moving, often drawing their legs under them and feigning death when disturbed. The larvae are likewise sluggish with few exceptions, and are soft-bodied, and like the rove beetle larvae have grasping mandibles and jointed cerci, but they are readily distinguished by their biforous spiracles.

Some of the more common forms are *Hololepta fossularis* Say, one of the largest species, nearly 10 mm. in length, found under the bark of poplar and tulip trees, where the larvae are predaceous, and numerous species of *Paromalus*, *Plegaderus*, and *Hister*, found in the galleries of bark beetles. They are probably all predaceous on small forms in these situations.

Family BYRRHIDAE

The Pill Beetles

Several species of the genus *Byrrhus* are occasionally found injuring young trees in forest nurseries or plantations. These are small, oval, and strongly convex beetles about 5 to 10 mm. long, black and grayish colored with the body denseiy covered with hairs. The larvae superficially resemble those of the May beetles, but the body segments are more platelike dorsally and not transversely folded, the gula is more distinct, and the galea two-jointed.

An undetermined species of *Byrrhus* is common in the Lake States, in sandy soil, and occasionally causes injury to seedlings.

FOREST LEAF CHAFERS AND WHITE GRUBS
LAMELLICORNIA

By Lee E. Yeager

The lamellicorn beetles are characterized by the peculiar terminal structure of each antenna, which is a club composed of three, and in one genus six or seven, leaflike plates. The lamellicorns are here treated under four families, namely Trogidae, Passalidae, Lucanidae, and Scarabaeidae. Of these families the Scarabaeidae is by far the largest and most important, as it includes a large number of injurious species. This family, the Scarabaeidae, consists of two general subdivisions, the lamellicorn scavengers and the lamellicorn leaf chafers, of which only the latter need be treated here. The Passalidae and Lucanidae are of interest because of their habit of living in decayed wood, in the eastern forests, being especially associated with hardwoods. The Trogidae are known as skin beetles, and as they characteristically occur on dead animal material, they will not be further considered.

INJURY IN NURSERIES AND PLANTATIONS

From the viewpoint of the forester, damage by lamellicorn beetles and larvae must be considered both in nurseries and forest plantations. Each of these two conditions presents its own problems, but in general the control of injury to plantations, because of the absence of intensive cultivation and the large areas involved, offers the greater difficulty.

Although the chief damage is caused by the feeding of the grubs on seedling roots, the adults injure trees by eating the foliage. Serious defoliation may result when beetles of the genus *Phyllophaga* concentrate on hardwood trees in large numbers. Two other genera, *Macrodactylus* and *Pachystethus*, may appreciably defoliate oaks and pines, respectively, and other genera may occasionally be injurious. In comparison with the work of other defoliators, lamellicorn defoliation is more or less negligible, although in some instances hardwoods may be completely stripped and pines heavily defoliated.

Seedling mortality traceable to grub feeding has occurred in nurseries and plantations throughout the Eastern States. The percentage of injury runs from near zero to as high as 90 percent. The higher percentage of injury occurs on certain types of trees on the Marquette National Forest, in Upper Michigan. Such mortality, however, is unusual. Losses of from 5 to 20 percent of the stock in nurseries and young plantations is far more common than higher losses.

From the studies of the last several years a few generalizations can now be drawn in regard to grub injury and control. The first of these is that serious injury in the East appears to be caused by only a few out of the 30-odd genera known to occur. These injurious groups are *Phyllophaga*, *Ochrosidia*, *Polyphylla*, *Diplotaxis*, and *Serica*. Several other genera, such as *Autoserica*, *Popillia*, *Anomala*, and *Cotinis*, may be injurious in nurseries, but they are not often of much importance. Also, *Diplotaxis* and *Serica* larvae seem to be relatively unimportant, as they caused fatal injury to less than 20 percent of experimental seedlings, even when dense populations were tested. It appears doubtful that this degree of mortality occurs in the field. The genus *Polyphylla* has not been extensively investigated.

Of the groups known to be destructive, the *Phyllophaga*, or June beetles, are by far the most important, because of their wide distribution, the large number of species, their dense populations, and their destructive feeding habits. The other genera listed as injurious occur only locally, in more or less scattered populations, and are not of great importance in forest management.

In the Gulf States there is relatively little damage by white grubs, as compared with that in forest nurseries in the Appalachians, the Piedmont region, the New England, and the Lake States. For a more complete treatment of the subject the reader is referred to the following authors: Criddle (*121*); Fluke, Graber, and Koch (*159*, *160*); Forbes (*161*, *162*, *163*, *164*); Hadley and Hawley (*206*); Hawley and Hallock (*211*); and Sweetman (*404*, *405*). Control of these beetles is discussed on page 28.

To enable the reader to understand better the descriptions of the various insects, a diagrammatic drawing is presented of a typical scarabaeid larva, *Popillia japonica* Newm. (fig. 38), in which the names of many of the parts are given.

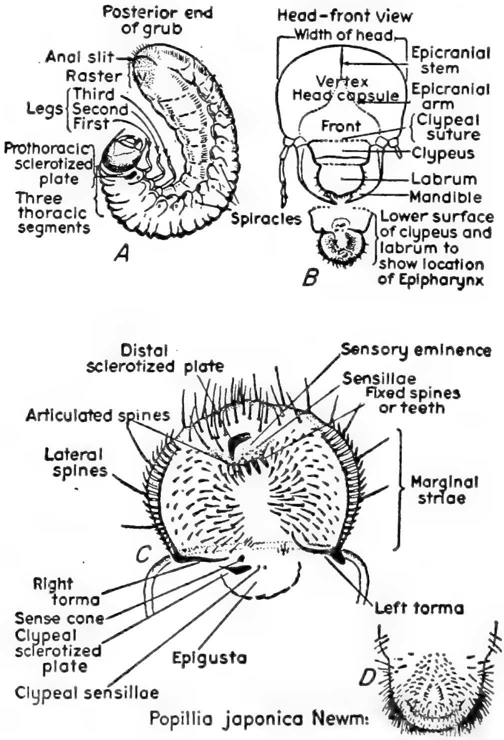

FIGURE 38.—Diagrammatic drawings of larva of *Popillia japonica* with various anatomical parts and characters named: *A*, Lateral view of grub; *B*, front view of head; *C*, outline of epipharynx (roof of the mouth); *D*, lower surface of last segment, showing anus and spines.

KEY TO THE GENERA OF LAMELLICORN BEETLES IMPORTANT TO FORESTRY IN EASTERN NORTH AMERICA [19]

1.	Plates of antennal club not capable of being opened and closed	2
	Plates of antennal club capable of being opened and closed	7
2.	Mentum deeply emarginate; body elongate, flattened; black beetles with heavily ridged wing covers, about 35 mm. long. (Family Passalidae) *Popilius* [20]	DD
	Mentum entire; mandibles very large, extending well beyond the labrum. (Family Lucanidae)	3
3.	Antennae elbowed at 1st joint, which is about as long as all others combined	4
	Antennae straight or curved, not elbowed	6
4.	Wing covers smooth or nearly so, usually reddish; front tibiae with distinct teeth on outer edge *Lucanus*	CC
	Wing covers more or less grooved and punctate, or rugose	5
5.	Eyes strongly notched by the margins of the head; 15 to 27 mm. long *Dorcus*	BB
	Eyes entire, or only slightly notched by the margins of the head; 10 to 14 mm. long *Platycerus*	V
6.	Front of head depressed, especially in males; 10 to 16 mm. long *Ceruchus*	W
	Front of head not depressed elevated strongly in males, normal in females, and with a horn in the former and a tubercle in the latter sex; strongly rugose dorsally; form cylindrical; 15 to 20 mm. long *Sinodendron*	X
7.	Sides (epimera) of mesothorax not reaching the coxae; wing covers rough, covered by wartlike protrusions; often covered by dirt and dried animal matter. Family Trogidae, not further considered in this key.	
	Sides (epimera) of mesothorax reaching the oblique coxae; wing covers smooth, hairy, punctured, ridged, or more or less rugose, but never covered by wartlike protrusions (Family Scarabaeidae)	8
8.	Abdominal spiracles in part situated on the superior portion of the ventral segments, the rows of spiracles feebly diverging. Includes the more typical leaf chafers. (Subfamily Melolonthinae)	9
	Abdominal spiracles, except the 3 front ones, situated on the dorsal portion of the ventral segments, forming 2 rows which diverge strongly	15
9.	Form elongate, more or less slender; legs proportionately long; dorsal color metallic green, bronzed, or dull yellowish	10
	Form robust and often quite large; dorsal ground color dark brown, reddish, or black; with or without colored hair or scales above	11
10.	Wing covers not, or only very slightly, scaled, hairy or not; claws minutely to noticeably cleft at apices; thorax as wide or wider than long. (Melolonthinae) *Dichelonyx*	B
	Wing covers with slender hairlike scales; claws widely, distinctly cleft at apices; thorax always noticeably longer than wide. (Melolonthinae) *Macrodactylus*	D
11.	Abdomen with 5 ventral segments; wing covers with shallow, punctured, longitudinal furrows, or without furrows and punctured finely and uniformly. (Melolonthinae) *Diplotaxis*	C
	Abdomen with 6 ventral segments	12
12.	Hind tibiae always progressively widened from base to apex and flattened greatly, with irregularly placed spines; head usually with a notch at each side margin at the point of juncture of the clypeal apex and the exposed labrum; claws short, finely cleft at apex; size usually less than 11 mm.	13

[19] This key is in part adapted from Blatchley (*50*), and in part original. L. W. Saylor examined this portion of the manuscript in its entirety and made a number of very helpful suggestions. The writer is also indebted to the Milwaukee Public Museum, through its staff members, T. E. B. Pope, curator of Lower Zoology, and Kenneth MacArthur, assistant curator of Lower Zoology, for permission to study certain lamellicorn groups and for photographs of the beetles.

[20] The letters to the right of the generic names of the groups included in the adult key refer to the letters in figure 39, in which a typical species of each genus considered is illustrated.

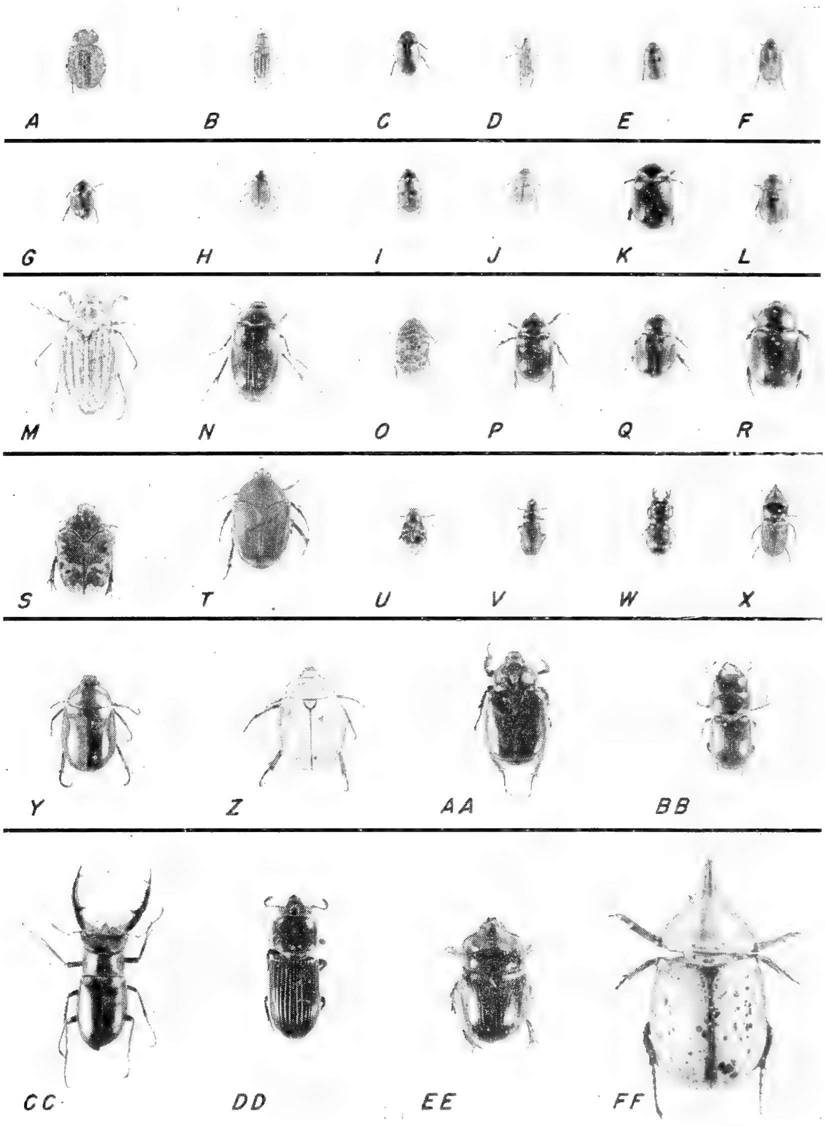

FIGURE 39.—Adults of lamellicorn beetles; *A*, *Trox asper* Lec.; *B*, *Dichelonyx albicollis* Burm.; *C*, *Diplotaxis sordida* (Say); *D*, *Macrodactylus subspinosus* (F.); *E*, *Autoserica castanea* (Arrow); *F*, *Serica sericae* (Ill.); *G*, *Popillia japonica* Newm.; *H*, *Strigoderma arboricola* (F.); *I*, *Anomala binotata* Gyll.; *J*, *Pachystethus oblivia* (Horn); *K*, *Polymoechus brevipes* Lec.; *L*, *Ochrosidia villosa* (Burm.); *M*, *Polyphylla decemlineata* (Say); *N*, *Phyllophaga drakei* (Kby.); *O*, *Euphoria inda* (L.); *P*, *Aphonus tridentatus* (Say); *Q*, *Ligyrus gibbosus* (Deg.); *R*, *Ligyrodes relictus* (Say); *S*, *Gymnetis sallei* Schaum; *T*, *Cotinis nitida* (L.); *U*, *Trichiotinus piger* (F.); *V*, *Platycerus depressus* Lec.; *W*, *Ceruchus piceus* (Web.); *X*, *Sinodendron rugosum* Mann.; *Y*, *Pelidnota punctata* (L.); *Z*, *Cotalpa lanigera* (L.); *AA*, *Osmoderma eremicola* Knoch; *BB*, *Dorcus parallelus* Say; *CC*, *Lucanus elaphus* F.; *DD*, *Popilius disjunctus* (Ill.); *EE*, *Xyloryctes satyrus* F.; *FF*, *Dynastes tityrus* (L.). All beetles reduced to about one-half natural size. (Milwaukee Public Museum.)

KEY TO THE GENERA OF LAMELLICORN BEETLES IMPORTANT TO FORESTRY IN EASTERN NORTH AMERICA—Continued

	Hind tibiae slender and not, or only slightly, flattened, never progressively widened from base to apex, usually slender throughout, surface with sparse hair; labrum not connate with clypeus and not visible from above; claws long, not cleft but with submedian (subbasal in some species) tooth; size more than 11 mm.	14
13.	Clypeus with a low, broad, longitudinal elevation or ridge along median area; hairs along top of head reddish, comparatively coarse, and pointing directly back; confined to Middle Atlantic States. (Melolonthinae) *Autoserica*	E
	Clypeus without an elevation or ridge along median area; hairs along top of head comparatively fine and nearly erect, not pointing directly back; throughout the United States. (Melolonthinae) *Serica*	F
14.	Antennae terminated by a club of 3 leaflike plates; clypeus rounded or 2-lobed, never square in front; dorsal surface of eastern species never with scales (except *P. lanceolata*); color uniform brownish or dark, except a few prairie species which may appear to be striped. (Melolonthinae) *Phyllophaga*	N
	Antennae terminated by a club of 6 or 7 very large leaflike plates; clypeus square on front; dorsal surface always more or less scaled; color variable, usually brownish or with brown and white striped longitudinally. (Melolonthinae) *Polyphylla*	M
15.	Claws of tarsi unequal in size, the inner claw usually much more slender than the outer. (Subfamily Rutelinae)	16
	Claws of tarsi equal in size, except front tarsal claws of some *Ochrosidia* in which one claw of the male may be heavy and twisted	22
16.	Wing covers with a membranous margin; antennae 9-jointed; mandibles, in repose, not projecting beyond the clypeus	17
	Wing covers without a membranous margin; antennae 10-jointed; mandibles usually visible beyond the clypeus	20
17.	Body more or less flattened dorsally	18
	Body distinctly convex dorsally	19
18.	Pygidium with a patch of white hairs on each side; head and prothorax bronze green; wing covers deep reddish tan with green marginal line. (Rutelinae) *Popillia*	G
	Pygidium without such spots; head and prothorax dull blackish green or brownish; wing covers dull yellowish to very dark or piceous. (Rutelinae) *Strigoderma*	H
19.	Middle pair of legs nearly or quite touching, being separated by a very fine, hardly obvious, line or ridge. (Rutelinae) *Anomala*	I
	Middle pair of legs well separated by a projecting lobe like process. (Rutelinae) *Pachystethus*	J
20.	Prothorax without a marginal line at base; dorsal color dark brown. (Rutelinae) *Polymoechus*	K
	Prothorax with a marginal line at base; dorsal color predominantly yellowish, or tan with black spots	21
21.	Clypeus without a suture between it and the front; wing covers (in Eastern States forms) with a total of 6 black spots and prothorax with 2 black spots. (Rutelinae) *Pelidnota*	Y
	Clypeus distinctly separated from the front; wing covers predominantly yellowish, each with a depressed line along the lateral area. (Rutelinae) *Cotalpa*	Z
22.	Body distinctly convex dorsally; front coxae transverse, not prominent. (Subfamily Dynastinae)	23
	Body somewhat flattened to nearly level dorsally; front coxae conical and prominent. (Subfamily Cetoniinae)	28
23.	Head and pronotum unarmed in both sexes; front claws of some males unequal, 1 being very heavy and bent. (Dynastinae) *Ochrosidia*	L
	Head or pronotum, sometimes both, armed, or at least bearing a tubercle, in both sexes	24
24.	Size not over 30 mm. long; color piceous or dark reddish brown	25

KEY TO THE GENERA OF LAMELLICORN BEETLES IMPORTANT TO FORESTRY IN EASTERN NORTH AMERICA—Continued

Size over 40 mm. long; color greenish gray with black spots or uniform dark brownish, or with both color patterns. (Dynastinae) *Dynastes* FF

25. Hind tibiae with several blunt, rounded teeth at tip; vertex of head with horn in male, tubercle in female. (Dynastinae) *Xylorycetes* EE
Hind tibiae cut off squarely at tip and fringed with spines; head with a low, transverse ridge, indistinct in *Aphonus* 26

26. Mandibles not toothed on outer side; clypeus with a 3-toothed process just before the tip. (Dynastinae) *Aphonus* P
Mandibles toothed on the outer side; clypeus usually bidentate at tip 27

27. Front margin of pronotum always with a tubercle, posterior to which is a shallow depression; union of clypeus and front marked by a low ridge which, in some species, is slightly more pronounced at each end. (Dynastinae) *Ligyrus* Q
Pronotum never with a tubercle followed by a depression; union of clypeus marked by 2 low ridges, one at a right angle to each lateral margin, area between ridges not, or only very slightly, elevated. (Dynastinae) *Ligyrodes* R

28. Wing covers sinuate on the sides posterior to the basal humeral angles; sides (epimera) of mesothorax visible from above 29
Wing covers not sinuate on the sides posterior to the basal front angles; sides (epimera) of mesothorax conspicuous from above 31

29. Pronotum lobed or pointed at base, the lobe covering the scutellum 30
Pronotum not lobed at the base so as to cover the scutellum, which is roughly triangular; mentum normal in shape; clypeus narrow, reflexed; color never predominantly black. (Cetoniinae) *Euphoria* O

30. Head of both sexes with a distinct frontal and clypeal horn, the latter being proportionately wide and thin; wing covers greenish with a tan or gold lateral border. (Cetoniinae) *Cotinis* T
Head unarmed in either sex; wing covers black and white mottled; confined to Southwest. (Cetoniinae) *Gymnotis* S

31. Body hairy dorsally; color variegated; size less than 13 mm. long; wing covers little longer than wide; pronotum rounded at base. (Trichiinae) *Trichiotinus* U
Body not hairy dorsally; color very dark brown to piceous; wing covers heavy and leatherlike; sculpture smooth or rough; size 18 mm., or more, long. (Trichiinae) *Osmoderma* AA

KEY TO THE GENERA OF LAMELLICORN LARVAE IMPORTANT TO FORESTRY IN EASTERN NORTH AMERICA

All larvae of the lamellicorn group have 5-jointed legs, with the tarsal joint fused with the single claw into a terminal spine (so far as treated in this key). There is a median epicranial suture present; the tenth abdominal segment is well developed, being usually about as large as or larger than the ninth, to which it is sometimes fused dorsally. When shorter than the ninth the tenth segment is provided with a pair of large anal pads. The spiracles are sievelike in structure (except in some species of *Trox*, which are not included here) and all are lateral. These insects constitute the series Scarabaeoidea.

1. Form scarcely curved; 3rd pair of legs poorly developed; antennae 3-segmented; anal slit transverse. In decayed wood, especially hardwood. (Family Passalidae) (*Passalus*) *Popilius*
Form curved, tip of abdomen usually touching legs; 3rd pair of legs developed normally 2

2. Anal segment strongly bilobed on caudal aspect; stridulating organs on 2nd and 3rd pairs of legs; anal pads very large and conspicuous; labrum trilobed. In decayed wood, especially hardwood. (Family Lucanidae) 3

KEY TO THE GENERA OF LAMELLICORN LARVAE IMPORTANT TO FORESTRY IN EASTERN NORTH AMERICA—Continued

	Anal segment not trilobed on caudal aspect; stridulating organs on mandibles (except in one dung-inhabiting genus not included in key); anal pads normal, not conspicuous; labrum trilobed or not. In soil, decayed wood, manure, or litter. (Family Scarabaeidae)	7
3.	Dorsal shield of prothorax anteriorly with a triangular process on each side; lateral anal lobes plainly elliptical, superior lobe small. In decayed wood of logs and stumps *Sinodendron*	
	Dorsal shield without process	4
4.	Left mandible bidentate or tridentate. In decayed wood of moist logs *Ceruchus*	
	Left mandible bearing 4 or 5 teeth	5
5.	Claw straight; 10th abdominal segment very hairy; left mandible with 5 teeth. In decayed wood of stumps and roots *Lucanus*	
	Claw curved; 10th abdominal segment only slightly hairy	6
6.	Left mandible with 4 teeth. In decayed wood of moist logs *Platycerus*	
	Left mandible with 5 teeth. In decayed wood of moist logs *Dorcus*	
7.	Raster with a pair of distinct, well-separated patches of spines; anal slit broadly Y-shaped	8
	Raster with spines in 1 transverse, 2 longitudinal or oblique rows, or, with setae, in a scattered arrangement, never in distinct rows	9
8.	Setae present between anus and the paired patches of spines. In soil in open pine or hardwood stands, nurseries, pastures, etc. (Melolonthinae) *Dichelonyx*	
	Setae absent between anus and the paired patches of spines; spines in 2 or 3 overlapping rows and in V-shaped arrangement. In sandy soil of pine stands, nurseries, etc. (Melolonthinae) *Diplotaxis*	
9.	Spines in 1 transverse or 2 longitudinal rows	10
	Spines, with setae, in a scattered arrangement	22
10.	Spines semicircularly arranged in 1 transverse row	11
	Spines in 2 longitudinal or oblique rows	12
11.	End of third pair of legs with short, blunt claws. In soil in gardens, fields, lawns, etc. (Melolonthinae) *Autoserica*	
	End of third pair of legs with long spinelike claws. In soil of hardwood stands, pastures, gardens, lawns, etc. (Melolonthinae) *Serica*	
12.	Anal slit transverse and sinuate, or V- or Y-shaped; free margins of upper anal lip obtusely or acutely projecting	13
	Anal slit transverse and arcuate; free margin of upper anal lip concave	15
13.	Anal slit with lobes at each end; free margins of upper anal lip obtusely projecting; free margin of lower anal lip entire and covered with several irregular transverse rows of hooked setae; spines of raster 8 to 12 on each side, irregularly placed, single toward head, 2 or 3 together toward caudal ends. In sandy soil nurseries, pine stands, etc. (Melolonthinae) *Polyphylla*	
	Anal slit V- or Y-shaped; free margin of upper anal lip sharply projecting; free margin of lower anal lip inflected at the end of a median longitudinal groove on the lip, which may or may not have a single transverse row of hooked setae	14
14.	Claws of third pair of legs much longer than the claws of the first and second pairs of legs. In soil of hardwood stands, pastures, nurseries, lawns, etc. (Melolonthinae) *Phyllophaga*	
	Claws of third pair of legs equal in length to the claws of the first and second pairs of legs. In sandy soil of scrub oak uplands, gardens, nurseries, lawns, etc. (Melolonthinae) *Macrodactylus*	
15.	Epipharynx with a single large chitinous tubercle on distal area	16
	Epipharynx with 3 or 4 sharp, pointed teeth on the distal area rather than a single large tubercle	17
16.	Antenna with a distinct ocellar spot at base; labrum not distinctly trilobed, and almost as long as wide. In decayed wood, especially hardwood. (Trichiinae) *Trichiotinus*	

KEY TO THE GENERA OF LAMELLICORN LARVAE IMPORTANT TO FORESTRY IN EASTERN NORTH AMERICA—Continued

Antenna without an ocellar spot at base; epipharynx with a narrow, chitinous semicircle between base of tubercle and the distal margin. In decayed logs or stumps or in sandy soil under dried manure. (Rutelinae) _Polymoechus_

17. Spines of lower anal lip hooked; claws tapering to a point; anterior margin of labrum entire and arcuate; left mandible without teeth between bidentate apex and molar structure 18

Spines of lower anal lip not hooked; labrum distinctly trilobed; left mandible with 2 lateral teeth between bidentate apex and molar structure 21

18. Spines of raster plainly fewer in right row than left row. In sandy fields, dunes, pastures, etc. (Rutelinae) _Strigoderma_

Spines of raster approximately equal in number in each row 19

19. Rows of spines strongly curving toward head and with 6 or 7 spines in each row. In soil under turf, garden margins, parks, etc. (Rutelinae) _Popillia_

Rows of spines not strongly curving toward head and with 9 or more spines in each row 20

20. Rows of spines with 9 to 10 in each row. In soil in pine stands, fields, pastures, etc. (Rutelinae) _Pachystethus_

Rows of spines with more than 10 (about 15) in each row. In soil of woods, pastures, lawns, etc. (Rutelinae) _Anomala_

21. Lower anal lip with strong straight setae; raster with 2 convex rows of spines enclosing an elongate oval naked area. In sandy soil. (?) (Cetoniinae) _Gymnetis_

Lower anal lip with minute, fine hairs; raster with a pair of jagged rows of rather inconspicuous spines; head chestnut-brown to blackish. In soil in open areas or under manure and decaying vegetation. (Cetoniinae) _Cotinis_

22. Labrum symmetrical and trilobed; epipharynx with a curved single row of small teeth in median part of distal end; left mandible with 2 lateral teeth between bidentate apex and molar structure 23

Labrum not symmetrical and not trilobed; epipharynx without a curved row of small teeth in median part of distal end, but with a dark, blunt, toothlike process in its place 24

23. Claw cylindrical and distinctly obtuse; teeth of epipharynx in one nearly semicircular row; raster well clothed with spines and setae which, in some species, may be arranged in irregular longitudinal rows. In old horse manure, sawdust, litter, etc. (Cetoniinae) _Euphoria_

Claw short, thick, conical, and pointed; teeth of epipharynx in one slightly curved row; raster thinly clothed with large and small spines without order. In decayed tree cavities, stumps, snags, etc. (Trichiinae) _Osmoderma_

24. Stridulating teeth of maxillary stipes long, slender, pointed, and curved 25

Stridulating teeth of maxillary stipes short, being as broad as long, often obtuse, not curved 26

25. Claws long, distally tapering to a point; spines of raster hooked; 2 teeth on top of both left and right mandibles; setae around lateral margin of epipharynx distinctly flattened and increasing in length toward distal end; raster well clothed with setae and hooked spines. In sandy soil in open woodlands, fallow fields pastures, etc. (Rutelinae) _Cotalpa_

Claws short, cylindrical, slightly curved, distally obtuse; spines of raster not hooked; 3 teeth on top of left and 2 teeth on top of right mandible; setae around lateral margin of epipharynx short, strong, and pointing more or less downward, not out; setae on raster sparse. In decaying wood, especially still firm hardwood stumps. (Rutelinae) _Pelidnota_

26. With a single ocellar spot at base of antenna. In manure or heavily manured soil. (Dynastinae) _Ligyrodes_

Without ocellar spot at base of antenna 27

KEY TO THE GENERA OF LAMELLICORN LARVAE IMPORTANT TO FORESTRY IN EASTERN NORTH AMERICA—Continued

27.	Spines of raster strongly hooked; abdominal spiracles increasing somewhat in size toward caudal end, with the eighth the largest; left mandible without lateral teeth between bidentate tip and molar structure. In soil under turf of lawns, golf courses, etc. (Dynastinae) *Ochrosidia*	
	Spines of raster not hooked, but are straight or slightly curved	28
28.	Epipharyngeal plate produced into 2 or 3 processes or teeth	29
	Epipharyngeal plate produced into a single large tooth	30
29.	End of epipharynx in front of plate beset with forked, brushlike setae; left mandible with 1 lateral tooth in front of molar structure; abdominal spiracles approximately the same in size. In sandy soil in plowed and fallow fields, gardens, etc. (Dynastinae) *Ligyrus*	
	End of epipharynx in front of plate not beset with forked, brushlike setae; spiracles variable in size; head strongly punctured, and, with mandibles, nearly black; prothorax with a large, brown, heavily chitinized, deeply bipunctate area on sides; extremely large grubs at maturity. In decayed wood, especially hardwood. (Dynastinae) *Dynastes*	
30.	Last, or eighth, abdominal spiracle distinctly smaller than the preceding ones; left mandible with 1 lateral tooth; head very dark to blackish. In humus layer of heavy hardwoods; sometimes in much decayed wood or litter. (Dynastinae) *Xyloryctes*	
	Last 3, or sixth, seventh, and eighth, abdominal spiracles distinctly smaller than the preceding spiracles: head medium brown, covered with robust setae placed in deep pits, front of head with a distinct purplish-brown spot; head capsule reduced in size, being smaller than thoracic segments; left mandible without a lateral tooth. In sandy soil of open forests; probably in soil of gardens, golf courses, etc. (Dynastinae) *Aphonus*	

Families PASSALIDAE and LUCANIDAE

The Stag Beetles

The two families Passalidae and Lucanidae contain small to very large beetles closely resembling the Scarabaeidae, and distinguished from them chiefly by having the plates of the antennal club rigid and incapable of being opened or closed. Some of the Lucanidae, however, differ conspicuously in that they have very large, hornlike mandibles which project in front of the head.

The larvae of these two families also resemble those of the Scarabaeidae, but, unlike them, have anal lobes that are developed into two large lateral pads, and have stridulatory or "sound" organs on the third pair of legs rather than on the mandibles.

The stag beetles are all borers in dead or decaying wood and consequently of little importance except to the forester or recreationist who may be piscatorially inclined. Then, a knowledge of the breeding habits of these forms will serve the angler with a supply of excellent grubs for fish bait.

The Passalidae are represented by only one species in the United States. This is *Popilius disjunctus* (Ill.) which is of interest because of its social habits, the adults tending the larvae in the ample brood galleries, where all move about freely in a very deliberate and ponderous manner. The common name of "betsy-bug," or "bess-bug," is given this species, probably because of the "bess-bess" note made by the adults when molested. This beetle was discussed by Pearse, Patterson, Rankin, and Wharton (*347*).

The Lucanidae contain 7 genera and about 31 species in North America, of which 5 genera are important enough in the eastern part of North America to be mentioned here. Two species of *Lucanus* Scop. are frequently found in the roots of dead stumps, whereas *Platycorus quercus* Web., *Ceruchus piceus* (Web.), and *Dorcus paralleus* Say are all found in moist logs, so decayed that they can be readily torn apart with the hands. *Sinodendron rugosum* Mann. is a very rugose, cylindrical, black beetle which breeds in decayed alder, willow, aspen, and other poplars, and is not abundant in eastern North America. The numerous western species breed largely in decayed fir, redwood, and other coniferous logs.

Family SCARABAEIDAE

The Lamellicorn Leaf Chafers

The Scarabaeidae are a very large family containing about 1,000 American species, most of which are represented in eastern North America. They vary greatly in size and form, but usually are stout bodied and awkward at both crawling and flying. The last 3 to 6 or 7 segments of the antennae are flat and leaflike, and are capable of being opened and closed. The front legs are fitted for digging.

On the basis of their feeding habits, the scarabaeids may be divided into two well-defined groups: The lamellicorn scavengers, ordinarily known as dung beetles; and the lamellicorn leaf chafers, containing the forms known as the June beetles (in some regions known as May beetles and June bugs), flower beetles, rose chafers, goldsmith beetles, figeaters, the Japanese beetle, the Asiatic garden beetle, and numerous other groups more or less unimportant from the forestry viewpoint. Only the leaf chafer group will be considered in this discussion, as the scavengers, in both the adult and larval forms, feed chiefly on animal wastes, and therefore have little direct effect on the forests.

The lamellicorn leaf chafers may be injurious in both the adult and larval stages, but they are by far the more destructive in the latter stage. The adults feed chiefly on leaves of plants, the larvae on living roots, decaying vegetable matter, rotten wood, leafmold, and in some cases, old manure. The leaf-eating and root-eating species are of considerable economic importance in the forests. The June beetles, the most common type, are often abundant in woodlands or in sod and waste areas, and in some areas appear in large flights every 2, 3, 4, or 5 years, depending on the time required for their development. In other areas, such as the Carolinas, the overlapping of generations appears to be such that the beetles occur in about the same number from year to year.

The periodic or annual flights of these beetles occasionally cause serious defoliation to forest trees around fields or woodlots. The larvae of these and certain other forms have proved to be destructive pests in nurseries and young plantations, particularly to some of those on recently cleared ground or in hardwood forest or shrub growth. During the early thirties in the Lake States, New England, the South Atlantic States, and elsewhere, losses of 10 to 90 percent due to these grubs have occurred in many plantations, the smaller figure being by no means uncommon.

The root-eating larvae in this family apparently are not selective feeders as, under experimental conditions they consumed both hardwood and coniferous roots, as well as those of grasses and a small series of herbs. The relative size of roots and grubs, however, seemed to determine somewhat the manner of feeding. For example, large *Phyllophaga* usually cut off seedlings just below the ground surface, whereas small *Phyllophaga*, *Serica*, and *Diplotaxis* generally consumed lateral roots and stripped the bark from the tap roots. Apparently this feeding difference is due to mechanical adaptations of the various-sized grubs rather than to selective feeding. The feeding patterns of the various genera are not characteristic, especially for larvae of the same size, and for this reason a key based on feeding patterns is considered impractical. The rate of feeding seems to be dependent on the species, size, and vigor of the grubs.

As far as determined, the lamellicorn leaf chafers generally lay their eggs in the immediate vicinity of their food plants. Some females may fly a few hundred yards or more before they oviposit, but extensive collections show that grub concentrations are directly proportional to the proximity of adult food. It is for this reason that nurseries and plantations in or very near forest stands, hardwoods generally, and pines in the Carolinas and elsewhere, may sometimes suffer heavy grub injury. Losses of nursery stock may occur in decreasing severity for 4 or 5 years in nurseries on newly cleared ground, resulting from the infestation present in the soil at the time of clearing.

Many leaf chafers, in that they prefer tender, succulent foliage in season, show a successional nature in their feeding habits. In the Lake States, *Phyllophaga drakei* Kby. is the most important and one of the earliest emerging species, and on the Huron National Forest it feeds on aspen at the time of emergence, undoubtedly because this is the first available and attractive food. A few days later the leaves of Juneberry (*Amelanchier* spp.) are out, and *P. drakei* promptly includes them as food. Black oak and white birch leaves appear next, and the inclusion of these is immediate. Willow and New Jersey tea follow in turn, the latter not becoming available before the middle of June. Oak is the most important food of *P. drakei* on the Huron National Forest, both because it is relatively abundant and because its leaves remain attractive to the beetles over a long period. Other kinds of trees may be the most important food elsewhere. Feeding changes are not abrupt, but gradual, as the various foods become available.

The lamellicorns' adaptability to a large number of food conditions, and to changing conditions in foods is undoubtedly very important. For the more variable feeders, of which *Phyllophaga drakei* is an outstanding example, this adaptation makes possible a large supply of food at all times, and a more certain supply during seasons unfavorable to one or more plants. As one probable result, *P. drakei* is the most abundant species of the important leaf chafers in the Lake States. Further study will likely result in the determination of other very successful species over given areas.

The food preferences of the lamellicorns deserve careful study. From published records, it appears that collectors may have been inexact in their use of the term "host plant." For example, four seasons of study on the Huron National Forest failed to disclose a single instance in which *Phyllophaga* beetles took coniferous leaves as food, either as determined by nightly collections from food plants or in many food-study cages. Still, every species except *P. anxia* (Lec.) was taken from one to many times from both jack and red pines. It is positively known that the *Phyllophaga* so collected were not feeding; they are believed to have been newly emerged individuals resting after the initial or an early flight. Such individuals could more or less properly be recorded under "host collections," but certainly not under "food-plant" collections. It is very easy to detect feeding, as the feeding beetles nearly always remain stationary until removed. Future collections, it is suggested, should be recorded as "collected feeding on," or "resting on," or under other specific headings.

The general habits of leaf-chafer adults vary, as would be expected. In South Carolina little activity has been recorded at temperatures below 60° F., whereas on the Huron National Forest there may be some feeding at temperatures as low as 52°. On the more northern national forests, especially the Upper Michigan and the Chippewa Forests, adults have been observed feeding at much lower temperatures, indicating that the species are adaptable to local conditions, or that various biological races may occur.

All lamellicorns have their natural enemies, but do not seem to be threatened by them. Numerous birds and mammals are known to be predators, of which skunks and ground-frequenting birds are outstanding. The Food Habits Section of the Fish and Wildlife Service of the Department of the Interior has found the gray fox and crow to be important predators. As to parasites, observation over a 3-year period on the Huron National Forest showed that less than 0.01 percent of the larvae are affected by dipterous and hymenopterous forms. Some evidence of mites has been noted on both adult and larval *Phyllophaga*, and a fungus of the genus *Cordyceps* infrequently attacks these grubs. The subterranean habits of the developmental stages and the partial soil-dwelling habits of the adults suggest that the lamellicorns may be exposed to relatively few natural enemies. For the control of these beetles see page 28.

Subfamily MELOLONTHINAE

The Melolonthinae contain the most typical and by far the most important leaf chafer beetles. They may be distinguished from the other subfamilies by the position of the abdominal spiracles, which in part are on the superior portion of the ventral segments, with the rows feebly diverging and the last spiracle usually visible behind the wing covers. They also have longer legs than most other lamellicorns, and the color is generally some shade of brown.

The genus *Dichelonyx* Harris has no common name, and the habits of the adults are variable. *D. albicollis* (Burm.), a shiny, greenish beetle about 12 mm. long, feeds on pine foliage, jack pine probably being its choice of food. This is the best-known species feeding on coniferous trees in the East, and it feeds both day and night, but appears to be chiefly diurnal. *D. elongata* (F.), a smaller and somewhat darker species, seems to feed only at night and exclusively on the leaves of hardwoods, especially black oak. Several other species are known in the Eastern States. Certain western species are pronounced coniferous feeders. The larvae in this genus are typical, comparatively inactive grubs, and never exceed 18 or 20 mm. in length. In feeding experiments, they are known to take coniferous rootlets in small quantities, but, on the basis of present information, they cannot be said to be destructive to nurseries and plantations. Larvae have been collected in both pine, especially jack pine, and hardwood stands. The heaviest concentration so far discovered was in a heavy stand of nearly mature aspen-white birch on the Huron National Forest. The species probably overwinters in both the adult and larval stages. The life cycle is 2 or 3 years, and the adults are most common in June and July.

The genus *Diplotaxis* Kby. is another one of the little-known groups, as yet without a recognized common name. The adults are more oval-shaped than those of *Dichelonyx*, and are light brown to blackish. The exoskeleton is exceedingly hard and rigid. All species seem to be nocturnal, and most of them feed on conifers, the pines being the preferred food.

In the jack pine and red pine stands in the Lake States, *Diplotaxis sordida* (Say), a slate-colored beetle having the pronotum covered with yellowish hairs, and *D. liberta* (Germ.), a smooth, blackish species, appear to be the most abundant. *D. haydeni* Lec. has been taken on the Hiawatha National Forest, and undoubtedly occurs in other northern areas. This is a large, shiny beetle, much lighter in color than the two forms named above. Various other species are known in the Eastern States.

Diplotaxis larvae, under experimental conditions, fed on the roots of coniferous seedlings. They cannot, however, be said to be destructive to nurseries and plantations except, perhaps, where extremely heavy concentrations occur. Under such conditions they destroyed less than 20 percent of the 1–0 and 2–0 pine seedlings used in connection with the experiments. It is believed that this degree of injury would seldom or never occur in the field.

The group has a 2- or 3-year life cycle. Adults are most abundant in June and July, at which times hundreds of *Diplotaxis liberta* have been collected at light traps in a single night. *D. sordida* does not seem to be particularly attracted by lights. Larvae, as far as known, have never been collected far from pine trees, and the genus, in the Lake States, apparently is not associated with pure hardwoods. The heaviest grub concentrations were collected in the immediate vicinity of open, mature jack pine.

The long-legged, tan beetles of the genus *Macrodactylus* Latr. are about 10 mm. long and are well-known pests of rose and flower gardens. They are appropriately called rose chafers. During the mating season, in gardens and some forested areas, they may literally cover certain flowering plants. Adults appear in June in the more northern localities. The initial emergence is sudden and swarmlike, soon after which the beetles gather on the nearest flowering plants. In the Lake State forests these are New Jersey tea, the numerous species of roses, and various flowering herbs. The beetles are actively mating during the first few days, following which the adults scatter to black oak and other hardwood species and soon die. The rose chafers have a 1-year life cycle, and overwinter in the larval stage. In the Lake States, oviposition seems to be heaviest around clumps of New Jersey tea, as indicated by larval concentration near these plants.

The chief species is **the rose chafer** (*Macrodactylus subspinosus* (F.)), but a few other forms are known. Rose chafer larvae are slender and never exceed 15 mm. in length. Their food, presumably, is the roots of plants. In heavy concentration and under experimental conditions, they fed lightly on the rootlets of pine seedlings. As practically none of the seedlings were killed, it appears that the species may be relatively unimportant in forest plantations. Very large numbers in nurseries may cause more or less injury.

The beetles of the genus *Serica* MacL. resemble the June beetles more than any other of the lamellicorn group, except for the size and ridged wing covers of the latter. The *Serica* beetles are much smaller, little more than one-fourth the size of most *Phyllophaga*. *S. sericea* (Ill.) is an abundant, iridescent, purplish-brown, hairy species. *S. vespertina* (Gyll.) and *S. intermixta* Blatch. are also very common, but are smooth, and dark brown and light brown, respectively. A number of other species occur in the Eastern States. It appears that this genus is less abundant in Minnesota than in Michigan, but *S. sericea* has been observed in large numbers on the flowers of June-berry in Minnesota.

As far as known, all species feed on hardwood leaves. The eastern species are essentially nocturnal, though feeding and flying individuals have often been observed during the interval between sundown and dark. Adults are most abundant in June, but the period of emergence, in the latitude of the Huron National Forest, is from the middle of May to the middle of August. In pure hardwood stands, the several species may be so abundant as to cause some defoliation, and on such areas they may be collected at night by the hundreds. Larval populations are heaviest in such places.

The larvae are very active, but are small, probably never exceeding 15 or 18 mm. in length. Heavy concentrations, under experimental conditions, fed appreciably on coniferous roots, killing between 15 and 20 percent of the seedlings used in the experiments. In plantations it is very doubtful that serious loss by *Serica* grubs would occur, but such losses may occur in heavily infested nurseries. Like *Diplotaxis*, the *Serica* grubs prune the roots rather than cut off the taproot near the ground surface.

The group has a 2-to 3-year life cycle. In the latitude of central Michigan the insects overwinter in both the larval and adult stages. Pupation occurs from July into September, and the adults appear before the hibernation period begins. Adults of some species are not particularly attracted to lights, but others have been taken only in this manner.

One species of the exotic genus *Autoserica* Brenske, **the Asiatic garden beetle** (*A. castanea* (Arrow)), has been introduced into this country from Asia and was first collected in New Jersey in 1922. It has now spread to numerous localities in the Atlantic Seaboard States. More of a garden than a forest insect, it is included here because of the very close morphological similarity between *Autoserica* and *Serica* adults and larvae. Owing to its apparent preference for garden crops, it may never prove destructive to forest plantations, but because of its association with cultivated soil and the heavy larval concentrations known to occur, it may become a problem in eastern forest nurseries. The fact that it may produce two generations a year may prove a factor in its capacity for injury (Hawley and Hallock, *211*).

Most of the species composing the genus *Polyphylla* Harris are southern, southwestern, and western in distribution. The group has been little studied, although known to contain a number of injurious species. These are chiefly in the Southwest, but *P. variolosa* (Hentz) and *P. occidentalis* (L.) occur in the East, and **the ten-lined June beetle** (*P. decemlineata* (Say)) occurs in both the Eastern and Western States. Under experimental conditions in South Carolina, *P. occidentalis* fed heavily on the roots of pine seedlings, although it normally feeds on the roots of sedge grass. In the more western of the Central States, *P. hammondi* Lec. is found, and this appears to be one of the few species of the genus to oviposit in rotten wood.

The adults are somewhat larger than the June beetles, and can be instantly recognized by the six to seven leaflike plates making up the antennal club. Most species are brown-and-white striped, but some are all brown. In habits, life history, and economic importance, they appear to be very similar to the *Phyllophaga.*

The very large number of species, wide distribution, and generally destructive habits of the genus *Phyllophaga* Harris place the June beetles first in importance among all lamellicorn leaf chafers. Well over 100 species are known in the region covered by this publication. Many of them are most abundant in forest-fringed grasslands, and no doubt, as the genus is further studied, other general habitat preferences will be determined.

In this genus, the life cycle by species and according to latitude is from 2 to 5 years in duration. Otherwise, the different species are generally very similar. All females oviposit in soil, apparently within the near vicinity of the food plants of the adult beetles, and the larval stage is passed in the ground. Larval food consists of living roots and, on the basis of recent studies, some species also use decaying material in the form of dead roots and other rotting vegetation. Most species pupate in late summer and early fall and therefore overwinter in the larval and adult stages. Other species pupate in May and June and overwinter only as larvae. The egg stage varies, but averages 2 to 3 weeks.

The species of *Phyllophaga* are probably chiefly nocturnal, and except for a few known to feed on southern pines and one known to feed on cypress, they feed on hardwood leaves. The choice of the hardwood feeders is very wide, although the oaks appear to be a general favorite. More or less feeding has been observed on almost all common hardwoods, and also on grasses and a variety of herbs, notably aster. The food choices by species are, of course, less variable, but most forms take the foliage of a number of different trees. Only a small number of *Phyllophaga* appear to be restricted to leaves of a few species, and no form seems to be limited to one or two foods, with the possible exception of *P. taxodii* Langs., which feeds on cypress. The feeding patterns of the genus can be distinguished from those of some other genera by the fact that the leaves are eaten off squarely, including the larger veins or ribs, whereas *Serica*, *Macrodactylus*, and other small forms do not usually cut the ribs. For further information the reader should consult Luginbill (*277*); Sim (*378*, *379*); and Travis (*411*, *412*, *413*). In the following annotated list the best-known forest inhabiting *Phyllophaga* are briefly discussed.

Phyllophaga drakei is known from eastern Canada south to Georgia and Texas, but apparently is not found along the southern

Atlantic coast. A shiny, dark-brown beetle about 23 mm. long, it is probably most abundant and important in the northern portions of the Lake States. Apparently the adults prefer oak and aspen areas, but feed readily on a very large number of plants, which may account in part for its wide distribution.

The life cycle ranges from 3 years in Mississippi to probably 5 years in upper Michigan. The larvae are aggressive feeders, and are undoubtedly responsible for most of the nursery and plantation injury in northern Michigan, Wisconsin, and Minnesota. Pupation occurs from July to September, and the adults reach maturity in 2 or 3 weeks. The species overwinters in the adult and larval stages. The males are attracted by lights.

Phyllophaga marginalis (Lec.) is found from New York to South Carolina and west to Iowa. This is another shiny, dark-brown form, about 17 mm. long, apparently most abundant in heavy oak stands. A more selective feeder than *P. drakei*, it is not generally distributed over all its range, but is concentrated in heavy oak, aspen, birch, and probably other hardwood areas. The larvae used in experiments fed on less than 5 percent of the coniferous seedlings provided, but their habits in the field have not yet been determined.

Phyllophaga fervida (F.) ranges from New York to Georgia, and west to Mississippi, Missouri, and Iowa. The habits of this feebly shining, dark-brown species, about 22 mm. long, are little known, but it has been taken feeding on pecan in Mississippi. Its wide distribution suggests general feeding, and it is a common species in hardwood stands in its range. The feeding habits of the larvae are not known. *P. vehemens* (Horn) is found mostly in Iowa, Illinois, and Kansas, but its range extends south to Mississippi. It is a large species, about 22 mm. long, and is deep brown, with moderately shining wing covers. The adults are known to feed on leaves of ash, walnut, gum, oak, maple, pecan, poplar, rose, and willow, being therefore rather general in this respect. The feeding habits of the larvae are not known.

Phyllophaga fusca (Froel.) ranges from Canada south to northern Georgia, west to Kansas, Colorado, Idaho, and Washington, having therefore probably the most northwesterly distribution of any species of the genus. It is a very dark brown, shining, but somewhat variable species, and is about 21 mm. long. This beetle occurs on both prairie and wooded areas, and feeds on a very large number of hardwood trees. The larvae have been reported from numerous localities as injurious to nurseries and plantations. Adults and larvae may be abundant locally.

Phyllophaga anxia (Lec.) is found from eastern Canada to Montana and south to South Carolina, Mississippi, and Texas. The species is dark brown, moderately shining, and about 22 mm. long. It resembles *P. fervida*. *P. anxia* is a fairly general feeder on hardwoods and is seemingly associated with lowland areas. The larvae are known to be injurious to coniferous seedlings, but the species is relatively unimportant because of its small numbers and because its lowland habitat is removed from most of the planting areas.

Phyllophaga nitida (Lec.) ranges from Canada south to Pennsylvania, and west to Illinois, Iowa, Utah, and Montana. It is a shining, uniformly deep-brown species, about 18 mm. long, and very similar to *P. anxia*. It is common in northern Minnesota. Adult food plants are hazel, oak, basswood, birch, and others. The life cycle and feeding habits of the larvae are unknown. The adults are not strongly attracted by lights.

Phyllophaga prunina (Lec.) is a species found from western Michigan south to Mississippi, apparently a Mississippi Valley form, and more abundant in its southern than northern range. It is common along Lake Michigan in lower Michigan, but scarce elsewhere in the Lake States. It is purplish and pruinose, and about 18 mm. long. Adults feed on oaks, hazel, sassafras, pecan, hawthorn, and other hardwoods. This is an unimportant species, partly because of its small numbers. Nothing is known of the food habits of the larvae.

Phyllophaga rugosa (Melsh.) occupies a rather large area, Massachusetts to North Carolina, west to Texas, and north to Colorado and Minnesota. The species is about 22 mm. long and uniformly dark brown. It has been observed more in sod lands adjacent to hardwood stands than in forested areas, but in Minnesota and probably elsewhere large populations are known to occur in the aspen-white birch type. The adults feed on a large number of hardwoods. At Cass Lake, Minn., the larvae were very destructive to red pine and white pine seedlings under experimental conditions. This is the most destructive species occurring in the extensive conifer nurseries at Cass Lake.

Phyllophaga luctuosa (Horn) is an Atlantic and Gulf coast species, and is confined to the sandy oak-pine regions in its range. The adults are uniformly dark brown, with shining wing covers, and are about 21 mm. long. This is one of the few species known to feed on pine leaves, of which loblolly and longleaf pines are preferred, but hardwood leaves represent the most important food supply. The species has been collected from several kinds of oaks, black gum, pecan, hickory, and about a dozen other hardwoods. The life cycle covers 2 or 3 years. The eggs are laid in spring and summer. The first winter is spent in the second and third instars. In late summer of the second year about 75 percent of the larvae pupate and in 2 or 3 weeks reach the adult stage. These pass the second winter as adult beetles. The remaining 25 percent pass the second winter as third instars, pupate in the following late summer and fall, and pass the third winter as adults. Emergence is in the spring for both classes. Thus, about three-fourths of a given brood requires 2, and one-fourth 3, full years to complete the life cycle. The females are prolific, as caged beetles averaged 90 eggs each, and they may produce more. The larvae are known to be destructive to nursery stock and probably to seedlings planted elsewhere.

Phyllophaga forsteri (Burm.) is found from New York to South Carolina and Mississippi and west to Iowa. This is a medium-brown, shining species, about 16 mm. long, with a dusky head. Adult food plants are oaks of several species, hickory, pecan, persimmon, and others. The life cycle is very similar to that of *P. luctuosa* so far as study has shown. The larvae have proved destructive to nursery stock and would probably be injurious in plantations.

Phyllophaga bipartita (Horn) ranges from Iowa to Mississippi and west as far as Texas and Nebraska. It is a uniformly deep-brown, somewhat shining species, about 17 mm. long and apparently more of a prairie than a forest insect. Its distribution seems to be general rather than locally concentrated. Recorded adult food plants are oak, pecan, and willow, and undoubtedly other hardwoods are taken. Little is known of the feeding habits of the grubs.

Phyllophaga gracilis (Burm.) has been taken from eastern Canada to Georgia, west to Mississippi, and north to Michigan. This is one of the small species, being only about 13 mm. long. It is pale brown to tan and has shining wing covers. Oaks are the favorite food, but collections have been made from Juneberry, rose, and New Jersey tea. The life cycle covers 2 or 3 years, and differs from that of most *Phyllophaga* in that pupation occurs in the spring, at least in the latitude of central Michigan. Here the adults emerge about the middle of July, but earlier southward. Two or three varieties of the species are known The larvae destroyed coniferous seedlings under experimental conditions, but by no means to the same degree as *P. drakei* in the same locality. The flight period is comparatively very short, being only 2 or 3 weeks, whereas *P. drakei*, *P. crenulata*, and other species are active in the Huron National Forest for 10 to 12 weeks. The adults are strongly attracted by lights.

Phyllophaga crenulata (Froel.) is a species found from New York west to Michigan and Iowa, and south to Mississippi and the Carolinas. Dense populations seem to be uncommon. The adults are hairy, uniformly dull brown, and 16 to 20 mm. long. It feeds only on hardwood leaves, and in Michigan shows a distinct preference for Juneberry. In Mississippi it is a variable feeder, involving about 20 trees and shrubs. In South Carolina it has been taken from hickory, persimmon, and black gum. On the Huron National Forest, hundreds were collected, but never at a height above 5 feet. In Mississippi it destroys flowers on pecan trees, certainly at a much greater height. The species appears to be more common in bushy upland than in heavy timber stands. The life cycle is 2 or 3 years in duration, with pupation occurring in the fall. The larvae, under very limited tests, were destructive to seedlings, but to a much less degree than *P. drakei*. Neither sex is much attracted to lights.

Phyllophaga soror (Davis) is known to occur in North and South Carolina but probably occurs in adjacent States along the Atlantic. The adults are light brown and about 15 mm. long, being therefore only slightly larger than *P. gracilis*. Their recorded food plants are elm, water oaks, and black oaks. The life cycle is probably 2 years in duration. Pupation occurs in June, the species being similar to *gracilis* in this respect, and peak emergence is in July. Heavy infestations occur locally in the Carolinas and perhaps elsewhere. The grubs, as in the case of *P. marginalis*, only slightly injured seedlings used in experiments.

Phyllophaga futilis (*Lec.*) is found in eastern Canada, south to Virginia and Mississippi, and west to Iowa, Kansas, and Nebraska. This light-brown, shining species is about 15 mm. long and is sometimes very abundant locally. The principal food plants of the adults are oaks, pecan, elm, butternut, hawthorn, hazel, and basswood, but a dozen others have been recorded. The life cycle covers 2 or 3 years, with pupation occurring in the fall. The feeding habits of the larvae have not been determined.

Phyllophaga tristis (F.) is a species occurring from New York to South Carolina, west to Mississippi, and north to Iowa and Minnesota. This small, hairy species is only about 12 mm. long, yellowish brown, and distinctly broadened caudally. It is sometimes very abundant in Iowa, but scarce throughout much of its range. The chief food plants are oaks, persimmon, maple, elm, and willow; but many others are known. A 2- to 3-year life cycle, with pupation occurring in the fall, has been determined for the species. The larvae have caused serious damage to red pine transplants at the Chittenden Forest Service Nursery in Michigan. Neither sex seems to be attracted by lights.

Phyllophaga lanceolata (Say) ranges from South Dakota to Arizona, and east to Nebraska, Kansas, and Texas. This is a prairie form, about 16 mm. long, moderately shining, and dark brown. Food plants of the adults consist of the leaves of a very large number of trees, shrubs, and herbs, including numerous vegetables and field crops. The life cycle is 1 to 2 years in duration, and pupation occurs in late spring or early summer. The larvae are destructive to wheat and other small grains, and would probably feed readily on the roots of coniferous seedlings.

Phyllophaga ilicis (Knoch) is widely scattered from New York to South Carolina, west to Mississippi, and north to Minnesota, and seemingly never a very abundant species, though known to be common in an area along the eastern shore of Lake Michigan. Its food plants are oaks, hickory, persimmon, pecan, ash, aspen, hazel, and numerous other trees. The adults are large and robust, about 22 mm. long, hairy, and yellowish brown. The life cycle is 2 to 3 years, pupation probably occurring in the fall. The feeding habits of the larvae are not known.

Phyllophaga prununculina (Burm.) is apparently confined to the South Atlantic and Gulf coasts. The species is very shiny, dark reddish to brown, and about 15 mm. long. Its food plants seem to consist of pines, with loblolly and longleaf pine preferred, and various oaks. The life cycle is probably 2 to 3 years. Peak emergence in South Carolina is late in June and early in July. The larvae are very destructive to nursery stock. The species is attracted to lights.

Subfamily RUTELINAE

Except for *Strigoderma* and the introduced *Popillia*, the Rutelinae are convex and usually robust beetles. Most of the forms have the labrum short, the scutellum usually rounded behind, tarsi with cylindrical joints, and the epimera visible from above. The adults are largely diurnal and feed chiefly on foliage, but *Popillia* is also a destructive fruit eater.

Little study has been made of the native species of the genus *Anomala* Sam., but an introduced species, **the oriental beetle** (*A. orientalis* Waterh.), has received considerable attention. The American species, of which more than 20 are known, have not been given common names. The oriental beetle is at present confined to the Atlantic Coast States, and the native forms occur throughout the eastern half of the United States. The adults are much smaller than those of the *Phyllophaga*, seldom being more than 12 mm. long, and usually smaller. In color, they are extremely variable, ranging from dull yellow to black, and the wing covers are shiny and distinctly convex. The life cycle is completed in 1 year; adults are most abundant late in the spring and early summer. Some species pupate in the fall, others in the spring.

Many species seem to prefer fields to heavily wooded lands, being, therefore, a farm and prairie as well as a forest group. Adults are leaf feeders, and many shrubs, herbs, cultivated plants, and trees are attacked. Severe defoliation may occur locally. The larval food habits are unknown, except that the larvae of the oriental beetle are destructive to vegetable gardens.

Pachystethus oblivia (Horn) appears to be a common species of an otherwise little-known group. It occurs in open, scrubby pine forests from Georgia north to New York and west to Lake Michigan. The female is larger and lighter colored than the male, being about 9 mm. long and light tan; the male is 6 to 7 mm. long and has a greenish-bronze head and pronotum and dark-tan wing covers. The males resemble Japanese beetles, but are smaller. The life cycle for *P. oblivia* has recently been determined for the latitude of central Michigan. As in other species of this genera, the cycle requires 1 year. Adults appear during the latter half of June, and after concentrating on jack pine, proceed immediately to feed and mate. These activities continue for about 10 days, by which time egg laying is complete. The eggs are laid in the soil within a few yards of the food trees and hatch in 10 to 15 days, the larval stage beginning toward the last of July. The larva is the overwintering form. Pupation occurs early in June, and 2 or 3 weeks later the adults have formed and are ready to emerge.

Injury is chiefly that of defoliation and is heaviest on open or orchard-type trees. Jack pine is the most heavily attacked in Michigan, pitch pine in New York may suffer a loss of 75 percent of the current year's needles, and Virginia, mountain, red, and white pine, among others, may be appreciably injured.

Defoliation is almost entirely in new growth, injury being due to a notch eaten in each leaf just above the bundle sheath. The needles bend down at this point, and die, giving the trees a brownish appearance. Such attack has resulted in over 75 percent defoliation in certain areas on the Manistee National Forest. In most instances the bases of the leaves do not die; late in the season of attack and the following spring, they frequently grow to about one-half their normal length. The food of the larvae includes rootlets, and doubtless other material. Of the seedlings used in about 80 tests, less than 1 percent were killed. Under natural conditions it seems that little or no damage should occur. Little is known of the feeding habits of the other species of this genus.

The genus *Strigoderma* Burm. is represented by only a few species, *S. arboricola* (F.) being the most important. Adults are oval-shaped, and about 12 mm. long. The head, prothorax, and scutellum are dull blackish green, and the wing covers are yellowish or piceous, and thinly clothed with long, grayish hairs. It is common in the Central States. This species has a 1-year life cycle, pupation occurring in the spring, and the larvae overwintering. The adults feed on the buds and flowers of roses and waterlilies, but the larval feeding habits are unknown. The larvae are said to occur in sandy wasteland or dunes.

The Japanese beetle (*Popillia japonica* Newm.) was introduced into New Jersey from Japan prior to 1916, and has now spread as far west as St. Louis. The adult has a shiny, bronze-green head and prothorax, deep-tan wing covers, and is about 12 mm. long. Two distinct white spots below the wing covers and at the tip of the abdomen are diagnostic. The legs and lower surface are greenish yellow. The beetles feed on practically all species of fruit and vegetation in their range. Trees and shrubs may be severely defoliated, largely by skeletonization. Turf, vegetables, and certain nursery stock have been destroyed by the larvae in many instances. In many eastern cities the Japanese beetle is considered one of the worst of insect pests. Both the adults and larvae may occur in extremely large numbers.

The 1-year life cycle is as follows: Adults, in the vicinity of Philadelphia, appear about the middle of June, and are most active to the last of August. Females lay from 40 to 60 eggs, mostly at night, and preferably in moist, loamy soil. Hatching in about 2 weeks, the larvae feed on rootlets and dead vegetation until late in October, at which time they go into hibernation. Larval growth is completed in the spring. The pupal stage begins about the first of June and requires 2 or 3 weeks, at the end of which time the beetles are ready to emerge. In the northern limits of its range and in very cold, damp soils, 2 years may be required to complete the life cycle.

Control of the adults by the use of DDT sprays is very effective, and traps have been more or less successful. Attempts at larval control have involved soil poisoning, applications of the milky disease, various cultural practices, and the importation of parasites. Parasites of the genus *Tiphia* promise to be effective, as up to about 40 percent parasitization has already occurred in heavily infested areas. Rainfall below a 10-inch combined total for June, July, and August results in the desiccation of many eggs and small larvae, and consequently a reduced infestation the following year. During dry summers beetles tend to oviposit in moist areas, and this results in the concentration of larvae and in localized injury.

At least four species of the genus *Pelidnota* occur in eastern America, of which *P. punctata* (L.), **the spotted pelidnota,** is best known. It occurs from New York to the Gulf and west to Kansas. This species is about 20 mm. long. reddish brown above, with three black spots on each wing cover and one on each side of the prothorax. The scutellum, base of the head, and entire body beneath are deep bronzed green. The adults are well known as pests of grape vines, wild or cultivated, but they undoubtedly take other food. The life cycle covers 2 to 3 years, the larvae typically occurring in decayed hardwood stumps, but sometimes in decaying roots and logs. Such wood serves as larval food, thus classing them as beneficial rather than injurious to forest stands.

Only two or three species of the genus *Cotalpa* occur in eastern America, and of these *C. lanigera* (L.) **the goldsmith beetle,** is best known. It is a large form, ranging from 22 to 26 mm., and is broadly oval and convex. It is lemon-yellow above, except for the head and prothorax, which are glittering and the color of burnished gold; the under side of the body is greenish to copper colored and covered by whitish wool. The species occurs from Canada to the Gulf and at least as far westward as the Great Plains. The beetles are common in the Chippewa National Forest nurseries at Cass Lake, Minn.

The adults, in the North, feed on leaves of aspen, willow, oak, and other hardwoods. The food habits in the South are unknown. Fairly extensive tests with all sizes of larvae indicate that they eat coniferous roots, but to a much less degree than do *Phyllophaga*, even in heavy concentrations. Certainly on the basis of present knowledge they cannot be classed as very destructive grubs, except possibly when there are very large numbers in nurseries. Ordinarily, the species appears to be widely scattered, and largely confined to sandy or loamy, often brushy or pastured, areas.

The life cycle is from 2 to 3 years in duration. Eggs are laid early in the summer. The pupae are encased in loose, thin, papery skins, which split at the time of emergence.

The most common species of the genus *Polymoechus* Lec., *P. brevipes* Les., is widely scattered through the eastern half of the United States. The beetle is convex, blunt, dark chestnut brown to piceous, and about 16 mm. long. The food of the adults is unknown, but the larvae occur most commonly in decayed hardwood stumps, roots, and logs. They have been found in the decaying wood of chestnut telegraph poles, and also under manure in sandy soil. The life cycle and economic status have been little studied.

Subfamily DYNASTINAE

The Dynastinae are convex, medium-sized to very large beetles with the labrum usually invisible. In all genera except for some males of *Ochrosidia*, the tarsal claws are equal, and except for this same genus, the head or pronotum, often both, is armed with horns or tubercles. Practically all the Dynastinae are nocturnal, spending the daylight hours under bark, duff, or similar material. The adults of some species feed on leaves, but the food habits of many others are unknown.

In the genus *Ochrosidia* Csy., two species, *O. villosa* (Burm.) and *O. immaculata* (Oliv.), have rather wide distribution in the Atlantic, Southern, and Central States. A few other species occur in the same area. They are pale to brownish-yellow, somewhat hairy beetles, about 14 mm. long, with head and thorax unarmed in both sexes. The adults, probably most abundant in June or July, are nocturnal, and are attracted by lights. Their food habits are not well known, but they are probably defoliators. The larvae occur mostly in fields, but they have been taken from decayed logs and stumps, pastures, manure, and other habitats, and are injurious to grain, lawns, pastures, manure, and other stock. They possibly rank next to *Phyllophaga* in destructiveness. The life cycle is 1 year in duration. Eggs are laid in soil and hatch after 9 to 25 days, and the partly grown larvae pass the winter in hibernation. Pupation occurs by the middle of June in most localities and lasts from 1 to 3 weeks. The species is often abundant in Illinois and adjacent States.

The genus *Ligyrus* Burm. is represented by a number of species in the Eastern States. The most important is **the carrot beetle** (*L. gibbosus* (Deg.)). A convex, robust species, it is reddish to dark brown above, and paler beneath. Adults are about 14 mm. long. Other species are more or less similar in appearance. *L. gibbosus* has a 1-year life cycle. In Illinois and adjacent States the adults emerge in the spring, and oviposit mostly in fields, but sometimes in decaying vegetation and well-rotted manure. Hatching requires 1 to 3 weeks, and the larvae grow rapidly. Pupation occurs late in summer; the adults are nocturnal and are attracted by lights.

At least four species of the genus *Ligyrodes* Csy. occur in the Eastern, Southern, and Central States. One, *L. relictus* (Say), is known from New York to Nebraska, and undoubtedly is found elsewhere. The adults, though larger, are somewhat similar to *Ligyrus*, being convex, shiny, and very dark brown. Almost nothing is known regarding the feeding habits of the adults. The larvae occur chiefly in soil under manure, but occasionally in decaying vegetation. It is probable that neither adults nor larvae are injurious to forests or other vegetation.

L. relictus is the only native lamellicorn herein discussed that may produce, in the latitude of Kansas, two generations per year. The beetles appear above ground in April or May for the spring flight, returning to the soil each day, where mating takes place. They disappear for a short time in June and July, and the new brood appears in July and August for a second period of flight. Both adults and larvae feed on the roots of carrots and other crops, but in addition the beetles are also said to feed on leaves. The larvae are considered as possible, though probably unimportant, nursery pests.

Very little is known in regard to the dozen or more species of *Aphonus* found in the region under consideration. In the Lake States, *A. tridentatus* (Say) is the most common; in New York, *A. castaneus* (Melsh.) is apparently the dominant form. The former is a shining, piceous-brown insect, dark reddish brown below, and about 15 mm. long. In Michigan it appears to be closely associated with New Jersey tea (*Ceanothus* sp.), as neither adults nor larvae have been collected by digging at a distance greater than a few feet from this plant. Extensive tests failed to identify the food of either adults or larvae, but it appears certain that neither form is injurious in forests or nurseries.

The three or four species of *Xyloryctes* occurring in the Eastern, Southern, and Central States are large, ranging up to about 28 mm. None of the forms are well known, the most common probably being *X. satyrus* (F.). This beetle is robust, shining, dark chestnut to piceous brown above and paler below, due to the thick clothing of reddish hairs. The male has a curved horn arising from the middle of the head, the female a tubercle on the same area. The species appears to be scarce over most of its range, but is found most frequently in hardwood stands, especially the more southern ones, and the larvae are said to occur here in the humus layer. It has been questionably reported that they injure ash trees by feeding on the roots, and also that the adults are usually found in the vicinity of ash trees. The feeding habits of none of the stages are definitely known.

To the genus *Dynastes* Kby. belong the largest of known beetles, either American or foreign. They are almost exclusively inhabitants of decayed hardwood stumps and logs. In the eastern part of the United States, *D. tityus* (L.), appropriately called **the rhinoceros beetle,** is the only known species. It occurs from New York and Indiana south to the Gulf. The males reach a total length of 55 to 60 mm.; the females are 5 to 10 mm. shorter. They are greenish gray or brown all over, or a combination of these colors. Males have two prominent horns in an over-and-under arrangement. The adults are said to feed on leaves, but if they do, they cause little or no damage. Larvae feed on decayed wood and are more beneficial than otherwise, although they enlarge the cavities in the bases of shade trees. Both male and female beetles have been taken at lights during the spring and summer.

Subfamily CETONIINAE

The Cetoniinae, or flower beetles, are flattened, essentially diurnal beetles, many species having the mouth parts furnished with a bunch of hairs used in gathering pollen.

The species of the genus *Cotinis* are fruit and foliage eaters. All are most active on bright days, but may often be seen flying late in the afternoon and at night. They most frequently occur in open woodlands or similar places around flowering shrubs and herbs. This genus is represented by three or four species in the area east of the Great Plains, **the green June beetle** (*C. nitida* (L.)) or **figeater,** being by far the best known. Throughout the Mississippi Valley, south of central Illinois, and along the Atlantic and Gulf coasts, it is common to abundant. Many boys and girls tie strings to this beetle and spend delightful hours, entertained by the zooming and loud buzzing flight of the captive. The adults are 16 to 25 mm. long, with the sides of the thorax and wing covers gold or tan.

The beetles feed on the foliage and fruit of many drupes and berries. Other trees and shrubbery may be attacked. Late June and July is the time of greatest abundance over most of its range. The 1-year life cycle is as follows: Eggs are laid in July and August in rich soil and usually near decaying vegetable material or dung in old corrals, on which the grubs feed until they go into hibernation. In the spring the larvae burrow close to the surface and feed on dead vegetation and living roots. After heavy rains they sometimes come out of the soil and crawl on their backs on the ground surface, and have been taken in forest nurseries at this time. They also exhibit the back-crawling trait when collected by digging. The grubs are full grown by midspring, when they change in an earthen cell to the pupal stage, and emergence soon follows.

The larvae are known to be destructive to the turf of lawns. The 1-year cycle would allow them to mature in seed and nursery beds before being disturbed by deep cultivation, and under such conditions, they may be injurious. They probably cause little damage in plantations.

The genus *Euphoria* Burm., containing at least a half-dozen species in the Central and Eastern States, none of which are well known, represents one of the "flower-beetle" groups. The adults, which vary widely in color, are broad and hairy, with triangular-shaped thoraxes, and are 9 to 18 mm. in length. They occur at sap flows, and on roasting ears, fruits, and flowers of many kinds. They are diurnal, fly with a loud, buzzing noise, and are probably most abundant in July and August. The larvae occur under manure, in decaying vegetation, and in rotting straw stacks. The species has a 1-year life cycle, and presumably overwinters in the larval stage. Both adults and larvae may be regarded as noninjurious.

The genus *Osmoderma* Serv. contains four Eastern and Central States species, of which *O. eremicola* Knoch, **the hermit flower beetle,** and *O. scabra* (Beauv.), **the rough flower beetle,** are fairly well known. Both are broadly oval and depressed dorsally, and have heavy leathery wings. *O. eremicola* is about 28 mm. long and is dark brown and shining. *O. scabra* is about 22 mm. long, and purplish black or bronzed. They emit a strong leatherlike odor when captured. Listed as nocturnal in some literature, both species are known to fly late in the afternoon and between sundown and dark. July is probably the month of greatest abundance. The adults probably feed on leaves and flowers. Larvae occur in the decayed cavities of dead or dying trees and logs. One nest of about 40 larvae was found when a hollow jack pine log on the Huron National Forest was cut into firewood. In this case the larvae ranged from about 1 to nearly 2 inches in length. Three years are required for full development. All other Cetoniinae, as far as known, have a 1-year life cycle. The larvae are not considered very injurious to the host tree.

The genus *Trichiotinus* Csy. contains eight hairy, variegated species, sometimes referred to as "flower beetles." In length they range from 9 to 15 mm., and have very long, slender legs, with long claws. All species are apparently diurnal, and are usually found around flowering trees and shrubs. In Michigan, wild cherries are favorite hosts. They are most abundant in June and July. The larvae occur annually in dead logs and stumps since the species have 1-year life cycles. Neither the adults nor larvae may be regarded as injurious.

Family **ELATERIDAE**

The Click Beetles

The click, or snap, beetles associated with forest trees are predominantly vegetable feeders. They are to be found under the bark or in their pupal cells in the wood, often overwintering in these cells. One of the most interesting characteristics is their habit of snapping or clicking by means of a springlike prothoracic sternal spine, which snaps into a groove on the mesosternum. By this mechanism they can, when placed on their backs, throw themselves forcibly into the air, eventually to land feet down. As larvae they eat the soft tissues under dead bark or burrow in dead, often well-decayed wood. In this role they are of little economic importance. However, a small number are voracious predators and quite beneficial.

The beetles are elongate, usually fusiform in shape, ranging from a few to over 40 mm. in length. They have 11-jointed, serrate antennae, which fit into grooves on the under side of the thorax. The larvae are also elongate, fusiform, and somewhat depressed or cylindrical, having a tough shining integument, and with the ninth abdominal segment often bearing a paired or a single-pointed process. The head is extended, labrum and clypeus fused into a nasale, mouth parts deeply retracted, gula reduced to a single suture, and the mandibles are of the grasping type without a molar structure. The legs are usually well developed and the spiracles bifore.

The eyed click beetle (*Alaus oculatus* (L.)) found in hardwoods and *A. myops* (F.) in pines are large beetles, 25 to 40 mm. in length, grayish black and marked with two large black eyelike spots surrounded by a ring of pale scales, on the thorax. The larvae are elongate, depressed, yellowish forms with a heavily chitinized head and thorax and strong bifurcate prongs on the ninth abdominal segment. They are voracious feeders on other wood borers. Caged specimens are recorded as devouring over 200 cerambycid larvae each during their development.

Adelocera discoidea (Web.) and *A. aurorata* Say in pine, *A. avita* Say and *Hemicrepidius bilobatus* (Say) in hickory, as well as *Chalcolepidius* spp. are also predaceous on wood borers. Several species of *Elater* are common under bark of dead and dying trees.

Families MELASIDAE and TRIXAGIDAE

The Cross-Wood Borers

The cross-wood borers resemble the Elateridae but lack their power to spring, although they are very active and difficult to catch and hold. They are most remarkable, however, because of the peculiar modification of larval characters, particularly a reduction of the mouth parts and mandibles and the development of sawlike teeth or keels on the side of the head for cutting the wood by a rasping movement. The larvae are elongate, parallel, much depressed, legless forms (except *Trixagus*= (*Throscus*)) with rudimentary mouth parts. The labrum and clypeus are formed into the nasale, and usually the mandibles are immobile. The thorax is often enlarged like that of the buprestids and bears strongly chitinized markings or T-like rods, and the ninth abdominal segment is formed into a broad dentate plate or bears a pair of spines.

The larvae of many species cut characteristic mines across the grain of the wood, which readily distinguishes their work. In the pupal cell they double up on themselves like buprestids. Certain forms with greatly reduced mouth parts can feed only by imbibing the liquids from the medium in which they are boring. In some forms the adults bore into the wood to make egg tunnels similar to those of the scolytids and some bostrichids. They are interesting forms but of little economic importance in the eastern part of the United States, confining their attack to dead, often somewhat rotted wood.

Melasis pectinicornis Melsh. *Isorhipis ruficornis* (Say), and *Fornax badius* (Melsh.) feed in beech, chestnut, hickory, maple, tulip, ironwood, sweetgum, pine, and other hardwoods, the wood of which is fairly firm, while *Trixagus constrictor* Say is found in moist logs on the ground. *Drapetes geminatus* (Say) is common in dead hickories, killed by the hickory bark beetle. *Dirhagus pectinatus* (Lec.) has been reared from sycamore; *Nematodes astropos* (Say) from oak, and *Dromaeolus striatus* (Lec.) from chestnut and pine, although they are not very abundant. For notes on the biology of this family see Van Horn (*421*) and Kirk (*266*).

Family RHIPICERIDAE

Of the family Rhipiceridae, *Zenoa picea* (Beauv.), a rare species, is mentioned because of its peculiar larva which mines in dead hardwood logs. This larva is an elongate, cylindrical, darkly chitinized form resembling some elaterids but with the head more globular and the ninth abdominal segment ending bluntly in an operculum enclosing the tenth segment. The adult is a robust, dark-reddish-brown beetle, with serrate antennae.

Family BUPRESTIDAE

THE FLATHEADED BORERS

By J. N. Knull [20a]

The Buprestidae or flatheaded borers are represented in our fauna by beautifully marked, metallic-colored beetles, varying greatly in size but usually somewhat flattened and elliptical or oval. They are characterized by 11-segmented serrate antennae inserted on the front, head inserted in the prothorax to the eyes, prosternum prolonged behind and fitting into the mesosternum, elytra usually covering the abdomen, abdomen with five or six visible ventral segments, the first two being fused.

The larvae are all plant feeders, and all but a few are wood borers. The pestlelike or hammer-headed shape produced by the enlargement of the first or prothoracic segment and occasionally the second and third is so characteristic as to give them the common name of flatheaded borers and readily distinguishes them from all other larvae found in trees. The head itself is deeply embedded in the prothorax and scarcely visible. The abdomen of the larva is slender and frequently doubled back on itself laterally while in its feeding galleries. The larvae are legless and further characterized by never having jointed cerci though occasionally some forms have two chitinous spines on the ninth abdominal segment. The tenth segment is terminal, the spiracles cribriform, the ventral mouth parts are soft and fleshy and not retracted. The dorsal and ventral surfaces of the prothorax usually bear a plate with characteristic markings either like an **I** or an inverted **V**.

General Habits

The bright-colored beetles of this family are true sun lovers, and frequently attract much attention around logging operations and mills, where they are seen running rapidly over logs, hesitating now and then in search of a place to lay their eggs. They are very alert, shy beetles and quickly conceal themselves or fly away when approached. On cloudy days they are inactive and rarely seen. They feed on pollen, foliage, or the tender bark of trees.

The flatheaded borers are of considerable importance in the forest, probably ranking next to the Cerambycidae, with which they have many habits in common. The greatest damage results from their boring into the sapwood of recently felled logs. Rustic work is also severely damaged, and a few forms attack the bases of poles, fence posts, and cross ties.

A number of species bore beneath the bark of living trees, particularly those that are weakened or gradually dying from some other cause. In such cases these borers may hasten the death of the trees. *Chrysobothris*, *Melanophila*, and *Agrilus* are typical of this group. It is difficult to determine definitely the economic status of such insects, however, because of their preference for plants in a weakened condition. Their effect on the forest was discussed by Burke (*74*) and by Hall (*207*).

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The galleries of the larvae are flattened, usually oval in cross section and winding, gradually enlarging as the larva increases in size. Pupation occurs in a widened cell at the end of the larval mine. These larval mines are always tightly packed with fine sawdustlike pellets or frass arranged in arclike layers, and the surface of the wood in the burrow is scarred with fine transverse concentric lines produced by the mandibles of the larva. The beetles on emerging through the bark or the wood leave very characteristic oval or elliptical exit holes which can hardly be mistaken for the work of any other group of insects.

The life cycle may be completed in part of one season, or may extend over several years in the case of the large stump borers. Some forms complete their development in the late summer, transform to adults, and hibernate in the pupal cells over winter. Some of the so-called bark-boring forms, as *Agrilus* and *Melanophila*, pupate in the bark or in the outer wood, depending on the thickness of the bark. Some species, such as those of *Agrilus* and *Eupristocerus*, work primarily in the small twigs. These often cause galls, and some of the species of *Agrilus* are twig pruners. Certain forms attack blazes or scars on living trees, and mine the sap or heartwood beneath; thus they prevent healing and even cause an extension of the injury. A few are cone borers, while others are leaf miners, spending the entire period of their development in the leaves, where they construct the pupal cell, and several bore in the stems of herbaceous plants.

KEY TO THE ADULTS OF THE EASTERN GENERA OF BUPRESTIDAE

1.	Hind coxal plates scarcely widened internally	2
	Hind coxal plates distinctly widened internally, front margin straight, hind margin oblique	10
2.	Prothorax truncate at base	3
	Prothorax lobed at base	5
3.	Mesosternum scarcely visible; breeds in small branches of oak *Mastogenius* Lec. and Horn	
	Mesosternum emarginate	4
4.	Scutellum indistinct *Acmaeodera* Esch.	
	Scutellum plainly indicated *Ptosima* Sol.	
5.	Antennae not received in grooves on under side of prothorax	6
	Antennae received in grooves on under side of prothorax	7
6.	First joint of hind tarsi scarcely elongate; gall formers on alder *Eupristocerus* Deyr.	
	First joint of hind tarsi as long as 3 following joints *Agrilus* Steph.	
7.	Tarsi over half as long as tibiae *Paragrilus* Saund.	
	Tarsi much shorter than tibiae	8
8.	Scutellum large; larvae leaf miners in certain leguminous plants *Pachyschelus* Sol.	
	Scutellum small	9
9.	Prosternum with posterior cavity; larvae leaf miners in various species of oak *Brachys* Sol.	
	Prosternum without cavity; leaf miners in *Scirpius* and other allied plants *Taphrocerus* Sol.	
10.	Antennal pores scattered on both faces of serrate joints	11
	Antennal pores concentrated in pits on these joints	12
11.	Apical third of elytral margin entire, or finely serrate; borers in pine stumps and logs *Chalcophora* Sol.	
	Apical third of elytral margins strongly serrate; borers in hardwood trunks *Chalcophorella* Kerr.	
12.	Front not narrowed at insertion of antennae; eyes scarcely approaching, often distant on vertex	13
	Front narrowed at insertion of antennae; eyes oblique, close together on vertex	21

KEY TO THE ADULTS OF THE EASTERN GENERA OF BUPRESTIDAE—Continued

13.	Prosternal spine obtusely angulated behind prothoracic coxae; epimera of metathorax not covered by adbomen	14
	Prosternal spine acutely angulated behind prothoracic coxae; epimera of metathorax partly concealed by abdomen	18
14.	Prosternal spine obtusely rounded at apex	15
	Prosternal spine acute at apex; larvae heartwood borers in oak and ironwood — *Cinyra* C. and G.	
15.	Mentum entirely corneous	16
	Anterior edge of mentum coriaceous — *Buprestis* L.	
16.	Elytra striate	17
	Elytra not striate — *Trachykele* Mars.	
17.	Scutellum small, round, oval — *Dicerca* Esch.	
	Scutellum large, trapezoidal; pronotum with smooth median line — *Poecilonota* Esch.	
18.	Anterior edge of mentum coriaceous — *Melanophila* Esch.	
	Mentum entirely corneous	19
19.	Base of thorax truncate	20
	Base of thorax sinuate — *Xenorhipis* Lec.	
20.	Last ventral segment of abdomen punctured like the segments preceding — *Anthaxia* Esch.	
	Last ventral segment of abdomen much more densely punctured than the preceding segments — *Agrilaxia* Kerr.	
21.	Hind tarsi with first joint considerably longer than second; third joint not prolonged at sides; sapwood and bark borers — *Chrysobothris* Esch.	
	Hind tarsi with first joint only slightly longer than second; third joint prolonged at sides; heartwood borers in various hardwoods — *Actenodes* Lec.	

KEY TO THE LARVAE OF THE MORE IMPORTANT GENERA OF BUPRESTIDAE

1.	Leaf miners, larvae spindle- or wedge-shaped	13
	Twig or bark borers or occasionally gall makers; larval form elongate, parallel, last segment ending in a pair of spines	14
	Wood or bark borers; larvae hammer-headed or pestle-shaped; no spines	2
2.	Dorsal plate of prothorax marked with an inverted Y, V, or U	3
	Dorsal plate of prothorax bearing only a single median impression or groove	12
3.	Dorsal plate of prothorax bearing chitinous rugosities	4
	Dorsal plate of prothorax smooth	8
4.	Rugosities on prothoracic plates strongly developed forming ridges; margins of plates distinct	5
	Rugosities on plates not forming ridges, dispersed; plates indistinct on margins	6
5.	Dorsal prothoracic plate marked with a distinct inverted Y; breeds in conifers — *Chalcophora*	
	Dorsal plate marked with an inverted V or U; breeds in hardwoods — *Chalcophorella*	
6.	Asperate areas of dorsal plate longer than wide; ventral area completely bisected by median groove; first abdominal segment smaller than second; mandible usually tridentate — *Melanophila*	
	Asperate areas of dorsal plate wider than long or of approximately the same dimensions; ventral area not completely bisected	7
7.	Dorsal plate marked by an inverted Y or U surrounded on the anterior half by the asperities suggesting a hood; ventral plate marked by a median groove extending from posterior margin forward but not completely bisecting plate; mandible usually tridentate, labrum usually tridentate — *Buprestis*	
	Dorsal and ventral asperate plates nearly circular; ventral bearing a median groove, which extends backward from the anterior margin about two-thirds of the distance; mandible usually bidentate; labrum entire — *Chrysobothris*	
8.	Metathorax bearing a dorsal and ventral pair of ampullae, ventral groove not bisecting prothoracic plate — *Anthaxia*	
	Metathorax normal; ventral groove bisecting plate	9

KEY TO THE LARVAE OF THE MORE IMPORTANT GENERA OF BUPRESTIDAE—Continued

9. Anterior end of dorsal inverted Y or V marking simple ---------- 10
Anterior end of both dorsal and ventral markings with broad reticulated ends ---------- 11
10. Dorsal marking an inverted Y; breeds in oak ---------- *Cinyra*
Dorsal marking an inverted V; breeds in willow and poplar *Poecilonota*
11. Dorsal marking an inverted V with a broad reticulated apex; mandible tridentate; breeds chiefly in hardwoods ---------- *Dicerca*
Dorsal marking an inverted Y, the apex surrounded by a depressed shining diamond-shaped area; mandible tridentate; breeds in conifers ---------- *Trachykele*
12. First abdominal segment smaller than the following; plates of prothorax whitish opaque; prothoracic grooves dark brown; breeds in redbud ---------- *Ptosima*
First abdominal segment broader than the second ---------- *Acmaeodera*
13. First segment as broad or slightly broader than the following; body gradually tapering to the twelfth, slightly wedge-shaped ---------- *Brachys*
First segment narrower than the following; body tapering both ways from about the middle, more acute at the posterior end; spindle-shaped ---------- *Pachyschelus*
14. Dorsal plate marked by two moderately separated dark-brown lines which converge anteriorly; breeds in alder ---------- *Eupristocerus*
Dorsal plate marked by a single median bisecting line; attacks various hardwoods ---------- *Agrilus*

SPECIES OF BUPRESTIDAE

The adult of *Acmaeodera pulchella* (Hbst.), **the flatheaded bald cypress sapwood borer,** is a blackish or blue-black beetle, 6 to 10 mm. long and about half as wide, with the posterior angles of the thorax and wing covers marked by irregular patches or bands of waxy yellow. The larva has the form typical of the group, and the plates of the prothorax are smooth and marked by a brownish median groove or line both above and below.

This insect occurs in Eastern and Southern States, boring in cypress and probably related species. It causes considerable damage to cypress girdled or deadened by the lumberman to dry it for logging and floating. It also attacks wounds on shade trees and mines the wood beneath.

The adult transforms in the wood in the spring and emerges in the early summer to lay eggs on recently dead or dying trees or logs. The larvae construct meandering galleries beneath the bark for a short distance before entering the sapwood, which they completely riddle.

Cypress to be felled should be girdled in the fall from October to December, after the flight period. This permits drying and avoids considerable injury. Unseasoned logs should not be left in the woods after the spring flight of this beetle has begun.

The two-lined chestnut borer (*Agrilus bilineatus* (Web.)) is a small beetle, 6 to 10 mm. in length, of a blackish-blue color, with golden yellow stripes on the sides of the prothorax and one on each wing cover. The larva is more elongate, flattened, and slender than most of the Buprestidae and has the last segment armed with a dark-brown pincerlike fork. Both plates of the prothorax, which is not so greatly widened as in many flatheads, are each marked by a single, median, brown line.

The species occurs throughout the Eastern and Central States attacking chestnut, oak, beech, blue beech, and ironwood. The importance of this insect has been the subject of some dispute among entomologists. There is no doubt that it attacks living trees that have sufficient resistance, in many cases, to heal over the galleries which are made on the surface of the wood. In fact, the tree frequently repels the attack of the insects, killing all the larvae. On the other hand, close examination of the host plant always indicates that it had been subject to some weakening effect such as root disease, insect defoliation, drought, over-grazing, fire, wind, severe frosting, or other causes that might ultimately have brought about the death of the tree. Considerable study by the Bureau of Entomology and Plant Quarantine and attempts to control the insect have led to the conclusion that it attacks only trees that are severely weakened and that it does no more than hasten the death of such trees. Following the droughts of 1930–36 in the Eastern States, great numbers of dying oaks have been attacked by this insect, as well as much beech in northern sections of the country.

The beetles emerge from the bark of the tree through characteristic D-shaped emergence holes in May or June, fly to the foliage where they feed for some time, and then deposit eggs beneath the bark scales of dead, dying, or weakened trees. The young larvae bore under the bark, constructing characteristic zigzag or meandering galleries on the wood surface frequently interrupted by a short detour into the wood. The pupal cell is finally constructed in the outer layers of the sapwood or sometimes in the bark. The attack usually begins in the topmost branches. These may be killed the first year, larger limbs the second year, and the entire tree may not succumb until the third year or later. In the North, two seasons are required to complete development (Chapman, *84*).

Usually no control is practicable, but watering the trees or applying fertilizers to stimulate growth may be beneficial or even save some trees that have been lightly attacked in the top. As the adults feed on the foliage, arsenical sprays or sprays containing DDT (p. 53) have been used to protect certain valuable shade trees where cost is no factor.

The bronze birch borer (*Agrilus anxius* Gory) resembles *A. bilineatus* in shape and size, but is uniformly olive bronze. It occurs in the north-central and northeastern parts of the United States and throughout the Rocky Mountains, attacking dying or weakened birches, beech, and aspens. Its life history and habits are very similar to those of *A. bilineatus*, and its economic status in the birch forests is regarded as the same as that of *bilineatus* in oak. It may hasten the death of overmature or defective trees left after logging operations and of defoliated or drought-affected trees. It frequently attacks shade trees and kills them (Slingerland, *381*). Pruning back the infested branches and stimulating growth by fertilizers and watering will often prevent the death of the tree. After a tree has been heavily attacked, however, control efforts are of no avail (Slingerland, *381* and Hall, *207*).

There are a large number of species of *Agrilus* of more or less economic importance, including such forms as *A. lateralis* (Say), which breeds in the stems of living sweetfern (*Comptonia peregrina* Coult.); *A. arcuatus* (Say), which prunes branches of beech, oak, and hickory, frequently causing considerable injury to hickory saplings; *A. politus* (Say), which forms galls on willow and striped maple; *A. politus pseudocoryli* Fisher, which forms galls on stems of hazelnut; *A. champlaini* Frost, which makes galls on ironwood (*Ostrya virginiana* (Miller) Koch.); *A. juglandis* Knull, which breeds in the bark of living butternut; *A. difficilis* Gory, which attacks living honeylocust and often is of considerable importance west of the Mississippi River in trees weakened by drought, or defoliation. *A. quadriguttatus* Gory breeds in unhealthy willows, *A. lecontei* Saund. and *A. celti* Knull in hackberry, and *A. cephalicus* Lec. in unhealthy dogwood. *A. vittaticollis* (Rand.) infests living *Crataegus*, wild crab, and serviceberry; *A. betulae* Fisher works in unhealthy river birch *A. fuscipennis* Gory breeds in living persimmon, and *A. egenus* Gory is a common species in locust in Ohio.

The turpentine borer (*Buprestis apricans* Hbst.) is a grayish-bronze, slightly flattened elliptical beetle about 30 mm. long by 3 to 9 mm. wide, with a greenish, metallic lustre. It has longitudinal rows of large punctures on each wing cover (fig. 40, *A*). The larvae have the typical flatheaded form and when fully mature are about 40 mm. long. The dorsal and ventral prothoracic plates are roughened with fine asperities, the dorsal marked by an impressed short-trunked Y and the ventral with a deep median groove extending about half its length from the posterior to the anterior margin.

This insect occurs throughout the coastal regions from North Carolina to Texas, attacking longleaf and possibly other southern pines, and slash. The adult beetles pass the winter in the pupal cells just beneath the surface of the wood and emerge on the first warm days in February and March. They feed for some time on the needles in the tops of the trees before laying eggs in season checks on the faces of turpentined trees, on blazes, or in fire scars. The larvae immediately bore into the wood, mining extensively through the sap- and heartwood for a period of 3 years. In their last season they construct the pupal cell late in the summer and transform to adults in the fall.

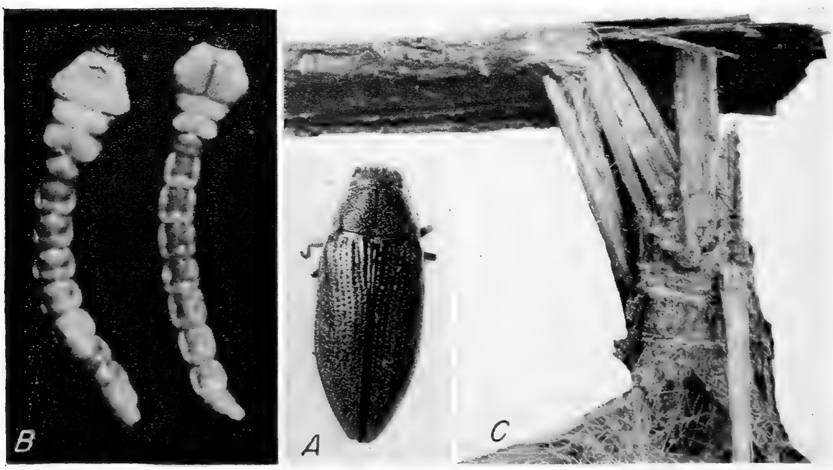

FIGURE 40.—*Buprestis apricans*: *A*, Adult beetle, × 2; *B*, a wind-thrown tree, a direct result of damage by the larvae.

The turpentine borer presents a very serious problem in the naval stores region, particularly in turpentining orchards. The meandering galleries of the larvae completely riddle the sap and heartwood, so weakening the trees that these break off in the wind (fif. 40, *C*). Often many of the turpentined trees are blown over during storms. Serious lowering of the grade of the lumber in the lower parts of the trees results from the worm holes and from the "pitching" of the wood around the larval mines. As this borer lays its eggs only in season checks of exposed wood, the most satisfactory prevention is to keep the turpentined faces covered with pitch and avoid dry facing. This calls for absolute protection of the faces from fire, and for the use of conservative turpentining practices such as are recommended by the United States Forest Service, which includes shallow chipping, narrow faces, sufficient spacing between faces, avoiding deep cuts for gutter insertion, and careful scraping of the gum so as not to expose the wood. Beal (*25*) discusses the control of this pest.

A number of species of the genus *Buprestis* occur rather commonly throughout the Eastern States and are frequently met with around logging operations. Some forms, particularly *B. decora* F., *B. striata* F., *B. salisburyensis* Hbst., *B. fascinata* F., and *B. rufipes* Oliv. are beautifully colored and attract considerable attention. *B, rufipes* breeds in dead elm, gum, beech, chestnut, oak, and hickory; all the others so far as known feed in conifers.

The large flatheaded pine heartwood borer (*Chalcophora virginiensis* (Dru.)) is a very large, dark-bronze, elongate-oval beetle, from 23 to 33 mm. long and 8 to 10 mm. wide. The thorax is wider than long, with a median line on an elevated prominence, bordered by a rough grayish groove on each side. The elytra are marked with dark or shining irregular elevations and rough, grayish depressions. The larva is creamy white and is the largest of the flatheaded borers, measuring 50 mm. or more in length and about 13 mm. in width at the prothorax. The plates of the thorax are roughened by interrupted rows of dark chitinous points forming ridges. The dorsal plate is marked by a distinct dark **Y** and the ventral by a median groove.

This insect occurs throughout the Eastern and Southern States and probably breeds in all the pines. The adults appear in the early summer and are often conspicuous, as they fly around logging operations, because of the distinct buzzing noise. The larvae mine for several years in the sapwood and heartwood of stumps and logs, converting the wood to a mass of sawdust with nothing but an outer shell remaining. Living trees are attacked through fire scars and blazes, the insects completely destroying the butt log. Pine logs left in the woods too long after cutting are severely damaged by this borer. No control other than prompt sawing is recommended.

Chalcophora fortis Lec., *C. liberta* (Germ.), and *C. georgiana* (Lec.) are three other species of similar appearance and habit, which are more or less abundant locally. As far as known, they are all pine feeders and often associated with *C. virginiensis.*

A beetle resembling *Chalcophora virginiensis* but somewhat more slender is *C. campestris* (Say), **the flatheaded sycamore-heartwood borer.** It has irregular markings on the elytra, forming four irregular ridges. The larva is likewise quite similar to that of *C. virginiensis*, but the chitinous points on the thoracic plates are farther apart and tend less to the formation of ridges. The dorsal plate is marked with a **V** or **U**, rather than a **Y**.

The distribution and seasonal history are about the same as for the preceding species, but this species feeds in hardwoods, principally sycamore, maple, tulip, beech, and linden. Blazes and wounds on shade trees are frequently attacked, and much of the heartwood beneath is riddled. The adults mature in the fall and pass the winter in their pupal cells.

The adult of **the flatheaded apple tree borer** (*Chrysobothris femorata* (Oliv.)) is an elongate-oval, flattened, shining beetle, dark bronze above and bright brassy beneath. The upper surface is indistinctly marked with spots or irregular impressions. The larva is of the characteristic flatheaded form, having the dorsal and ventral prothoracic plates beset with fine rugosities, the dorsal plate marked with an inverted **V** and the ventral with a groove extending backward from the anterior margin. This beetle is distributed throughout the Eastern and Central States and occurs in practically all hardwoods.

The first beetles appear late in the spring and others follow throughout the summer. They are nervous, active insects making a buzzing sound when flying. The eggs are laid beneath scales of bark, from which points the larvae extend their meandering galleries. When they reach full growth, the larvae extend their burrows a short length into the wood to make the pupal cells. They mature in one season, overwinter in the pupal cell, and transform in the spring.

Chrysobothris femorata is very injurious to weakened or injured hardwoods, such as transplanted trees and those subjected to defoliation, drought, sunscald, frost injury, or almost any factor that somewhat lowers the vitality of the tree. The larvae boring beneath the bark girdle the tree, thus causing its untimely death. Frequently, when they do not kill the tree, the mines produce deadening of large patches of bark which later peel off. Transplanted ornamental trees are frequently damaged or killed by this insect, and even forest plantings are at times considerably damaged. Fire injuries at the bases of trees are frequently infested. About the only satisfactory methods of control are to stimulate the tree with fertilizers or watering to make it more resistant, or use mechanical barriers, such as paper or burlap, around the stems of transplanted trees, to prevent attack. Repellent sprays have been recommended but are not fully satisfactory. Burke (*75*) published an extended discussion of the species, and Johnson and Fenton (*258*) published an article on its control.

The adult of **the Australian-pine borer** (*Chrysobothris tranquebarica* (Gmel.)), also called the mangrove borer, is a greenish-bronze beetle, from 12 to 17 mm. in length, with two lighter-colored impressions and one small basal impression on each elytron, and also impressions on the thorax. The larva has the dorsal and ventral prothoracic plates covered with irregular fine pointlike asperities, the dorsal segment marked with an inverted **V** and the ventral with a longitudinal groove extending back three-fourths the distance from the anterior margin.

The adults appear early in April, laying their eggs under irregularities of the bark. The young larvae bore through the bark and feed beneath it until fully grown, when they extend their larval mines into the wood to construct pupal cells late in the summer. This borer, attacking living red mangrove and Casuarina trees, causes the death and destruction of many trees, especially *Casuarina*, or "Australian pine," planted as ornamentals or for windbreaks in southern Florida.

The only satisfactory method of control is to cut out and destroy the beetle-infested wood, whether single branches or entire trees. This should be done late in the fall and winter, certainly before the beetles emerge in the spring. It is possible that DDT sprays will control this species.

Numbers of other species of *Chrysobothris* are common on slash. They are *C. pusillus* C. & G. in spruce and pine, *C. dentipes* (Germ.) in pine and larch, *C. floricola* Gory in pine, *C. harrisi* (Gentz) in pine, *C. scabripennis* C. & G. in pine and hemlock, and *C. trinervia* (Kby.) in pine. *C. verdigripennis* Frost breeds in wounds on living hemlock, *C. azurea* Lec. in oak, *C. concinnula* Lec. in oak, *C. chrysoela* (Ill.) in persimmon, and *C. sexsignata* (Say) in hemlock, larch, ash, maple, oak, beech, birch, hickory, walnut, and the bark of living butternut.

Dicerca divaricata (Say) is an elongate, oval beetle, bronze above and bluish beneath, from 17 to 22 mm. in length. The prothorax is nearly twice as wide as long, and the tips of the elytra are forked at the apex, sometimes ending in short spines. The larva does not have any chitinous points on the plates of the prothorax; the dorsal plate is marked with an inverted V, the apex of which is broadened into a reticulated area; the ventral plate is marked with a single impressed line bisecting the plate. This species is typical of a number of representatives of this genus breeding in dead and dying hardwoods. The larvae extend their mines through the sapwood and heartwood, often completely riddling the latter, but are seldom of much importance except as they attack injuries on shade trees and tunnel the wood beneath.

Other common species of *Dicerca* are *D. tenebrica* (Kby.) in poplars; *D. lurida* (F.) in dead hickory, blue beech, and alder; *D. obscura* (F.) in dead persimmon and sumac; *D. punctulata* (Sch.) in dead pine; *D. caudata* Lec. and *D. tenebrosa* (Kby.) in conifers; *D. tuberculata* (C. & G.) in wounds in hemlock; *D. scobina* Chev. in sour gum; and *D. pugionata* (Germ.) in living alder, witchhazel, and ninebark.

The adult of **the hemlock borer** (*Melanophila fulvoguttata* (Harr.)) is a relatively small, dark-bronze beetle, 6.5 to 12 mm. in length, having the wing covers usually marked with yellow spots. The larvae have the prothoracic plates covered with very fine rugosities, the dorsal side marked by a narrow inverted V and the ventral with a single impressed line. It occurs throughout the Eastern States in hemlocks and more rarely in spruce.

The adults emerge from the trees from the latter part of May until late in August and lay their eggs beneath the bark scales of weakened, dead, or dying trees, and of logs and windthrown trees if the cambium is still moist. The young larvae bore through the bark, usually cutting an oblique gallery, and by the end of the summer practically all sizes of borers will be present between the bark and the wood. Those that have completed their full growth usually go into the bark and construct cells in which they spend the winter and pupate the next spring. The younger larvae overwinter in their galleries between the bark and the wood, resume activity in the spring, and pupate and emerge as adults throughout the summer months. Development is generally completed in 1 year, but in the northern part of the range, larvae from eggs laid late in the summer may not complete development and emerge as adults until the second spring.

This species has attracted considerable attention, as it attacks green hemlocks weakened from defoliation, drastic thinning, drought, flooding, or other causes. Secrest, MacAloney, and Lorenz (*376*) have shown the injury it causes to be secondary, but it possibly hastens the death of the attacked trees. It does not seem to be sufficiently aggressive, however, to attack and kill healthy trees, and when the cause of the original injury subsides the borers disappear. In general, no control is recommended, although following defoliator outbreaks, it might be of some benefit to dispose of the borer-infested trees on the grounds that reduction in number of beetles gives some of the weakened trees a better chance of survival.

Other species of *Melanophila* which occur in the East but are not of much economic importance are *M. notata* (C. & G.) in pine; *M. acuminata* (Deg.) in pine, spruce, and fir; **the flatheaded fir borer** (*M. drummondi* (Kby.)) in spruce, fir, larch, and hemlock; and *M. aeneola* Melsh. in pine.

Poecilonota cyanipes (Say), **the flatheaded poplar borer,** is an elongate, oval, bronze beetle, from 11 to 14 mm. in length, with the tips of the elytra coppery, and the body beneath bluish. The larvae have the prothoracic plates smooth, the dorsal marked with an inverted V, the ventral with a single groove. The larvae feed beneath the bark of wounds on living poplar trees where they mine for 2 years. Their galleries are not very extensive, and they pupate beneath the bark. *P. thureura* (Say) is very similar and is found under the same circumstances in willow.

Ptosima gibbicollis (Say), **the flatheaded redbud borer**, is 6 to 7.5 mm. in length, dark blue and spotted with yellow above. Each elytron bears an elongated yellow spot extending from the base to beyond the middle and another like area near the apex. The larva is of the usual form, having the prothoracic plates very large, covering most of the segment, whitish opaque and without any rugosities. Each is impressed with a dark, median, longitudinal line or groove and the first abdominal segment is smaller than the following. It is found in the eastern part of the United States in redbud. The adults pass the winter in their pupal cells and emerge about the time the redbud foliage is expanding. They lay their eggs in wounds and irregular areas on trunks and branches. The larvae mine the sapwood and frequently hasten the death of the trees. No practical control has been developed.

The adult *Trachykele lecontei* (Gory), **the flatheaded bald cypress heartwood borer,** is a dark, ashy-bronze beetle, about 12 to 14 mm. long, marked with black, velvety spots. The plate on the prothoracic segment of the larva is smooth and marked by an inverted Y, which is surrounded at the apex by a broad impressed shining area. The beetle is in flight early in the spring along the coast from Virginia south to Louisiana and lays its eggs in dead and dying bald cypress or on blazes where the wood is exposed. The greater part of its mines are extended through the heartwood and for this reason, it frequently causes a serious degrade of lumber. The only control in logging operations is to move the logs promptly from the woods to the saw and not allow them to remain where they will be exposed to borer attack.

There are a number of other buprestids of minor importance. *Brachys ovatus* (Web.), *B. aerosus* Melsh., and *B. aeruginosus* Gory occur on the foliage of deciduous trees and frequently cause injury to the leaves by their feeding. The larvae are leaf miners and pupate in small cells between the layers of the leaves. *Actenodes acornis* (Say) works in the dry heartwood of maple, birch, beech, oak, and hickory and produces extensive burrows in the infested sticks. The adult is a dark, metallic-green beetle from 10 to 13 mm. in length. The ventral surface is dull cupreous. The prominent eyes, which are nearly united on the vertex, will serve to distinguish it from the other members of this family.

Agrilaxia flavimana (Gory) is recorded as breeding in the small branches of white oak and is not of any economic importance. *Cinyra gracilipes* (Melsh.) is a small, slender, brassy-brown beetle somewhat resembling a *Dicerca* in appearance. The larvae mine the wood of dead oak and ironwood branches. Four species of the genus *Anthaxia* occur in the Northeast. *A. aeneogaster* C. & G. breeds in conifers, *A. viridifrons* Gory in hickory and elm, *A. viridicornis* (Say) in willow, and *A. quercata* (F.) in redbud, *Crataegus*, white pine, larch, chestnut, and oak. The larvae mine under the bark and form pupal cells in the sapwood very much like the mines of Chrysobothris.

Family CISIDAE

The Minute Fungus Beetles

The minute fungus beetles are small subcylindrical black or brown beetles, rarely over 3 mm. in length, that have 8- to 10-jointed antennae, the last 3 joints forming a club. The margins of the thorax are distinct and often projecting in front. The larvae are thin-textured, elongate, cylindrical forms, having two conical spines on the ninth abdominal segment and a globular protuberant head. The mandibles are without a molar structure, the gula is rectangular, and the legs four- or five-jointed.

They are found in abundance in woody fungi growing on trees or logs, in which both larvae and adults feed. The whitish round fruiting bodies of *Polyporus volvatus* appearing on trees killed by *Dendroctonus* beetles 1 year after attack are invariably infested by several of these forms, chiefly *Cis* and *Ennearthron*. Some records indicate that furniture or the wood in houses is attacked, but this is probably only when it is somewhat rotted.

Family CLERIDAE

Checkered Beetles

The Cleridae or checkered beetles, as they are often called, constitute one of the most important families of predators attacking injurious forest insects. The small, active, brightly colored, antlike beetles are voracious feeders on adult bark beetles, and the clerid larvae, living in the burrows of bark beetles and wood borers, destroy the immature stages of these insects. They are distinguished by their conspicuous antennae, usually 11-jointed and generally serrate, with the outer joints larger, forming an open or compact club. All the tarsi are 5-jointed, the first and fourth joints small, and all but the fifth bearing a membranous appendage. They range in size from about 5 to 15 mm.

The larvae are adapted to crawling and gnawing in the burrows of wood-boring insects, where they are usually found. They are soft-bodied, elongate, parallel-sided or fusiform in shape, frequently highly colored, though often white and thin textured, and usually with ambulatory lobes well developed; they have five-jointed legs and often chitinized paired or pronged armature on the ninth abdominal segment. The spiracles are annular or pseudoannular, the head is extended, clypeus and labrum are present, the mandibles are of simple type, the ventral mouth parts are not retracted, and the gula is distinct (Böving and Champlain, *51*).

The habits of these beneficial beetles are fairly well known, and the records of the Division of Forest Insect Investigations were well summarized by Böving and Champlain (*51*).

Most species are quite restricted both as to the food they eat and the host plant in which they occur. *Monophylla terminata* (Say) and *Tarsotenus univittatus* (Rossi) are predaceous on bostrichids, lyctids, and ptinids in dry, dead wood. *Cymatodera bicolor* (Say), *C. inornata* (Say), and *Chariessa pilosa* (Forst.) feed on wood borers, principally of the families Cerambycidae and Buprestidae in recently dead or dying trees. They follow up the larval mines of these borers and after feeding on one larva search out and destroy another. In cages under artificial conditions some of these forms have been fed many times their weight in wood-boring larvae. Certain species, typically illustrated by *Neichnea laticornis* (Say), are predators within the egg tunnels of scolytids, where they feed on the eggs, young larvae, and parent adults. They remain during their entire life in the egg galleries of their hosts, where they mature and finally pupate.

Such forms as *Thanasimus dubius* (F.) and *Enoclerus quadriguttatus* (Oliv.) are typical associates of the bark beetles *Dendroctonus* and *Ips* in dying pine trees. The adults appear on the infested trees coincidentally with the bark beetles, which they catch and devour in great numbers. Their eggs are laid in the bark, and the larvae develop under the bark with the scolytid broods on which they feed. On maturing, the larvae pupate in the bark, or, with some species, in the ground at the base of the tree. The feeding habits of the adults are very characteristic and were described by Böving and Champlain (*51, p. 624*) as follows:

> * * * Sometimes they will attack insects much larger than themselves. In the usual method of attack the Clerid remains motionless until a wandering Scolytoid or some other insect approaches close enough. Then running with a rapidity that resembles a leap, it seizes the prey. Grasping it with the front and middle pair of legs and holding on to the bark by the hind pair, sometimes balanced by the tip of the abdomen against the bark, it proceeds to feed. With its strong jaws it breaks the chitin or separates the segments and feeds upon the soft tissue and viscera within.

One of the early attempts by entomologists to use beneficial insects for the control of destructive species, was an experiment conducted by Hopkins (*230*) in 1892 with *Thanasimus formicarius* (L.), a European clerid beetle, closely allied to *T. dubius*. At that time a widespread and destructive outbreak of the southern pine beetle was killing great quantities of spruce in West Virginia. Dr. Hopkins was much impressed with the beneficial effect of these clerid predators and believed that the establishment of the European species in this country would do much good. Lumber companies in the region of the outbreak provided funds for Dr. Hopkins to collect and liberate some 4,000 specimens. Unfortunately no beetles have been found since, and it is not likely that the species became established. The severe freeze of the winter of 1892 completely checked the bark-beetle outbreak, and no doubt the diminution of their natural food supply was an important factor in the failure of the European clerids to become established.

Where it is possible to so time bark beetle control operations as to prevent the destruction of these predators and utilize their beneficial effect along with control, it should be done. Observations indicate that they occasionally become so numerous during extensive bark-beetle outbreaks that they play a very considerable part in bringing the epidemic to a close.

KEY TO THE MORE COMMON GENERA OF CLERIDAE WHOSE LARVAE ARE FOUND ASSOCIATED WITH BARK BEETLES AND WOOD BORERS

1.	One or no ocellus	2
	Two or more ocelli	3
2.	Ninth segment without a chitinized plate — *Orthopleura*	
	Ninth segment bearing a chitinized plate — *Monophylla*	
3.	Three ocelli; associated with wood borers — *Cymatodera*	
	More than three ocelli	4
4.	Four ocelli; associated with powder-post beetles — *Tarsostenus*	
	Five ocelli	5
5.	No armature on ninth abdominal segment; found in egg galleries of scolytids — *Neichnea*	
	Armature present	6
6.	Body faintly bluish	7
	Body strongly colored; associated with bark beetles — *Enoclerus, Thanasimus*	
7.	Body robust; found in the galleries of wood borers — *Chariessa*	
	Body elongate; found in scolytid galleries — *Phyllobaenus*	

SPECIES OF CLERIDAE

Chariessa pilosa (Forst.) is a rather strikingly colored beetle 7.5 to 13 mm. in length, wedge-shaped, and depressed (fig. 41). The thorax is red with two wide black stripes and the wing covers are black. The eyes are notched in front, and the last three joints of the antennae are large and dilated. The larva is somewhat more robust than most clerids, widest in the middle and of a bluish tinge with five ocelli, several abdominal ampullae, and the ninth segment bearing two recurved hooks on a lightly chitinized plate with four rows of impressions. It is probably the most common clerid in the eastern part of the United States and is predaceous on a number of wood-boring larvae in various hardwoods. The adults are active throughout the summer, feeding on insects attracted to freshly cut logs. Eggs are laid in crevices of the bark, the larvae feeding for two seasons before they pupate in the spring, usually in the gallery of a wood borer.

Cymatodera bicolor (Say) is an elongate, subcylindrical, black beetle from 5 to 10 mm. in length, with thorax, palpi, and basal joints of antennae reddish yellow. The purplish larva is elongate, rather robust, with three ocelli, and the thoracic shield and ninth abdominal plate are well sclerotized; the latter has two recurved hooks. This

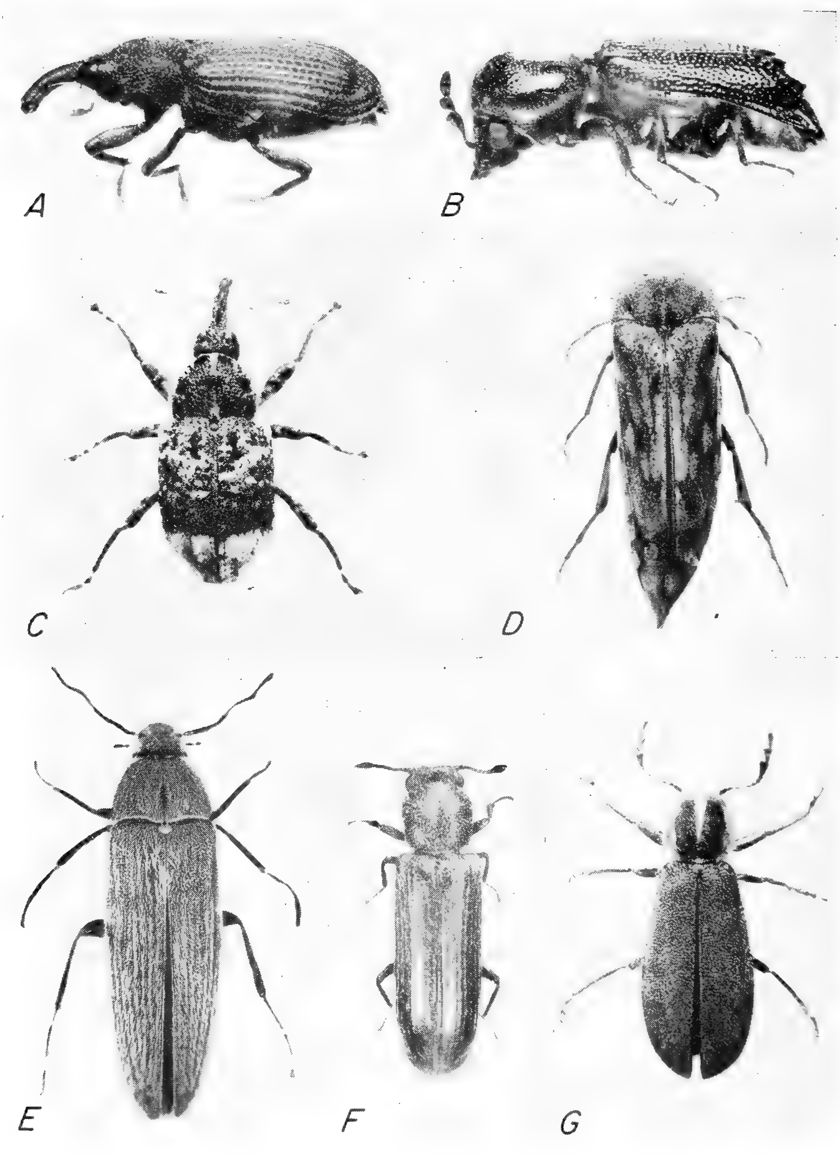

FIGURE 41.—Adult beetles: *A*, *Magdalis armicollis* (Say); *B*, *Xylobiops basilaris*; *C*, *Cryptorhynchus lapathi* (L.); *D*, *Tomoxia bidentata* Say; *E*, *Synchroa punctata* Newm.; *F*, *Lyctus planicollis* Lec.; *G*, *Chariessa pilosa*.

beetle is an important predator on roundheaded and flatheaded wood borers in hardwoods in the Eastern States. The larvae tunnel behind the borers and overtake and devour them, and when full grown, form pupal cells of whitish exuded material, often in the pupal cells of the host.

Two other species that are likewise common are *Cymatodera inornata* and *C. undulata* (Say), the latter usually found in branches attacking a variety of hosts.

Enoclerus quadrisignatus (Say) is a brightly colored, red-and-black beetle, 8 to 12 mm. in length, with the last three joints of the antennae forming a conical club. The thorax, head, base of wing covers, and under parts are dull red, but the remainder is black, with two yellowish cross bars on the wing covers.

In appearance and habits the larvae are similar to those of *Thanasimus dubius* (fig. 42) except that this form feeds in hardwoods, chiefly on *Scolytus* in hickory. The adults are nocturnal. They are found in the eastern part of the United States.

Enoclerus ichneumoneus (F.) is quite similar to *E. quadrisignatus* and feeds in hickory, but is diurnal. *E. lunatus* (Spinola) is common in the South on fruit trees attacked by *Scolytus rugulosus* (Ratz.). Both the adults and larvae of *E. quadriguttatus* are predaceous on scolytids in conifers and hardwoods. It is also found in the eastern part of the United States.

Thanasimus dubius is a very active, antlike, bright-colored, very hairy beetle, from 7 to 10 mm. in length. The head, thorax, under surface and base of the elytra, and usually the legs, are dull red. There are two red cross bars on the elytra. The larvae is elongate (fig. 42), fusiform, and with five ocelli. The thoracic shield and ninth abdominal plate are well chitinized, and the latter bears two recurved hooks. The larva is purplish with brown sclerotized markings.

This is one of the most important predators of destructive bark beetles in the eastern part of the United States and southwest to Texas. Both the adults and larvae are predaceous. Hopkins (*230, p. 262*) gave the following description of it:

> The American bark beetle destroyer * * * is often quite common on the bark of spruce trees infested with bark beetles. * * * It passes the winter in all stages from larva to adult in the bark in which it is bred, the latter sometimes in the loose bark and moss at the base of the tree. The adults appear in the spring, soon after the bark beetles commence to emerge from their winter quarters and fly to the trees, logs, or tops, which are infested with bark beetles. There they station themselves beneath loose flakes of bark, awaiting an opportunity to pounce upon any bark beetle that comes near. They also move rapidly about over the bark in search of the prey, or the entrances to the bark beetle galleries in which the females deposit their eggs. The eggs soon hatch into minute active worms which find their way into the egg and brood galleries of the bark beetles where they feast upon the eggs and young found there until they have attained their full growth, when they leave the inner bark and excavate cavities in the outer corky bark in which they change to pupae and adults. * * *
>
> This clerid attacks and feeds upon all kinds of bark beetles which infest spruce and pine and has been found attacking bark beetles in deciduous trees.
>
> It doubtless exerts a considerable influence in preventing the undue increase and devastations of pine and spruce bark beetles. * * *

Thanasimus nigriventris (Lec.) occurs in the Lake States and the Middle West. *T. undulatus* (Say) is generally distributed and has habits similar to those of *T. dubius.*

Monophylla terminata (Say) is an elongate, subcylindrical, black beetle, 5 to 7 mm. in length, having the thorax yellow with a black disk, and the sides of the elytra yellow. The eyes are deeply emarginate in front, and the last joint of the antenna is as large or larger than all others combined. The larva is elongate, white, and soft textured, and has one ocellus and two well-separated hooks on the ninth

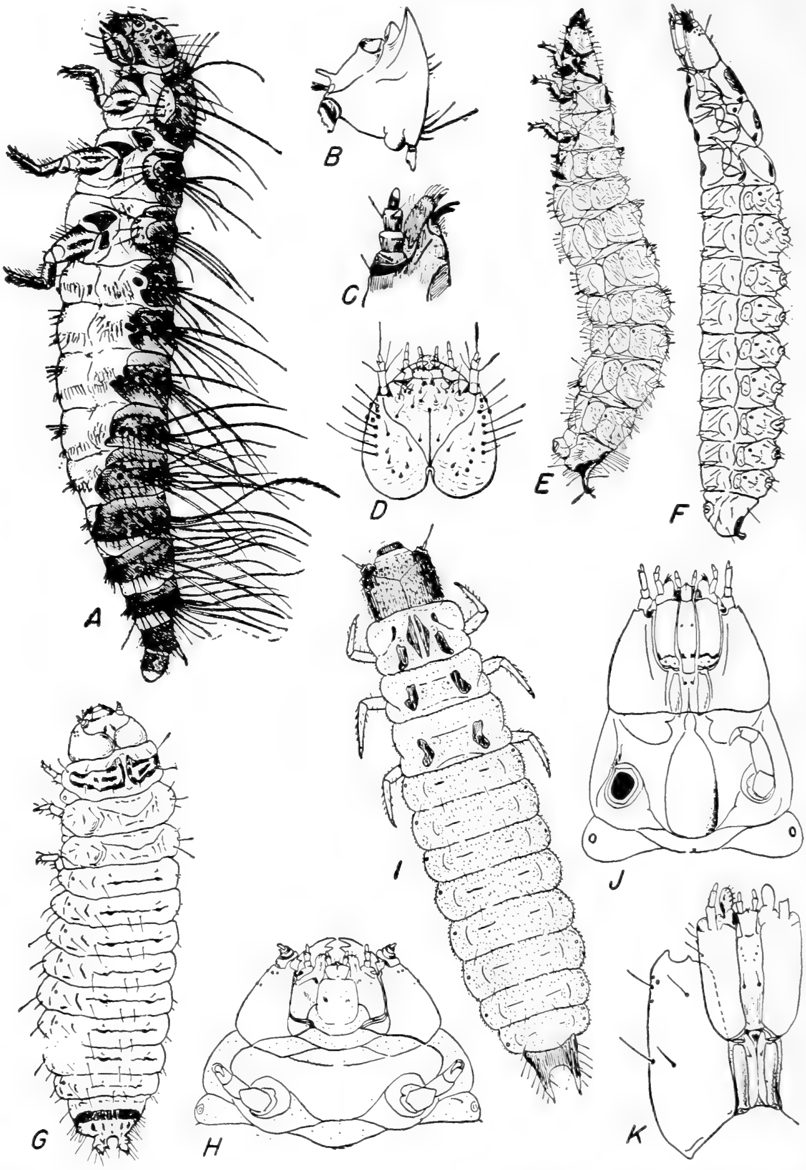

FIGURE 42.—Beetle larvae and structures: *A*, *Dermestes nidum*, lateral view of larva; *B*, mandible; *C*, maxillae; *D*, *Enoclerus* sp., dorsal view of head; *E*, *Thanasimus* sp., lateral view of larva; *F*, *Corticotomus cylindricus* Lec., lateral view of larva; *G*, *Thymalus marginicollis*, Chev., dorsal view of larva; *H*, ventral view of head; *I*, *Malachius auritus* Lec., dorsal view of larva; *J*, *Airora cylindrica* Serv., ventral view of head and thorax; *K*, *Temnochila virescens* F., ventral view of head.

abdominal tergum. It is found boring in hardwoods, feeding principally on *Xylobiops*, but on other woodborers as well. It is found in the eastern part of the United States.

Tarsostenus univittatus is small and slender, and shining black, except for a transverse white bar across the elytra at the middle of their length. The larva is very elongate and slender, of a light violet color with sclerotized parts of brown or yellow. It has four ocelli, the sixth and seventh abdominal segments are ampullate, and the ninth bears two recurved hooks. The larva is adapted to boring, following in the burrows of *Lyctus* and *Xylobiops* or other borers in dry, seasoned wood. It is a widely distributed and important predator of these powder-post beetles.

Neichnea laticornis is a small, slender species with the antennae terminated by three long segments. It is black except for the sides of the thorax and a spot on the head, which are golden yellow. The larva is an elongate, white, delicate form, having five ocelli and no armature. It is found in egg galleries of various bark beetles infesting twigs. It is an important predator on several species of scolytids occurring in twigs and branches, chiefly those of *Phloeosinus*, *Scolytus*, and *Phloeophthorus*. The clerid egg is laid in the entrance hole of the bark beetle, and the larva feeds on the adult bark beetle in the gallery, as well as on the eggs and young larvae. It is found in the Middle Atlantic States.

Placoptera thoracicus (Ovil.), *Phyllobaenus dislocatus* (Say), and *Orthopleura damicornis* (F.) bore in the twigs of deciduous trees, where they feed on the larvae of various wood borers and bark beetles. *Priocera castanea* Newm. is a predator on bark beetles in coniferous trees. *Hydnocera unifasciata* (Say) and *H. verticolis* (Say) feed on cerambycid larvae in small twigs. *Galeruclerus oculatus* (Say) feeds on a variety of small cerambycids and scolytids in hardwood and coniferous twigs.

Family DERMESTIDAE

The Skin Beetles

The skin beetles are small, compact, oval to convex forms, and dark, but a few are attractively patterned with spots of gray, brown, or orange hairs, which easily rub off. The head is small and deflexed, the antennae 9- to 11-jointed, with the last 1, 2, or 3 joints forming a club, which often fits into a pit on the under side of the prothorax. The legs are short and the tarsi 5-jointed. The larvae (fig. 42) are cylindrical, very hairy, the hairs often forming distinctive patterns. They may be quite soft or rather hard shelled and are extremely active and difficult to pick up. The head is globular and deflexed, the labrum distinct, and the mouth parts somewhat retracted. The lacinia bears one to several distinct spurs, the mandible is without a molar structure, ocelli are usually present, and the legs are well developed.

These insects are normally found feeding on skins, carcasses, dried meats, furs, carpets, and under the bark of trees where they devour insect remains. Some species are troublesome pests in collections of insects or stuffed animals. Only occasionally are they of interest to the forester or lumberman, as in cases of damage to valuable cargoes of lumber in shipholds that had previously held hides on which the dermestid fed and multiplied. In such cases, after the hides were removed and lumber placed in the hold, the larvae bored into the wood to pupate. **The hide beetle** (*Dermestes vulpinus* F.) (fig. 43) and **the larder beetle** (*Dermestes lardarius* L.) are the chief offenders in such cases.

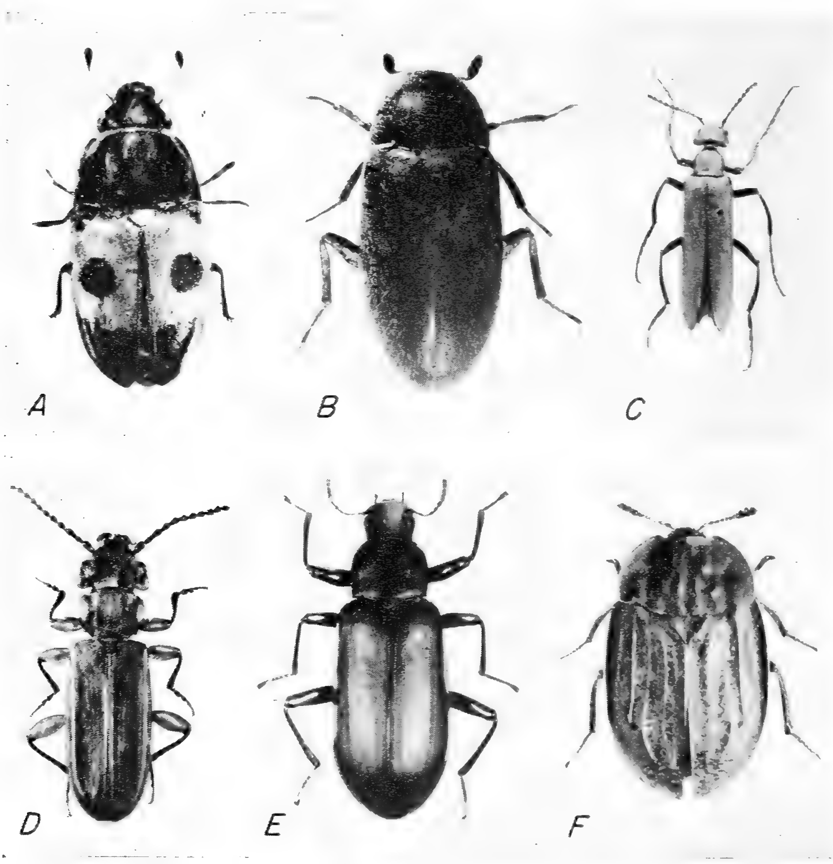

FIGURE 43.—Adult beetles: *A*, *Glischrochilus sanguinolentus* Oliv.; *B*, *Dermestes vulpinus*; *C*, *Pomphopoea sayi* Lec.; *D*, *Cucujus clavipes* F.; *E*. *Alobates Pennsylvanica* Deg.; *F*, *Silpha inequalis* F.

FAMILY OSTOMIDAE

Several beetles of the family Ostomidae are important and useful predators, ranking with the clerids in their destruction of injurious forest insects, whereas other members of the group feed on grain, decaying vegetable matter, or fungi. The predaceous forms are elongate, rather depressed beetles with a trapezoidal thorax, narrowest behind; having 11-jointed antennae, the last 3 joints forming a loose club; and 5-jointed tarsi, the fourth joint very long. The larvae closely resemble clerids, and in fact, can be separated only by the relatively deep retraction of the ventral mouth parts below the point of attachment of the mandibles. The prothorax, mesothorax, and metathorax often bear dorsal chitinizations or plates, which may be paired into two oval spots.

Temnochila virescens (F.) is a bright, iridescent, bluish-green beetle from 10 to 18 mm. in length, which feeds on bark beetles and wood borers beneath the bark and on scolytids crawling about the surface. It grasps and eats these beetles much as do certain clerids, but is a much less active insect. The larva (fig. 42) is likewise highly colored, usually with brownish or bluish shades, and the ninth abdominal segment has a chitinous plate bearing a pair of recurved hooks. It is also predaceous, following behind broods in the bark-beetle galleries, where it devours both eggs and larvae.

Tenebroides corticalis (Melsh.) and *T. dubia* (Melsh.) are smaller black forms, predaceous under the bark of logs or bark-beetle-infested trees. *T. bimaculata* (Melsh.) is predaceous on *Agrilus* in oak. *Thymalus marginicollis* Chev., *Ostoma ferruginea* (L.), and *Calitys scabra* Thunb. are found in woody fungi, but the larvae of *Ostoma* may be predaceous. The beetles are more oval in shape than *Tenebroides*. *Corticotomus* (*Nemosoma*) *cylindricus* (Lec.) (fig. 42) and *Airora* (*Alindria*) *cylindrica* (Serv.) (fig. 42) are common predators on the larvae of ambrosia beetles and cossonids in the wood of dead trees. The elongate, cylindrical form of the larvae permits them to follow into the burrows of these insects.

Family MALACHIIDAE

The Soft-Winged Flower Beetles

The larvae of certain malachiid beetles, some of which are predaceous, are found under the bark of dead trees and in the wood of branches, where they prey on bark beetles and wood-boring larvae. Anatomically they can scarcely be separated from the Cleridae and some of the Dermestidae, but the common forms have bright-colored orange or yellow bodies, with contrastingly colored head and caudal segments. They are often clothed with velvety pubescence, and the larvae are mostly slow-moving and inactive. Species of *Malachius* (fig. 42), *Dasytes*, and *Anthocomus* are commonly associated with bark and wood borers.

Family LAMPYRIDAE and Related Forms

The Glowworms and Fireflies

Several closely related families of beetles, *Lycidae*, *Lampyridae*, *Phengodidae*, and *Cantharidae* are remarkable because of the luminous powers of many of the larvae and some adults. The common fireflies belong to this group. Many of the larvae have mouth parts adapted to sucking the juices of plants or small insects and snails. Most of the adults are predaceous, and some are voracious feeders on plant lice. They are moderate-sized, elongate, often flattened, soft-bodied beetles with flexible, often spreading elytra. The thorax projects at the margins, and the legs are slender with 5-jointed tarsi, the fourth somewhat bilobed.

The larvae of this group are extremely variable in form, some being elongate-cylindrical; others broadly oval, depressed forms, often covered with a dense pubescence or margined with chitinized keeled plates and with well-developed legs and bodies fitted for slowly crawling about in logs or on the forest floor. The head is provided with grasping mandibles, or in many forms the mandibles are fitted for sucking, having a hollow longitudinal canal or composed of two longitudinal pieces, one sliding within the other. The ventral mouth parts are deeply retracted and the various parts more or less fused or atrophied. The labrum is fused with the clypeus into a nasale. Many of these larvae have luminous spots along several of the body segments or grouped in the caudal segments.

Eros trilineatus Melsh., *E. aurora* Hbst., *Plateros* spp., and *Calopteron reticulatum* F. are frequently seen on vegetation along the edges of a wood. The larvae are found in wet, well-rotted logs where they probably feed on decaying vegetable matter. The luminous larvae of species of *Phengodes*, *Chauliognathus* (fig. 44), *Caeniella*, *Cantharis*, *Photurus*, *Photinus*, and *Podabrus* often attract attention crawling about on the damp ground. The adults of many of these forms are predaceous. Some occur commonly on vegetation.

Family MELOIDAE

The Blister Beetles

The more common forms of blister beetles that are found eating forest vegetation are fairly large, soft-bodied, loose-jointed, sprawling beetles (Blatchley, *47*), of variable color, often green, gray, brown, or black, having a broad head on a distinct neck, soft elytra, abdomen often large and swollen, and tarsal claws cleft and appendaged. The larvae are parasitic on the egg masses of grasshoppers or in the nests of bees, and consequently rarely seen unless particular search is made for them.

The first-stage larva, the triungulin, is peculiar among the Coleoptera. The staphylinoidlike form differs markedly from the later semiparasitic stages. The triungulins are very active and well adapted to their search for a particular host. Some ascend to the flowers of plants, where they attach themselves to the hairs of visiting bees and are thus carried to the bees' nests. Another stage of the larva may be scarabaeoid in form, and the final stage superficially resembles the larva of a bee or wasp. The larvae of very few species are known.

Although the larvae may be injurious in bees' nests or beneficial in destroying grasshoppers, the adults of many forms feed on foliage and are very destructive when abundant. Anatomical details of the larvae are not given, as they are seldom seen by the forester and are not treated in the key. Serious damage by the adults of such forms as **the striped blister beetle** (*Epicauta vittata* (F.)), **the margined blister beetle** (*E. marginata* (F.)), *Macrobasis fabricii* (Lec.), *M. unicolor* (Kby.), *Pomphopoea aenea* (Say), and *P. sayi* Lec. often occurs to young trees in nurseries and to ornamental plantings, especially in the Middle West. For control measures suitable for use against these beetles see page 35.

Family BOTHRIDERIDAE

The Cocoon-Forming Beetles

The Bothrideridae are separated from the Colydiidae, with which they are often grouped, by their depressed form, 11-jointed antennae, widely separated coxae, and long first tarsal joint. The larvae are

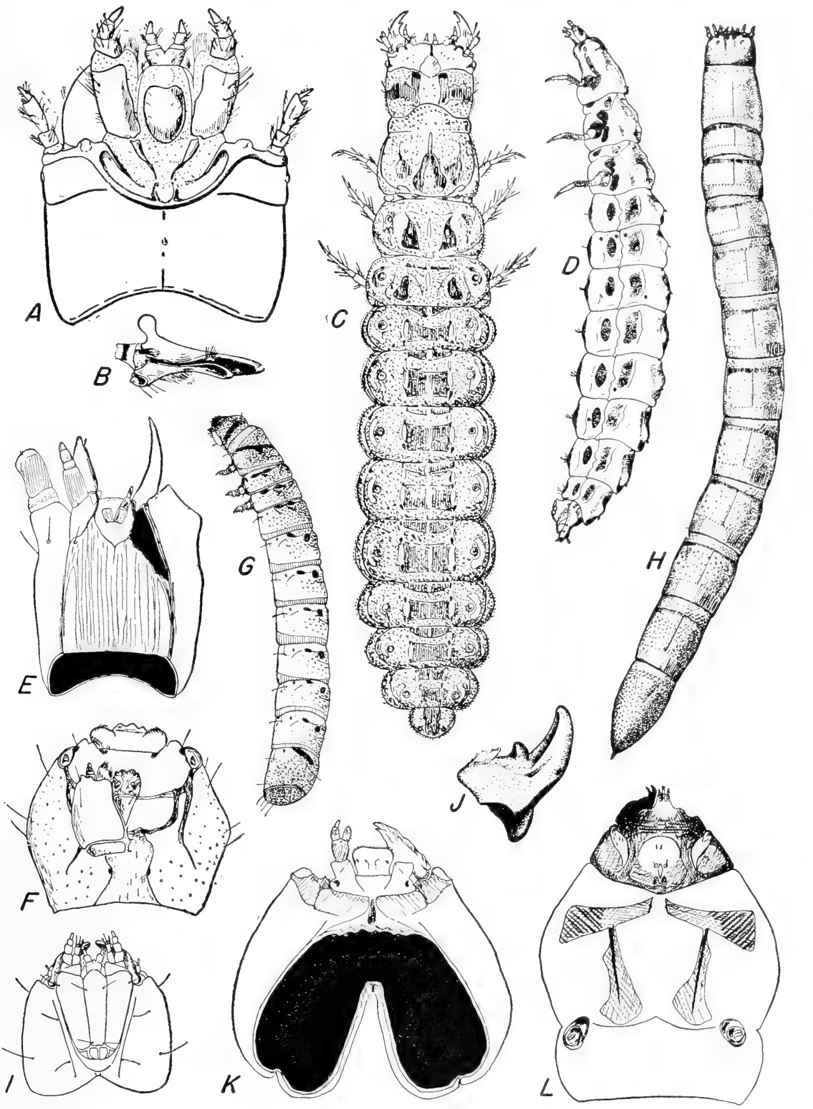

FIGURE 44.—Beetle larvae and structures: *A*, *Chauliognathus scutellaris* Lec., dorsal view of head; *B*, mandible to show canal; *C*, dorsal view of larva; *D*, *Calopteron reticulatum* F., lateral view of larva; *E*, ventral view of head; *F*, *Zenoa picea* (Beauv.) ventral view of head; *G*, lateral view of larva; *H*, *Elater rubricollis* Hbst., dorsal view of larva; *I*, ventral view of head; *J*, mandible; *K*, *Chalcophora virginiensis* Drury, ventral view of head; *L*, *Melasis pectinicornis* Melsh., ventral view of head and thorax.

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radically different from the colydiid forms, both in structure and habits. The body is of the soft-textured, spindlelike type, associated with parasitic habits, and has short fleshy legs; the ninth abdominal segment bears two recurved spines; the mandible is without a molar structure, and bears a small hook. These larvae are predaceous or parasitic on wood-boring larvae. After consuming the body contents of their host, they form oval, depressed, semitransparent cocoons on the walls of the burrows, in which the larvae pupate.

Bothrideres geminatus (Say) is an eastern species attacking borers in hardwoods. *Deretaphrus oregonensis* Horn, of similar habits, attacks wood borers in conifers in Oregon and California.

Family CATOGENIDAE

Catogenus rufus (F.) is a very common beetle under the bark of both hardwood and coniferous trees and peculiar in that its larva is parasitic on the larvae of wood borers. They are usually found in the pupal cells of the host. The adult is extremely variable in size, from 5 to 12 mm., probably depending on the food material secured by the larva. It is elongate, depressed, and reddish brown. The head has a transverse groove behind the eyes; the thorax narrows behind and is impressed with a median line posteriorly. The elytra are deeply striate. The larva is soft-bodied, white, spindle-shaped, with weak conical legs and small recurved hooks on the ninth tergum. The mouth parts are not retracted, the mandible bears a hook but no molar structure, and the labial palpi have only one joint. *Scalidia linearis* Lec. is similar in habits and larval characteristics to *C. rufus*. It has been observed feeding on bostrichid larvae in *Acacia* in southern Texas.

Family NITIDULIDAE

The Sap-Feeding Beetles

The Nitidulidae, are small, oval, depressed beetles, rarely 10 mm. in length, and usually not half that size, often of contrasting shining black, red, and yellow colors. They have club-shaped antennae and the sides of the thorax and elytra are often margined, the latter frequently truncate at the tips, exposing the abdomen. The larvae are elongate, depressed, and usually yellowish white, but sometimes colored, having five-jointed legs, bifore spiracles borne on short tubes, and the ninth abdominal segment often bearing paired and forked horny armatures. The head is broad and projecting with deeply retracted mouth parts. The mandible is provided with a molar structure and hook.

Both beetles and larvae feed on decaying and fermenting juices under bark or on those exuding from freshly cut logs or wounds on trees. Some are reported to be predaceous, but the writer's observations show no confirmation of this report. Many forms are common on fungi, decaying fruits, and dead animals.

Colopterus truncatus (Rand.), *Colopterus unicolor* (Say), *Carpophilus niger* (Say), *Carpophilus marginatus* Er., and *Prometopia sexmaculata* (Say) are frequently met with on freshly cut logs and sappy wounds, where they are attracted for feeding. *Glischrochilus fasciatus* (Oliv.), *G. sanguinolentus* (Oliv.), *G. confluentus* (Say), and

Epuraea spp. are common between the bark and wood of dead trees. The larvae of the first-mentioned species are commonly associated with the sap-exuding wounds of young locust borer larvae in the spring of the year. Often they are completely enclosed in the larval mines, especially in those in which the borer has died. They are not predaceous.

Family COCCINELLIDAE

The Ladybirds

The ladybird beetles are small round, convex, or hemispherical forms, usually less than 5 mm. in length, having their shining bodies often spotted or marked with red, yellow, black, or white. The broad hatchet-shaped joints of the maxillary palpi and the three-jointed tarsi are additional distinguishing characters.

The larvae of the lady beetles are soft skinned, fleshy, elongate, tapering, often humpbacked, and frequently highly colored, and are provided with numerous hairs, spines, or tubercles. They have a large, protruding, globular head and prominent well-developed, five-jointed legs. The ventral mouth parts are fleshy and deeply retracted. The mandible is sickle-shaped and provided with a molar structure grinding against a well-developed hypopharyngeal chitinization (except in *Epilachna*). The cardo is indistinct, and there are three ocelli.

Most forms commonly met with in the forest are decidedly beneficial, being predaceous on various species of plant lice, scale insects, insect eggs, and small larvae. Both adults and larvae have similar habits and are usually associated on the plant when their food is abundant. These beetles probably play a major part in holding down outbreaks of plant lice or scales, yet our knowledge of their behavior and importance in the forest is decidedly superficial. The larvae of these forms are so imperfectly known that it is not possible to treat them at this time. A few forms, as **the Mexican bean beetle** (*Epilachna varivestis* Muls.), feed on the leaves of plants and cause serious defoliation, while some others feed on pollen or spores of fungi.

The ladybird beetle lays its eggs, which are often colored, in clusters on the plant where its prey feeds. The larvae slowly move about, feeding until full grown, when they attach themselves by their tails to some object, usually the plant on which they fed, and there pupate. The larval skin is bunched behind the pupa. Several generations occur during the year. The beetles pass the winter as adults, some species congregating in great numbers to hibernate, at which time they are collected and then liberated in scale-infested orchards. Some of the forms more commonly represented in the forest-insect collections are the following:

The two-spotted lady beetle (*Adalia bipunctata* (L.)) is a broadly oval beetle, about 3 to 5 mm. long, having the head and thorax black, the former with two yellow spots between the eyes and the latter with yellow margins; the wing covers are red with a black central spot. This is a European species, but now very abundant in the Northern States, where it feeds on aphids on hardwood trees. It commonly hibernates in houses in the winter.

Anatis 15-punctata (Oliv.) is a rather large oval species, 6 to 8 mm. in length, with yellowish elytra, having seven black spots each and one common scutellar spot. A black disk on the thorax encloses two pale spots. It is a common form feeding on a variety of insects, including lepidopterous larvae, such as the gypsy moth larvae and cankerworms.

The twice-stabbed lady beetle (*Chilocorus stigma* (Say)) is a black shining species, 4 to 5 mm. long, with a rounded red spot on the disk of each elytra. The ventral segments are red. It feeds on scale insects on pines and hardwoods in the Northern States, and is reported by R. C. Brown as important in holding down the European beech scale in the Northeast. During the severe winter of 1933–34 the scales were killed above the snow line, and the following spring this predator nearly wiped out the infestation that remained.

There are numerous species of the genus *Scymnus* Kug. that are minute, pubescent forms. Those in the collections of the Moorestown, N. J., laboratory have been associated with scale infestations on pines. *Microweisea misella* (Lec.) is a minute, black, shining species, about 1 mm. in length, that is very abundant on scale infestations. *Coccinella novemnotata* Hbst., **the nine-spotted ladybird,** is a relatively large form, from 5 to 7 mm. in length, of a pale yellowish color, with four black spots on each wing cover and one on the suture. This species is common and widely distributed throughout the United States. It feeds on scale insects and aphids on conifers and hardwoods. *C. transversoguttata* Fald. feeds on scale insects on pines in the more northern States.

The convergent lady beetle (*Hippodamia convergens* Guer.) is an oblong-oval beetle, from 6 to 8 mm. in length. The head is black with a pale transverse center spot. The thorax has a pale margin and 2 distinct discal bars; the elytra are reddish with a black scutellar spot and 12 more or less distinct spots. This species is widely distributed in the United States, and it is often found in clusters of thousands of individuals. It feeds on scales and aphids.

Hyperaspis binotata (Say) is a small, black, shining beetle, about 2.5 mm. in length, strongly punctate, and with a rather large yellowish spot on the middle of the elytra and often a fainter apical spot. This beetle is widely distributed in the eastern part of the United States. Both the adults and larvae feed on scale insects, particularly on the pine tortoise scale (*Toumeyella numismaticum* Pt. & McD.), which is occasionally very destructive. It is very effective in controlling outbreaks of this pest. *Coleomegilla maculata* (Deg.) is a fairly large species, 5 to 7 mm. in length, of a general reddish color, with a red triangular spot on the front of the head, 2 on the thorax, and 10 on the elytra, 2 of which are on the suture. This is a common species hibernating gregariously and feeding on aphids and scales on a variety of plants.

Family CUCUJIDAE

The Flat Bark Beetles

The flat bark beetles form a small and relatively unimportant group in the forest, although some forms are very destructive in granaries. The forest species occur under the bark of dead and dying trees and logs, where they act as scavengers. The adults are usually very depressed, elongate, brownish or black beetles with entire wing covers and rather short legs.

The larvae are likewise, with few exceptions, very flat and are covered with a tough shining integument. The head projects, and the ventral mouth parts are somewhat retracted. The mixillary stipes is free with the articulating sclerite well developed, the mala is simple, the cardo undivided; the mandibles depressed with a well-developed molar structure and often a retinaculum, or hook. The legs are well developed and five-jointed. The spiracles are annular, and the ninth abdominal segment often bears armatures.

Cucujus clavipes F. (fig. 43, *D*) is a conspicuous, bright red, exceedingly flat beetle, 10 to 14 mm. in length with the sides of the head, thorax, and elytra nearly parallel. The antennae are black. The larva is readily distinguished by the bifurcate fork of the ninth abdominal segment. The larvae are very common under the bark of dead trees, where they feed on the decaying inner bark. They construct oval pupal cells between the bark and the wood, in which the larvae are often found. *Laemophloeus biguttatus* Say is a small depressed form found under bark. Its larva is peculiar in that the eighth abdominal segment is large and, together with the pronged forks of the ninth, forms a springing apparatus which can forcibly project the larva into the air. *Uleiota* spp. are small, dark, depressed beetles, the larvae of which have a pair of projections from both the eighth and ninth abdominal segments.

Family **COLYDIIDAE**

The Cylindrical Bark Beetles

The cylindrical bark beetles are represented by a number of small elongate, slender forms, rarely over 5 mm. in length, and often not more than half this size. They are reddish brown to nearly black and beautifully sculptured giving the appearance of being carved from copper. The small globular front and middle coxae, four-jointed tarsi, entire elytra and gradually thickening antennae, usually ending in a two-jointed club will distinguish these beetles from their allies.

The larvae are elongate, cylindrical, with projecting head, and two recurved spines with a saclike depression between, which occur on the ninth abdominal segment. The ventral mouth parts are deeply retracted and the maxillae free but not sickle-shaped. The mandible has a well-developed molar structure. The legs are well developed and 5-jointed, and the spiracles are bifore.

There are two types of larvae in the family representing quite different habits. *Aulonium ferrugineum* Zimm., *A. parallelopipedum* (Say), *Lasconotus pusillus* Lec., and *L. referendarius* Zimm., are of the more robust form and are found under bark associated with bark beetles. They are scavengers as far as records indicate. On the other hand, *Nematidium mustela* Pasc., *Bitoma carinata* (Lec.), and *Colydium lineola* Say are very elongate slender forms which follow in the tunnels of ambrosia beetles, cossonids, and some other borers destroying the larvae of these insects. *Synchita fuliginosa* Melsh. is associated with bark infested by fungi, especially the chestnut bark disease *Endothia*. The adults eat the sporophores.

FAMILIES BORIDAE, PYTHIDAE, and PYROCHROIDAE

The Flat Bark Borers

Several forms of flat bark borers are mentioned together because of their similarity in appearance. Both adults and larvae are greatly depressed, an adaptation to the habits of feeding between the fairly tight bark and wood of dead trees and logs.

Pytho americanus Kby. is a brown, soft-bodied beetle about 15 mm. long with the thorax rounded and narrowed behind, not margined, and the elytra entire and deeply striate. *Boros unicolor* Say is black, slightly smaller, more elongate, slender, and the elytra are smooth. *Neopyrochroa femoralis* Lec., about 15 mm., and *Dendroides canadensis* Lec., about 12 mm. long, are depressed, contrastingly colored beetles with black elytra and yellowish thorax. The elytra are soft-textured, widening behind and covering the abdomen. The head and prothorax are very small and narrow, the former restricted into a neck, and the antennae serrate or flabellate.

The larvae of all four forms are elongate and extremely depressed, and the ninth abdominal segment is fitted with pronged armature (fig. 45, *A*). The forms can be separated by characters mentioned in the key to families.

FAMILY OTHNIIDAE

Othnius fasciatus Bland is only occasionally found in the Appalachian region in dead pines infested by the southern pine beetle, but the western species are extremely abundant in trees killed by bark beetles. The gray, hairy, active adults are predaceous and resemble clerids, but the larvae are probably scavengers. The larvae resemble the Colydiidae, from which they can be distinguished by the fact that the Othniidae have an armature on the ninth abdominal tergum.

FAMILY MELANDRYIDAE

The Melandryid Bark Borers

The melandryids are small to large beetles of various forms, usually elongate to oval, loosely jointed, having the thorax margined at the sides, filiform antennae, front coxal cavities open behind, and four-jointed hind tarsi. The larvae are elongate, fleshy, cylindrical or subdepressed forms, superficially resembling cerambycid larvae, from which they are readily distinguished by the following characters: Deeply retracted mouth parts; free maxillary stipes; simple mala; mentum and submentum often heavily chitinized; cardo two-jointed; maxillary sclerite not chitinized; and the mandible with a poorly developed, smooth molar structure. The legs are well developed and have five joints. The ninth abdominal segment is terminal and often bears a pair of spines, and usually several abdominal segments have the pleural regions swollen and protuberant.

Although the adults of these forms are seldom seen, the larvae are very commonly encountered under the bark or in the wood of dead logs. They are usually associated with wood-decaying fungi—some apparently specific with certain fungi. Some of the more commonly met forms are: *Melandrya striata* Say, found in a wide variety of hard-

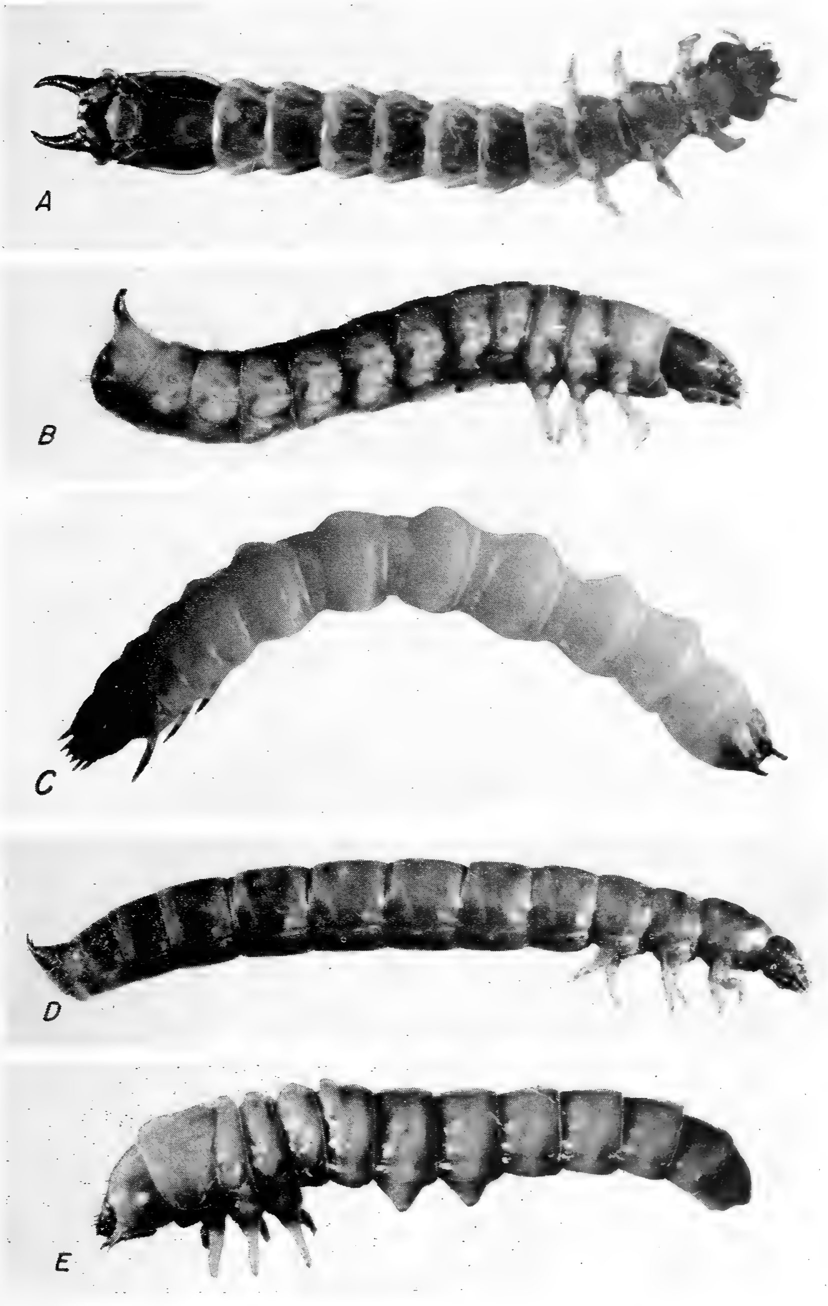

FIGURE 45.—Beetle larvae: *A*, *Dendroides* sp.; *B*, *Synchroa punctata* Newm.; *C*, *Monophylla terminata* Say; *D*, *Scotobates calcaratus* F.; *E*, *Nacerda melanura* L.

woods associated with black lines of decay; *Mycterus scaber* Hald., in oak, chestnut, and juniper; *Orchesia castanea* Melsh., in oak, maple, tulip, sycamore, and hickory; *Serropalpus barbatus* (Schall.) and *Eustrophus tomentosus* Say in conifers; *Holostrophus bifasciatus* (Say) and *Dircaea quadrimaculata* (Say), in a variety of hardwoods.

FAMILIES SYNCHROIDAE and ZOPHERIDAE

The larvae of *Synchroa punctata* Newm. (fig. 45, *B*) are commonly met with in oval cells under the loose bark of hardwood logs and stumps, where they feed on the decaying inner bark. They are elongate, slightly depressed forms, with two patches of chitinous asperities on the dorsal surface of two thoracic and five abdominal segments and bear two recurved spines on the ninth abdominal segment. *Phellopsis obcordata* Kby. closely resembles *Synchroa* in the larval form but has six abdominal segments provided with asperities and makes large tunnels loosely filled with coarse boring dust in the sapwood of dead hardwood logs and stumps.

FAMILY CEPHALOIDAE

Cephaloon lepturides Newm. is a common larva in the decaying wood of many species of coniferous logs and stumps. It is a white, fleshy form, resembling the melandryids, but has the submentum and gula fused and darkly chitinized, hypopharynx chitinized, and two nonchitinized, blunt protuberances on the terminal segment.

FAMILY OEDEMERIDAE

The Oedermerid Beetles

The oedemerid beetles are slender, semicylindrical to subdepressed, soft-bodied insects with the thorax narrower than the elytra, and not margined at the sides. The anterior coxal cavities are open behind, and the middle coxae are very large. The elytra are rather soft and entire, the hind tarsi four-jointed, the first and second being fine. The larvae are very elongate, slender, white, soft-bodied forms, with all the characters mentioned for the melandryids and, in addition, a well-developed grinding structure on the mandible and well-developed asperate ampullae on the dorsal and ventral surface of several abdominal segments. The dorsal surfaces of the mesothorax and metathorax are also asperate.

The larvae of most of these forms occur in dead and rotting woods, as do the melandryids, and are not of much importance, but one form, (fig. 45, *E*), **the wharfborer** (*Nacerda melanura* (L.)), is of economic importance in that it hastens the destruction of piling and decks under wharves, piling under buildings near the water, and boardwalks along the seashore. It is occasionally a pest of telegraph poles. This insect is nearly always found in very moist wood, and almost invariably some wood-rotting fungi are associated with its work. It occurs along the Atlantic coast and the Great Lakes, and is also present in Europe and New Zealand. For control measures for this type of borer see pages 38 and 69. *Calopus angustus* Lec. is a common form in the stumps of conifers that have been dead one or more years.

Family ALLECULIDAE (=CISTELIDAE)

The Comb-Clawed Beetles

The comb-clawed beetles are moderate sized, usually less than 10 mm. in length, glossy, elongate, convex, brown or black beetles, which can be distinguished from the Tenebrionidae by the pectinate tarsal claws. The adults are found on twigs, leaves, and flowers. There is no simple outstanding morphological character by which the larvae can be separated from the Tenebrionidae. Superficially, they are characterized by their uniformly cylindrical bodies and by the peculiar wriggling motion of the living specimens. The terminal segment posteriorly is usually smooth, bluntly (rarely sharply) rounded, and without armature or asperities.

The larvae feed more or less gregariously in a common cavity in dead or decaying wood, especially in stumps and logs on the ground, and more rarely in dead areas of living trees. Some larvae are taken in soil about the roots of plants and others are associated with the debris in nests of ants, termites, and birds, and in the feces of bats. The larval mines are filled with a characteristic, fine pelletlike frass. No forms are of economic importance, but a key is given by which the more common forms may be recognized.

KEY TO LARVAE OF SOME COMMON WOOD- AND FUNGUS-INFESTING ALLECULIDAE

1. Clypeus and labrum unarmed, median transverse portion of latter bearing 4 setae ____ 2
   Clypeus armed with seta-bearing tubercles; number of setae variable ____ 6
2. Back of mandible near articulating fossa bearing 2 long, backward-curved setae (from 2 to 3 times length of anterior one) ____ *Isomera*
   Back of mandible near fossa bearing 2 short straight setae (about length of anterior one) ____ 3
3. Terminal segment well-rounded posteriorly ____ 4
   Terminal segment somewhat sharp posteriorly ____ 5
4. Terminal segment subcylindrical in shape, obtusely rounded ____ *Hymenorus*
   Terminal segment subconical in shape, more acutely rounded ____ *Mycetochara*
5. Terminal segment drawn out into a sharp point; second antennal article decidedly longer (1½ times) than first ____ *Hymenorus*
   Terminal segment not drawn out into a sharp point; second antennal article nearly as short as first ____ *Lobopoda*
6. Clypeus bituberculate and with 4 setae; back of mandible near articulating fossa with 3 long curved backward directed setae ____ *Pseudocistela*
   Clypeus quadrituberculate and with 8 to 10 setae; back of mandible with only 2 long curved setae ____ *Capnochroa*

Of the more common forms, *Hymenorus* larvae infest decaying softwoods, such as pine and cedar and hardwoods as oak, chestnut, willow, redbud, and beech. They have also occurred in dead knots in living tulip poplar, and apple trees. On one occasion they were found associated with a termite nest. Larvae of *H. punctulatus* Lec., *H. pilosus* (Melsh.), and *H. discretus* Csy. have been found associated with ants. Larvae of *Mycetochara fraterna* (Say) infest decaying oak logs and rotting heartwood in living trees. Larvae of *Capnochroa fuliginosa* (Melsh.), in addition to excavating in such hardwood logs as chestnut and maple, occur occasionally in buzzards' nests, as do those of *Pseudocistela brevis* (Say). The latter species has also been found in the debris present in the nest of a ruffed grouse. Larvae of *Lobopoda punctulata* (Melsh.) occur in dead knots of hardwood trees, such as ash, and also in the soil of peach orchards. Larvae of *Isomera sericea* (Say) have been found in the soil beneath decaying wood.

Family TENEBRIONIDAE

The Darkling Beetles

The darkling beetles are small to very large beetles of exceedingly variable form and sculpture, often clumsy and slow-moving and usually sombre dark-brown or black. They have antennae of beadlike joints, and the hind tarsi have four segments instead of five, as have the other two pairs.

The larvae are elongate, slender, and usually more or less cylindrical, and the body covering is often horny and tough, resembling that of the wireworms. The head is more or less globular and protruding, with clypeus and labrum distinct and with deeply retracted mouth parts. The maxillary stipes is free, the mala simple and undivided, the cardo of one piece, and the hypopharyngeal sclerome is biscuspidate or tricuspidate, and usually heavily sclerotized and attached to a well-developed bracon and grinds against a large molar structure on the mandibles. The legs are well developed, with five segments, the first pair often the largest. The spiracles are annular, the ninth abdominal segment is terminal, and often ends in peculiar horny armature.

Although the Tenebrionidae is one of the largest families in the order, it is of little economic importance in the forests. Several species, however, are economically important to germinating seed, as well as to stored grain and cereals, and others, like the mealworms, are sold extensively as food for birds. A few species of *Strongylium* attack living trees at stubs or wounds and bore into the solid wood. They are probably associated with fungi. By far the greater number of forest forms are scavengers found under the bark of dead and dying or rotten trees and logs where they feed on decaying vegetable matter. Many species are definitely associated with decay or even live in the fruiting bodies of fungi. With the exception of the genus *Corticeus*, the larvae are more frequently seen than the adults. These beetles are frequently observed making their way in and out of ventilation holes and in the runways of bark-beetles in infested trees. The larvae are not gregarious in the wood, as are those of the comb-clawed beetles.

KEY TO LARVAE OF THE MORE COMMON WOOD- AND FUNGUS-INFESTING TENEBRIONIDAE

1. Terminal segment unarmed ---------- 2
   Terminal segment armed with two spines ---------- 6
2. Terminal segment dorsally excavate and with sharp margin; body cylindrical and well sclerotized, length to 34 mm.; in decaying logs and stumps ---------- *Meracantha*
   Terminal segment otherwise ---------- 3
3. Terminal segment broadly rounded; hypopharynx not projecting, transverse, rectangular and weakly sclerotized; body subcylindrical, soft; length to 8 mm.; under bark of beetle-attacked trees and logs ---------- *Corticeus* (*Hypophloeus*)
   Terminal segment pointed; hypopharynx projecting, strong, variable in shape ---------- 4

KEY TO LARVAE OF THE MORE COMMON WOOD- AND FUNGUS-INFESTING TENEBRIONIDAE—Continued

4. Apices of prothoracic coxae somewhat separated; mandibles nearly alike; body soft and provided with sparse, long setae; length to 10 mm.; under bark of logs ---------- *Doliema*
   Apices of prothoracic coxae nearly contiguous; mandibles distinctly different; body texture, setae, and hypopharynx variable- 5
5. Body cylindrical, well sclerotized, terminal segment with small depressions, hypopharynx tricuspidate and with the median portion well extended and grooved at tip; submentum distinct; length to 20 mm.; under bark and in wood of decaying logs- *Uloma*
   Body subcylindrical, soft; terminal segment without depressions; hypopharynx bicuspidate, submentum and gula fused; length to 6 mm.; in fungus and beneath bark of fungus-covered logs *Hoplocephala* (*Arrhenoplita*)
6. Terminal segment armed with backward-directed, weak spines; head capsule provided with paired corneous projections; mandibles above articulating fossa bearing a similar corneous projection; hypopharynx bicuspidate; body fleshy; length to 20 mm.; in woody fungi ---------- *Bolitotherus*
   Terminal segment armed with upward-directed, strong spines; hypopharynx tricuspidate ---------- 7
7. Segment anterior to spines raised into a transverse, sclerotized, dentate unit; hypopharynx with median portion well extended and grooved at tip; length to 30 mm.; beneath bark and in wood of living, dying, and dead trees ---------- *Strongylium*
   Segment otherwise; hypopharynx with or without extension of median portion ---------- 8
8. Terminal segment short, directed upward, provided with paired, strong, anteriorly recurved spines and articulates with preceding segment by means of lateral condyles; left mandible apically either bi- or tridentate ---------- 9
   Terminal segment otherwise; left mandible tridentate ---------- 10
9. Left mandible apically bidentate, with an additional tooth present along dorsal margin of cutting edge between apex and mola; cercus without prominent spines or projections at base on inner margin but often provided with a pair of small pits anterior to each one; length to 18 mm.; under bark of logs ---------- *Helops*
   Left mandible apically tridentate, with an additional tooth along cutting edge; spines with prominent projections on inner margins near base, without pits anterior to them; length to 22 mm.; under bark of logs ---------- *Haplandrus*
10. Left mandible without an additional tooth along dorsal margin of cutting edge between apex and mola ---------- 11
    Left mandible provided with such a tooth ---------- 13
11. Body well sclerotized; hypopharynx having median portion well extended and grooved at tip; first pair of legs only slightly larger than other two pairs; ninth abdominal segment without small spines anterior to strong terminal pair; length to 30 mm.; under bark and in wood of decaying logs ---------- *Scotobates*
    Body fleshy; hypopharynx without extension of median portion of sclerome; first pair of legs decidedly stronger than the rest; ninth abdominal segment with small seta-bearing spines anterior to strong terminal pair ---------- 12
12. Terminal segment with median pair of small seta-bearing spines bifid and larger than the others; back of mandible near articulating fossa bearing a single seta; length to 40 mm.; under bark and in wood of decaying hardwood logs ---------- *Merinus*
    Terminal segment with median pair of spines simple; back of mandible near fossa bearing two setae; length to 30 mm.; under bark and in wood of decaying hardwoods; a northern and western species ---------- *Upis*
13. Epipharynx provided with many short, spinelike setae on median portion of soft-skinned part; length to 25 mm.; under bark of decaying hardwoods; an eastern and southern species- *Xylopinus*
    Epipharynx provided with only a pair of prominent, short, spinelike setae on median portion of soft-skinned part ---------- 14

KEY TO LARVAE OF THE MORE COMMON WOOD- AND FUNGUS-INFESTING TENEBRIONIDAE—Continued

14. Trochanter and femur of all legs similarly armed with small, seta-bearing spines; length to 42 mm.; under bark of decaying hardwoods and softwoods; a northern and western species _*Iphthimus*

Trochanter and femur of all legs not similarly armed; anterior pair provided with large, coarse, blunt, seta-bearing spines or granules; the second and third pairs armed with much smaller ones; length to 42 mm.; from beneath the bark of decaying hardwoods; and eastern and southern species _________________________ *Alobates*

COMMON TENEBRIONIDS

Adults and larvae of *Corticeus* (*Hyphophloeus*) (fig. 46, *J*) are found in the runways of barkbeetles on infested trees, especially pines, where they occur as associates. Many of the earlier investigators believed these forms to be predaceous, but Struble (*400*), after conducting numerous tests with fungi and beetles, reported them in 1930 to be entirely phytophagous. The beetles appear as soon as the primary invading bark beetles' tunnels and ventilation holes are completed. The adults are small, cylindrical, elongate, reddish brown or black, and about 3/16 inch long. The larvae are elongate, fleshy forms, less than 1/3 inch long. The terminal segment is brownish, and often nearly semicircular in shape.

The common eastern form, *Corticeus parallelus* Melsh., infests burrows of the southern pine beetle (*Dendroctonus frontalis* Zimm.) in various southern pines and the burrows of *Ips* engraver beetles in these and various pines occurring in the Eastern and Central States. *C. cavus* Lec. has similar associations, and also infests the galleries of the hickory bark beetle (*Scolytus quadrispinosus* Say) and tunnels of ambrosia beetles, such as *Xyleborus celsus* Eich., in dead hickory trees. *C. glaber* Lec., in addition to being associated with *Ips avulsus* Eich. in southern pines like longleaf pine, also inhabits the tunnels of *Polygraphus* (*Lepisomus*) *rufipennis* Kby. in red spruce. *C. Tenuis* Lec. is sometimes found in association with *Pityophthorus* species in white pine. *C. thoracicus* Melsh. occurs in tunnels of *Xyleborus* sp., as well as in those of insects which infest sweetgum. *C. piliger* Lec. has been taken in the burrows of *Ips calligraphus* Germ. in yellow pine in the East.

Next to *Corticeus*, the genus *Strongylium* is of interest because of the habit of attacking wounded areas in living trees. Larvae of *S. tenuiolle* Say (fig. 46, F) and *S. terminatum* Say have been found in fire-scarred and injured areas in living trees such as chestnut, beech, red gum, oaks, hackberry, maple, sour gum, and yellow poplar, and also in pine.

Other tenebrionids which are commonly found in decaying hardwoods, such as yellow poplar, chestnut, hickory, oak, maple, birch, ash, gum, and persimmon are *Mercantha contracta* Beauv. (fig. 46, *K*), *Scotobates calcaratus* F. (fig. 45, *D*), *Alobates pennsylvanica* Deg., *Xylopinus saperdioides* Oliv., *X. aenescens* Lec., *Uloma imberbis*, Lec., *Merinus laevis* Oliv., and *Haplandrus femoratus* F. *Scotobates* sometimes infests pine logs also. *Alobates* has been found in hackberry, as well as in the other hardwoods mentioned, *Iphthimus* sp. infests decaying tamarack and pine, as well as sycamore and other hardwoods. *Upis ceramboides* L. attacks hardwoods as white birch, maple, etc.,

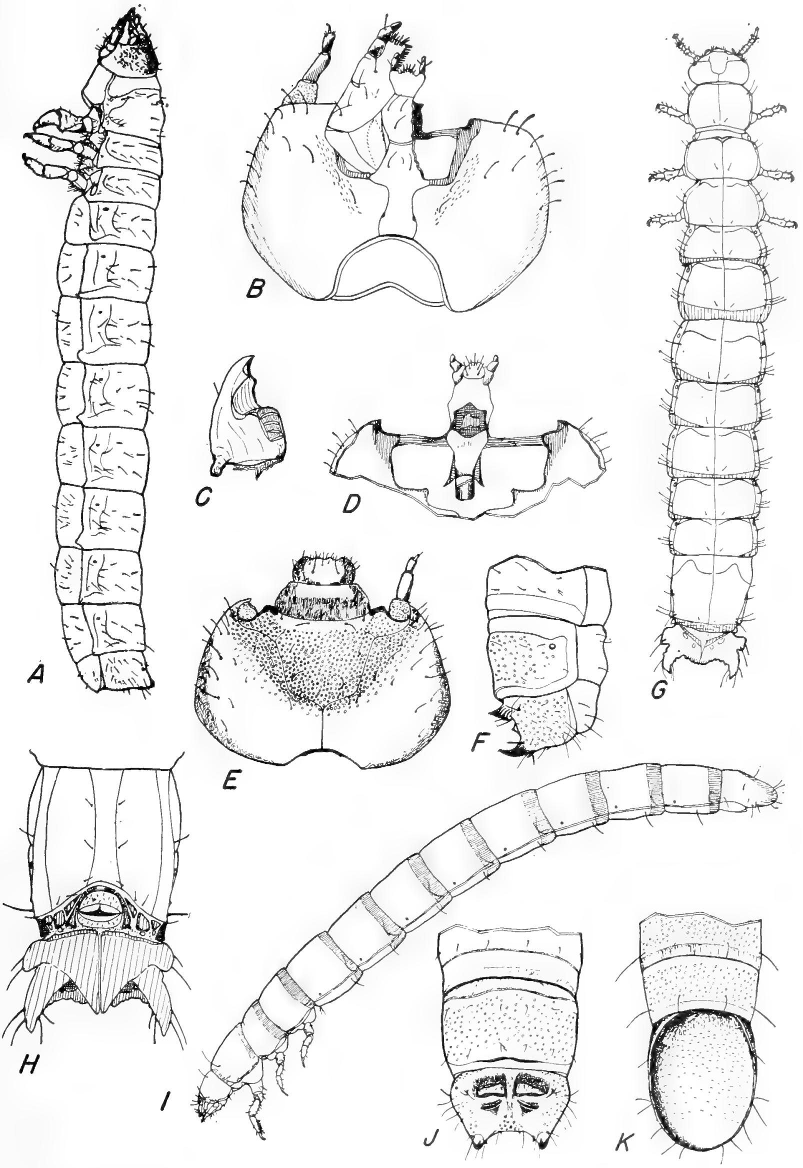

FIGURE 46.—Beetle larvae and structures: *A*, *Alobates pennsylvanica* larvae; *B*, ventral view of head; *C*, mandible; *D*, hypopharynx and labium; *E*, dorsal view of head; *F*, *Strongylium tenuicolle*, lateral view last segment; *G*, *Boros unicolor* Say, dorsal view of larva; *H*, ventral view of last segment; *I*, *Capnochroa fuliginosa* Melsh., lateral view of larva; *J*, *Corticeus* sp., dorsal view of last segment; *K*, *Meracantha contracta* Beauv., dorsal view of last segment.

and also larch and spruce. The larvae of *Helops* sp. occur beneath the bark of both decaying hardwoods and softwoods, as well as in the soil, and have been found in packing about plants intercepted at ports of entry.

In addition to the wood-inhabiting forms just mentioned, beetles of the genera *Hoplocephala* (*Arrhenoplita*), *Bolitotherus*, and a few others infest various kinds of fungi attached to decaying wood. The males of both of the genera named have hornlike protuberances coming from their bodies. Adults of the former are small, elongate, oval, and greenish in color; those of the latter genus are larger, being nearly ½ inch long and having brownish, cylindrical, warty protuberances on their bodies. *Hoplocephala* prefers a soft, light, papery, shelflike fungus, whereas *Bolitotherus* infests a brown, woody *Polyporus* fungus in which to complete its development.

Family LAGRIIDAE

Arthromacra aenea (Say) is a common beetle, 9 to 13 mm. in length, of a metallic blue, green or bronzy color, collected on shrubby foliage along woods roads. The larvae feed in decaying leafmold and are easily recognized by the clavate second joint of the antenna and the biconical spine on the tip of the ninth abdominal segment. The body is cylindrical and horny, and in other characters the larvae resemble the tenebrionids.

Family LYMEXYLIDAE

The Ship-Timber Beetles

The larvae of the ship-timber beetles are wood borers. The beetles are elongate and slender, with serrate antennae and large, four-jointed maxillary palpi. The head is deflexed, the eyes are large, the thorax is margined, and the elytra entire. The legs are slender and have five-jointed tarsi. The larvae are elongate, cylindrical forms, having the abdominal and thoracic segments provided with minute chitinous asperities. The ninth abdominal segment is conspicuously armed, and the tenth is ventral, not terminal. The legs are five-jointed and well developed. The head is globular with a well-developed hypopharyngeal bracon and chitinization of the hypopharynx. The clypeus and labrum are present, and the maxillary mala bears a terminal groove, indicating a division into lacinia and galea.

The species of *Melittomma* have the ninth segment of the larvae truncate, rimmed with serrate teeth. They feed in chestnut. *Hylecoetus* spp. have the ninth larval segment ending in a long spur, and they feed in poplar, birch, maple, and other hardwoods.

The chestnut timber worm (*Melittomma sericeum* (Harr.)) is an elongate, subcylindrical, brown beetle, 11 to 15 mm. in length, clothed with fine silky pubescence. The beetles fly about the time the chestnut is in bloom. The adult is nocturnal and rarely seen, but the larva (fig. 47, *A*, *B*, *C*) and its work are very common where chestnut still exists. Formerly this was a very important destructive insect, causing worm holes in 50 to 90 percent of the chestnut trees, thus unfitting the wood for many purposes. The eggs are laid in season checks on the surface of the wood where it is exposed through wounds or fire scars. It occasionally attacks white oak. The larvae bore deep into the wood,

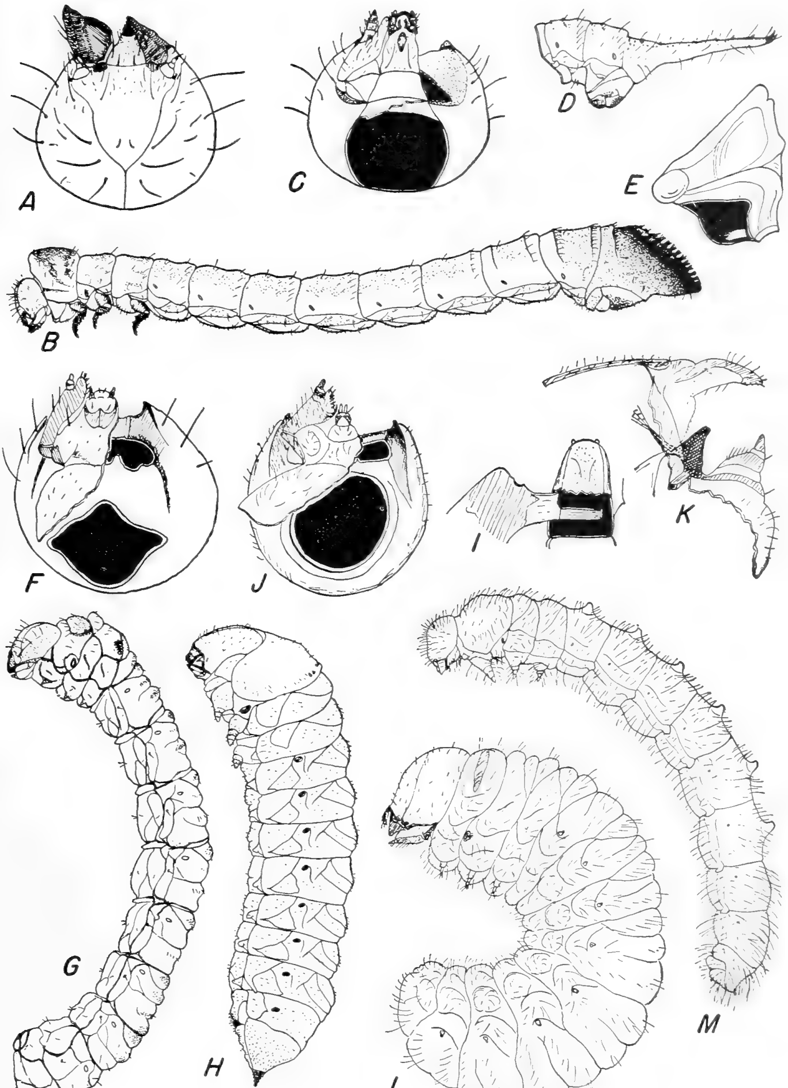

FIGURE 47.—Beetle larvae and structures: *A*, *Melittomma sericeum*, dorsal view of head; *B*, lateral view of larva; *C*, ventral view of head; *D*, *Hylecoetus lugubris* Say, last abdominal segment; *E*, *Arrhenodes* (*Eupsales*) *minuta* (Drury), mandible; *F*, ventral view of head; *G*, lateral view of larva; *H*, *Tomoxia bidentata* Say, lateral view of larva; *I*, labium and bracon; *J*, *Euparius marmoreus* Oliv., ventral view of head; *K*, section of head; *L*, lateral view of larva; *M*, *Mordellistena* sp., lateral view of larva.

enlarging their mines until they are full grown, when they construct pupal cells near the surface. The same wound is utilized for years as a point of attack. This type of defect is easily recognized by the varying size of the open, darkly stained holes, ranging from $\frac{1}{32}$ to nearly $\frac{1}{4}$ inch in diameter (fig. 48). For control of these borers see pages 27 and 38.

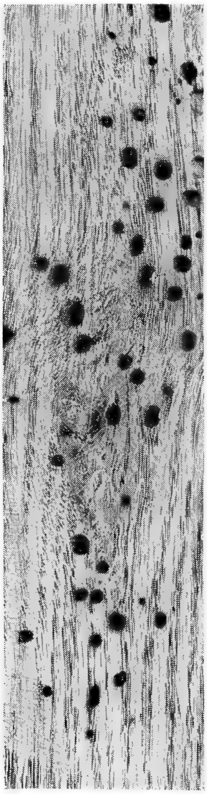

FIGURE 48. — Holes made by the chestnut timber worm (*Melittomma sericeum*).

The sapwood timber worm (*Hylecoetus lugubris* Say) is a slender rufous or blackish beetle from 10 to 12 mm. long. The larvae extend their round mines under the bark and crosswise through the sapwood of poplar, birch, and tulip, and the grubs are readily distinguished by the slender barbed spine on the ninth segment.

FAMILY MORDELLIDAE

The Tumbling Flower Beetles

The representatives of the family Mordellidae are small, wedge-shaped beetles, with the head bent downward and the body strongly arched and prolonged posteriorly into a style, often spotted with yellow or silver. They are generally dark colored and densely clothed with silky pubescence. These beetles frequent flowers, but are difficult to catch, as they jump, tumble, and run with such activity that they can scarcely be picked up. The larvae are white, soft-bodied, fleshy, and cylindrical, with a protruding pleural fold. The ninth abdominal segment terminates in a single truncate process or bears two recurved hooks. The legs are weak and conical. They have a globular head, a triangular mandible without a molar structure, a large ligula, and a labrum, but no gula. Some species of *Mordella*, *Tomoxia*, and *Mordellistina* feed in decaying wood, while other species of *Mordellistina* bore in the pith of living plants. None are of economic importance in the forest, but they are frequently taken by collectors.

FAMILIES PTINIDAE and ANOBIIDAE

The Death-Watch Beetles

FAMILIES BOSTRICHIDAE and LYCTIDAE

The Power-Post Beetles

The beetles belonging to the families Ptinidae and Anobiidae, the death-watch beetles, are small, seldom exceeding 5 mm. in length, rounded, convex, or odd-shaped forms, having the thorax extended hoodlike over the retractile heads, the antennae 9- to 11-jointed, often serrate or pectinate. The elytra are entire and cover the abdomen, which is composed of five ventral segments. The tarsi have five distinct joints.

The adults of the families Bostrichidae and Lyctidae, the powder-post beetles, are distinguished from the Ptinidae chiefly by their larger size, elongate subcylindrical form, and the short first joint of the tarsi which is more or less immovably attached to the second.

The larvae of these four families are very similar. They are white or yellow, soft-bodied, hairy forms, with prominent globular head and are curved like the white grubs or larvae of the snout beetles. They have well-developed, five-jointed legs. The ventral mouth parts are fleshy, and the submentum is continuous with the prothoracic skin (no gula); the maxillary mala is free and usually divided into a lacinia and often a spurlike galea. No hypopharyngeal bracon is present. They are further distinguished from closely related forms, as certain chrysomelids, by their wood-boring habits.

The members of these four families are all wood borers, usually working in dry, well-seasoned material, and do considerable damage, especially in finished products, such as rough stock for implement handles or gun stocks, joists, beams and flooring of buildings, and stored high-grade lumber. The actual loss of the material is often only a small part of the damage. The value of the finished product, the replacement of damaged wood, or the inconvenience resulting from attack is frequently of much greater consequence.

Many species continue to work for years in the same material, gradually consuming all the sapwood until nothing remains but a hollow shell or a core of heartwood. Some species are definitely associated with fungi, which produce a slow decay favorable to their existence, but whether or not this relationship is necessary for most forms is yet to be determined.

A few forms such as *Scobicia*, which prefers freshly cut material, and *Xylobiops* which infests most heavily wood cut from 3 to 6 months, are injurious to stock used for rustic furniture, malls, etc. *Xylobiops* adults have also been found attacking dying persimmon trees that had recently become weakened as the result of a wilt infection. Some bostrichid adults have the curious habit of boring through solid objects apparently out of pure curiosity to see what is on the other side. Twigs of trees, dry boards, and loaves of stale bread on the camp table, are attacked and tunneled. One western species, **the lead-cable borer** (*Scobicia declivis* (Lec.)), has won a notorious reputation because of its bad habit of drilling into lead-sheathed telephone cables at the point of support, which frequently results in short circuits (Burke, Hartman, and Snyder, *76*). Recently, one of its eastern relatives, the **apple twig borer** (*Amphicerus hamatus* (**F.**)), has been found occasionally to have the same habit.

In many species of these families the parent beetles cut egg tunnels much like those of the scolytids, boring directly in through the surface for a short distance, the gallery then turning at right angles and continuing under the surface of wood in limbs, completely girdling the material. The larval mines are tightly packed with frass.

Many species are cosmopolitan, having been widely distributed in the products of commerce. The control of these beetles has been discussed on pages 39–42.

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KEY TO MORE IMPORTANT POWDER-POST LARVAE

The four families and their more important genera, into which the larvae are usually divided, are characterized and separated in the following key. The genera and species are not described, because they have not been thoroughly worked up and are difficult to characterize on the basis of present knowledge.

1.	Head almost entirely protruding from the prothorax; mandible usually dentate; terga usually hairy or asperate	3
	Head deeply embedded in prothorax, cutting edge of mandible gougelike, rarely toothed; terga never asperate	2
2.	Last abdominal spiracle much larger than all others; mandible with a fleshy process on dorsal inner edge *Lyctus*	
	Last abdominal spiracle not abnormally large; mandible with or without fleshy lobe *Bostrichidae*	12
3.	First spiracle pushed forward into anterior margin of prothorax; terga without asperities; usually found in stored plant material, seed, etc *Ptinus*	
	First spiracle between prothorax and mesothorax; terga usually asperate	4
4.	Chitinization between labium and mentum narrow and U-shaped or lacking; mala divided	5
	Chitinization arrow-shaped and pointing posteriorly; mala simple, no inner lobe; spiracles large, annular without spoutlike projection from side *Ptilinus*	
5.	Inner lobe of mala consisting of a strong curved spine *Xestobium*	
	Inner lobe of mala fleshy, usually with several smaller spines or setae	6
6.	Inner lobe of mala smaller than outer. Spiracles with a short or long spoutlike process	7
	Inner lobe of mala about as large as outer; spiracles with a short spoutlike process	9
7.	Claw short and curved; a fleshy lobe at base; feeding in stored plant products and seeds *Lasioderma*	
	Claw usually slender, no lobe; wood borers	8
8.	Spiracles with long spoutlike process; mandible with 3 lateral teeth on dorsal edge *Anobium*	
	Spoutlike process on spiracles only indicated; each side of prothorax bearing curved rodlike impression.	
	Mandible with three lateral teeth *Hadrobregmus*	
	Mandible with two lateral teeth *Microbregma*	
9.	Labrum about twice as wide as long *Ernobius*	
	Labrum about as wide as long	10
10.	Tergal asperities in about two transverse rows *Xyletinus*	
	Tergal asperities in about four transverse rows	11
11.	Posterior tergal fold with long soft hairs *Nicobium*	
	Posterior tergal fold densely beset with short spinelike hairs *Trichodesma*	
12.	Mandible with a large grinding lobe and a soft fleshy lobe on upper inner margin; no impressed line on side of prothroax; tarsi all bearing chitinized claws	13
	Mandible without chitinous or fleshy lobe; a curved impressed line on side of prothorax, usually only first tarsal claw chitinized	16
13.	Prothorax bearing a chitinized tubercle in front of spiracle; no ocelli; cutting edge of mandible entire	14
	No tubercle; ocelli present; cutting edge of mandible dentate	15
14.	Inner edge of molar lobe of mandible carinate *Heterarthron*	
	Inner edge of molar lobe of mandible smooth *Polycaon*	
15.	Six ocelli; breeds in conifers *Stephanopachys*	
	Breeds in bamboo *Dinoderus*	
16.	Maxillary mala without projecting style or spine on inner edge; labrum trilobed	17
	Maxillary mala with a free projecting style or spine on inner edge; labrum entire	18

KEY TO MORE IMPORTANT POWDER-POST LARVAE—Continued

17. Chitinization of labium broken in middle; prothoracic spiracle larger than antennal ring ---------------- *Dendrobiella; Xylobiops*
Chitinization of labium continuous across middle; prothoracic spiracle smaller -- *Scobicia*
18. Two ocelli; labrum entire ----------------- *Lichenophanes armiger*
No ocelli -- 19
19. Spiracle with a spoutlike process; style shorter than lacinia *Lichenophanes bicornis*
Spiracles without process; style longer than lacinia *Amphicerus; Apatides*

SPECIES OF PTINIDAE

The white-marked spider beetle (*Ptinus fur* L.) is a small (about 3 mm.), brown, oval, long-legged beetle, whose habitus suggests a spider, is cosmopolitan and frequently found in buildings and warehouses, where it feeds on dried vegetable or animal matter. It is sometimes injurious to collections of seeds and dried plants and has been found boring in pine and oak woodwork. **The brown spider beetle** (*Ptinus brunneus* Dufts.) has been taken from pine boards in old buildings.

SPECIES OF ANOBIIDAE

Anobium punctatum Deg. and *Petalium bistriatum* Say have similar habits. The former is a small elongate subcylindrical brown beetle, 2.5 to 4 mm. in length, which is cosmopolitan, and infests pine flooring, joists, and furniture, and the larvae often cause much damage. Some species of *Catorama* sometimes infest stored pine cones in the South; another has been found in the seeds of juniper in Arizona. *Dorcatoma* spp. are found in woody fungi.

Ernobius mollis (L.), a small brown beetle 4 to 5 mm. in length, native to Europe, is established in this country, occasionally doing much damage to pine and spruce woodwork, especially flooring, in houses. Apparently it is becoming more abundant. It sometimes damages lumber containing bark, especially that held for 2 or 3 years. *E. granulatus* Lec. is recorded as attacking stored pine cones in Louisiana, and *E. alutaceus* Lec. as attacking the sapwood of larch and spruce logs in the Northeast.

Hadrobregmus carinatus (Say) and *H. gibbicollis* (Lec.) are small, elongate, subcylindrical, reddish-brown beetles from 3.5 to 6.5 mm. in length, whose larvae feed in flooring and beams of buildings, often causing much damage. *H. umbrosus* Fall attacks the woodwork of furniture.

The cigarette beetle (*Lasioderma serricorne* (F.)) is a small elongate, oval, light-brown beetle, which is a common pest of tobacco and a great variety of stored vegetable matter, and, occasionally, of stored animal products. It interests the foresters chiefly because of its damage to herbarium specimens and seeds.

Microbregma emarginatum (Duft.) is a brown beetle, 4 to 5 mm. in length, which feeds in the outer bark of pine and hemlock trees. It has also been recorded from hickory wood but is seldom injurious. *Nicobium hirtum* (Ill.) is a European species found in furniture in Virginia, South Carolina, and Louisiana, and is probably well established in this country. Snyder (*391*) reported it as having been found in yellow pine woodwork of buildings. *Oligomerus brunneus* (Oliv.) is occasionally found in furniture. *Petalium seriatum* Fall feeds in the dead twigs of oak, pine, and bittersweet, and *P. bistriatum* (Say) in pines.

Ptilinus ruficornis Say is a small, black, cylindrical beetle, about 3 to 4.5 mm. in length, which is a rather common and injurious pest of woodwork in houses and stored wood products. It has been recorded in beech, maple, oak, sycamore, and mesquite, and probably attacks other hardwoods. *P. pruinosus* (Casey) feeds in cottonwood.

Trichodesma gibbosa (Say) is a somewhat more robust species than most others of the Anobiidae, ranging in size from 4.5 to 6.5 mm. and is densely clothed with grayish recumbent hairs. It attacks sweetgum joists and studding in tidewater Virginia, becoming very injurious in some of the old historic buildings.

Trypopitys sericeus (Say) is occasionally found in flooring, sills, and furniture in buildings. *Xestobium rufovillosum* (Deg.), an oblong, rather stout beetle, 6 to 7.5 mm. in length, dark brown, spotted with patches of yellowish hairs, is occasionally found in the woodwork of moist cellars in the New England States.

Xyletinus peltatus (Harr.) is an elongate brownish beetle clothed with fine silky yellow pubescence, and ranging from 3.5 to 5 mm. in length. It is widely distributed in the East and often does great damage to the cellar joists and flooring in damp buildings. In unoccupied, closed-up buildings the woodwork, composed of both softwoods and hardwoods, is sometimes so reduced to powder that the floors collapse. It appears to require moist conditions and associated fungi.

SPECIES OF BOSTRICHIDAE

The Large Powder-Post Beetles

The apple twig borer (*Amphicerus hamatus* (F.)) feeds in the dead branches and stems of hickory, pecan, oak, ash, Chinese elm, and beefwood (*Casuarina*). At times it also attacks partially seasoned southern red oak, ash, and pecan lumber. *A. hamatus*, *Stephanopachys punctatus* (Say), and *Xylobiops basilaris* (Say) (fig. 49) have been found in lumber imported into England from America. *A. cornutus* (Pallas) has been taken from locust twigs and *A. punctipennis* (Lec.) from Australian pine. *A. cornutus* is a South American species, probably established in California and occasionally found in woodwork shipped into the Eastern States.

Dendrobiella asperum (Lec.), *D. sericans* (Lec.), and *D. quadrispinosa* (Lec.) are all southwestern species that are frequently found in hardwoods shipped into the Eastern States.

Dinoderus minutus (F.) is a cosmopolitan species breeding in bamboo and is frequently shipped into this country. Beetles are sometimes found in buildings after emerging from bamboo articles. It is very destructive in the West Indies.

Lichenophanes armiger (Lec.) breeds in oak in the Middle West and Southwest, chiefly in dead and dying trees. *L.* (*Bostrichus*) *bicornis* (Web.) breeds in dead branches and is occasionally injurious to oak, hickory, sycamore, and locust lumber and to stored stock.

Polycaon stouti (Lec.) is an important powder-post beetle in California, attacking arbutus, willow, hickory, and many other woods, and furniture. It is frequently shipped to the Eastern States. It is especially injurious to thick veneer plyboard, attacking the center softwoods, like basswood. Such veneer stock frequently becomes infested while in storage prior to being made into furniture. *P.* (*Heterarthron*) *femoralis* (F.) has been reared from mesquite and *Casuarina*.

The lesser grain borer (*Rhizopertha dominica* (F.)) is a cosmopolitan species found in this country attacking oak, hickory, and ash.

FIGURE 49.—Cross section of persimmon low showing the wood destroyed by grubs of the powder-post beetle *Xylobiops basilaris*. (Natural size.)

Scobicia bidentata (Horn) is a common species in the Middle West in freshly cut wood and lumber of hickory, elm, hackberry, oak, chestnut, and sassafras.

Stephanopachys substriatus (Payk.) is a very common species, probably cosmopolitan, working chiefly beneath the bark of pine and other coniferous woods. Occasionally it infests oak tan bark, causing considerable damage. *S. densus* Lec., *S. cribratus* Lec., *S. punctatus* (Say), and *S. rugosus* (Oliv.) breed in pine.

Xylobiops basilaris (Say) is probably the most common bostrichid of the East, attacking practically all freshly cut and partially seasoned hardwood, and frequently is very injurious to furniture and rustic work. It has been found attacking partially seasoned pecan lumber in the South.

SPECIES OF LYCTIDAE

The Lyctus Powder-Post Beetles

The two most destructive species of *Lyctus* in the Eastern States are *L. planicollis* Lec. and *L. parallelopipedus* (Melsh.). The species *L. brunneus* (Stephens) and *L. linearis* (Goeze) cause considerable damage at times. *Lyctus* spp. are all small, elongate, slender, dark-brown to black beetles, ranging in length from 2.5 to 5 mm. All but *L. parallelopipedus* are cosmopolitan. These beetles are, from an economic standpoint, the most important insects in this group of families. Annually, they bring about the loss of thousands of feet of seasoned lumber and destroy large stocks of tool handles, gun stocks, and other manufactured materials. They attack the sapwood of several large-pored hardwoods, including ash, hickory, oak, walnut, locust, and cherry; and also some of the woods with smaller pores, such as sweet birch, poplar, and red gum.

Southern firms shipping export stock to Europe have much trouble with these beetles, as the damage is usually hidden until after unloading and storing for a time in the foreign port. The eggs are laid in the pores of the wood, and small-pored woods are seldom attacked. Only seasoned wood is attacked, usually that below 15 percent in moisture content. *L. parallelopipedus* can complete its life cycle in 3 months in the extreme South, whereas other species there take from 9 to 12 months. All species in the North require 1 year under outdoor conditions. *Minthea rugicollis* Wlkr. is a cosmopolitan species introduced into California and New York in mahogany furniture. For the control of these beetles see pages 39–42.

Family CERAMBYCIDAE

THE ROUNDHEADED BORERS

The roundheaded borers, longicorns, or cerambycids, as they are variously called, are very abundant and widely distributed. They probably come to the attention of the forester more frequently than do representatives of any other group. Thus, aside from their great economic importance, they are of much interest as well.

Primarily they are feeders on dead wood. Their most important role in the economy of the forest might be said to be the part they play in the disintegration of slash and dead and dying trees. A number of forms, however, attack living trees, causing much injury or ultimate death. Such forms as *Romaleum*, *Hammoderus* and *Goes* in oaks, *Saperda* and *Plectrodera* in poplars, and *Megacyllene robiniae* (Forst.) in locusts are examples of this type.

The roundheaded borers cause serious defects in lumber. Some of this injury results from their attack on the living tree, in other cases on the recently felled tree before the logs are sawed. Such defects cause a reduction in the grade and consequent loss in the value of the wood products. This type of injury probably causes a far greater monetary loss than that caused by the borers that kill trees. The defects in living trees are frequently enlarged by other borers, such as *Parandra* beetles or the carpenter ants, which continue excavating until the heartwood is completely destroyed.

Occasionally great storms sweep through forested regions and blow down many thousands of feet of commercial timber. It usually follows that certain of these borers attack the fallen trees, totally destroying the wood for commercial purposes before it can be utilized.

The roundheaded borers frequently attack shade trees, particularly when other factors, such as defoliation, diseases, drought, frosts, or transplanting weaken the trees, making them susceptible to attack. Under these circumstances, it is often difficult to place the exact responsibility for the ultimate death of the tree. Long experience and observation of those wood-boring forms that attack living trees lead to the conclusion that the death of the tree is caused by the mechanical weakening of the tree by these borers and the resulting breakage, in contrast with the bark beetles, which cause the death of trees by their initial attack, and the coincident introduction of fungi, which cut off the water-conducting tissue of the plant. Occasionally, as with the locust borer, particularly in dry seasons, the outer water-conducting rings will be completely girdled and the tree killed.

It is the larval or immature forms that the forester encounters in this group. The adults are rarely seen in association with the damage and are consequently of much less interest. Emphasis is therefore placed on the larval and work-characteristics of the species, rather than on the adult characters.

The long-horned beetles have, as their name indicates, long antennae, longer than the head and thorax, in fact, often longer than the entire body. The beetles are usually elongate, more or less cylindrical, though occasionally quite flattened. Their size varies greatly, ranging from less than 1/4 inch to over 3 inches in length. Many of them are very beautifully marked, while others, particularly the night feeders, are somberly colored. They are active fliers or runners, shy, often feigning death when disturbed. Many forms, when picked up, make a squeaking or rasping noise by rubbing the thorax over the scutellum. These borers were the subject of two papers by Craighead (*107*, *110*) and one by Webb (*427*).

Feeding and Work Habits

Most of the adults are short-lived, nocturnal, and shy, and are rarely seen by the forester. On the other hand, some brightly colored forms, such as the lepturids and the locust borer, are pollen feeders and on bright days congregate in large numbers on the flowers of favored plants. Most forms do not feed in the adult stage, but others eat the bark of twigs (*Monochamus*), leaves (*Saperda*), or the sporophores of fungi (*Leptostylus*).

The eggs are laid in a few simple ways. Usually they are placed firmly under crevices of the bark, where they are well concealed. Certain forms having strong ovipositors insert the eggs deep into soft bark or wood or, as *Prionus*, into the earth at the base of trees. Some forms (*Acanthocinus*) take advantage of the entrance burrows or emergence holes of scolytids. Others, feeding in dry wood, place the eggs in season checks (*Hylotrupes bajulus* (L.)) or, rarely, lay them conspicuously on the surface (*Chion cinctus* (Drury)). Some (many lamiids) that feed on herbaceous plants, lay the eggs in the axils of the leaf petioles or gnaw conspicuous egg pits into which the egg is inserted under the bark. *Oncideres* and *Oberea* girdle the twigs for the purpose of ovipositing, then oviposit through the bark, the former on the severed portion, the latter on the intact part.

Cerambycid larvae can be found in a great variety of wood conditions, from living trees to thoroughly decayed logs or dry seasoned wood. Within each species the limits are very exacting for normal development. Each stage of a gradually disintegrating tree will have its particular species, some in the living parts, others in the recently dead material, and after the wood is seasoned for several years other forms attack it. Pine rafters of old buildings seasoned for years are suitable for *Hylotrupes bajulus*, whereas species of *Goes* and *Hammoderus* breed only in living trees, and the larvae die if the tree is cut before they are mature.

The larvae feed in a great variety of places, some, as *Encyclops* and *Microclytus*, spending their entire larval period in the dry, scaly bark of trees, whereas other feeders in dead bark, as *Acanthocinus*, go deeper into the phloem. Most forms feed beneath the bark, either going into the wood or into the bark to pupate. The thickness of the bark frequently governs the position of the pupal cell. The presence of bark is necessary for the protection of the early stages of nearly all forms. *Neoclytus caprea* Say, *N. acuminatus* F., *Hylotrupes bajulus*, and certain species of *Eburia* and *Smodicum* are powder-post-forms and spend but a small part or none of the larval period under the bark. Many roundheaded borers, as *Prionus*, *Distenia*, *Tetraopes*, and *Mecas*, are root feeders on the roots of living trees, shrubs, or herbaceous plants. One prionid, *Homaesthesis*, feeds on the roots of sod-forming grasses.

A very characteristic mode of feeding is found among the twig girdlers and pruners. This peculiar habit appears in many unrelated genera of the family. The twigs are girdled either by the adult beetle, as *Oncideres* and *Oberea*, or by the larva. Some larvae (*Xylotrechus quadrimaculatus* Hald.) sever the branch about where the egg was laid, whereas others bore down the stem, gradually hollowing it and cutting off the twig at several places and finally entering the root to pupate. The manner in which the twigs are cut is characteristic of the different species of borers and serves to identify them.

A few forms, such as *Desmocerus*, are pith feeders in shrubby plants. Several forms among unrelated genera cause galls, as *Saperda obliqua* Say, in alder, *Desmocerus piperi* Webb in elder, and *Xylotrechus aceris* Fisher in red maple. The seeds of some plants are attacked by cerambycids and the dry, hard cones of *Pinus attenuata* frequently contain larvae of *Paratimia*.

Just as the galleries of many species are characteristic, so is the boring dust or frass pushed aside by the larva in excavating its tunnels. Some forms produce fine, powdery frass, others flaky chips or long fibrous, excelsiorlike shreds. These types of frass are usually characteristic of certain types of mandibles. The frass may be either plugged tightly behind the larva or pushed out and the burrows kept continually open. Some forms use the opening through which the frass is extruded to emerge as adults, but in most forms the adult and not the larva gnaws the exit hole.

The pupal cells and the place of pupation in the bark, sapwood, or heartwood show endless variation. Many forms produce a simple oval cell and others an elongate curved cell, with curious trapdoor arrangements or peculiar wads plugging the exit. Some of the root-feeding forms make a pupal cell of earth firmly held together by a secretion.

All these characteristics are just as distinctive of the species as are the anatomical features and are used to a large extent in keys and in the discussion of the various forms.

The roundheaded borers can be distinguished from all other wood-boring larvae by a few prominent larval characters. They are always fleshy, thin-skinned, white or yellowish in appearance, and more or less cylindrical or slightly depressed in form. They may taper somewhat posteriorly, but the anterior segments are never suddenly and conspicuously larger than the following segments, as with the flat-headed borers. They are never curved with the last segments curled up beneath, toward the head, as are the white grubs, nor are any found with the last segment developed into prolegs or gripping processes.

Between each of the body segments are two overlapping, circular bands of skin which permit longitudinal expansion and contraction and, together with the dorsal and ventral pads (ampullae), form an efficient device for movement of the larva in its burrow. The tenth segment is modified into two or three small retractile (anal) lobes. The fleshy appendages on the under side of the head, the ventral mouth parts, are never attached far back on the head, and are always about on a line with the base of the mandibles. The larvae may or may not have small legs.

CLASSIFICATION OF ROUNDHEADED BORERS BY CHARACTER OF WORK

The roundheaded borers can be conveniently grouped as follows:

I. Larvae found girdling twigs or stems.
II. Larvae found in galls on living plants.
III. Larvae found boring in the bark proper of living plants.
IV. Larvae found boring under the bark or in the wood of living trees.
V. Larvae found in roots of living plants.
VI. Larvae found beneath bark or in wood of recently dead, dying, or felled trees.
VII. Larvae found in older, moist wood in contact with the ground.
VIII. Larvae found in dry, seasoned wood, or cat faces or fire scars of living trees

These sections are further subdivided by characters related to their work and also anatomical differences, as will be shown under the following subheadings with their more detailed keys.

KEY TO THE TWIG GIRDLERS

The twig girdlers sever small twigs or branches from the living trees. These branches may be seen hanging in the tree or lying on the ground in late summer, fall, or winter. They are severed either by the adult insect, which gnaws the bark cleanly through, while the central part of the stem is roughly broken, or by the larvae, which cut the twig from within, hollowing out the central part of it, cutting the edge off cleanly, and leaving the bark irregularly broken. This class also includes certain borers that attack shrubs, such as rhododendron, sassafras, sumac, seedling oaks, and chestnuts. These larvae cut off the twig or stem after they have finished feeding in it and move to the lower part of the plant, often to the roots.

1. Twigs cut from the outside, never hollowed out at point of severance............ 2
   Twigs girdled from within, a part of stem always hollow............ 3
2. Egg punctures and feeding scratches on twigs; head of larva bearing a transverse row of ridges above............ *Oncideres*
   No evidence of egg scars or feeding scratches; severed twigs never containing larvae............ *Oberea*
   On sassafras............ *O. ruficollis*, p. 256
   On rhododendron and azaleas............ *O. myops*, p. 255
   On elm, dogwood, apple............ *O. tripunctata*, p. 256
   On sumac............ *O. ocellata*, p. 255
3. Larvae found in girdled portion............ 4
   Larvae boring into green portion of stem, remaining on plant; girdled portion having a series (sometimes but a few) holes through bark............ 7
4. Twigs cut off by spiral incisions; sides of twig not perforated with holes............ 5
   Twigs cut by completely hollowing; twig having a series of small holes through bark, usually in a straight line............ 6
5. Larvae having two ocelli on each side of head; pronotum white, shining............ *Hypermallus villosus*, p. 245
   Larvae having but one ocellus on each side of head; pronotum brown and velvety............ *Xylotrechus quadrimaculatus*, p. 269

KEY TO THE TWIG GIRDLERS—Continued

6. Pronotum of larva shining; head wider than long *Aneflomorpha subpubescens*, p. 246
   Pronotum of larva roughened with small points; head longer than wide *Oberea*
7. Found in twigs of larger trees; pronotum roughened with small points; mandible pointed; in poplars *Oberea schaumii*, p. 256
   Found in shrubby plants; larvae boring down into base or roots; plant usually severed at surface of ground 8
8. Pronotum roughened with small points; mandible pointed *Oberea*
   In sassafras *O. ruficollis*, p. 256
   In sumac *O. ocellata*, p. 255
   In rhododendron and related plants *O. myops*, p. 255
   Pronotum smooth, shining; mandible rounded *Aneflomorpha subpubescens*, p. 246

KEY TO THE GALL MAKERS

The gall makers include certain borers that cause galls or swellings on the twigs or branches, along the trunk, or at the base of trees and shrubs. The larva, or borer, is to be found either in the swelling proper or in the larval mine above or below the gall where the pupal chamber may be constructed.

1. Galls found on twigs and branches:
   On poplars and willows
   Pronotum having four impressed lines, the inner being darker and oblique *Oberea ferruginea*, p. 255
   Pronotum having but two impressed lines, these parallel *Saperda concolor*, p. 264
   S. moesta, p. 266
   On thornapples *Saperda fayi*, p. 266
   On oaks *Goes debilis*, p. 248
2. Galls found on main stem or trunk
   On willow *Oberea ferruginea*, p. 255
   On maple (*Acer rubrum*) *Xylotrechus aceris*, p. 269
3. Galls found at base of plants
   On alders *Saperda obliqua*, p. 267
   On elders *Desmocerus*, p. 244

KEY TO THE BORERS IN THE BARK OF LIVING TREES

Certain roundheaded borers feed only in the bark proper of living trees. Some few enter the inner bark or bast, one (*Romaleum*) to construct its pupal cell, causing serious defects and stain in the resulting timbers; another (*Tylonotus*) in ash, often mines a great deal in the bast, causing the death of large branches or entire trees. Some of these forms are of economic importance in connection with forest diseases.

1. Larvae found only in the corky bark of living trees:
   In elm *Physocnemum brevilineum*, p. 259
   In mulberry *Elaphidion incertum*, p. 246
   In white oak (*Quercus alba*); dorsal and ventral surfaces of body bearing small tubercles *Encyclops caeruleus*, p. 247
   In thick-barked rock oak or chestnut oak (*Quercus prinus*) *Romaleum cortiphagus*, p. 263
2. Larvae boring into inner bark and often destroying the cambium:
   In chestnut and oaks; at bases of trees or in crotches of branches in moist conditions *Anoplodera* (*Leptura*) *nitens*, p. 251
   In ash trees; often causing dying of branches or entire trees *Tylonotus bimaculatus*, p. 269
   In thick-barked rock oak or white oak; larvae often going beneath the bark to make the pupal cell; old scars present on bark of trees *Romaleum cortiphagus*, p. 263

KEY TO THE BORERS UNDER THE BARK OR IN THE WOOD OF LIVING TREES

Group IV includes those larvae that are borers *in living trees* and are not included in Groups I, II, and III. In this group are included some of the most destructive roundheaded borers. A few spend the greater part of the larval period boring beneath the bark, destroying the cambium, but most of them riddle the sapwood and heartwood, so weakening the tree that the branches or the main stems of small trees break off in the wind.

1. Larvae feeding gregariously; the mines overlapping and meandering — 2
   Larval mines essentially individual — 3
2. In heartwood at base of large trees
   Pronotum shining
   Stenodontes and *Archodontes* (*Mallodon*), p. 252
   Pronotum asperate — *Parandra*, p. 258
   Beneath bark of firs, hemlocks, and larches — *Tetropium*, p. 268
   In and beneath bark of ash or at base of privet
   Tylonotus bimaculatus, p. 269
   At the base of living poplars — *Xylotrechus obliteratus*, p. 270
   Beneath bark and in wood of elms — *Saperda tridentata*, p. 267
   Beneath bark and in wood of lindens — *Saperda vestita*, p. 268
3. Feeding beneath the bark and then boring directly up through the wood; boring frass exuded through a small hole in bark — 4
   Feeding in branches or main stems and hollowing a long excavation through center of branch or trunk — 7
4. In the main trunks or branches — 5
   At base of trees — 6
5. Head of larvae longer than wide; fibrous frass exuded from openings of larval mines:
   In fig trees and alders — *Ptychodes*, p. 262
   In oaks, beeches, elms, and hickories
   Goes and *Hammoderus*, p. 247
   In poplars — *Saperda calcarata*, p. 264
   In cactus — *Coenopoeus*, p. 242
   Head broader than long; exuded frass granular:
   In oaks — *Romaleum rufulum*, p. 263
   In locusts — *Megacyllene robiniae*, p. 243
   In maples — *Glycobius speciosus*, p. 260
6. In small oaks, shadbush, and chestnuts — *Hammoderus tesselatus*, p. 248
   In apples, shadbush, thorns, etc — *Saperda candida*, p. 264
   In poplars:
   Pronotum asperate — *Saperda calcarata*, p. 264
   Pronotum velvety pubescent and brownish
   Plectrodera scalator, p. 260
7. Last segment of larva horny; in mesquite — *Aneflus protensus*, p. 239

KEY TO THE ROOT BORERS

A few cerambycid larvae feed in the roots of living trees, shrubs, and herbaceous plants. *Prionus* and *Tetraopes* are true root feeders, confining themselves to this particular part of the host during the entire larval period. Some of the other species here included spend only the later stages of the larval development in the roots, having previously bored in the stems above ground. Some of these cause serious injury to the plants.

1. Larvae feeding entirely in the roots or directly at the base of plants — 2
   Larvae feeding in the roots but the stem above always tunneled for some distance; in shrubs — 3
2. In the roots of milkweeds — *Tetraopes*, p. 268
   In elder, sometimes causing a swelling at surface of ground, basal portion of stem often hollowed — *Desmocerus*, p. 244
   In roots of large hardwood trees or various shrubs — *Prionus*, p. 261
   In sod or in roots of herbaceous plants — *Homaesthesis*, p. 230

KEY TO THE ROOT BORERS—Continued

3. Mandible round at apex, pronotum smooth
Aneflomorpha subpubescens, p. 246
Mandible pointed at apex; pronotum roughened with fine points
Oberea, p. 255
In sassafras — *O. ruficollis*, p. 256
In sumac — *O. ocellata*, p. 255
In rhododendron and related plants — *O. myops*, p. 255

KEY TO THE BORERS BENEATH THE BARK OR IN THE WOOD OF RECENTLY DEAD OR FELLED TREES

In class VI are included those borers that usually attack wood only when the bark is present and still rather fresh and green. Nearly always, after the wood has seasoned from 4 to 6 months, it is immune to attack by these borers. Trees dying gradually are often subject to attack. These borers cause great losses in rustic work and log houses, also in lumbering operations where the trees cut during the winter are left lying on the ground throughout late spring and early summer. Cordwood and pulpwood are also damaged.

The character of the frass is used here to distinguish certain species. In some forms it is fibrous or shredded, in others granular. This distinction is not difficult to make, the only possible confusion arising from the plug closing the pupal chamber, which in nearly all forms is fibrous.

1. Larvae found in coniferous trees — 2
Larvae found in hardwood trees — 9
2. Frass or boring dust behind larvae composed of granular, closely packed material (never fibrous or shredded, except in pupal cell) — 3
Frass or boring dust composed largely of fibrous or shredded material — 8
3. Frass cast out by larvae through a small hole — 4
Frass tightly packed behind larvae, filling entire larval mine — 5
4. Under side of head having four small tubercles; in pines, spruces, junipers, and cedars — *Callidium antennatum; C. janthinum*, p. 240
Under side of head without tubercles, but as in figure; principally in cedars and junipers — *Oeme*, p. 257
5. In cypress, last segment of larvae bearing two dark-brown spots beneath — *Physocnemum andreae*, p. 259
In cedars, junipers, and Douglas-fir — 6
In pines, spruces — 7
6. Larvae having no ocelli and no spines on last segment
Semanotus ligneus, p. 250
Larvae having one ocellus and two small spines on last segment above — *Atimia confusa*, p. 237
7. Head wider than long; form cylindrical:
Larvae having two small spines on last segment above; mandible pointed at apex
Asemum; Criocephalus; Nothorhina, p. 237
Larvae without spines; mandible rounded at apex
Xylotrechus, p. 270
Head longer than wide; ampullae velvety pubescent; form depressed — *Acanthocinus*, p. 236
8. Head broader than long; last segment of body having two small dorsal spines — *Asemum; Criocephalus; Nothorhina*, p. 237
Head broader than long, slightly keeled at sides; larvae very depressed — *Stenocorus lineatus*, p. 262
Head longer than broad; last segment without spines
Monochamus spp., p. 252
9. Frass entirely granular — 10
Frass containing much fibrous material — 11

KEY TO THE BORERS BENEATH THE BARK OR IN THE WOOD OF RECENTLY DEAD OR FELLED TREES—Continued

10. Frass tightly packed behind larvae:
    Pronotum of larvae smooth, white; legs very small; found in ash, oak, and other trees; larval mines chiefly in wood — *Neoclytus*, p. 253
    Pronotum of larvae covered with velvety pubescence (yellowish) legless; larval mines chiefly under bark — *Xylotrechus*, p. 269
    Frass exuded through a small hole, burrows mostly open;
    One ocellus on each side of head; larvae yellowish and rather elongate; chiefly in hickory — *Chion cinctus*, p. 238
    Two ocelli on each side of head — *Elaphidion mucronatum*, p. 246
    Three ocelli on each side of head:
        Found in hickory — *Megacyllene caryae* (Gahan), p 242
        Found in mesquite — *Megacyllene antennatus*, p. 242
11. Pronotum brown, velvety pubescent; small irregular tubercles on body segments above and below — *Leptostylus* and related genera, p. 251
    Prothorax above armed with chitinous points, as well as the dorsal and ventral surfaces of body segments — *Saperda*
        In elms — *S. tridentata*, p. 267
        In basswood or linden — *S. vestita*, p. 268
        In hickory — *S. discoidea*, p. 267

KEY TO THE BORERS IN OLDER WOOD IN MOIST CONDITION OR IN CONTACT WITH THE GROUND

In class VII are grouped the borers found in wood that has been cut a year or more and that is in contact with the ground. They are rarely found in recently dead or dying trees. Several forms included here are also considered in the preceding group (*Asemum*, *Criocephalus*, *Nothorhina*), as the larvae may continue to bore for several years in stumps or logs lying on the ground.

Cross ties, mine props, fence posts, utility poles, foundation timbers, and fire-killed timber are subject to serious injury. Two genera (*Parandra* and *Mallodon*) are often found in the bases of living trees where heartwood is exposed and cause a great deal of damage to shade trees by riddling the bases, so that the trees are easily blown over. This is especially true of *Parandra*.

This group is composed mostly of large borers working in great numbers in the same stick of wood until it is completely riddled.

1. Pronotum armed with small recurved chitinous points — *Parandra*, p. 258
   Pronotum brown, covered with very fine (almost velvety) hairs or points; last segment bearing two small spines above — *Asemum; Criocephalus; Nothorhina*, p. 237
   Pronotum white, shining, sometimes a little roughened or rugulose — 2
2. Dorsal and ventral surfaces of body smooth, having two transverse impressions above — 3
   Dorsal and ventral surfaces of body covered with small tubercles — *Leptura*, p. 250
3. Front of head just above mandibles projecting in teeth or tubercles — 4
   Front of head projecting in transverse dull carina (sometimes divided in middle) — 5
4. Four rounded tubercles; body skin finely wrinkled — *Ergates* (western)
   Four flat, sharp-edged teeth; body skin finely wrinkled — *Tragosoma*, p. 269
   Two flat, projecting teeth; body skin smooth, shining — *Orthosoma* (*Derobrachus*), p. 258

KEY TO THE BORERS IN OLDER WOOD IN MOIST CONDITION OR IN CONTACT WITH THE GROUND—Continued

5. Three eye spots or ocelli on each side of head; body cylindrical
Stenodontes and *Archodontes* (*Mallodon*), p. 252
One ocellus on each side of head; body wedge shaped, tapering posteriorly; in pine ---------------------- *Prionus pocularis*, p. 262

KEY TO THE BORERS IN DRY, SEASONED WOOD

These borers, termed "powder-post borers," continue to work year after a year in the same wood until nothing is left but a thin outer shell filled with a mass of powder. Indication of their activity is the presence of small piles of powdery dust falling and collecting beneath the infested timbers. Certain of these borers attack only recently cut wood, but if the wood, after being attacked, is placed in buildings or stored in drier situations, the larval period is prolonged for several years. Under normal conditions these larvae would have transformed into adults and emerged in a year or two. Cases are on record where normally a 1-or 2-year larval period has been thus extended to 8 or 12 years.

The classes of wood most frequently damaged are stored lumber exposed to attack before storing, structural timbers in houses, especially rafters and beams, and often bridge trestling.

Three ocelli on each side of head; boring in coniferous woods
Hylotrupes bajulus, p. 248
One ocellus on each side of head:
Under side of mouth frame bearing four small projecting tubercles; boring in coniferous woods -------- *Callidium antennatum; C. janthinum*, p. 240
Mouth frame not so toothed:
Boring in bamboo ------------------------ *Chlorophorus annularis*, p. 240
Boring in hardwoods
Legs minute, smaller than palpi:
Under side of prothorax bearing a triangular smooth white area -------------------------- *Smodicum cucujiforme*, p. 268
Under side of prothorax not so marked; legs very small; dorsal and ventral surfaces of body dull, finely granulated
Neoclytus caprea; N. acuminatus, p. 253
Legs distinct, larger than palpi ---------------------- *Eburia*, p. 245

DISCUSSION OF THE ROUNDHEADED BORERS

The pine-bark borers, *Acanthocinus* spp., are elongate, rather depressed beetles, from 10 to 25 mm. in length. The body color is usually black, mottled, or striped with grayish white or brown pubescence. The antennae are extremely long, the basal joints fringed with hairs beneath, and the females have an elongated ovipositor. The larvae are rather depressed, having the head longer than wide and very flat, the mandibles are long, slender, and obliquely pointed at the apex. The pronotum and ampullae are posteriorly velvety pubescent. The larvae are legless and have no spine on the last segment.

Certain species occur in all parts of the United States, chiefly in pines, but also in spruce and fir. *Acanthocinus nodosus* (F.) is a large conspicuous form common in the Southeast; *A. obsoletus* (Oliv.) is a smaller form of the Northern States. From early to late in the summer the adults fly and lay their eggs in dying pines, either in a scar gnawed by the female or in holes made by scolytid beetles. The larvae of some species feed entirely in the bark, whereas others go beneath the bark, making extensive meandering mines. All complete development in one season. The pupal cell is constructed in the bark.

These borers are not destructive to the trees, as they attack only those that are dying or dead and mine only in the bark, but they are so often met with in connection with injurious forms that they are worth noting. During extensive outbreaks of *Dendroctonus* beetles these larvae also often become very abundant and so completely destroy the inner bark that they starve out a great part of the scolytid broods, which develop more slowly.

The species of two genera of pine-stump borers, *Asemum* Esch. and *Criocephalus* Muls., are considered collectively, as the adults are very similar and the character of the work is about the same. They are elongate, slightly flattened, brownish-black beetles, having the sides of the thorax rounded but never margined. The eyes are somewhat emarginate and the ligula corneous. The larvae are easily recognizable by the heads being wider than long, the sides bearing dense recurved hairs, and the mandibles being sharply pointed with a striated plate in the inner face. The pronotum and ampullae are velvety or asperately pubescent, and the last segment bears two chitinous spines or points on the dorsal surface. Legs are present.

Species of *Asemum* and *Criocephalus* are found throughout the United States in pines, spruces, and related conifers. *A. moestum* Hald. and *C. obsoletus* (Rand.) are the species most commonly met. The adults appear from early in the summer to early in the fall and deposit eggs under bark scales of recently cut or dying trees. The larvae mine the sapwood or heartwood, making extensive burrows filled with a mixture of fibrous and pelletlike frass. When abundant they destroy large portions of the sapwood. From 1 to 3 years (more commonly 2 years) are required to complete development. These insects cannot be considered of much economic importance, as they are usually found only in the stumps of felled trees or in standing dying trees in the woods. They contribute to the decay of *Dendroctonus*-killed trees by destroying the base and roots and thereby causing trees to fall that might otherwise stand for some years.

Atimia confusa (Say), **the small cedar-bark borer,** is a small, rather stout beetle from 6 to 10 mm. in length, of a mottled gray to slaty color, covered by scattered pubescence and irregular shining spots. The thorax is wider than long, rather quadrate, and the tips of the elytra are truncate. The larva is slender, tapering, and rather quadrangular because of the strongly lobed and projecting ampullae. The head is wider than long, with dense recurved hairs on the sides, and the pronotum is dark, and velvety pubescent, except for an irregular glabrous area in the center. Two spines occur on the last segment, and legs are present. It feeds beneath the bark of cedars and junipers and makes a pupal cell in the sapwood. It attacks cedars, junipers, and related trees throughout the Eastern and Central States.

The adults appear very early in the spring, with the first signs of plant activity, and again early in the fall and lay their eggs beneath the bark scales of recently cut trees. The larvae feed entirely between the wood and bark, packing fibrous frass behind them. Late in summer most of the brood goes into the sapwood to construct simple pupal cells plugged with wads of fibrous frass. Many emerge the same season, but others may overwinter as adults or larvae and emerge early the next spring. Rustic work constructed from cedars and junipers is attacked by these insects unless it has been properly seasoned. They mine the inner bark, causing it to dry and peel off. These borers may be controlled by methods outlined on page 38.

The banded hickory borer (*Chion cinctus* (Drury)), is an elongate, cylindrical beetle from 16 to 33 mm. in length, brownish, but clothed with grayish pubescence. The thorax is acutely spined at the sides, and the elytra bear crescent-shaped yellowish bars near the bases and spines at the tips. The larva (fig. 50, *A*; 51, *B*) is an elongate, slender, yellowish borer having the head wider than long, the mandible rounded at the tip, one pair of ocelli, and the under margin of the head roughened. The posterior area of the pronotum is white and finely

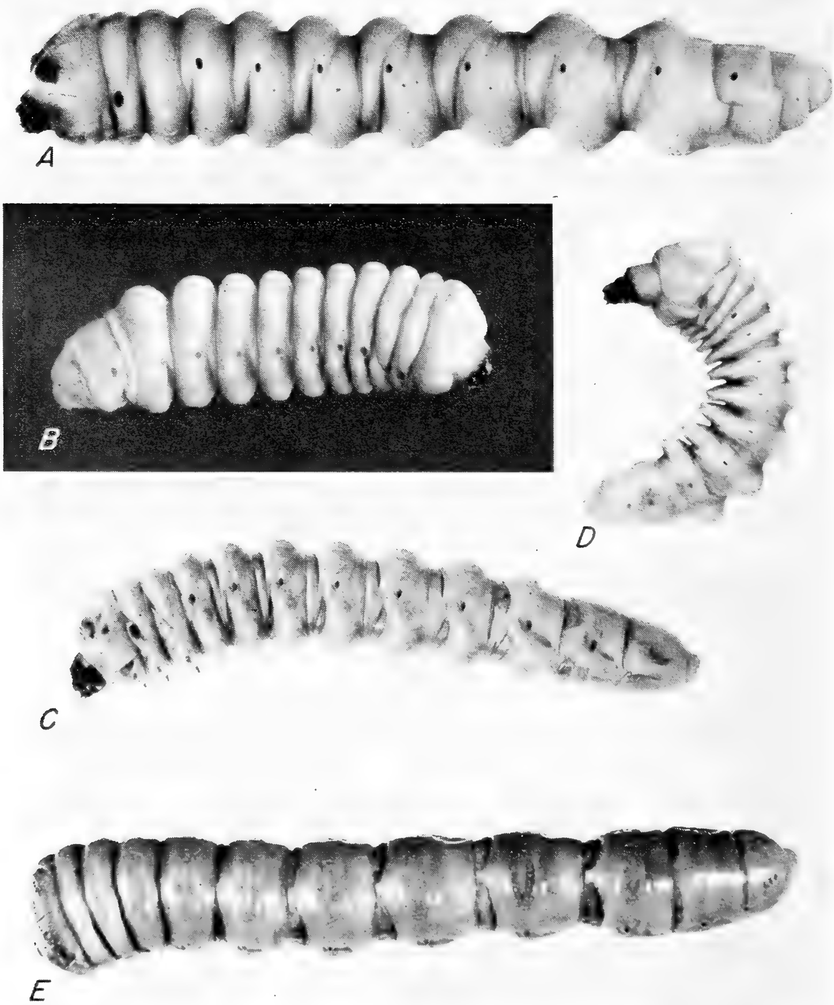

FIGURE 50.—Cerambycid larvae: *A*, *Chion cinctus*; *B*, *Megacyllene robiniae*; *C*, *Prionus laticollis* (Drury); *D*, *Oncideres cingulatus* (Say); *E*, *Goes tigrinus*.

striate, while the ampullae are prominent and granulate. Legs are present. The larva feeds in dead hickory, oak, and other hardwoods throughout the Eastern and Central States, making long tunnels under the bark and through the wood, exuding quantities of granular frass.

The adults appear from early to late in the summer, depositing the eggs beneath crevices of the bark or directly on the wood. For the first season the larvae feed beneath the bark, deeply scarring the wood and exuding large quantities of granular frass through small circular openings. During the fall and the following summer, they bore deeply and extensively through the wood, often completely honeycombing sticks 2 or more inches in diameter. These mines are loosely packed with frass. At the end of the wood burrow the pupal cell is made between two wads of fibrous frass, one of which protrudes from the bark through a hole made by the larva and through which the adult emerges. Pupation takes place in the fall, with either the pupa or the adult overwintering, or in the spring. Cordwood and rustic work are attacked and seriously injured by these borers, and the exudation of large quantities of frass frequently becomes a nuisance. For control measures see page 42.

Aneflus protensus Lec., **the mesquite-branch borer,** is a very elongate, cylindrical beetle from 20 to 30 mm. in length, light or dark brown, marked with grayish pubescence. The basal joints of the an-

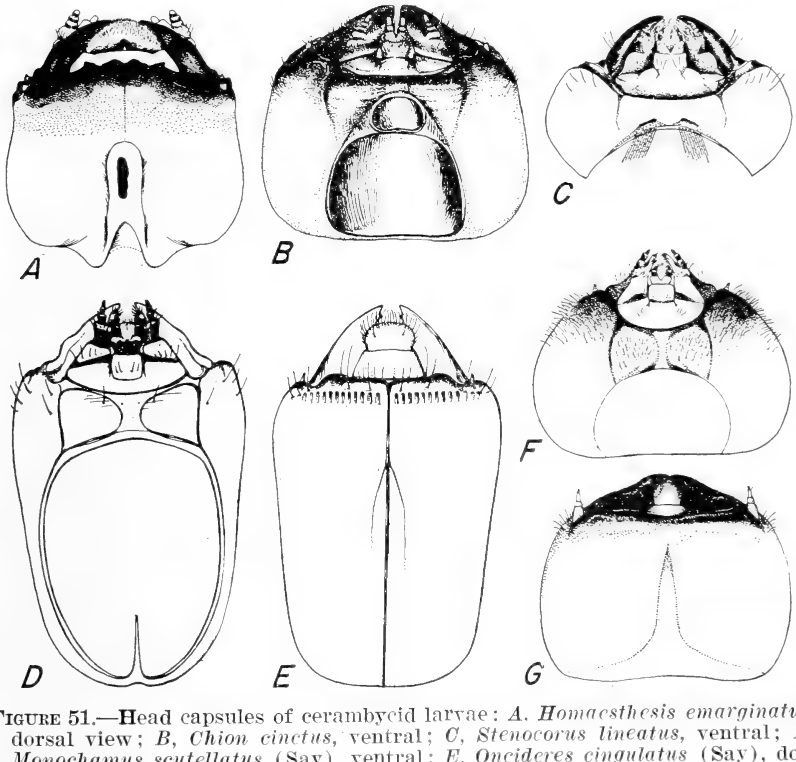

Figure 51.—Head capsules of cerambycid larvae: *A. Homaesthesis emarginatus*, dorsal view; *B, Chion cinctus*, ventral; *C, Stenocorus lineatus*, ventral; *D, Monochamus scutellatus* (Say), ventral; *E, Oncideres cingulatus* (Say), dorsal; *F, Asemum nitidum*, ventral; *G. Tylonotus bimaculatus*, dorsal.

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tennae and tips of the elytra are provided with spines. The larva can be recognized by its elongate, slender, cylindrical form, with the last segment heavily chitinized and bearing many minute spines. The head is wider than long, having the mandible rounded at the apex and bearing one ocellus on each side. The posterior area of the pronotum is white, shining, and finely rugulose, as are the ampullae. Legs are present. It feeds in mesquite in Texas and the Southwestern States.

The adult flies early in the summer and deposits the eggs in crevices of the bark at the forks of small living branches. The larva hollows out the stem, working downward through the green wood and at intervals opening small holes to the surface for the exudation of frass. From these holes a black, watery liquid drips, staining the foliage or soil beneath. Stems 2 inches in diameter and the main trunks of small trees are often found infested. The interior of the larvae mine is always black and stained. Two years is required to complete the development. Branches and young trees are occasionally killed by this borer. Defects caused by it in the wood of larger trees are enlarged by the entrance of secondary insects, such as ants. About buildings the dripping of the black liquid from the laval mines is the most objectionable feature. Control measures for this borer may be found on page 24.

The two insects *Callidium antennatum* Newm., **the black-horned pine borer,** and *C. janthinum* Lec., **the black-horned juniper borer,** are so similar in all characteristics that they can be treated together. They are flattened, blackish-blue beetles, from 9 to 14 mm. in length, having the thorax rounded and with an impression on each side of the middle (fig. 52, *F*). The larva is rather depressed, with a tough skin of shining texture. The head is wider than long, the mandible rounded at the apex, with one ocellus and four small tubercles on the under anterior margin of the head. Feeding beneath the bark and in the sapwood of dry coniferous wood, they make extensive mines and exude large quantities of granular frass. They feed in pines, spruces, hemlocks, junipers, and cedars throughout the United States.

The adults appear early in the spring, laying their eggs beneath scales of bark on wood that has seasoned over winter. The larvae feed beneath the bark, deeply scarring the wood, and making long prepupal chambers in the sapwood. Large quantities of granular frass are exuded from small holes in the bark, which are enlarged as the larvae grow and which mark the opening of the pupal cells. The pupal cell is plugged deep in the wood with a wad of fibrous frass. Normally the life cycle is completed in 1 year. Considerable injury is caused by these insects to rustic work and houses built of coniferous wood. The wood is badly riddled and weakened and the bark is so loosened that it falls away. Lumber sawed and stored with the wane is frequently injured. For control measures see page 38.

Chlorophorus annularis (F.), **the bamboo borer,** is an elongate, subcylindrical, blackish beetle, about 10 mm. in length, with **X**-shaped markings of yellow on the wing covers. The thorax has pale greenish markings. The outer part of the 11-jointed antenna is black and the inner is red. The first two pairs of legs are red and the third pair black. The mature larvae are about 20 mm. long, and are slender and tapering. The head is wider than long, the mandible rounded at the apex, and there is one ocellus on each side of the head. The legs

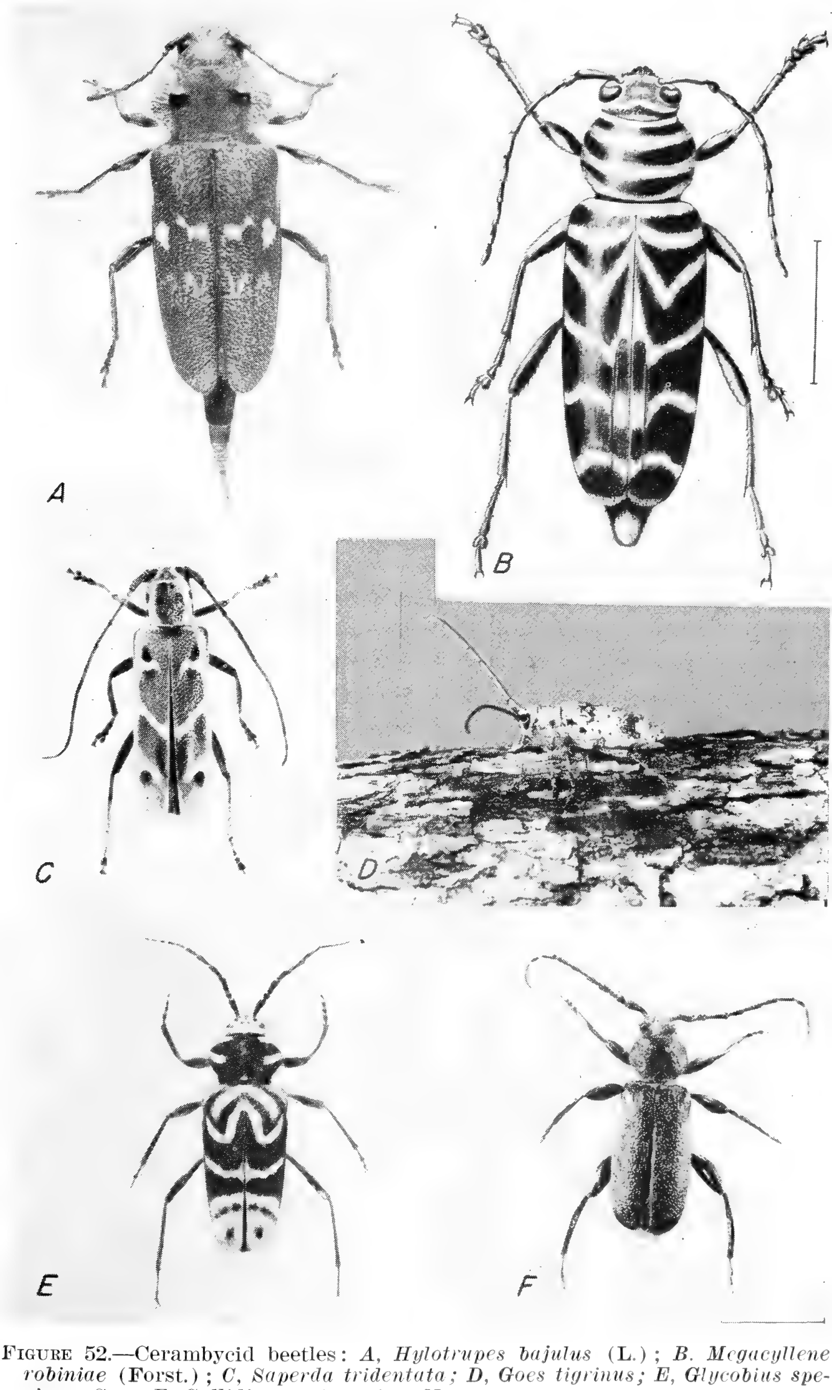

FIGURE 52.—Cerambycid beetles: *A*, *Hylotrupes bajulus* (L.); *B*. *Megacyllene robiniae* (Forst.); *C*, *Saperda tridentata*; *D*, *Goes tigrinus*; *E*, *Glycobius speciosus* Say; *F*. *Callidium antennatum* Newm.

are minute and 3-jointed. They make extensive mines in culms of bamboo.

The adults emerge in the open during the early spring months, but inside heated buildings they appear in February and March. They attack well-seasoned bamboo, reducing it to a fine powder which is packed solidly behind them, as they bore through the wood. Infested material has been taken in this country at Fort Worth, Tex., Los Angeles, Calif., Portland, Oreg., Savannah, Ga., and Grand Rapids, Mich. It is a serious pest of bamboo in Japan and India, and now is probably becoming established in this country where quantities of stock are kept in storage continually. Fumigation or heat treatment (see page 41) may be used to control these insects.

Coenopoeus palmeri (Lec.), **the cactus borer,** is a stout, robust, blackish beetle from 20 to 25 mm. in length, having the elytra broadly splotched with brownish-gray pubescence. The larvae are large, cylindrical, legless borers having the head longer than wide, and very flat, and the pronotum and ampullae beset with many minute chitinous points. The larval mines are extended through the centers of the stems of several species of branching cacti in the Southwestern States.

The adults emerge and fly during the midsummer, laying their eggs in small holes gnawed in the sides of larger branches. As soon as the larva hatches, it bores directly into the center of the stem and excavates a large gallery, following the pith. From the point where the egg was laid, sap and boring dust is exuded—the best indication of the presence of the grub. The pupal cell is plugged off at the top of the mine, and the adult gnaws through the wood and bark to escape. In parts of Arizona this borer is very common in shrubby branching cacti, such as achoya. It causes large defects in the stems, often produces a swelling, and is especially injurious to ornamental gardens. It may be controlled by the method outlined on page 25.

Megacyllene antennatus (White), **the mesquite borer,** is a large, robust beetle from 18 to 23 mm. in length, brownish black, marked with white or gray pubescence. The thorax is light with a dark spot in the center. The larva resembles *M. caryae* in all essential characteristics. It feeds in mesquite and acacia in Texas and the Southwestern States, boring beneath the bark and deep into the wood and exuding large quantities of granular frass. Craighead and Hofer (*117*) gave measures for protecting cordwood and posts.

The adults fly early in the fall and again early in the spring, placing the eggs in crevices of bark of wood that has been cut not more than a few months. For a short time the larvae feed beneath the bark but soon enter the wood and excavate extensive mines. Great quantities of frass are exuded through a hole in the bark, which is gradually enlarged and through which the adult finally emerges. The pupal cell is made late in the summer behind a wad of fibrous frass.

This insect chiefly injures mesquite cordwood, and in a region where other fuel woods are scarce, it becomes a serious pest. Stores of cordwood are often so badly damaged by this larva that the fuel value is reduced 50 percent or more. Fence posts are also greatly weakened or destroyed. Proper seasonal cutting will prevent attack by these insects. Trees cut from November 15 to January 15 will rarely be attacked, and wood for fuel should be cut during this period.

The painted hickory borer (*Megacyllene caryae* Gahan) resembles

M. robiniae so closely that for present purposes it need be separated only by its habits, although the larvae can be distinguished from those of *M. robiniae* by having oval instead of circular spiracles. During the entire winter the pupa is found in the wood. It is of a yellowish color with darker, rather greenish, markings on the wing pads and small chitinous points on the dorsal surface of the segments. The larva feeds in freshly cut wood, exuding large quantities of granular frass. It attacks hickory and occasionally Osage-orange, hackberry, grape, and ash throughout the Eastern and Central States.

Very early in the spring, when the leaves are first unfolding, adults are found laying eggs beneath scales of the bark on logs cut in the winter. For about 8 weeks the larvae feed beneath the bark and then enter the sapwood and later the heartwood, where they excavate deep mines. All the frass is exuded through a small hole, which is enlarged as the larva grows. Early in the fall the matured larva pupates behind a wad of fibrous frass at the end of the larval mine. It overwinters in the pupal stage, the adult emerging through the exudation hole. Hickory cordwood cut in the winter and held over the summer is injured, and by the middle of the summer it may be completely riddled and the spaces between the ricked sticks of wood filled with the exuded dust. Rustic work put up during the winter is ofttimes injured. The adults frequently emerge from wood stored for fuel in warm cellars and cause annoyance.

The locust borer (*Megacyllene robiniae*) is a medium-sized, robust beetle from 14 to 18 mm. in length, black marked with yellow cross bands (fig. 52, *B*). One of those on the elytron is W-shaped. The thorax is wider than long. The larva (fig. 50, *B*) is short, robust, and subcylindrical, having the head wider than long, the apex of the mandible rounded, and three pairs of small black ocelli. It feeds beneath the bark and in the wood of living black locust trees, exuding the frass, and is now distributed practically throughout the United States except possibly in California and Oregon.

In the fall when the goldenrod is in full bloom, the adults are found feeding on the pollen of this plant. They lay the eggs beneath the bark scales of black locust, the young larvae hatching before the leaves fall and overwintering in the outer corky bark. During early spring they feed in the bark, and the sap flowing freely from the wound indicates their presence. About the time the new foliage appears they bore through the bark and enter the wood, where they continue to feed. Extensive mines are made through the heartwood (fig. 53) and the granular frass is exuded through a hole marking the point where the egg was laid. In July the larva pupates behind a wad of fibrous frass at the end of its burrow and emerges about the time the first goldenrod is in bloom, coming out through the hole maintained for the exudation of frass.

The locust borer is the most serious pest of black locust. It has in the past destroyed thousands of acres of plantations and greatly discouraged the planting of this valuable tree. Locust has the ability to do fairly well on poor, run-down soils; consequently, it is widely used to reclaim waste land and to stop erosion. Borer attack does not interfere with these uses, but it does prevent the realization of commercial products such as posts and poles. Plantations are seldom attacked until the fourth or fifth year, after which the injury increases for several years until the trees are about 6 inches in diameter. As the bark becomes thicker, survival of the larvae is lower, and stands that escape severe destruction are relatively free from injury after reaching this size. The damage results from the breaking off of the stems and branches weakened by the borer mines in the sapwood and heartwood. Moisture is probably the governing factor in inhibiting the survival of the young larvae. During dry springs many larvae survive, and stands that have been relatively free from damage have been observed to be completely destroyed following very dry seasons.

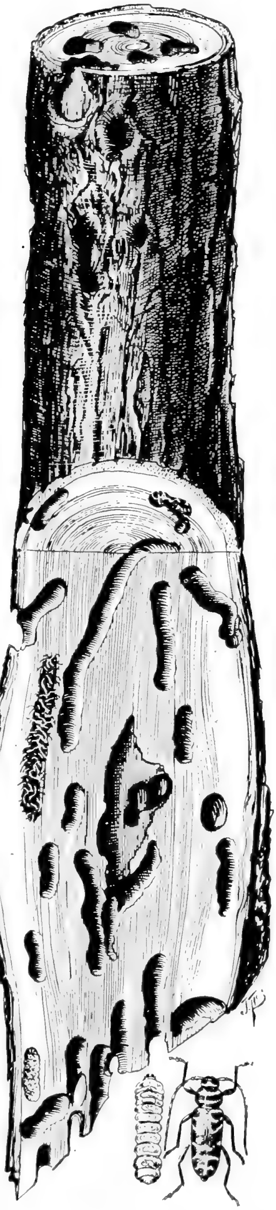

FIGURE 53.—Section of trunk of locust tree dying from injury by the locust borer (*Megacyllene robiniae*).

No satisfactory control or prevention has been developed for this insect. Hall (*208*) pointed out that damage is least in rapidly growing stands and greatest in slowly growing trees. Avoidance of poor sites, except for soil-reclaiming purposes, and utilization of measures that tend to stimulate growth are recommended. Shade produced by dense stands or mixed plantings seems to prevent considerable damage, especially on better sites. Badly damaged stands should be clear cut during the winter and allowed to sprout. Coppice stands seem to be relatively immune, at least for some years. Shade, ornamental, and valuable trees should be sprayed as recommended on page 26. This insect has been further discussed by Craighead (*108*), St. George and Beal (*372*), and Garman (*181*).

Desmocerus palliatus (Forst.), **the elder borer,** is a rather large, elongate, robust beetle of strikingly contrasted, bright yellow, orange, and blue colors. It has a small head narrowed behind into a neck. The eyes are deeply emarginate and the last joints of the antennae are velvety black. The larvae are of shining texture and robust form, having the head suborbicular, wider than long, with three ocelli on each side and the mandibles triangularly pointed. The pronotum is rugulose and shining, and the tubercles of the ampullae are confluent. The legs are well developed. These larvae feed in the roots and base of elders, eating out the pith and filling the mines with coarse, rather fibrous frass, much of which, however, is cast out.

This species occurs throughout the Eastern States wherever elders grow. The adults fly about the time the host flowers are in bloom. They lay the eggs in crevices of the bark at the base of the stem and the larvae, upon hatching, bore down into the roots, where they feed for 2 or 3 years. The mines are packed with fibrous frass and finally extend through the center of the stem to the level of the ground or above, where the simple pupal cell is made. Some species cause a large gall at the base of the stem. When these insects become numerous, they not only cause serious injury to the plants but often kill them outright. Elders used for ornamental purposes are occasionally rendered very unsightly by the destruction of many canes.

Beetles of the genus *Eburia* are readily recognized by the two pairs of ivory-white spots on each wing cover. A typical form is *Eburia quadrigeminata* (Say), **the ivory-marked beetle,** which ranges from 14 to 24 mm. in length. It is elongate, subcylindrical, and pale yellow. Each wing cover has two small longitudinal ivory spots close together at the base and a second similar pair just behind the middle. The thorax has two blackish tubercles dorsally and a short, sharp spine on each side. The larvae are rather robust and wedge-shaped, tapering gradually posteriorly, with tough, shining integument sparsely covered with golden hairs. The head is wider than long, with the apex of the mandible rounded. The legs are distinct, long, and four-jointed.

The larva is a true heartwood borer and prefers dry, solid wood, in which it excavates large contorted mines very tightly packed with frass. Mature oaks having "catfaces," or scars, through which the larvae can gain access to the heartwood are often badly damaged. Lumber in the process of seasoning is also subject to occasional attack by the adult beetles. Oak, hickory, ash, chestnut, maple, and cypress are liable to infestation. Beetles sometimes emerge from flooring and furniture several years after these are placed in a building, but it is not definitely known to attack such material after it is in use. Fumigation or removal of infested woodwork (p. 44) are recommended for control of house infestations.

The twig pruner (*Hypermallus villosus* (F.)) is an elongate, subcylindrical, brownish beetle from 10 to 17 mm. in length, having spines on the first few antennal joints and at the tip of the elytra. The thorax is nearly cylindrical. The larva can be recognized by the elongate, slender form and shining texture, having the head wider than long, two ocelli on each side, and the apex of the mandible rounded. The pronotum is shining and somewhat striate, the two segments just behind bear an X-shaped impression above, and the ampullae are shining. Legs are present. The larvae feed in the branches of many hardwoods, and cut these branches from the trees.

This species occurs throughout the eastern part of the United States. The adults fly about the time the oak leaves begin to form, and deposit the eggs near the tip of the twigs in the axil of a leaf. The young larva mines down the stem, increasing in size as it goes, until late in the summer it severs the branch by several concentric cuts from the center outward, except for the thin bark. These branches, from 1/4 inch to 2 inches in diameter, break with the wind and fall to the ground. The larva retreats up the fallen stem and secures itself between two wads of fibrous frass, where it pupates early the following spring, or in the fall. Shade and park trees are frequently so severely pruned by this insect that the shape and appearance of the tree is altered. It is not unusual to see the ground thickly strewn with these severed twigs (McDaniel, *282*). For control measures see page 23.

The adult of *Elaphidion mucronatum* (Say), **the spined bark borer,** is larger than that of *Hypermallus villosus*, measuring from 15 to 20 mm. in length, is more robust, and has stronger spines. The larva is not so hairy and feeds beneath the bark, exuding much granular frass. It attacks many hardwoods throughout the Eastern States.

The adults fly early in the summer, laying the eggs beneath bark scales of dead branches of various hardwoods exposed to the weather. For the first year the larva feeds beneath the bark, exuding great quantities of granular frass, entering the sapwood the second year and making a long pupal mine at the end of which a cell is shut off with a plug of fibrous frass. The pupal gallery has an opening through the bark where the frass was exuded, Many species of hardwoods used in the construction of rustic work are attacked by this insect. Rustic furniture is frequently injured. For control measures see page 42.

Elaphidion incertum Newm., **the mulberry bark borer,** closely resembles *E. mucronatum*, but the larva feeds in the outer bark of living mulberry trees throughout the Eastern States. It does not cause serious damage but, because it is found in living bark, it is frequently mistaken for an injurious insect.

Aneflomorpha subpubescens (Lec.), **the oak-stem borer,** is a very elongate, slender beetle, from 15 to 22 mm. in length, and of a uniform light-brown color. The thorax is elongate, subcylindrical, and widest in the middle. Both the basal joints of the antennae and the tips of the elytra are provided with spines. The larva is very elongate and slender, having the head wider than long, and the apex of the mandible rounded. On each side of the head are one prominent ocellus and six very long curved hairs. The rear edge of the pronotum is abruptly raised and finely striate, and the ampullae project prominently. Legs are present. The oak-stem borer feeds in the stems of shrubby plants, exuding the frass through a series of holes.

This species is found in the Southeastern and South Central States on oak and chestnut. The adults appear about the time the oak foliage is fully formed and lay the eggs at the leaf bases near the tips of twigs on small seedling plants. The larva mines in the center of the twig, working downward and successively cutting off sections of the branch. The frass is exuded through a straight series of small round holes. Toward fall, the full-grown larva burrows to the base of the main stem and often enters the root, making a pupal cell between two wads of fibrous frass. The stem is usually cut off near the surface of the ground by a nearly transverse incision. It rarely attacks branches of larger trees. The development is completed the following spring. Young seedlings and sprouts from 1/4 to 1 inch in diameter are attacked and destroyed by this larva. Occasionally this borer becomes very abundant and kills large numbers of plants. It may be controlled as indicated on page 23–24.

In the Southwestern States another species, *Anepsyra tenue* Lec., **the western oak pruner,** the adult and larva of which resemble *Aneflomorpha (Elaphidion) subpubescens*, is found girdling oaks, much as does the twig pruner (*Hypermallus villosus*) (p. 245). The control methods are similar to those used for the latter.

Encyclops caeruleus (Say), **the oak-bark scaler,** is a small, slender, bright greenish-blue beetle. The head of the larva is extended and wider than long, and the ampullae are strongly bilobed and protuberant. It bores in the outer bark of living white oaks and many other hardwoods, causing the dry scales to peel off. Although of no economic importance, it is frequently found associated with other borers in the Eastern States.

There are various species of beetles belonging to the genera *Goes* and *Hammoderus* that bore in the trunks of trees and are commonly known as **trunk borers.** These are robust, cylindrical, prettily blotched or spotted beetles from 11 to 30 mm. in length. The thorax is cylindrical, with a spine on each side. The antennae are long and the legs rather short and equal in size. The larvae are elongate, cylindrical, of shining texture, having the head longer than wide and very depressed and the mandibles obliquely pointed at the apex. The pronotum is posteriorly covered with fine velvety-brown asperities, and the ampullae bear four rows of finely asperate tubercles. There are five species of economic importance that work in the branches or trunks of living hardwood trees, making large mines through the heartwood and exuding fibrous frass.

The general features of all species can be treated together. About the time the chestnut is in full bloom, the adults emerge, feed on the thin bark of young twigs and the bases of leaf petioles, and shortly afterward begin to oviposit. The female gnaws oval pits through the bark and then inserts in each pit a single egg between the wood and inner bark. Within 20 to 30 days the young larvae hatch out and begin feeding. Some species, as *Goes tigrinus*, *G. debilis*, and *G. pulverulentus*, do little feeding beneath the bark but directly enter the sapwood, whereas the others feed beneath the bark through this and the following season. After entering the wood the larval mine is extended upward through the wood and usually deep into the heartwood. From 2 to 4 years is required to complete the larval development. During the spring of the last year an enlargement of the larval mine is constructed and extended outward toward the bark. In this cell pupation takes place above a wad of fibrous frass. The adult gnaws its way out through wood and bark. During the entire larval feeding period fibrous frass is exuded from a hole at the point of the egg scar.

It rarely happens that these species actually kill the tree in which they are working, as so much of the feeding is done in the wood that the growing tissue is not greatly damaged. Occasionally *Goes pulcher* girdles the trees or branches, causing their death. **The oak sapling borer** (*Hammoderus tesselatus*), however, kills a great many young oak saplings by entirely cutting them off at the base. Frequently young trees are broken off by ice or wind at the point where the heartwood has been destroyed by these larvae. The defects in the resulting timber constitute by far the most serious damage. In many localities scarcely a matured oak can be cut that does not show one or more of the abandoned larval mines. Secondary insects, as carpenter ants, occupy the abandoned galleries and enlarge the cavities in the heartwood. The burrows likewise open the heartwood to wood-destroying fungi. For control of these species see page 24.

Goes debilis Lec., ***the oak-branch borer,*** is from 11 to 15 mm. in length. The general color is brown, with the head, thorax, and apical third of the elytra clothed with reddish-yellow pubescence, while the basal half of the elytra is mottled with grayish pubescence. The larvae feed in the lateral branches of oaks in the Eastern States, often forming a gall-like swelling. Two years, and occasionally 3, are required to complete the development.

Goes pulcher (Hald.), **the living hickory borer,** ranges from 18 to 23 mm. in length. The body is dark brown, covered with yellowish pubescence, having the elytra clay yellow with a conspicuous darker band across the base and another about the middle. The larvae feed from 2 to 4 years in the trunks and branches of hickory trees throughout the Eastern States. A considerable portion of the mine is extended beneath the bark.

Goes pulverulentus (Hald.), **the living beech borer**, is from 19 to 23 mm. in length. It is brown, uniformly clothed with short, whitish hairs, and the elytra are indistinctly barred at the middle and at the base, with darker pale-brown pubescence. The larva feeds in the main trunk, if it is of small diameter, or in branches of various trees, chiefly oak, beech, ironwood, blue beech, elm, and sycamore throughout the Eastern States. Three or 4 years is required to complete the development.

The oak sapling borer (*Hammoderus tesselatus* (Hald.)) is from 20 to 23 mm. in length, dull brown, and clothed with prostrate brownish hairs. The elytra are covered with small spots of yellowish hairs in irregular rows. The larvae feed in the base and roots of small oak and, rarely, in chestnut saplings from 1½ inch to 2 inches in diameter, from Pennsylvania south and throughout the Middle West.

Goes tigrinus (Deg.), **the white-oak borer,** is the largest species of the genus *Goes*, ranging from 25 to 30 mm. in length. It is dark brown, but rather densely clothed with white pubescence (fig. 52, *D;* 54, *B*). The basal third of the elytra is roughened with small, black, elevated points. The larva feeds in the trunk of trees from 2 to 12 inches in diameter and in branches of larger white oak trees in the eastern part of the United States. Four or 5 years is required to complete the development from egg to adult.

The old house borer (*Hylotrupes bajulus* (L.)), a flattened, slaty-brown beetle from 10 to 20 mm. in length, is sometimes found boring in the timbers of old houses. The thorax is rounded, with several small tubercles at the side, and has a black polished line and spots on the disk. The wing covers are marked with whitish spots forming two irregular bands near the middle (fig. 52, *A*). It is a European species introduced into this country and yearly becoming more abundant throughout the United States, attacking only coniferous wood. The larva can be recognized by the thin texture of the skin, and the fact that the head is wider than long, the apex of the mandible is rounded, and there are three ocelli on each side of the head. The prothorax is smooth and shining and the ampullae reticulated, approaching tuberculate. Legs are present. It feeds in dry, seasoned, coniferous woods, filling the extensive galleries with loose granular frass.

Adults appear late in summer and deposit the eggs in season checks or irregularities of the wood. The resulting larvae feed from a few to many years in the dry sapwood, until it is completely destroyed.

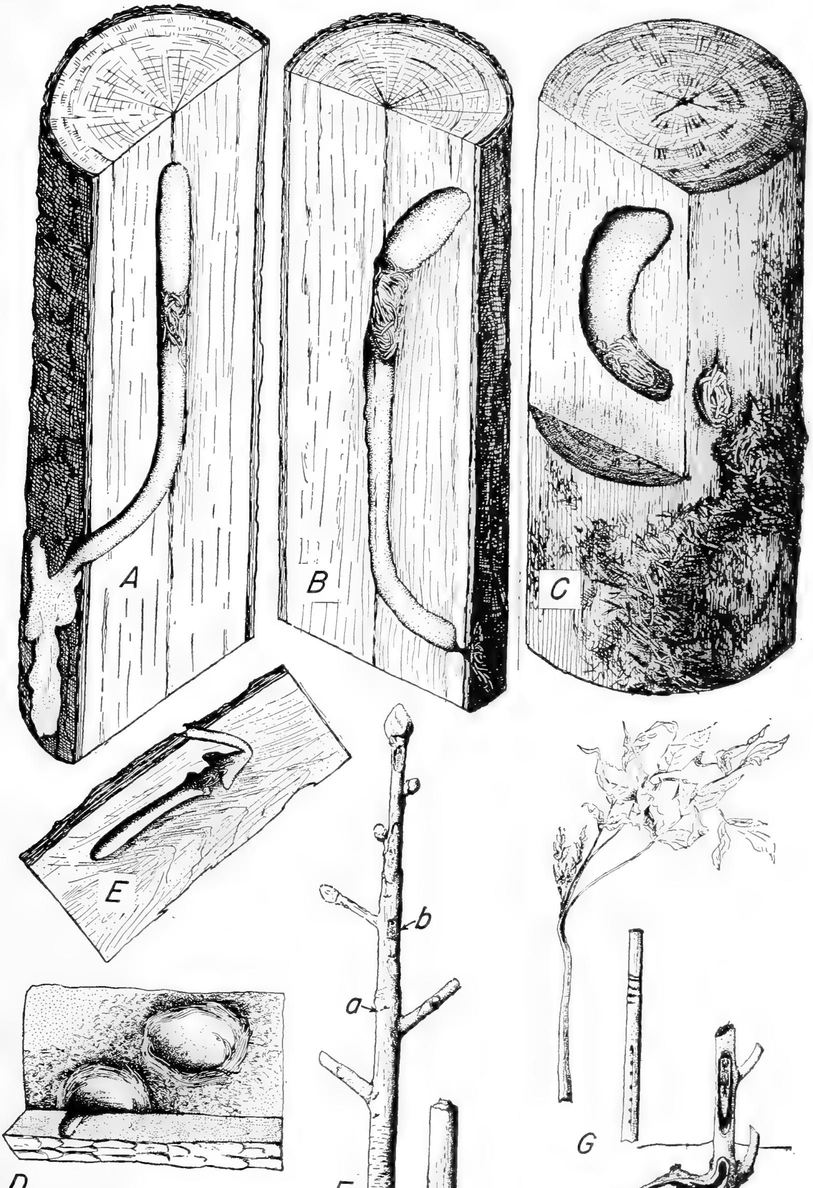

FIGURE 54.—Work of cerambycids: *A*, Larval mine and pupal cell of *Romaleum rufulum* in oak; *B*, larval mine and pupal cell of *Goes tigrinus* in oak; *C*, larval mine and pupal cell of *Monochamus scutellatus* in pine; *D*, pupal cell of *Stenocorus lineatum* in pine; *E*, pupal cell of *Oeme rigida* in juniper; *F*, hickory twig severed by *Oncideres cingulatus* showing egg and feeding scars; *G*, diagrammatic illustration of work of *Oberea ocellata* in sumac.

The mines are loosely filled with granular frass, some of which may fall out and reveal their presence. This frass forms a distinguishing characteristic, being composed of tiny pellets and fine, powdery material. The usual larval feeding period is probably 3 years, but in many instances it may extend to 5 years or more. Pine and spruce woodwork and possibly the woods of other conifers, in rather dry situations are subject to attack and destruction by these larvae. The rafters and flooring in buildings, and bridge timbers are frequently so thorougly riddled as to necessitate replacement. The old house borer is becoming an increasingly serious pest in this country, especially with the more extensive use of second growth timber with its large proportion of sapwood. It does not attack the heartwood. Control measures for borers in seasoned timber will be found on pages 40–44.

The cedar tree borer (*Semanotus ligneus* (F.)) is a rather flattened beetle from 7 to 16 mm. in length. The thorax is dark, rounded, and hairy, except for several shining spots on the disk. The elytra are sometimes black, but usually dark blue marked with yellow or orange. It is found throughout the United States, principally in cedars and junipers, but also in practically all coniferous trees, though rarely in pine.

The larva is of shining texture having the head wider than long and the apex of the mandible rounded. There are no ocelli, but the cheeks, or gena, have many recurved bristles. The pronotum is rugulosely striate and the ampullae granulate. Legs are present. The larvae feed beneath the bark and on the sapwood of dying and recently dead cedars, tightly packing the mines with granular frass.

The adults fly in the spring of the year, laying eggs beneath scales of bark of dying or recently cut trees. The galleries are excavated beneath the bark, deeply scoring the wood, and are tightly packed with granular frass. Pupation takes place in a cell in the sapwood behind a plug of fibrous frass. The life cycle is completed in 1 year. Rustic work is often damaged. The insect may be controlled by measures outlined on page 38.

The flower-loving long horns of the genera *Leptura* and *Anoplodera* are rather robust, sometimes elongate but usually more or less triangular-shaped beetles. They vary greatly in size, some being small, others quite large and nearly always prettily colored and hairy about the head and thorax. They are quick, active insects, usually found on flowers. The larvae are with difficulty separable from other related genera and are treated as a group. They are elongate, cylindrical, tapering posteriorly, and of rather smooth and shining texture. The head is circular, wider than long, strongly protruded, and the mandible is sharply pointed at the apex. From one to three ocelli are present. The pronotum is shining and the ampullae covered with four rows of shining tubercles. No spines are developed on the last segments. The legs are quite large. The many species are widely distributed throughout the United States, the larvae feeding in dead, usually moist, wood.

The adults can be found on flowers from late in the spring until late in the summer. They lay the eggs in crevices of bark or wood in moist situations, and, as a rule, follow the attack of other insects. Little preference is shown for any particular species of host plant. The larvae feed from 1 to 3 years in the wood, excavating extensive galleries packed with fibrous frass. They continue to oviposit in and reinfest the wood until it is completely disintegrated. Very few species complete the development in 1 year. Wood in contact with the ground, as poles, cross ties, and similarly located material, are attacked and often completely destroyed. Certain species feed in the heartwood of living trees when they can gain entrance through some wound, and continue the work until the center of the tree is completely honeycombed.

Anoplodera (*Leptura*) *nitens* (Forst.), **the chestnut-bark borer,** is an elongate, robust beetle from 10 to 15 mm. in length, of a velvety black ground color, marked with golden yellow bands, occurring on the margins of the thorax, and four on the elytra, the latter being broader at the middle. The larva can be distinguished from species of *Leptura* by its more depressed form and the fine asperities on the tubercles of the ampullae. It feeds in moist, thick bark at the base and in crotches of living chestnut and oak trees in the Eastern States.

Shortly before the chestnut is in blossom and throughout the remainder of that summer the adults can be found on flowers. They lay the eggs in crevices of the thick bark at the bases and in crotches of branches of living trees. The larvae feed in the bast tissue, sometimes destroying the cambium and making very extensive mines packed with fibrous frass, or some frass may be exuded. Two or 3 years is required to complete the development. Pupation occurs in an oval cell in the bark. After the advent and spread of the chestnut bark disease, this insect became abundant in the cankers of this fungus. In such situations they develop more rapidly and propagate in enormous numbers. Very rarely does the feeding of this larva seriously injure the tree, but occasional instances have been noticed where it killed large patches of bark. Its habits of making wounds in the living bast, permitting the entrance of the spores of the chestnut bark disease, played an important part in the rapid destruction of the host.

A number of roundheaded borers, principally the species of *Leptostylus* Lec., *Liopus* Serv., *Lepturges* Bates, and *Hyperplatys* Bates, feed in the adult stage on the spores and pustules of bark fungi. They are all small, rather stout or somewhat depressed beetles, usually of a dark brown or grayish appearance, more or less marked or spotted and having a spine on each side of the thorax. The most common one, *Astylopsis* (*Leptostylus*) *macula* (Say), **the chestnut blight spore feeder,** is brownish with a whitish stripe on each side of the thorax and a broad irregular white blotch on each wing cover. The larvae are usually depressed and legless, having the head longer than wide, the pronotum often dark velvety pubescent (*Leptostylus* and *Hyperplatys*) or shining, and the ampullae bearing irregular tubercles (*Leptostylus* and *Liopus*) or two regular rows (*Lepturges* and *Hyperplatys*). They feed beneath the bark, packing the mines with fibrous frass and pupating either in the bark or in the outer sapwood. The chestnut blight spore feeder has become adapted to feeding in the cankers of the chestnut-bark disease and there develops in great numbers. In infestations of this disease several years old the beetles have become so numerous as to feed on and destroy 75 percent or more of the pustules. Under such conditions they presumably have a marked beneficial effect.

Stenodontes (*Mallodon*) *dasystomus* (Say), **the hardwood stump borer,** is a very large, elongate, somewhat flattened, reddish-brown beetle from 30 to 45 mm. in length, having the sides of the prothorax armed with many small flat teeth. The head is large. The larva is large and cylindrical, with a smooth shining skin, having the head wider than long, retracted into the prothorax, and the front produced in a smooth transverse carina, or scarcely projecting. Two small groups of 5 to 12 chitinous points are found on the under side of the prothorax. The ampullae bear two transverse impressions. Legs are present.

The larvae feed gregariously for 3 or 4 years in the heartwood of living trees, particularly in the bases, making large mines which are packed with coarse fibrous frass. They completely honeycomb the heartwood of willow, oak, boxelder, sycamore, and other hardwoods from Virginia south and west throughout the Southwestern States. The pupal cell is constructed deep in the wood, closed behind by a fibrous plug of frass. The adult gnaws out through the wood in mid-summer. Cross ties and similar material in contact with the ground are often badly damaged. The heartwood of shade trees often becomes infested, and an entire tree may be hollowed out, frequently resulting in its breaking over during a storm. For the control of such borers see page 24.

A related species of the hardwood stump borer, *Archodontes* (*Mallodon*) *melanopus* (L.), is injurious to trees in the Southern and Southwestern States. It is recorded as injurious to the roots of living oaks, causing the formation of large galls and often killing the trees or causing stunted growth.

Four species of *Monochamus* are of economic importance in the East: **The southern pine sawyer** (*M. titillator* (F.)) in the Eastern and Southern States, **the white-spotted sawyer** (*M. scutellatus* (Say)) throughout the United States, except the southern part, **the northeastern sawyer** (*M. notatus* (Drury)) in the Northern States, and **the balsam-fir sawyer** (*M. marmorator* (Kby.)) in the Northern States. These are large, elongate, cylindrical beetles from 15 to 30 mm. in length, black to brownish-black, and more or less mottled with whitish or grayish pubescence. The thorax is cylindrical, having a spine at each side, and both the antennae and legs are very long.

The larvae are elongate, somewhat flattened, or cylindrical when full grown, having the head longer than wide and very depressed, and the mandibles obliquely pointed at the apex. The pronotum is posteriorly brownish and finely asperate, and the dorsal ampullae bear four rows of finely asperate tubercles. They are legless. Boring beneath the bark of recently killed or felled pine, spruce, and balsam-fir trees, the larvae fill the mines with fibrous frass (fig. 54, *C*).

Shortly after the pine pollen is shed, the adults appear and gnaw oval pits through the bark of trees felled or killed the preceding spring or winter and insert from one to several eggs in each. The young larvae bore beneath the bark for 40 to 60 days, converting the inner bark and wood into coarse shredded frass. Much of the frass may be exuded. Later the larvae enter the wood to make a deep **U**-shaped cell through the sapwood and heartwood, the entrance being plugged with frass, while the opposite end is enlarged into a pupal cell. Pupation occurs in the following spring or early summer, and the adult gnaws a round hole out through the wood and bark the same season. In the South the development is completed in less than a year. These borers render unfit for use great quantities of storm-felled pines and logged material if the logs are allowed to lie in the woods over the summer season. *Monochamus marmorator* attacks standing green balsam firs and hastens the death of trees weakened from other causes, such as defoliation or root fungi. Control measures suited to these borers are given on page 38. Webb (*426; 427*) discusses these species.

A moderate-sized, elongate, subcylindrical beetle, from 15 to 18 mm. in length is found in the Eastern and Central States and southwest to Arizona in ash, mesquite, and, rarely, in white oak. This beetle, *Neoclytus caprea* (Say), **the banded ash borer**, has cross bands of yellowish-white on the front margin of the thorax and four on the elytra, the first two meeting, almost forming circles. The tips of the elytra are yellowish white, and the thorax has a longitudinal ridge on the center. The larva is robust, cylindrical, and rather hairy, having the head wider than long, the anterior ventral margin very thick, the mandibles rounded at the apex, and one pair of ocelli. The pronotum is posteriorly dull white and finely granulate, as also are the broad flat ampullae. The legs are very minute.

Early in the spring when the red maples are blossoming these adults fly to ash logs cut during the winter and deposit their eggs in crevices of the bark. The young larvae feed for several weeks beneath the bark before entering the wood, where they continue to feed until late in the summer. The entire sapwood is honeycombed with mines which are tightly packed with granular frass (fig. 55, *A*). The borer transforms to the adult in the fall but does not gnaw an exit hole until the following spring. A complication of the life history ensues when infested logs are sawed and stored. When the wood is dried out the larvae feed for several years and emerge at irregular intervals. Serious damage results to ash logs left in the woods or stored with the bark on. The adults do not oviposit on the seasoned wood; consequently, most of the infestation occurs before the material is sawed. Occasionally some operators find the entire winter cut rendered useless for any purpose because of the work of these larvae. The control of these borers is discussed on page 38.

The red-headed ash borer (*Neoclytus acuminatus* (F.)) is an elongate, slender, cylindrical beetle from 6 to 18 mm. in length, reddish brown marked with yellow cross bands on the elytra. The thorax bears four to six small transverse ridges on the median longitudinal ridge. The larva resembles *N. caprea*, from which it can be distinguished by the anterior ventral margin of the head, which is smooth and not thickened, as in that species. It feeds in the unseasoned wood of numerous hardwood trees, completely honeycombing the sapwood and packing the mines tightly with granular frass. Although the range is similar to that of *N. caprea*, this species attacks nearly all hardwoods, but chiefly ash, oak, hickory, persimmon, and hackberry.

In the extreme South some of these beetles emerge very early in the spring (about the middle of February), and they are on the wing from then on until the middle of November. About 3 months is required to complete the development from egg to adult, and much overlapping of generations occurs. Another heavy flight of adults occurs late in May and in June. In the North but one generation

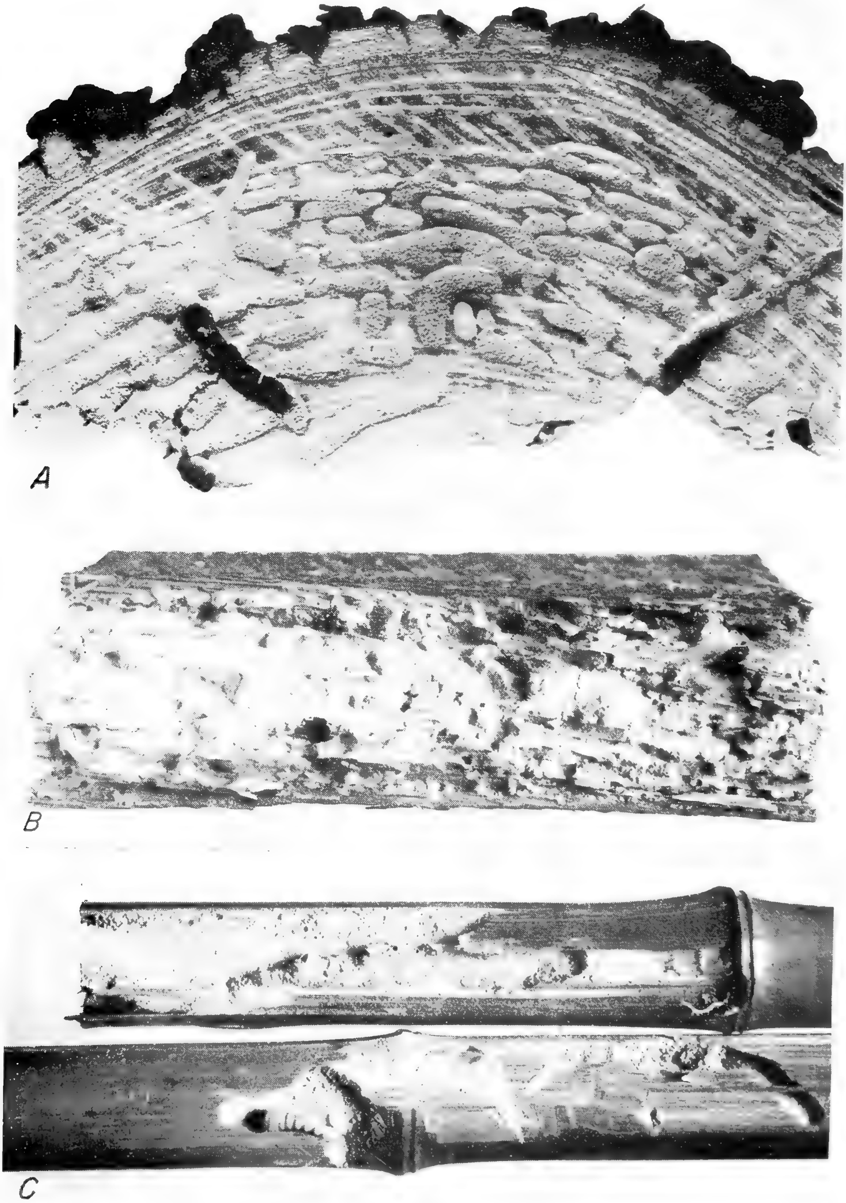

FIGURE 55.—Work of cerambycids: *A*, *Neoclytus caprea* in ash; *B*, *Hylotrupes bajulus* in pine floor; *C*, *Chlorophorus annularis* work in bamboo.

matures each year, the beetles appearing in June. The young larvae feed from 4 to 6 weeks beneath the bark, then enter the sapwood and completely destroy it. The pupal cell is constructed near the surface of the wood, the adult gnawing the exit hole.

Frequent serious loss is reported of ash, hickory, and oak logs left exposed during the flight of these insects. Only unseasoned material containing bark is attacked. Cuts of over one million feet of ash logs completely destroyed by these borers have been observed. For control see page 38.

The *Oberea* beetles are very slender, elongate, cylindrical stem borers of variable size. The front is moderately convex, the eyes are emarginate, and the antennae are not longer than the body. The thorax is cylindrical and unarmed but usually bears spots of contrasting color, and the last joint of the hind tarsus is rather long. The larvae are very elongate, slender, and cylindrical, having the head longer than wide, and nearly circular in cross section. The pronotum is posteriorly armed with strong recurved asperities and bears two dark, oblique, deeply impressed lines. Also the ampullae project prominently and bear fine erect asperities. Practically all the species are of economic importance, and control, where needed, may follow the suggestions given on page 24. The adults can be recognized by the color pattern and the larvae by host plant and habits.

Oberea ferruginea Casey, **the willow-branch borer,** is a uniformly pale reddish beetle from 10 to 11 mm. in length, having four black spots on the thorax arranged in a semicircle and a dark spot at the humeral angle of each elytron. The larva feeds in the stems of willows, hollowing out the center and ejecting the frass. The egg scars are characteristic, shaped like a horseshoe. The smaller branches of willows are sometimes killed in the Rocky Mountain and Plains regions.

The adult of *Oberea ocellata* Hald., **the sumac-stem borer,** measures from 13 to 15 mm. in length and the underside of the body, the head, and the thorax are red, and the thorax has two black spots on the disk. The elytra are black. The larva feeds in the stems and roots of sumac, girdling the plant at the surface of the ground. It occurs throughout the Eastern and Central States. After the new growth of the sumac is fully formed the adults appear and girdle these tips. Just beneath this girdle an egg is placed. The young larva bores down through the pith to the roots, where it feeds for two seasons, excavating long tunnels in the center of the roots. Much frass is exuded through an opening near the surface of the ground and from holes along the stem (fig. 54, *G*).

In the fall of the second summer the plant is cut off near the surface of the ground by an oblique incision, and the stub is plugged with a wad of frass. A short distance beneath this plug pupation takes place the next spring. In plantations of ornamentals this insect can be of considerable economic importance. Sumac plantings are frequently injured by the cutting off of stems from ½ to ¾ inch in diameter.

Oberea myops Hald., **the rhododendron stem borer,** is from 12 to 16 mm. in length. It is a pale yellow, with two black spots on the thorax and only the margins of the elytra darker. The head is yellow. The larva feeds in the stems of rhododendron, laurel, azalea, and re-

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lated plants, cutting off the plants near the surface of the ground and boring down into the roots. The habits in all respects are similar to those of *O. ocellata.* This is a serious pest in ornamental plantings of rhododendron. It seems to be well distributed through the Northeastern States, and frequent reports are received relative to damage caused by it. Early in the summer the tips of the branches are girdled by the adult.

The adult of *Oberea ruficollis* (F.), **the sassafras stem borer,** ranges from 15 to 18 mm. in length. It is pale reddish-yellow, with the antennae, tibiae, and tarsi black, the elytra are densely clothed with gray pubescence. The larva bores in the stems and roots of sassafras, making a series of round holes along the stems for the exudation of frass. The habits of this species are similar in all respects to those of the sumac stem borer, except that only rarely are the stems cut off at the base by the larvae. The plants are more often badly deformed than killed.

The adult of *Oberea schaumi* Lec., **the poplar twig borer,** is from 11 to 16 mm. in length. It is usually pale yellow, with the antennae and elytra often black, and with four round, smooth spots arranged in a curve on the thorax.

Early in the summer, throughout the Central States, the eggs are laid in the small twigs of poplars, often three or four in the same branch. The larva feeds in the small branches under the bark, causing the death of the twigs, which still hang onto the tree. The appearance of shade trees is often greatly marred by large numbers of these dying twigs. Numerous complaints are received from the Mississippi Valley of the injury done by this insect to poplars.

The adult beetle of **the dogwood twig borer** (*Oberea tripunctata* (Swed.)) measures from 10 to 15 mm. in length. It is usually yellow, with three black spots on the thorax, and the wing covers are blackish along the sides and down the middle.

Early in the summer, in the Eastern and Central States, the adult appears, and after girdling the tip, deposits the eggs in living twigs of elm, dogwood, viburnum, and many fruit trees. The larva feeds down the center of the branch, making a long series of closely placed round holes for the exudation of frass. At intervals it cuts off parts of the twig from within, proceeding on down into the green wood. It pupates between two wads of fibrous frass and may or may not previously girdle the portion containing the cell. The development is usually completed in 1 year. Ornamental shrubbery is injured by the girdling of the branches. This borer seldom appears in numbers.

The beetles of the genus *Oncideres* are stout, very cylindrical insects of medium to large size. They are dark gray or grayish brown, often prettily marked. The antennae are as long or a little longer than the body. The thorax often has a spine on each side. The larvae are cylindrical, shining borers, having the head longer than wide and the anterior margin of the front beset with a transverse row of short carinae or ridges. The pronotum is raised, very shining, and finely striate; and the ampullae bear two, or rarely three, regular rows of tubercles. The larvae are legless (Linsley *276*).

Three species have been recorded as of economic importance in the Eastern, Southern, and Southwestern States. The habits are so similar that they can all be treated alike.

The twig girdler (*Oncideres cingulatus* (Say)) is found in the Eastern States in hickory, persimmon, elm, poplar, gum, basswood, honey-locust, dogwood, and some fruit trees (fig. 54 *F*). *O. texanus* Horn, **the pecan twig girdler,** is found in Texas in leguminous plants, and *O. pustulatus* Lec., **the huisache girdler,** occurs in the Southwestern States, in huisache, mesquite, and acacia (High *225*).

Late in the summer or early in the fall these beetles appear and feed on the thin bark of twigs before laying their eggs. The adult female girdles branches of the host tree by cutting a circular incision through the bark and deep into the wood. The twigs so girdled range from ¼ inch to 1½ inches in diameter in the larger species. In these twigs the eggs are deposited in small scars gnawed through the bark. These branches soon die, and most of them fall to the ground. Until the middle of the following summer the larvae feed in the wood, loosely filling the mine with frass, although much of the frass falls out. The pupal cell is firmly walled with fibrous frass. One year is required to complete the development, but in more northern localities many of the larvae feed through the second year before pupating. A high mortality occurs in the larval stage, owing to there being too many borers in the same twig or to excessive drying of the branches.

These beetles become so numerous at times that trees are badly deformed, dozens of branches often being cut from a single tree. Young hickory seedlings are frequently cut off near the ground.

Control of these borers may be obtained by following the measures outlined on page 23.

The adults of the genus *Oeme*, **the cypress and cedar borers,** are elongate, slender, light- to dark-brown beetles, from 12 to 22 mm. in length. The thorax is subglobose and constricted at the base. They occur throughout the eastern part of the United States, the Rocky Mountains, and the Southwest in cypress, cedars, junipers, and pines. The larvae are of an elongate, slender form, having the head wider than long, the mandible rounded at the apex, and the anterior ventral margin of the mouth frame squarely emarginate in the middle. One ocellus is present on each side of the head, surrounded by many recurved hairs. The pronotum is smooth and shining, and the ampullae are alutaceous and shining. Legs are present. The larvae bore beneath the bark of dying or dead conifers, exuding granular frass and constructing a peculiar pupal cell.

The hosts and habitats of three species are known. *Oeme rigida* (Say) occurs throughout the Eastern States in juniper and cypress, *O. costata* Lec. in the southern Rocky Mountains and Southwest in pines, and *O. strangulata* Horn through the Southwest in cedars and junipers. The adults fly early in the spring or late in the summer, according to locality, laying the eggs beneath scales of bark of recently cut or dying wood. The larvae feed beneath the bark, exuding large quantities of granular frass, and later enter the wood, often completely riddling smaller logs. The very peculiar pupal cell is illustrated in figure 54, *E*. It is opened through the bark but plugged farther back by a wad of fibrous frass. Normally 1 year is required to complete development. Deadened cypress, and rustic work constructed from wood that has not been thoroughly seasoned, is often severely injured, causing the bark to peel off or even the destruction of pieces of wood from 1 inch to 3 inches in diameter.

Control measures given on page 38 should be followed.

Orthosoma brunneum (Forst.), **the brown prionid** is a large, elongate, flattened beetle from 22 to 40 mm. long, dull reddish brown, with the sides of the prothorax margined and bearing three sharp teeth. The larvae are elongate, cylindrical, and of very shining texture. The head, wider than long, is retracted into the thorax, and has the front produced in two transverse, sharp-edged, dentate carinae. The dorsal ampullae bear two transverse impressions. Legs are present. These insects feed gregariously in coniferous or hardwood trees that have been dead several years in moist situations, making large mines packed with coarse fibrous frass. They are found in the Atlantic States and the Middle West.

Like other prionids, the adult flies late in summer after the flowering of the chestnut. The female inserts her eggs in the wood of timbers that have been dead for several years. The larvae make extensive excavations tightly packed with coarse fibrous frass. When they feed in large numbers in moist heartwood, little is left of the original wood. Overly wet wood is not favorable to the feeding of this insect. The pupal cell, deep in the wood, is plugged behind with fibrous frass, the opening to the exterior being made by the adult. Under favorable conditions the larva matures and pupates within 2 years, but more commonly 3 years is required. About 1 month is passed in the pupal stage. Cross ties, telephone poles, and all structural timbers in contact with the ground or in moist exposed situations are subject to injury by this insect. Since several generations continue to feed in the same timbers and because the larval mines are so extensive, serious destruction follows. Control may be effected by the methods given on page 43.

Parandra brunnea (F.), **the pole borer,** is an elongate, oblong, somewhat depressed, brown beetle, from 9 to 18 mm. in length. The prothorax is subquadrate, having the sides and wing covers margined. The fourth joint of the tarsus is distinct. The larva is elongate, slightly tapering posteriorly, having the head wider than long and retracted into the prothorax. The mandibles are sharply pointed. The pronotum is coarsely asperate, the ampullae are finely wrinkled, and the legs are developed. This larva bores gregariously in the dead, but moist, heartwood of practically all hardwood and many coniferous trees in contact with the ground and also in cavities in living trees throughout the United States east of the Rocky Mountains.

The adult appears shortly after the blossoming of the chestnut, laying a large number of eggs deep in any exposed heartwood. In this wood the larvae feed gregariously for 3 or 4 years, completely honeycombing it and packing the mines with granular frass. The oval pupal cell constructed in the wood is plugged behind with a wad of fibrous frass. Pupation takes place about a month before the adults emerge. This is one of the most destructive borers attacking shade trees, cross ties, telephone and telegraph poles, and any structural wood in contact with the ground or in moist situations. A small wound near the base of a living tree may offer a place of entrance for the young larvae, which will continue to feed in the heartwood until nothing remains but a shell of sapwood. Under certain circumstances the adults do not emerge but mate and lay eggs in the same cavity in which they are working. Often the wound where they gained entrance heals over and shows no sign of their presence. It is a most important factor contributing to wind breakage of shade trees. For control, see pages 24 and 38.

Phymatodes testaceus (L.), **the tanbark borer,** is an elongate depressed beetle from 8 to 13 mm. in length. The thorax of this borer is rounded and yellowish, and the elytra may be either yellowish or blue. The larva is somewhat depressed, having a thick, shining skin, the head wider than long, one black ocellus beneath the chitin, and the apex of the mandible rounded. The pronotum is irregularly striate to granulate behind, and the ampullae are covered with small flattened granulations. Legs are present. The larva feeds beneath or in the bark of dead oaks and sometimes in stored hemlock bark in the Eastern and Central States.

The adults fly in the spring, laying eggs beneath scales of the bark. The larval mines, extending within or beneath the bark, are loosely filled with frass. In tanbark removed from the trees the larvae mine entirely in the bark. Pupation takes place in the bark or sapwood. The life cycle may require 1 year, 2 years, or longer. This insect is of economic importance only when it attacks bark of oak and hemlock stored and piled for tanning purposes. Under such conditions it will often destroy a great quantity of the material. A. D. Hopkins reports the destruction of over $50,000 worth of bark at one tannery. To avoid such losses the bark should be used before it is 3 years old.

Physocnemum andreae Hald., **the cypress bark borer,** is a rather large, robust beetle, from 11 to 21 mm. in length, and of a reddish-brown color. Near the base of the thorax occurs a small tubercle and on each elytron a white arcuate mark. The femora are club-shaped. The larva is elongate and slightly depressed, having the head wider than long, and the apex of the mandible rounded. The pronotum is irregularly striate, and the ampullae are alutaceous and shining, with the last two ventral ones corneous at the sides. Legs are present. The larva feeds between the bark and wood of recently dead or dying cypress.

The adults fly early in the summer, laying the eggs beneath scales of bark. The larvae feed beneath the bark and excavate very large mines packed with granular frass, and deeply scar the sapwood. The pupal cells are constructed the following spring in the sapwood, the adults chewing their way out through the bark. In lumbering operations in the cypress swamps of the South this insect causes much damage to the wood of felled and girdled cypress. Often the sapwood is completely destroyed. It is also injurious to rustic work constructed from these trees. Control measures for use against this insect are given on page 38.

Physocnemum brevilineum (Say), **the elm bark borer,** is an elongate, depressed, bluish-black beetle, from 12 to 16 mm. in length. The thorax is subglobose with a rounded tubercle on each side near the middle, and each elytron bears three short raised whitish lines. The femora are clubbed. The larvae resemble those of *P. andreae* but lack the chitinous plates on the last ventral segments. They feed in the corky bark of living elm trees in the eastern part of the United States.

The adults appear late in the summer and deposit the eggs beneath scales of the bark on living elm trees. The larvae excavate meandering galleries packed with granular frass in the living bast tissue, sometimes reaching the xylem. Two years are sometimes required to complete the life cycle.

The feeding causes the outer bark to scale off, and occasionally wounds penetrate into the cambium, deadening large patches of bark, which finally fall off and open the wood to attack by other insects. This borer may prove to be of importance in the transmission of Dutch elm disease. Attack by the elm borer (*Saperda tridentata* Oliv.) often follows the work of this species.

The adult of **the sugar-maple borer** (*Glycobius speciosus* (Say)) is a large, robust, somewhat elongate beetle from 23 to 25 mm. in length, black, marked with bright-yellow cross bands. The head and tip of the elytra are entirely yellow, though the latter has a black spot in the center. One of the bands near the base of the wings is W-shaped. The larva is rather large and robust, having the head wider than long. There are three ocelli on each side, and the apex of the mandible is rounded. The pronotum is posteriorly reticulate and rugulose and extends forward medianly; the ampullae are flat and dull granulate. Legs are present. It excavates long mines beneath the bark of living hard maples, exuding the frass, together with much moisture. It is present in the Northeastern States and south through the Appalachians.

The eggs are laid under bark scales or in crevices of the bark from which point the larvae mine directly between the bark and the wood, cutting a deep channel obliquely transverse to the grain of the wood. These mines frequently girdle and kill the branches or smaller trees. During the second year the larva finally bores deep into the wood to construct a pupal cell, the exit from which is opened prior to pupation. Aside from directly killing parts of the tree, the healing of the larval mines causes large unsightly ridges, wounds, or gall-like swelling on the bark surface of the branches that live. Watery exudations and sawdust are associated with the presence of living larvae. Nothing in the way of control can be done in the forest; for control in shade trees, see page 24.

The adult **cottonwood borer** (*Plectrodera scalator* (F.)) is a large, subcylindrical, robust beetle from 25 to 30 mm. in length, black, thickly checkered with white pubescence in broken transverse rows. The thorax is cylindrical with a small spine on each side. The larva is an elongate, robust, cylindrical borer, having the head flattened, longer than wide, and the anterior ventral margin very much thickened. The pronotum is posteriorly dark, velvety pubescent, and the ampullae bear four rows of tubercles. This larva feeds in the wood at the base of living poplars and willows, exuding quantities of fibrous frass. It occurs in the Central and Southern States.

The adults appear in midsummer and feed on tender bark before depositing the eggs in small pits gnawed through the bark of living trees near the surface of the ground. The larvae mine both beneath the bark and in the wood, although feeding most of the time beneath the bark and exuding considerable frass. Before constructing the pupal cell, the larva makes a hole through the bark for the adult to emerge. A period of 2 years is required to complete the development. Large numbers of young poplar and willow trees are killed where this insect becomes abundant. The larvae often completely girdle the bases of the trees, cutting off the sap movement, which results in the death of the trees. Small trees are badly damaged by the deeply gnawed egg scars. Also, the stems are greatly weakened so that the trees break off in the wind. For description and habits of this insect, see Milliken (*304*).

Control measures are given on pages 24–26 of this publication.

The root-boring prionids of the genus *Prionus* Geoff., are heavy, robust, black or brownish-black, shining beetles from 25 to 45 mm. long, having the sides of the prothorax margined and bearing three teeth. The antennae are imbricated in the males. The larvae are elongate, rapidly tapering posteriorly, with a tough shining skin. The head is wider than long, retracted into the prothorax, and the front is produced in a straight smooth carina divided in the middle. On each of the first six abdominal segments is a small radially striate disk just below the spiracles. Legs are present. Several weeks or a month after the chestnut is in full bloom the adults fly, soon laying their eggs and then dying. All the larvae studied require 4 or occasionally 5 years to mature. The pupal stage extends from 4 to 8 weeks.

These borers (*Prionus pocularis* Dalm. excepted) feed in the root bark on living trees or shrubs during the early larval stages but soon enter the wood, completely hollowing large roots and often severing them. They crawl through the ground from root to root, feeding also on the outer surfaces of the smaller roots and causing many injuries and wounds. Often the hollowed roots are here and there filled with a mixture of coarse pelletlike excrement and coarse fibers and earth. In the early spring months the matured larvae come to within 3 to 5 inches of the surface, where they make a large oval cell of compact earth in which the pupal stage is passed.

It is difficult to estimate the extent of the injury resulting from feeding by these borers. They are very often associated with the *Armillaria* root disease and seem to prefer mature trees in open stands. These borers are abundant in pastures and hill slopes on gravelly well-drained soil, in places where the trees grow under unfavorable conditions, and in much-used parks where the ground is packed and no humus is present. On certain park areas where these insects were abundant many roots were badly eaten and many were completely severed. For many years these trees were under observation by Dr. Hopkins, who says that they gradually died limb by limb. The foliage appeared irregularly and was thinner and lighter in color on many branches than healthy foilage. Under other conditions where the soil was poor, no humus was present, and certain root diseases and secondary insects were associated with these borers, malformation and death of the trees was very rapid. It is believed that the presence of these borers in numbers usually indicates other unfavorable conditions under which the trees are struggling.

Shrubbery and small trees are attacked by certain species of these borers, and the roots may be occasionally cut off near the surface of the ground, resulting in rapid death of the plant. Four species may be mentioned by name.

The tile-horned prionus (*Prionus imbricornis* (**L.**)) occurs most commonly through the Southeastern States and is probably the most injurious of the species here considered. It is chiefly found on oak and chestnut but will attack other hardwood trees. **The California**

prionus (*P. californicus* Mots.) is economically as important as *P. imbricornis*. It occurs throughout the southern Rocky Mountains and the Pacific States, chiefly in oaks but also in sumac (*Rhus*) and other shrubby plants. **The broad-necked root borer** (*P. laticollis* Drury) occurs most abundantly through the Northeastern States. Its habits are similar to other species of *Prionus*, but it is more commonly found on smaller trees, fruit trees, and shrubs. *P. pocularis*, **the pine-stump prionus,** is the only species of this genus that has not been found in living trees but only in dead coniferous logs and stumps. It occurs in the Middle Atlantic and Southern States and is of little economic importance except occasionally in cross ties. It is rarely abundant enough to do any serious damage to timbers in use.

Ptychodes trilineatus (L.), **the fig-tree borer,** is a large, elongate beetle, from 18 to 25 mm. in length, and widest about the middle. It is uniformly grayish in appearance, marked with small, reddish-yellow spots and has three irregular, white stripes along the entire body, one median dorsal and one on each side. The larva is an elongate, robust, cylindrical borer having the head very flat and longer than wide. The posterior portion of the pronotum is dark, velvety pubescent, and the dorsal ampullae bear four rows of shining tubercles. Beneath the anal lobes occur a group of 5 to 8 short acute spines. Legs are present. It feeds in the trunks and branches of living and dying fig trees and occasionally in alder, excavating mines in the wood and exuding fibrous frass. It is found in the Southern and Southwestern States.

The females lay their eggs early in summer in small holes gnawed through the bark. For some time after hatching each larva feeds beneath the bark, often girdling the limbs before entering the heartwood to make a long mine, at the top of which the pupal cell is constructed. Much frass is exuded by the larva, and the adult gnaws the exit hole. Several years are normally required to complete the development. These larvae seriously injure figs and alders, often killing branches or small trees. For control of this borer see page 24.

Stenocorus lineatus Oliv., **the ribbed pine borer,** is a rather robust, dark beetle from 13 to 18 mm. in length, completely mottled with grayish pubescence. The thorax is cylindrical, bearing a spine on each side, and the elytra each bear three strongly raised lines. The larva is elongate and very depressed, having a flat, extended head wider than long, with mandibles deeply notched at the apex. The pronotum is smooth and shining, and the ampullae are dull, finely pubescent, and feebly tuberculate. Legs are well developed.

Very early in spring the adults emerge and lay the eggs in crevices of the bark of dead pines and many other conifers cut or dying during the winter. The larva feeds entirely beneath the bark, filling the space with great quantities of fibrous frass. Late in the summer it constructs an oval nestlike pupal cell (fig. 54, *D*) of fibrous frass and an exit hole extended almost through the bark, then pupates and transforms to an adult, overwintering in this form.

The species is found throughout the United States, but is of no economic importance, as it never injures the wood. It is mentioned because of its abundance and because it is so frequently found along with injurious species.

Romaleum rufulum (Hald.), **the red oak borer,** is an elongate, subcylindrical beetle from 22 to 28 mm. in length, brownish, with spots of lighter pubescence. The thorax is cylindrical, with two small tubercles on the disk and a triangular smooth spot behind. The larva is elongate, robust, and of a shining texture. The head is wider than long and has one large ocellus on each side. The apex of the mandible is rounded. The pronotum is shining and irregularly striate, and the ampullae are alutaceous and shining. Legs are present.

The adults appear when the chestnut and chinquapin are in bloom and lay the eggs beneath scales of bark on living oak trees. The young larva feeds the remainder of that season and the early part of the following beneath the bark in the cambium, killing a large spot of bark and exuding granular frass from a hole which is enlarged as the larva grows. Moisture also flows from this wound conspicuously marking the point of injury. During the second season a large excavation is carried directly upward and into the heartwood, at the top of which the larva pupates behind the plug of fibrous frass (fig. 54, *A*), after cutting a hole through the bark for the adult to emerge.

The insect is found throughout the Eastern and Central States, where locally a large percentage of the oaks are attacked, causing defects and serious degrade in the timber. Ants and fungi entering these wounds extend the injury. Occasionally the beetles become numerous enough to kill branches or the entire tree. Such is the case in some southern parks and cities, where hundreds of fine old shade trees have been lost. All sizes of trees are attacked, but large mature trees seem to be preferred. For useful control methods see page 24.

Both the adult and larva of *Romaleum cortiphagus* Craighead and Knull, **the oak-bark scarrer,** very closely resemble the preceding insect, but the larva can be distinguished by small transverse wrinkles across the under side of the head, whereas in *R. rufulum* this region is longitudinally wrinkled. It feeds only in the thick bark of mature oak, causing a characteristic scar on the surface of the bark. It occurs in the Eastern States and west through the Ozark Mountains.

The adult appears while the chestnut or chinquapin is in full bloom, or a little later, and deposits the eggs in crevices of the bark. The larvae feed at first in the thick ridges of the bark, going deeper as they increase in size. The mines are tightly packed with granular frass. After 3 or more years they burrow deep into the inner bark, where a large excavation is made for the pupal cell. This cell usually injures the cambium, resulting in a large black defect, which defaces many annual layers of growth and causes the formation of the characteristic scar on the outer surface of the bark. This defect is commonly found in the wood of large thick-barked oak trees throughout the Appalachian Mountains and westward, and causes considerable degrade of the lumber. No practical control measures can be recommended in the forests. The utilization of the bark of certain species of oaks for tannin extract destroys many of the larvae.

The borers of the genus *Saperda* F. are large to medium-sized, cylindrical, variously colored beetles. The front of the head is quadrate and very flat, the antennae are about as long as the body, and the thorax is cylindrical and without spines or tubercles. The first joint of the hind tarsi is quite elongated. The larva is elongate, cylindrical in form, having the head longer than wide, and the mandible obliquely pointed. The posterior part of the pronotum is covered with coarse recurved asperities and never bears the two dark oblique impressed lines, as *Oberea* (p. 255). The ampullae also bear fine erect asperities. They are legless. A number of these species are of considerable economic importance. They can be recognized as adults by the color pattern and as larvae by the host plant and their work.

The poplar borer (*Saperda calcarata* Say) is from 21 to 30 mm. in length, reddish brown, and densely clothed with gray and yellow pubescence. It has three yellowish stripes on the thorax and lines and blotches of orange yellow on the elytra. The larva (fig. 56, *A*) feeds in the trunks of living poplars throughout the United States.

In early to late summer, according to the locality, the adults fly and feed on the bark of the young twigs or leaf bases. The female gnaws an oval hole through the bark in which one or two eggs are inserted. In about 3 weeks the young larva hatches and extends its mines beneath the bark. Not until the next season does it enter the wood, in which it continues to feed until matured. The fibrous frass is exuded in large quantities from a hole marking the point of oviposition. This hole is enlarged as the larva grows, and through it the adult emerges. The pupal cell is at the end of the gallery in the wood and is plugged beneath by a wad of fibrous frass. Three years is required to complete the life cycle.

Hofer (*227*) considered this one of the most serious pests of poplars. Small trees are often killed by the larvae girdling beneath the bark, but greater damage results from the decay in the abandoned mines and the breaking off of the trees where the heartwood has been weakened. Poplar plantations have been totally ruined. Shade trees also suffer severely. Almost all species of poplars have been found to be attacked by this insect, but a variety of the common cottonwood of the Mississippi Valley seems to be immune. For control see pages 24–26.

The roundheaded apple tree borer (*Saperda candida* F.) is about 20 mm. long, of a brownish color striped above for the entire length of the body with two bands of white meeting at the front. The antennae are gray and the under side of the body is white. The larvae feed in the wood at the base and roots of living serviceberry, thorn apple, mountain-ash, and many fruit trees in the eastern part of the United States.

Early in the summer the adults fly and deposit the eggs in small scars gnawed at the bases of the trees. The larvae feed beneath the bark for a year, then bore into the wood, making large excavations, riddling the base, and exuding much fibrous frass. Two or more years are required to complete the development. The adult gnaws an exit hole above the point where frass was exuded.

In the forests this insect cannot be considered of great importance because of the slight value of the trees in which it feeds. In ornamental plantings and orchards, however, where they are of greater value, these plants are frequently attacked and killed, or the base may be so riddled that the trees are broken off by the wind. Control measures are indicated on page 24.

Saperda concolor Lec., **the poplar-gall saperda,** is a smaller species than *S. tridentata* (fig. 52), from 10 to 12 mm. in length and uniformly light gray in color. The antennae are annulate. The larva feeds in the branches of living poplars and willows, causing a swelling or gall

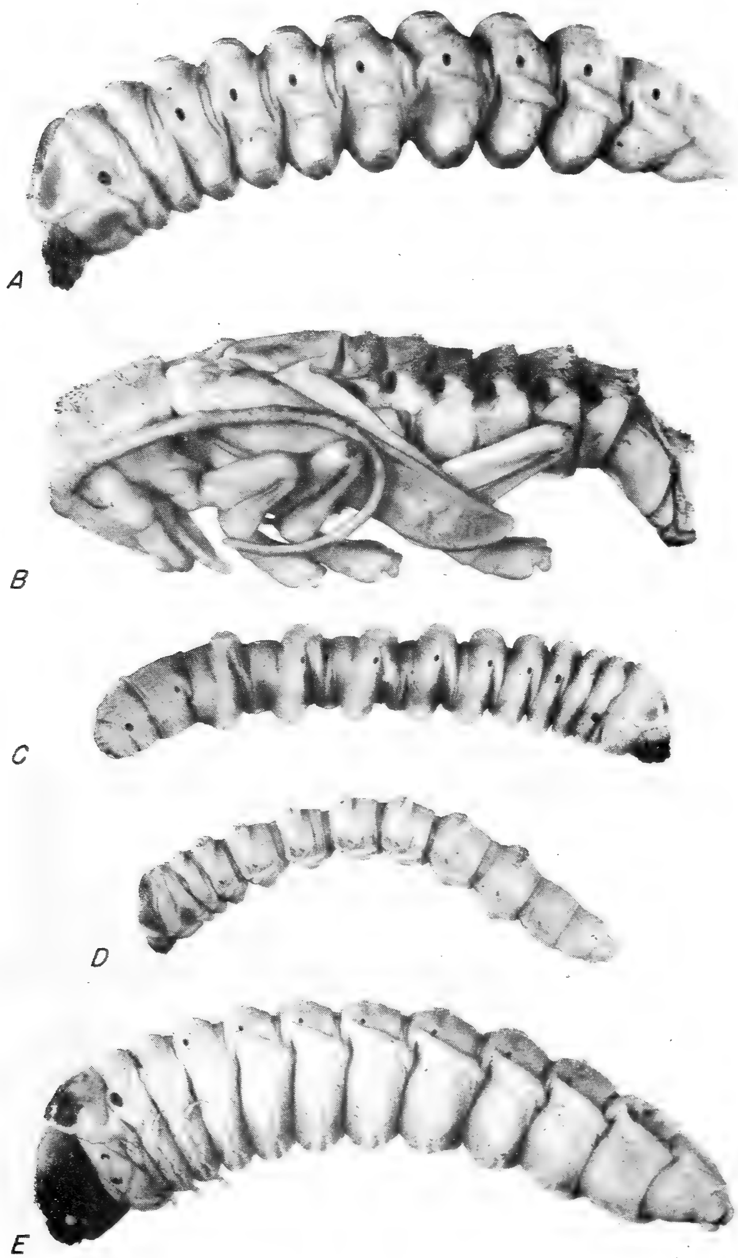

FIGURE 56.—Immature stages of cerambycid beetles: *A*, *Saperda calcarata;* *B*, pupa of same; *C*, *Aneflormorpha subpubescens;* *D*, *Oberea ruficollis;* *E*, *Leptura canadensis.*

from $1\frac{1}{2}$ to 2 inches in diameter (fig. 57). It occurs in the Eastern and Central-Western States. The eggs are laid early in the summer in a small hole gnawed through the bark. The young larvae feed beneath the bark, later entering the wood, as the gall-like swelling increases in size. Finally a straight burrow is extended up or down the center of the stem, at the end of which the larva pupates. Little frass is exuded. The galls produced by this insect on ornamental plants occasionally cause the death or breaking off of the branches. Control measures are given on page 24.

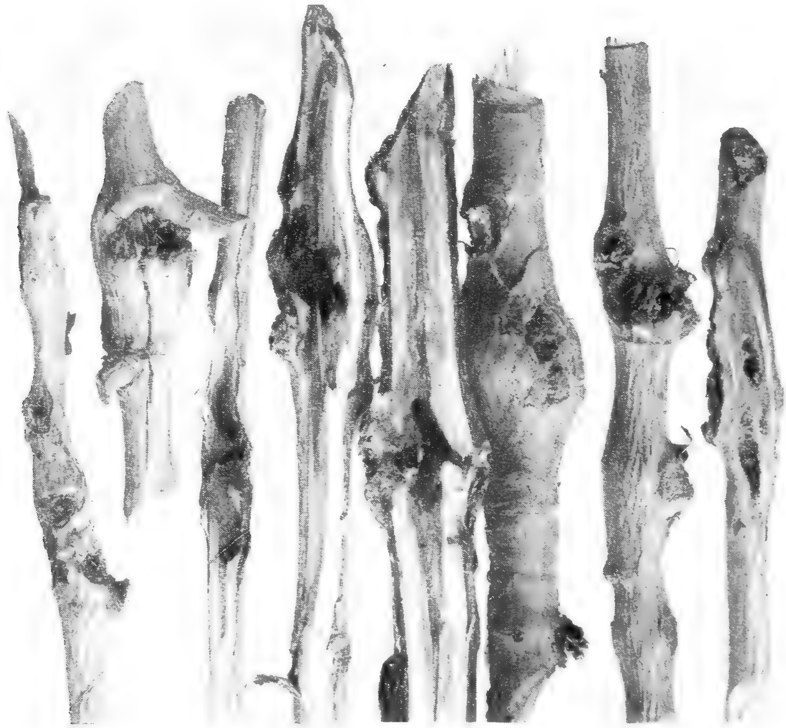

FIGURE 57.—Galls of *Saperda concolor* on poplar.

The adult of *Saperda fayi* Bland., **the thorn-limb borer,** is a small reddish-brown beetle from 10 to 12 mm. in length. The under side is gray, and the upper surface bears white blotches arranged as two stripes on the thorax, two at the base and tip of the elytra, and a large spot between these. The habits are similar to those of *S. concolor*, this species causing galls on thorn apples in the Northeastern and Central States. Another species with similar larval habits, causing galls on the stems and branches of poplar across the northern parts of the country, is *S. moesta* Lec., **the poplar-twig borer.** The adult of this species measures about 10 mm. in length, is uniformly dark gray in color, darker than *S. concolor*, and the antennae are annulate. Control measures suited to these borers are given on page 24.

The adult beetle of *Saperda discoidea* F., **the hickory Saperda,** ranges from 10 to 16 mm. in length, the female being larger than the male. The male is blackish, bearing three lines of grayish pubescence on the thorax and silvery white hairs beneath. The female is reddish brown, clothed with yellowish hairs, and the wing covers have two spots with a crescent-shaped bar between. The species occurs in the Eastern and Central States. The larvae feed gregariously beneath the bark of dying or weakened hickories and butternut, making extensive meandering mines.

The adults appear in the spring and oviposit in crevices of the bark or in holes in the galleries of scolytid beetles. The larvae feed entirely between the bark and wood, destroying the inner bark and making extensive interlapping mines packed with fibrous frass. The pupal cell is constructed in the sapwood or bark, the adult making the exit hole. Most of the larvae mature in 1 year, but an overlapping of generations occurs. Hickory trees attacked by the hickory bark beetle are usually found infested by this insect also, and trees which are attacked only in the top by bark beetles may be killed outright.

The adult beetle of *Saperda obliqua* Say, **the alder borer,** measures from 10 to 15 mm. in length. It is reddish brown, with two darker bands along the top of the thorax and four oblique bands on the wing covers. The antennae are annulate. It is found in the Lake and Northeastern States. Early in the summer the eggs are laid in a small hole gnawed through the bark at the base of the shrubs. The young larvae feed beneath the bark, often girdling the stem before entering the wood. A considerable swelling takes place at the point of attack unless the stem is killed. Much frass is exuded through the enlarged egg scar. The larva bores from 3 to 6 inches up through the stem. At the top of this mine it pupates above a wad of fibrous frass and later the adult gnaws an exit hole. The development is completed in 1 year. In parks and ornamental plantings, the alders are frequently killed by this borer. Its attack is not general, but it frequently becomes locally abundant.

The adult beetle of **the elm borer** (*Saperda tridentata* Oliv.) is from 9 to 14 mm. in length and is rather densely clothed with grayish pubescence. The thorax and elytra bear narrow orange stripes on the sides, and the latter also bear three oblique cross bars. The species occurs in the eastern part of the United States. The adults fly from early to late summer, laying eggs in small holes gnawed in crevices of the bark of weakened or dying elm trees. The larvae feed by boring beneath the bark, filling the mines with fibrous frass and completely destroying the inner bark and cambium. Usually limbs and injured portions of the trees are attacked first and from there the mines are pushed into the healthy tissue. The pupal cell is constructed either in the sapwood or in the bark. Very little frass is exuded. One year is normally required to complete the development, but many larvae fail to mature in this period and the generations overlap.

Park and shade trees are severely injured by this borer, especially old, mature trees or those in an unhealthy condition. Trees defoliated by the elm leaf beetle or caterpillars and trees closely confined in city pavements are susceptible to attack. The death of the tree is usually slow, large branches dying one after another. It is very commonly associated with trees attacked by the Dutch elm disease. This and the next species may be controlled by methods outlined on page 26. When only part of the tree is attacked, the affected branches should be cut off below all evidences of dead bark and be destroyed by burning. Should the injury be confined to a portion of the main trunk, cut away the bark back to healthy tissues and cover with a protective paint.

The adult of **the linden borer** (*Saperda vestita* Say) is from 12 to 21 mm. in length, dark reddish brown, clothed with dense olive-yellow pubescence, with three small black spots on each wing cover. It occurs in the Eastern States, its habits are similar to those of the elm borer, and both may be controlled by the methods given on page 26.

The larva feeds in weakened or dying linden trees, boring beneath the bark, often deep into the wood, exuding fibrous frass. Park and shade trees are severely injured or killed by this borer. Old, mature trees in a somewhat unthrifty condition seem to be more susceptible to injury, but when the insects are abundant young trees are often attacked. The trees die slowly, large branches going first.

Smodicum cucujiforme (Say), **the flat oak borer**, is a small, elongate, very depressed, shining beetle from 7 to 10 mm. in length, of a pale dull yellow color. The eyes are strongly emarginate, the thorax is longer than wide, and the femora much dilated. The species occurs throughout the Eastern States. The larva is short, cylindrical, of shining texture, having the head wider than long, and retracted into the prothorax. The apex of the mandible is rounded. The prothorax above is finely striate, and beneath it bears a triangular plate and very small legs. The ampullae are dull alutaceous. The larvae excavate extensive meandering galleries in dry heartwood of oak and hickory, packing them tightly with fine granular frass.

The adults appear in July and August, laying the eggs in crevices of exposed wood. The pupal cell is merely an enlargement of the mine brought near the surface of the wood, through which the adult gnaws a way to escape. The life cycle is normally completed in 1 year, but often in dry places the larvae feed for several years. The heartwood of oak and hickory shade trees is often riddled by this insect when access is given through a scar or wound. Stored lumber is frequently found infested, the larvae continuing to feed in it until the wood is thoroughly riddled. Control measures adapted to this borer will be found on page 38.

The adults of **the milkweed borers**, *Tetraopes* spp., are the stout, cylindrical, brick-red beetles spotted with black, found on the flowers of milkweeds. The larvae are also stout and cylindrical, and densely hairy, legless grubs having the head longer than wide and very much wrinkled beneath and the posterior area of the pronotum velvety pubescent. The ampullae bear large irregular tubercles. The larvae feed on the roots of milkweed and injure ornamental groupings in gardens.

Tetropium cinnamopterum Kby., **the eastern larch borer,** is an oblong, cylindrical beetle of a brown to blackish color. The eyes are completely divided into an upper and lower part, except for a fine line-like bridge. The larvae are elongate, cylindrical, having the head wider than long, retracted into the prothorax, and beset with numerous long hairs on the sides. The apex of the mandible is oblique and rather blunt. The pronotum and ampullae are velvety pubescent, the last abdominal segment above bearing two short spines. They feed gregariously beneath the bark of living and dying coniferous trees, especially larch, packing mixed granular and fibrous frass behind them in the mines. It is not of much economic importance but is frequently associated with other species.

Tragosoma harrisi Lec., **the hairy pine borer,** is a rather large beetle from 20 to 40 mm. in length and of a uniform brown. The thorax has one tooth on each side and is very hairy, as is also the under side of the body. Several raised lines occur on the wing covers. The larva is a large tough-skinned grub having four sharp-edged tubercles on the front of the head and three pairs of ocelli. It occurs in the Northeastern States and westward through the western mountains, attacking all conifers. The habits and economic features resemble those of *Orthosoma* (p. 258). It may be controlled by the measures indicated on page 43.

Tylonotus bimaculatus Hald., **the ash and privet borer,** is an elongate, subdepressed beetle from 12 to 16 mm. in length, dark brown, with two light spots on each elytron. The thorax is nearly cylindrical, having the median line and two small spots smooth and shining. Some antennal joints, especially the third and fourth, have two grooves on the outer face. The larva is of shining texture, elongate, with the head wider than long and the apex of the mandible rounded. One ocellus occurs on each side of the head. The posterior area of the pronotum is finely striate, and the ampullae are finely alutaceous and shining. The legs are very small.

The adults fly early in summer in the Eastern and Central States, laying the eggs beneath scales of bark on living or dying ash trees or at the base of privet plants. In ash the young larvae feed principally in the bast tissue of the bark but when more fully matured go deeper, scarring the wood. In privet they mine more extensively beneath the bark and in the wood. They make broad meandering mines packed with granular frass which is not pushed out. Sap oozing from the wound marks the point of attack. In ash trees first the large branches are usually attacked and killed and later the main trunk, but in privet these borers always mine the base. The pupal cell is constructed in or beneath the bark. The larval stage extends over a period of 2 years. In certain localities this insect becomes abundant and causes the malformation or death of many ash trees. Old, mature trees and drought-injured trees are attacked and gradually die branch by branch, especially those in parks or windbreaks. Privet hedges frequently suffer severely when these insects become abundant. A single larva is sufficient to kill an entire stem, and larvae are very difficult to find before the plant dies. For control measures see page 24.

The gall-making maple boxer (*Xylotrechus aceris* Fisher) and **the beech and birch girdler** (*X. quadrimaculatus* (Hald.)) resemble one another closely in both the adult and larval stages. The adult of *X. aceris* is somewhat smaller than that of *X. quadrimaculatus*, and has spots on the thorax much less distinct and the markings of the elytra stronger.

Xylotrechus aceris occurs in the Eastern States. The larva is cream colored, rather robust, having the head wider than long, one ocellus on each side, and the mandible rounded at the apex. The posterior area of the pronotum and the entire ampullae are covered with rather stiff, brownish, velvety pubescence. It is legless. It feeds in the trunks of living red maples.

In midsummer the adults appear and lay their eggs at the base of a small dead twig or in a wound. The larvae bore directly into the sapwood and later into the heart of the stem, completely destroying the center of the tree. A swelling or gall forms about the wound. The second summer a straight excavation is made directly upward or downward at the extremity of which the pupal cell is constructed. The frass is tightly packed behind the larva, and the adult gnaws through this and emerges near the point where the egg was laid. This insect never kills the tree outright but causes deformities and wounds through which secondary insects or fungi gain entrance and continue the destruction. It is not uncommon to find 75 percent of red maples in a neighborhood infested and many of them broken off at the point of injury.

Xylotrechus quadrimaculatus is an elongate, moderately robust beetle, from 12 to 15 mm. in length, having the thorax black, marked with four distinct yellowish spots and the elytra pale brown with indistinct whitish markings. It occurs in the Eastern States. Its larva resembles that of *X. aceris*, but only the perimeter of the ampullae are velvety pubescent.

In midsummer the adults appear and lay their eggs at the axil of a small twig where the branch is to be girdled. The young larvae feed beneath the bark, often girdling and killing the branch in a short time. Then by concentric circles cut toward the center the branch is almost severed, except for the few strands of wood not cut between the concentric burrows. On reaching the pith, the larva bores toward the tip of the branch, packing the mine tightly with granular frass. About 10 inches from the end of the branch a simple pupal cell is constructed, the adult gnawing out through the wood and bark. The development is completed in 1 year.

In certain localities this insect becomes abundant enough to girdle many branches on beech and birch shade trees and sometimes maple. It is not uncommon to find branches 2 inches thick cut off by this larva. To control this borer, collect branches and destroy them during the winter.

Xylotrechus obliteratus Lec., **the poplar-butt borer,** is an elongate, moderately robust beetle, from 10 to 18 mm. in length, uniformly dark, with yellow cross bands at the anterior and posterior margins of the thorax and three across the elytra—the first oblique, the middle curved, and the last transverse. The larva of this beetle also resembles that of *X. aceris*, but the velvety pubescence is finer. It feeds in the base of living poplar trees, chiefly aspen.

The adults fly very late in summer, laying their eggs in irregularities of the bark or exposed wood of living poplars. The young larvae feed that fall beneath the bark, and the next season enter the wood, where they work for several years. The entire heartwood is completely honeycombed because, after a tree is once attacked, adults continue to lay eggs in the same butt until the tree dies. A great proportion of the feeding is done beneath the surface of the ground. The matured larva makes an upward excavation extending outward toward the bark for a pupal chamber. The adult gnaws the exit hole.

Above 7,000 feet in the Rocky Mountain region extensive areas of aspen are destroyed by these larvae. In many places 90 percent of the trees are found to be attacked each year, some breaking off during the winter storms. Following severe ice storms stands have been examined where nearly every tree was felled and each showed the hollowed butt, where it was broken. It would be impractical under present forestry conditions to attempt the control of this insect, as both the stumps and roots would have to be removed to destroy the larvae.

The rustic borer (*Xylotrechus colonus* F.) is a dark-brown beetle from 8 to 17 mm. in length with irregular variable whitish or yellowish markings. The larvae are found under the bark of almost all dead hardwoods; in fact, it is one of the commonest of all cerambycids in the Eastern States. *X. sagittatus* (Germ.), a somewhat larger species, from 15 to 20 mm. long, is lighter brown in color. It bores in the wood of most conifers, particularly pine, and in many localities where pine predominates is the most abundant wood borer, with the exception of *Monochamus* spp.

Family CHRYSOMELIDAE

THE LEAF BEETLES

By H. J. MacAloney

The leaf beetles, or chrysomelids as they are sometimes called, belong to a very large family which is closely related to the roundheaded borers, there being no definite and constant differences. As a rule, however, the adults are very different in general appearance; usually they are medium-sized or small, short-bodied, and more or less oval in shape. The legs are generally short; but in some species the femora of the rear pair are enlarged, thus fitting them for jumping. There is a great variation in coloration and markings. More commonly the adults are spotted or patterned in brightly contrasting nonmetallic colors, but some have a bright metallic sheen on the thorax and elytra; still others are dark or straw-colored. In some cases the coloration varies greatly within the species. Many species are hairless, whereas others are pubescent or are covered with scales or scalelike hairs.

The larvae are usually soft-bodied and frequently have highly pigmented or well-chitinized sclerites on the integument. They are usually free living, except the leaf miners, root feeders, and casebearers, and the form varies greatly from short and compact to depressed cuneiform in the leaf miners. The head is usually protuberant, except in the leaf miners, and bent down for feeding. There is no hypopharyngeal bracon, the mandibles are of the biting type without a molar structure, the gula is soft and fleshy, and the ventral mouth parts are compacted into a unit with the maxillary sclerite indistinct or fused, and not cushioned as in the Ptinidae, Cerambycidae, and related families. The legs are usually well-developed, five-jointed, or occasionally wanting; the ninth abdominal segment sometimes bears paired processes, and the tenth segment is small.

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GENERAL HABITS OF THE CHRYSOMELIDAE

As the common name implies, nearly all the members of this family as adults or larvae, or both, feed on the leaves of plants. The adults of all North American species are diurnal feeders. They usually move rather slowly over the surface of the leaves. Most of the flea beetles, however, have stout hind femora and can leap some distance when disturbed. The species that are free living in the larval stage are gregarious in their feeding habits, and it is a common thing to find the adults and larvae of two or more instars on a leaf at the same time.

The eggs are generally yellowish and are, as a rule, laid in groups or clusters on the lower surface of a leaf or on the stem of the host plant and secured by a mucilaginous secretion. The eggs of the leaf-mining species may be laid on the leaf or thrust into punctures made by the female.

A few species are leaf miners in the larval stage, and most of these are solitary feeders. When two or more mines are in one leaf the larvae generally feed apart, but if the mines join usually only one larva completes development. The few casebearing species mentioned are not important as foliage feeders in the larval stage.

When ready to pupate, many of the free-living larvae of the Chrysomelidae fasten themselves to the surface of a leaf by the last abdominal segment. Others pupate in the ground. Many of the leaf miners pupate within the leaf where they developed, but some bore out of the leaf into the ground. The casebearers transform within their sealed cases.

The feeding pattern of the adults is characterized by holes cut through the leaf or a skeletonization, generally of the lower surface. The free-living larvae remove the epidermal layers on the upper or lower surfaces of the leaf, or both, whereas the leaf-mining larvae devour the tissues between these epidermal layers. Some species restrict their activities to certain tissue layers of the leaf. Heavy feeding, by either of these larval forms, causes a distinctly brown or burned appearance of the trees attacked.

According to Leng (*273*) and Leng and Mutchler (*274*, *275*), about 1,250 species of this family are known to occur in North America north of Mexico, many of which (as the Colorado potato beetle, the asparagus beetles, and the cucumber beetles) are of great importance to agriculture. Only a few of the species are serious forest or shade tree pests, and the most important of these are of European origin. They attack mainly broadleaved trees, although a few feed on conifers. All of them can be controlled by a stomach poison (p. 52). In leaf miner infestations, spraying should be done at the time the leaves are developing, in order to kill both the adults and the larvae before the latter bore into leaves. For species whose larvae feed externally, the spray operation should be carried out when the larvae are first noticed, and care should be taken to cover the under surface, as well as the upper surface, of the leaves. If there is a second generation the same procedure should be followed.

KEY TO THE MORE IMPORTANT LARVAL GROUPS OF THE CHRYSOMELIDAE [21]

1.	Leaf Miners	2
	External feeders, legs well developed	3
2.	Legless, ninth abdominal segment terminal:	
	Feeds in poplars — *Zeugophora*	
	Feeds in birches, oak, hazel — *Syneta*	
	Legs present, eighth abdominal segment terminal:	
	Feeds in locust — *Chalepus*	
	Feeds chiefly in basswood, sometimes oak — *Baliosus*	
3.	Larva enclosed in a case; head flat on dorsal surface, acting as a lid to case — *Coscinoptera, Pachybrachis, Cryptocephalus, Bassareus*	
	Larva usually not in a case; head not flat on dorsal surface	4
4.	Tarsi long, slender, without pad, usually no ocelli *Xanthonia, Glyptoscelis, Tymnes, Nodonota, Colaspis*	
	Tarsi short, curved, usually with a pad *Diabrotica, Galerucella, Blepharida, Altica, Calligrapha, Plagiodera, Chrysomela*	

DISCUSSION OF THE CHRYSOMELID BEETLES

Zeugophora scutellaris Suffr., **the cottonwood leaf-mining beetle,** according to Strickland (*399*) is a European species. Cottonwood and other poplars are attacked, and, although the insect is not often injurious, it is at times so abundant that trees are completely defoliated. The adults are about 3 to 4 mm. in length. The coarsely punctuate elytra and abdomen are black and the remainder of the body yellow. The adult skeletonizes the lower surface of the foliage, preferring the first leaves that appear. After feeding for a short time, the females lay their eggs singly in small punctures in the lower surface of the leaves. The larvae mine in the soft inner tissue, chiefly against the upper surface. They are solitary in their feeding habits, and when there are two or more mines in a leaf they are usually completely separated. If several mines join, only one larva usually survives. The full-grown larvae vacate the mines, drop to the ground, and prepare small, oval, earthen cells below the surface, where they pupate. The combined feeding of adults and larvae often causes complete defoliation. The beetle is found from New York and New Jersey west to Montana and south to New Mexico.

Colaspis pini Barber, **the pine colaspis,** is an elongate, oval, convex beetle about 5 mm. in length, rusty yellow or brown, with faint greenish reflections. The adults damage the 1-year-old needles of pine reproduction and occasionally older trees by irregularly chewing the edges in to the midrib, causing the ends of the needles to turn brown, but leaving the bases green. Later, with heavy feeding, the entire needle may be destroyed. The damage occurs locally throughout the Gulf States in small areas up to 10 acres. From a distance the damage appears as though fire had swept through the stand or reproduction field, but a close inspection reveals that only the needles on the tops of the trees are dead. The damage occurs on both high and low ground. Heavy feeding, especially on poor soil, checks the growth of trees, but it is doubtful if permanent injury results. Plantations of young pine

[21] Many of these larvae are imperfectly known and poorly represented in available collections. It is impractical, with the material at hand, to carry this key down to species.

trees have been successfully sprayed with lead arsenate at Bogalusa, La. Snyder (*393*), however, did not consider the cost justifiable, except for esthetic reasons.

The adult of **the imported willow leaf beetle** (*Plagiodera versicolora* (Laich.)) is a small, moderately stout, metallic-blue or greenish-blue beetle, about 3 mm. long, closely resembling some of the common flea beetles in appearance. The ventral surface, the legs, and the antennae are also blue, although the latter at times appear to have a reddish-brown sheen. The eggs are yellow. The head and legs of the larvae are black, and the body bears numerous black and brown markings. When full-grown, the larvae are about 5 mm. long. The pupae are straw-colored at first, darkening later, and are about the same size as the adult.

This beetle, which is a pest of ornamental trees, is of European origin. It was first reported in the United States from Staten Island in 1915, although records indicate its presence there since 1911. It is now common throughout New England and has been collected as far west as Little Falls, N. Y., and as far south as Virginia. Both smooth and glossy-leaved willows are severely attacked. The black willow (*Salix nigra* Marshall) and the shiny willow (*S. lucida* Meuhl.) are very susceptible, whereas some species, such as the weeping willow (*S. babylonica* L.) and the sandbar willow (*S. longifolia* Meuhl.), do not appear to be favored. Lombardy poplar (*Populus nigra* var. *italica* Du Roi) has also been recorded as fed upon by this beetle.

The winter is passed as an adult under bark and in other sheltered places. Activity is resumed about the time the foliage appears, and the beetles feed for a time by cutting holes in the leaves. The eggs of the first generation are laid from late April to June, depending on the weather and the locality. They hatch in about a week, and the larvae skeletonize the leaves, feeding on both the upper and lower surfaces, although more commonly on the latter. Pupation takes place on the leaves, and at times, according to Dowden (*137*), a high percentage of the pupae are destroyed by a parasite, *Schizonotus sieboldi* Ratz. In southern New England and New York there are at least two complete generations; in some localities in that region and in Virginia, there may be three and a partial fourth.

Closely related and very common on willows, poplars, and alders, wherever they grow in the eastern part of the United States, as well as farther west, are **the cottonwood leaf beetle** (*Chrysomela scripta* F.), and two European species *C. interrupta* F. and *C. tremulae* (F.). Both adults and larvae feed on the foliage and at times chew the tender bark at the tips of the twigs. Severe infestations are not common, but when they occur, considerable damage is done. When the culture of basket willow flourished about 35 years ago in some parts of western New York, these insects were important pests.

The adults of *C. scripta* and *C. interrupta* measure from 5 to 8 mm. in length. There is a great variation in the coloration of both species. In *C. scripta* the head and thorax are black, with marginal markings or dark yellow or red on the latter. The elytra will vary in color from almost pure golden to almost black, but most often they are yellowish with black interrupted stripes. In *C. interrupta* the head and thorax are similar to *C. scripta*, but the elytra are a deep yellow or red, variously spotted with black marks. The adults of *C. tremulae* are a little larger than those of the other two species, and the coloration in solid reddish brown without spots on the elytra, and the head and thorax are green without pale sides. The larvae of all species are black when young and change to a dirty yellow with age, are very similar in appearance, and are difficult to distinguish.

Several species of the genus *Calligrapha* are rather common on the foliage of broadleaved trees, but *C. bigsbyana* (Kby.) is the only one that is at all important. This medium-sized, light-brown to straw-colored beetle, ornamented with variously shaped bronze or greenish markings, is often very abundant on willows in the Northeastern States, causing complete defoliation over wide areas.

The adult of **the elm leaf beetle** (*Galerucella xanthomelaena* (Schr.)) (fig. 58, *B*) is yellowish to dull green in general color with a black stripe, sometimes indistinct, along the sides of the elytra, and is about 5 mm. long. The antennae and the legs are yellowish, the eyes are black, and there are black spots on the head and thorax. The eggs are orange yellow, and the larvae are yellow spotted with black. When full grown, they are about 10 mm. in length. The pupa is orange yellow to golden yellow, and approximately the same size as the adult. (See Britton, *55* and Readio, *360*.)

This beetle was introduced from Europe about 110 years ago, and was first collected at Baltimore, Md. It is now well established over most of the United States. All the elms are attacked, and though the European species are usually the most injured, the American elm is also severely damaged.

The elm beetles hibernate in the adult stage in sheltered, dry places, such as barn lofts, sheds, attics, and stone walls. They become active when the buds begin to swell in the spring, and feed on the developing foliage. The females deposit their eggs in groups of 5 to 25 on the lower surface of the leaves. Oviposition begins late in May and lasts for several weeks, during which time each female lays from 400 to 800 eggs. These hatch in about a week, and the larvae feed on the under side of the leaves until full grown. They then crawl away to pupate in crevices in the bark on the bole or larger branches, or at the base of the tree. The larval period lasts from 2 weeks to a month and the pupal period about 10 days. The new adults emerge and lay eggs. There may be one or two complete generations in the Northeast, depending on the locality and weather conditions. Farther south the longer growing season may permit at least a partial third generation. Most of the damage is done by the larvae of the first generation.

Under forest conditions in this country, the elm leaf beetle is not a serious pest, but it is of very great importance as a defoliator of shade and ornamental trees. It can be controlled under these conditions very easily by sprays (p. 52) applied to the lower surface of the leaves. Usually one spraying operation during the flight of the first generation is sufficient, but in some cases it may be necessary to spray again when the second generation is hatching. It is also advisable to take advantage of the mass hibernating habit of congregating in attics and belfries of old buildings, and trap and destroy them during the fall and winter. Two species of European parasites have been liberated in various parts of the country, but there have not been any recoveries. According to Berry (*28*), a native species, *Tetrastichus brevistigma* Gahan, is at times a very effective pupal parasite.

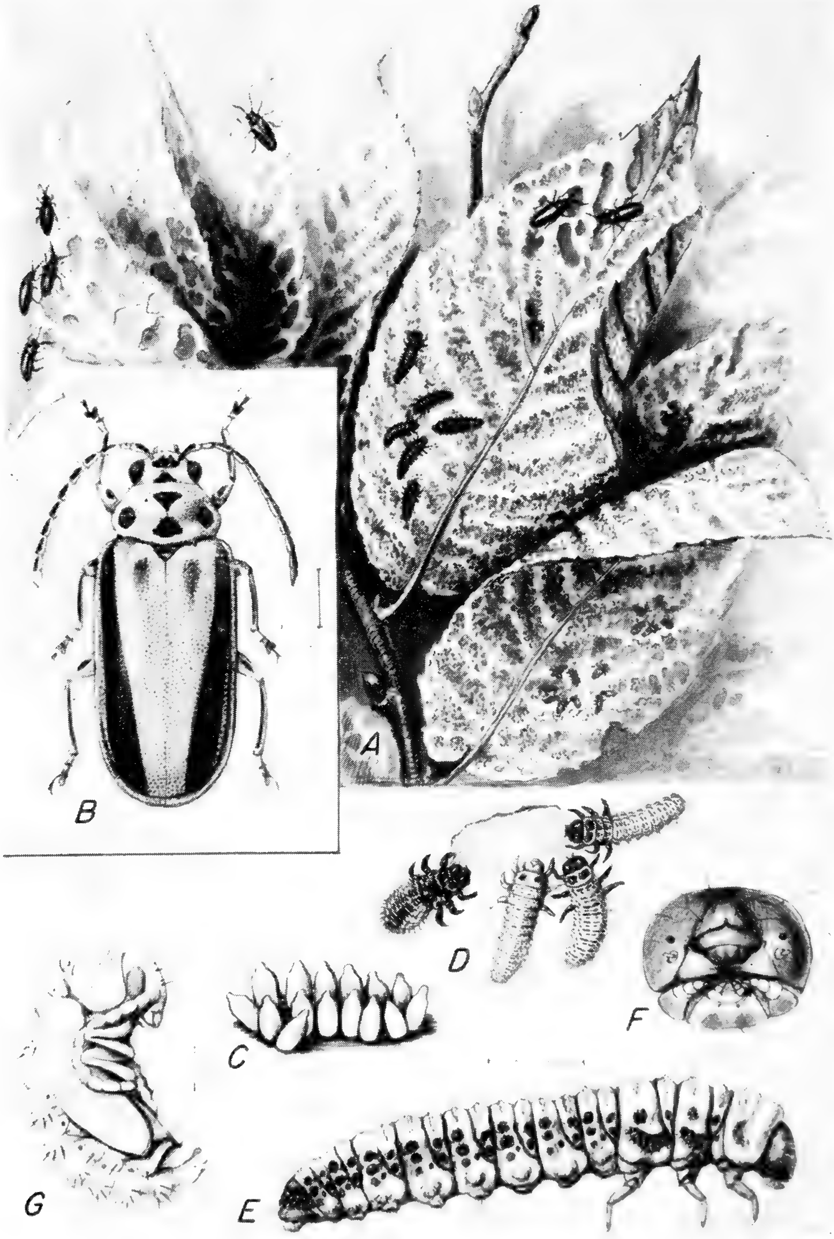

FIGURE 58.—The elm leaf beetle (*Galerucella xanthomelaena*): *A*, Elm leaves showing the feeding of adults and larvae (slightly reduced); *B*, adult beetle; *C*, eggs; *D*, young larvae; *E*, full-grown larva; *F*, mouth parts of mature larva; *G*, pupa (*B, C, D, E, F*, and *G* greatly enlarged.)

Blepharida rhois (Forst.), a species that affects the sumacs, is found from Maine and southern Canada to Florida, and west to Montana and Texas. It is a straw-colored, oval beetle, averaging about 6 mm. in length, and has prominent red spots on the upper part of the body. It is common but not important. Several species of the genera *Oedionychis* and *Crepidodera* feed on the foliage of broad-leaved trees, but they are not important as forest pests.

The adult of **the alder flea beetle** (*Altica ambiens* var. *alni* Harr.) ranges in color from cobalt blue to greenish blue. The under surface and the legs are bluish black. It is one of the largest of its genus averaging 5 to 6 mm. in length. The thorax is broader than long, the elytra are distinctly wider at the base than the thorax, and the surface is finely but distinctly punctate. The eggs are pale orange, with the surface densely marked with fine pits. The full-grown larva is a little longer than the adult, and is dark brown to almost black above, and dark yellow underneath. The pupa is bright orange yellow at first, darkening during the transformation to the adult stage. It is about the same size as the adult. Woods (*436*) has published an extensive account of studies on this flea beetle.

This species feeds on the foilage of alders, and is found from Maine and southern Canada to Minnesota and New Mexico. The beetles hibernate in dry, sheltered places, and appear in the spring when the foliage is developing. The adults feed for a time, eating small holes in the leaves, and then the eggs are laid on the lower surfaces of the leaves. These hatch in about a week, and the larvae feed on both surfaces of the leaves, sometimes as many as half a dozen being present on one leaf. The larval period in Maine is about 5 weeks and the pupal period about 10 days. In Maine and Minnesota there is one generation a year; farther south there may be two.

The beetles are usually scarce, but they may occur more or less periodically in enormous numbers. The heavy defoliation is confined almost entirely to the alders, and, although these are not of great economic importance as forest species, the defoliation along roadsides and in parks is very unsightly.

Several other species of *Altica* are found on broadleaved trees, both adults and larvae chewing the foliage. The adults are small, from 3 to 5 mm. in length, and metallic blue, green, or bronze. *A. ulmi* Woods, and *A. carinata* (Germ.), have been collected from elm foliage in the Northeast, and south to Florida. *A. betulae* Schffr. is common on birch foliage in northern New York, but seldom does widespread damage.

The adult of **the locust leaf miner** (*Chalepus dorsalis* Thunb.) is about 6 mm. long with the head, antennae, legs, ventral surface, and a triangular area, widening posteriorly on the inner margins of the elytra, black. The outer margins of the elytra and the thorax are reddish orange. The thorax and elytra are densely punctured, and the latter are also deeply ridged. The milky-white eggs are thin, flat, and oval. The young larva is white, but when full grown is yellowish white and slightly longer than the adult. The honey-colored pupa is about the same length as the adult.

The beetles hibernate in sheltered places, and resume activity as the foliage is developing. They feed for a short time, making small holes in the leaves. The eggs are deposited on the lower surface of the leaves in groups of three to five, overlapped and glued together, and covered with excrement. They hatch in about a week, and the young larvae from one group, all enter a leaf and make a common mine. As they grow older, each larva makes its own mine, and several new mines may be made before the larva becomes mature. The larval stage is about 1 month. Pupation takes place within the mine. For further details on this species see Chittenden(*86*).

This leaf miner is found on locust throughout the Northeast, west to Missouri, and south to Mississippi.

Feeding by the adults is not especially harmful, but the larval feeding causes blister-like spots or brown patches on the leaves, and at times a single mine will cause a leaf to die. Usually, however, a leaf will have more than one mine. Heavy feeding gives the tree a burned appearance and causes an early dropping of the leaves. The second generation may destroy the new crop of leaves, increasing the damage. As a rule this defoliation, coming late in the season, does not seriously injure the trees, but at times young trees in plantations and shade or roadside trees are heavily attacked and rendered unsightly.

Baliosus ruber (Web.), a broad wedge-shaped, reddish-yellow beetle, with indistinct darker markings on the sides and apical half of the elytra, is about the same size as *Chalepus dorsalis*, and has a somewhat similar life history. Basswood is the favorite host, but oak is also attacked.

Orsodacne atra (Ahr.), a species which is found on the blossoms and leaves of birches and willows, as well as on many other plants, is common over most of Canada and the United States, except in the extreme southern States. It is of interest chiefly because of the many color variations in the adult beetles, these ranging from solid black through reds and yellows. Nothing is yet known about the life or structure of its larva.

Syneta ferruginea (Germ.), a small reddish-yellow beetle, is very common throughout the Northeast. The adults feed on the foliage of the various birches, and have also been collected from oak and hazel, but seldom do appreciable damage.

The rose leaf beetle (*Nodonota puncticollis* (Say)) is common in the Northern States. In Connecticut it is very generally present on the foliage of low sprout growth in cut-over woodlands, and has also been reported as causing injury to the leaves of young Japanese chestnut. In Minnesota it has been found feeding on the young shoots of willow.

Reference should also be made to the cucumber beetles, *Diabrotica* spp., since they defoliate black locust seedlings in forest nurseries. The best method of control is to plant the seeds as early as possible and keep the seedlings in a healthy condition, so as to get good height growth before the beetles resume activity in the spring and become abundant.

Fairly common species, which are not usually sufficiently abundant to cause serious injury or alarm are *Coscinoptera dominicana* (F.) on gum and oak, *Pachybrachis peccans* Suffr. on birch and hickory, *Cryptocephalus basalis* Suffr. and *C. mutabilis* Melsh. on birch, *Bassares literatis* (F.) and *Glyptoscelis barbata* (Say) on hickory, *Xanthonia 10-notata* (Say) on oak, beech, and elm, and *Tymnes tricolor* F. and *T. metasternalis* Cr. on oak and hazel.

Family BRUCHIDAE

The Pea Weevils

The pea and bean weevils are pests of the seeds of the cultivated pea or the American bean. The family to which they belong is closely allied to the true chrysomelids, but differs from most species of that family in having short, serrate antennae, and the tip of the abdomen exposed. They differ from all chrysomelid species in having the mentum distinctly pedunculate. The bruchids also closely resemble the anthribid weevils, but the labrum and palpi are of the ordinary form, and the head is only slightly prolonged in front.

The larvae, which are found in seeds, are small, soft-bodied, and curved, having the head deeply embedded in the thorax. The legs are weak and fleshy and have three to five joints. The mandibles are gougelike, the ventral mouth parts somewhat retracted and fleshy, and the labial stipes and mentum are fused and bear a distinct shieldlike plate. The ligula is large and fleshy, there are no labial palpi, and the hypopharyngeal bracon is absent.

Amblycerus robiniae (F.), which is distributed over the eastern part of the United States and west to Texas, is the only important bruchid in the forest. The reddish-brown, oval beetles, which are about 7 mm. long, have five transverse rows of black spots on the elytra, and are clothed with grayish-yellow hairs. They frequent the leaves and bark crevices of honeylocust on the pods of which the eggs are laid, and the larvae feed in the seeds. *Gibbobruchus mimus* (Say) attacks the seeds of redbud (*Cercis canadensis* L.). *Caryobruchus gleditsiae* (L.) has been reared from palmetto seeds in Louisiana. One of the most satisfactory methods of treating stored seed is to add about 1 pound of naphthalene to each bushel of seed and keep the seed in a tight container. Paradicholorobenzene is also effective. Fumigation with certain other chemicals should be resorted to when large quantities of seed are involved (Back and Cotton, *11*).

RHYNCHOPHORA

THE SNOUT BEETLES

By H. J. MacAloney

The snout beetles, or Rhynchophora, form a natural group that can be readily distinguished from the remainder of the Coleoptera by the head of the adult which is more or less prolonged to form a beak or snout, the gular sutures, which are united in a median line, and the joints of the palpi, which are usually rigid. This suborder has been treated extensively by Blatchley and Leng (*49*).

The larvae of these weevils, with the exception of a few unusual forms, are superficially so similar that for present purposes it is impractical to describe them by any easily recognized characters. For the same reason, larval keys for only the more distinct family groups have been treated in the discussion of the order Coleoptera.

The body form of the larvae is quite characteristic and similar throughout the group, being typically curved like a closed finger, fleshy, and soft-textured. The thoracic and abdominal segments bear conspicuous transverse folds or ridges. The first, or mesothoracic spiracle, is apparently pushed forward into the prothorax. Legs are wanting except in the Brentidae and Anthribidae, and in these they are two- or three-jointed. The head is usually globular, having a well-developed hypopharyngeal bracon, but no chitinized sclerite on the hypopharynx. The clypeus and labrum are distinct, and the ventral mouth parts are fused into a fleshy trapezoidal unit. The maxillary mala is undivided, and, except in the Anthribidae, the mandible is of a simple biting type, without a molar structure. There are several families of Rhynchophora of economic importance in the forests, including many of our most destructive beetles.

Family BRENTIDAE

The Timber Worms

The timber worm family of long slender beetles is almost entirely tropical. The beak is straight, directly continuing the long axis of the body, often so thick at the base as to comprise an elongation of the head. The thorax and the abdomen are elongated.

The oak timber worm (*Arrhenodes minuta* (Drury)) is the only native species affecting forest trees in the eastern part of the United States. There is considerable variation in size in each sex, the males measuring from 7 to 18 mm. and the females from 6 to 14 mm. The adults are shiny reddish brown with the elytra marked by narrow, elongate, yellowish spots, often united to form two or three nearly complete cross bars. The thorax is longer than broad, the elytra are not wider than the thorax, and are more than twice as long as wide. The head of the adult female is prolonged into a slender snout, whereas that of the male is broad and flat, and has powerful jaws, which are said to be used as weapons in protecting the female.

The larva is an elongate, cylindrical, soft-skinned form with the thoracic segments both above and below and the abdominal segments above provided with minute chitinous asperities. The head is globular and protruding. The tenth abdominal segment is large, somewhat wider than the others. The legs are minute and two-jointed.

The eggs are deposited in May and June in cylindrical holes made by the slender snout of the female in recently felled or dying hardwoods, chiefly oak, beech, and poplar. The larvae bore into the sound wood, and extend their pinhole burrows in all directions. At times white oak stave bolts are seriously damaged (Blatchley and Leng, *49*). The work is quite similar to, and is often confused with that of the chestnut timber worm. Occasionally in local sawmill operations a very high percentage of oak timber may be found so damaged by these pinholes that it is unfit for tight cooperage or other special purposes. Infestations of this kind usually result from mechanical injuries on the living tree, such as fire scars, which expose the sapwood to oviposition of the beetles. Control measures that may be employed against the oak timber worm are given on page 27.

Brentus anchorago (L.) is a tropical American species occasionally found in southern Florida under the bark of various trees. It is similar in appearance to the oak timber worm.

Family ANTHRIBIDAE

The Fungus Weevils

The fungus weevils are brown to whitish mottled beetles, with short, broad beaks. In this family the labrum is present, the palpi are flexible, in contrast to the rigid palpi of other Rhynchophora, the antennae are not elbowed, and the terminal joints rarely form a compact club.

In form and general appearance, the larvae resemble the curculionid type. They can readily be distinguished, however, by the maxillary mala, which is divided into a galea and lacinia, the latter terminating in a chitinous spine. Also, the hypopharynx bears a heavy chitinization providing a grinding surface against the well-developed molar structures of the mandible. The legs are absent in some forms, but when present they may be one-, two-, or three-jointed.

None of the species found in the United States is important from a forestry standpoint, but the family is mentioned here because several species, such as *Neanthribus cornutus* (Say), *Eusphyrus walshii* Lec., *Ormiscus saltator* Lec., and *Euparius marmoreus* (Oliv.), have been bred from woody fungi and the dead wood of hickory, beech, and maple. The larvae cut circular, well-like tunnels into the decaying wood directly beneath the sporophore, and also extend them up into the woody part of the fungus.

Family CURCULIONIDAE

THE CURCULIOS, OR WEEVILS

According to Imms (*251*), the curculio family has more species than any other in the animal kingdom. Four-fifths of the species of the superfamily Curculionoidea belong to it. All the curculionids are typical snout beetles, the head being prolonged downward into a well-defined and usually curved beak. The family is one of the most complex units, and has been subdivided into more than 60 subfamilies. These differ greatly in their characteristics and in their habits. There are species that breed in buds, flowers, fruit, stems, bark, wood, and roots, and a few even feed as leaf miners. Some of the larvae are capable of free locomotion, while others are relatively quiescent. Some are external feeders in the larval stage, whereas others are confined to protected places. The larvae of some species form pupal cells of their excrement in the place where they have fed, others form silken cocoons, and still others enter the soil and make an excavation of earth.

The larvae of the leaf-mining snout beetles, such as those of the genera *Rhynchaenus* and *Prionomerus*, are usually very flat, and do not resemble superficially the larvae of other weevils. The larvae of the genus *Smicronyx* and some of *Apion* form galls in the buds, stems, and roots of various plants and complete their development in them. A few species of the latter have been recorded from birch, oak, willow, and locust. Others, such as the species of *Curculio* and some of *Conotrachelus*, are fruit burrowing and do great damage to hickory nuts, walnuts, etc. Only a comparatively small number of species attack woody plants in the Eastern States, but among them are some of the most important pests. The white-pine weevil, for example, is in many localities the most serious of all pests of the eastern white pine. The annual reduction in the value of white pine lumber due to knottiness and crookedness from the attacks of this insect is enormous, and many trees are so completely ruined as not to be fit for sawlogs. Two species of *Hylobius* are also of great importance in young pine stands.

The adult **white-pine weevil** (*Pissodes strobi* (Peck)) is a somewhat elongate, brownish snout beetle, from 4 to 6 mm. long and is marked irregularly with groups of brown and white scales (fig. 59). The curved snout, as long as the prothorax, is one of its most striking characters. The pearly white eggs, about 1 mm. long, are usually laid singly, but occasionally in groups of two or three. The larvae are white and footless, and when full grown are slightly longer than the adult weevil. The pupa is mostly creamy white with the mandibles and eyes light brown. The length is the same as in the adult stage.

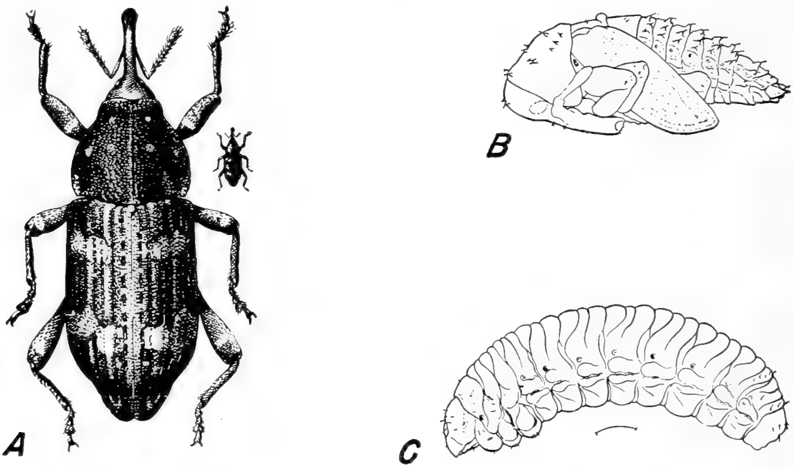

FIGURE 59.—The white-pine weevil (*Pissodes strobi*): *A*, Adult (smaller figure is natural size); *B*, pupa; *C*, larva (hair line shows actual length).

This species occurs over the entire range of the eastern white pine, which is its most common host. In addition it frequently attacks Norway spruce. Attacks are common on jack pine, pitch pine, Japanese red pine, western white pine, limber pine, foxtail pine, Scotch pine, and red spruce, but occur only occasionally on western yellow pine, mugho pine, or black spruce, and, according to MacAloney (*279*), are rare on red pine, Himalayan blue pine, blue spruce, white spruce, and Douglas-fir.

The winter is passed in the adult stage in the litter, and activity is resumed, depending on locality and altitude, from March to May. The eggs, which are placed in small punctures in the bark of the leader, hatch in a week to 10 days, and the grubs, boring downward, feed on the inner bark as they girdle and kill the shoot. By August of the same year, the larvae become full grown, change to the pupal stage, and then to adult weevils. Spread to new areas is by flight. The following spring the first evidence of attack is the appearance of tiny glistening droplets of resin on the preceding year's growth, exuding from holes made by the adult weevils in feeding or laying eggs. As the terminal is girdled, the new shoot of the current year's growth withers, and the tip bends over and turns brown (fig. 60). This is usually noticeable by early June in the southern part of the range and progressively later toward the North. Examination of the dead shoots will show the white larvae, pupae, or young adults beneath the bark or in the wood and pith. Two years' growth is always killed—often three and occasionally four or more.

FIGURE 60.—White pine terminal dying from attack by the white-pine weevil.

This is the most serious insect pest of white pine in the East. Except in the comparatively few, intensively managed stands where special efforts are being made to grow high-quality white pine, this insect continues its attacks practically unchecked. Indeed, in some sections of New England it is difficult to find a sizeable tree which has escaped attack. Most of the present naturally seeded stands are composed largely of forked and crooked trees of little value, and a considerable number of the planted stands promise nothing substantially better. The loss in stumpage value during the last half century amounts to millions of dollars. In the Adirondack region in New York, the weevil has injured Norway spruce plantations so severely that they are practically worthless.

Severely weeviled young stands, 6 to 7 feet in spacing, can be reclaimed. Briefly, the treatment is one that involves seeking out the least injured trees, with due regard for crown class, or vigor, and spacing, and favoring them for development as final-crop trees. Such trees should be pruned, and competing scrubby dominants should be girdled so that they will be gradually removed from the stand. Where possible, the most advantageous measure is to grow the susceptible species in mixture with some nonsusceptible species, such as the better hardwoods, which will be of value in the final crop. Cline and MacAloney (*95*, *96*) have published articles on the reclamation of weeviled stands.

Direct control measures, such as removing and burning the infested tips, or jarring the tips at the time of feeding and egg laying so that the adults will fall into a net, are prohibitive in extensive stands and plantations because of the expense. Isolated young plantations, however, may be protected by these measures. Ornamental trees, which are of great value for their form, can be protected each year, at the time the buds are swelling, by thoroughly spraying the leading shoot with a concentrated lead arsenate spray. Recent experiments indicate that control in plantations and reproduction may be effected by spraying from the air, using a 12.5 percent solution or emulsion of DDT, at the rate of 3 to 4 gallons per acre early in the fall or early in the spring, when the adults are feeding. On small areas or on oramentals the leaders may be protected in the spring with a 3-percent DDT emulsion. This type of spray may also be used in plantations to prevent attack. It should be understood, however, that it is not expected to be a substitute for silvicultural methods but something to be used to remedy a bad situation.

This weevil has become an important pest of jack pine in the recently established plantations in the Lake States. In many cases, because the terminal growth of jack pine develops very quickly early in the spring the eggs are laid in this growth rather than that of the previous season. Control by spraying with concentrated sprays as suggested above is obviously not practicable. Observations made during a plantation-insect study in 1941 indicate that in jack pine, as in white pine, the use of mixed stands tends to reduce the severity of weevil damage.

The deodar weevil (*Pissodes nemorensis* Germ. (*deodarae* Hopk.)) is very often injurious to deodar cedar, and it also attacks the imported Atlas cedar and Cedar of Lebanon, as well as various pines. The adults, which were long confused with those of *P. strobi*, have a slightly longer and more slender beak, and different range and habits. They puncture the bark on the small twigs and leading shoots, and eat a considerable area of the inner bark and wood around the hole, often causing the twig to break. In the South the adults attack the cedars in the late fall, and the twigs and leaders begin to die by the middle of January. The larvae feed in a manner somewhat similar to those of *P. strobi*, girdling the stem and killing it. They pupate in March, and the adults issue in April. Apparently they aestivate in the ground litter and reappear in the fall. Healthy trees are attacked, and may lose their leading shoots, while weakened trees are attacked also on the twigs, and very often are killed. The native pines are attacked only when either dead or greatly weakened, and then on only the trunk and larger limbs and roots.

Pissodes approximatus Hopk. resembles *P. strobi* so closely that it is almost impossible to distinguish adults of the same size. They may be separated by their feeding habits. The natural habitat for *P. approximatus* is the under side of freshly cut logs, stumps, blowdowns, or the bases of young trees weakened by some other agency, whereas *P. strobi* always attacks the leading shoot, or the tip of a lateral that is striving for leadership. *P. approximatus* may be important occasionally in attacking young trees.

Pissodes dubius Rand., a grayish-brown to black weevil, mottled with black and white scales, attacks recently dead or dying balsam fir. Swaine, Craighead, and Bailey (*403*) considered it the most aggressive insect attacking dead and dying trees after budworm defoliation. The larvae, however, never develop to maturity unless the tree is almost dead. Two or three successive attacks may be made on the same tree apparently before the tree's vitality is at such a low ebb that the larvae can survive and mature. This weevil is also common on trees weakened or killed by the fir bark louse. It is essentially a secondary insect. *P. similis* Hopk., and *P. affinis* Rand. are two fairly common species in the Eastern States. The first is found on balsam fir, and the second on white pine. *P. rotundatus* Lec. attacks weakened spruce trees in somewhat the same manner as *P. dubius* attacks balsam fir. None of these last three are of economic importance.

The pales weevil (*Hylobius pales* (Hbst.)) is a robust weevil, 7 to 10 mm. in length, dark brown to reddish brown, and marked irregularly and somewhat sparsely on both thorax and elytra with gray or yellowish hairs. The beak is stout, with the antennae inserted well in front of the middle. The eggs are pearly white. The larvae are white and footless, and when full grown are slightly longer than the adult. This weevil is found from Nova Scotia to Florida, and west to the Lake States. Eastern white pine is the most favored host, and red pine is commonly attacked. Carter (*82*) placed other conifers in both planted and natural growth, within the range of the insect, as also susceptible.

The beetles pass the winter in the litter, becoming active, depending on locality and altitude, from April to June, during which time they feed on the tender bark of the twigs of saplings, and at the bases of seedlings. The eggs are laid singly, about July 1, in the inner bark of freshly cut pine logs or the large roots of freshly cut pine stumps. They hatch in about 2 weeks. The new adults emerge in September, and it is at this time that the severe damage occurs on the young trees.

Most of the feeding is done at night, or below the surface of the litter in the daytime. The first evidence of attack is when the young seedlings wither, and it is then too late for control measures.

This is a very serious pest in cut-over pine lands, often causing almost complete mortality of the seedlings unless there are several thousand to the acre, as found by Peirson (*348*). Cutting is recommended in a seed year, or thinning before the cutting, in order to stimulate an overabundance of pine reproduction. To prevent attack, cut-over areas should not be planted with conifers until the third season after cutting. This is standard practice in some parts of the New England States. Freshly sawed pine lumber should not be piled near young stands or plantations, as the pine odor will attract the strong flying adults from a considerable distance.

The adult of **the pine root-collar weevil** (*Hylobius radicis* Buch.), a recently described species, resembles that of *H. pales* so closely that a superficial examination will not suffice to separate them. The habits of the two species, however, enable one to identify them readily. This weevil has injured Scotch pines ranging in diameter from 1½ to 5 inches. Injury to red, jack, Corsican, and Austrian pines was observed by York (*438*) and by Maxwell and MacLeod (*294*). The soil around the base of the attacked trees is blackened and soaked with pitch, and the larvae are found in this material or in the cambium region around the root collar. During the latter part of the season, larvae, pupae, and adults are found in the burrows. Pupation often occurs in the tunnels extended out into the resin-infiltrated soil. In some cases the trees are entirely girdled below the surface of the ground. This habit of feeding serves to distinguish this species very clearly from *H. pales*. It may also be found associated with *Pissodes approximatus*, but the two species are not the same color, and *H. radicis* is considerably larger and restricts its work to the root-collar region, whereas *P. approximatus* attacks above the root collar. The pine root-collar weevil is now known to be present in northern New York, Long Island, Connecticut, Massachusetts, and Pennsylvania and has also been found in Minnesota and Michigan. **J. V. Schaffner, Jr., and H. L. McIntyre**, working in New York, obtained good control with an emulsion containing 25 percent of ethylene dichloride and 5 percent of dichloroethyl ether, or one containing 25 percent of ethylene dichloride and dinitro-o-cyclohexyl phenol (100 percent) at the rate of 0.5 ounce per gallon of the emulsion. These emulsions should be applied directly around the bases of the infested trees.

Another species, *Hypomolyx piceus* (Deg.), closely related, but larger than *Hylobius radicis*, and with somewhat similar habits, attacks Scotch pine, red pine, pitch pine, and occasionally white pine, from Nova Scotia and New England to the Lake States.

The poplar and willow borer (*Cryptorhynchus lapathi* (**L.**)) is a medium-sized weevil about 7 to 10 mm. in length, and dark brown to black, mottled with light brown and with gray scales. The posterior portion of the elytra, the sides of the thorax, and parts of the legs are densely clothed with pale scales having a slight pinkish cast. This European beetle was first noticed in the United States about 1882. It has since become established from Maine west to Ontario and northern Wisconsin, and south to Virginia. It has recently been found also in Washington and Idaho, and is spreading to other areas. It attacks willow, alder, poplar, and birch.

This insect hibernates as a partly grown larva in the sapwood. When plant growth is resumed in the spring the larvae develop rapidly, and pupation takes place in June. The adult beetles are found in July and August feeding on the young shoots. The eggs are laid singly or in groups of two to four in slits cut in the corky bark, often in scar tissue. The young larvae feed in the soft tissue of the inner bark and outer layer of sapwood until cold weather. In the spring feeding is resumed, the boring usually proceeding around the branch or stem, and often causing girdling. When ready to pupate the full-grown larva bores upward and inward, and constructs the pupation cell in the center of the stem.

Injury by this weevil is often very serious. All poplars and willows over a year old are subject to attack, and recently planted trees and nursery stock are particularly susceptible. The base of the tree is usually most seriously affected. Where basket-willow culture is practiced the monetary loss at times is considerable. Slender-stemmed species are not attacked in any degree, probably because of the small diameter of the stems and twigs. In the forests of the Northwest, where willow is an important ground cover and game browse, extensive areas are being destroyed.

A penetrating oil emulsion sprayed or wiped on the affected parts of the tree during the first period of warm weather in the spring will kill the larvae, as they are then close to the surface of the bark. Carbolineum emulsion has proved very satisfactory, but it should not be allowed to reach the roots. Very badly infested trees, or the most seriously infested branches, should be cut and burned before early summer. For discussion of other applicable measures see page 26.

Several other species of *Cryptorhynchus*, such as *C. parochus* (Hbst.), *C. bisignatus* (Say), *C. fuscatus* (Lec.), and *C. fallax* (Lec.), have been collected from hardwoods. *C. fallax* commonly breeds in hickory killed by the hickory bark beetle. *Apteromechus ferratus* (Say) sometimes does great damage, killing sassafras trees up to 10 inches in diameter. It has been found from New York to Florida.

The white-fringed beetle (*Pantomorus leucoloma* (Boh.)), a native of South America, has very recently been introduced into Florida, Mississippi, Louisiana, and Alabama. Since 1936 the adults have been found feeding on more than 50 species of plants and the larvae on 20 species. Although it is primarily considered as a larval pest on agricultural crops, the adult has been observed feeding on the foliage of pecan, hackberry, black gum, poplar, blackjack oak, hawthorn, and sassafras. The feeding by the adults, however, is of minor importance, as compared with the damage by the larvae, which feed on the stems and taproots of crop plants. Injury to tree species by the larvae has not yet been reported.

The female beetle is robust, about 12 mm. long, dark gray, with a lighter band along the margins of the elytra and two paler longitudinal lines on each side of the thorax and head. The body is densely covered with pale hairs, those on the elytra being longest. The true wings are rudimentary and the species cannot fly. So far as is known there are no males, and reproduction is parthenogenetic. The oval-shaped eggs are about 1 mm. long and are deposited in masses, usually of from 15

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to 25, in the soil or on debris. They are sticky and adhere to objects or to one another. They hatch in about 2 weeks and the larvae begin to feed, and as they grow larger they chew away the lower part of the stems and the taproots of the food plants, but do not injure the lateral rootlets. At times the larvae burrow into and devour seed before it has had time to germinate. The full-grown yellowish-white larva is about 12 mm. long, and the pupa slightly less than that. Pupation takes place in the soil.

Nine species of *Magdalis* are fairly common in the Eastern States. They all attack partly dead or dying trees or broken branches. *M. perforata* Horn and *M. austera* Fall attack conifers, chiefly the pines, and *M. piceae* Buch. breeds in blue spruce. *M. olyra* (Hbst.) and **the black elm bark weevil** (*M. barbita* (Say)) breed in hickory trees attacked by the hickory bark beetle, and also in broken branches and slashings. *M. salicis* Horn has been reared from willow and chestnut, and *M. inconspicua* Horn from butternut, *M. barbicornis* (Latr.), *M. pandura* Say, *M. barbita*, and **the red elm bark weevil** (*M. armicollis* (Say)) have been reared from elm, according to Britton and Friend (*62*). The last two are of some importance in connection with the Dutch elm disease in this country. While they have not been shown to be vectors of this disease, the fact remains that they are agents in weakening decadent trees.

Acorn and Nut Weevils

The acorn and nut weevils belong to the genus *Curculio*. There are more than 40 nominal species in the United States, at least 8 of them of some importance in the East. The body is robust, and in some species the beak of the females is much longer than the body; in others it is the same length or shorter. The beak of the male is always shorter than the body. The elbowed antennae are very long and slender, and in the female are inserted well back of the middle of the beak; in the male they are usually inserted at or near the middle of the beak. In this genus the mandibles move vertically instead of horizontally, as in most Coleoptera, and are used by the females in drilling holes—the length of the beak in each species (Blatchley and Leng, *49*), generally speaking, depending on the thickness of the husk and shell of the host nut. The adults are generally a rich, light brown, mottled and spotted with gray or yellowish-brown hairs. Brooks (*63*) said that all species closely resemble a common type.

The beetles issue from the ground in July and August, and egg laying continues from the time the meat in the nut begins to form until the nut is full grown. The eggs hatch in 1 to 2 weeks. The full-grown larva cuts a circular hole in the shell, emerges, and enters the earth to hibernate in a small cell. Pupation takes place the following June or July. Occasionally, in some species, the larvae may transform in the fall and hibernate as adults. Sometimes a small percentage may hold over and emerge as adults with those of the succeeding generation. Some of the species have their preferred hosts, to which they adhere with considerable regularity, but *Curculio nasicus* Say has been reported from at least 5 species of oak, and the chestnut weevil (*C. auriger* (Casey)) from chestnut and at least 11 oaks. The 2 species attacking hickory and hazlenuts are specific on these species.

Probably the most important species is **the pecan weevil** (*Curculio caryae* (Horn)). It attacks practically all species of hickory from Connecticut west to Iowa and south to Florida. The adults emerge late in the summer, and several eggs may be laid in each nut. Only two or three larvae survive, and the entire kernel is devoured in about a month. The larvae hibernate in a cell in the ground, but as a rule do not transform to pupae until the second summer after entering the soil. This weevil is not considered a very important pest in the northern part of the range, as hickory nuts are not of commercial importance. In the South, however, some pecan growers consider it the most destructive pest of the pecan. At times as much as 65 percent of the crop has been reported destroyed. The insect does not spread very rapidly, and only occasionally is the damage severe.

The virtual elimination of chestnut by the blight has decreased the importance of **the large chestnut weevil** (*Curculio proboscideus* F.) and **the chestnut weevil** (*C. auriger*), although they still are capable of considerable injury wherever chestnut trees may be found. The acorn weevils, *C. nasicus* Say, *C. baculi* (Chitt.), and *C. confusor* (Ham), and *C. obtusus* (Blanch.), **the hazelnut weevil,** are occasionally abundant and make it difficult to collect a viable crop of seeds for planting.

It is difficult to apply satisfactory control measures. Apparently the nuts that drop earliest are the most wormy. Therefore, the pecan nuts that drop should be gathered immediately and the main crop harvested as soon as possible. All nuts should be placed in tight-bottomed boxes, to prevent the larvae reaching the ground. Bissell (*34*), after 12 years' work in Georgia, stated in 1939 that the only practical way to prevent damage is to jar the adults from the trees onto sheets before they have a chance to lay eggs in the nuts. Recent experiments have shown that DDT sprays are very effective.

Several species of *Conotrachelus* are of some importance in the nut industry, at times becoming numerous enough to cause considerable loss. The genus is not, however, so important economically as the true *Curculio* genus. They hibernate as adults and deposit eggs in immature nuts, which drop while they are still small. The species that attack walnuts and hickory nuts often cause a heavy drop early in the season, and the infestation may pass unnoticed. *Conotrachelus juglandis* Lec. on butternuts, *C. retentus* (Say) on walnuts, *C. affinis* Boh. on hickory nuts, and *C. aratus* (Germ.) on hickory shoots are very similar in appearance, habits, and seasonal activities. The first two attack the nuts, tender shoots, and leaf petioles of at least two species of *Juglans*, and are present wherever trees of this genus grow. *C. affinis*, however, apparently confines its attacks to the immature hickory nuts, and *C. aratus* confines its attacks to the young shoots and leaf petioles (Brooks, *64*).

Conotrachelus anaglypticus (Say), **the cambium curculio,** is common from Massachusetts to Florida and west to Iowa, and attacks a variety of fruit, shade, and forest trees, those of the latter, according to Brooks and Cotton (*65*), including in 1924 hickory, birch, beech, maple, chestnut, and oak. The eggs are laid around fresh wounds; the larvae do not mine extensively and, as a rule, cease feeding when the tissue grows old and tough. There are two generations a year in Georgia, but only one in West Virginia and farther north.

Other Weevils on Eastern Trees

From time to time other, less common weevils become noticeable either because of their abundance or the damage caused by their attack in a localized area. Their appearance and the character of the damage are briefly described in the following paragraphs.

The pine gall weevil (*Podapion gallicola* Riley) forms galls on the twigs of scrub, pitch, and red pines. The spherical gall is formed on the 2-year-old twigs, and appears merely as an enlargement of the stem. The interior is hard and woody. The galleries are full of liquid resin while the larvae are active, but in an old, vacated gall the resin hardens. The eggs are probably laid in the 1-year-old twigs in June, and they may be laid singly, in which case the gall is small, or several may be laid in a small area along the stem, causing a much larger, compound gall. Little is known of the life history, although in available literature it is stated that the egg or larva remains in the wood without forming the gall until the following spring. The writer has found full-grown larvae in galls in northern Minnesota in early May and small larvae in freshly formed galls in northern Michigan in August. One or more adults may develop in a gall.

Dorytomus subsimilis Blatch. feeds as a larva in the catkins of poplar. *Myrmex myrmex* (Hbst.) breeds in the dead and dying twigs of sycamore killed by the sycamore blight, and the adults feed on the fruiting bodies on the bark.

Pseudocneorrhinus setosus Roelofs, a Japanese weevil, is fairly common in and near New Haven, Conn. It was first reported from Westville on burr marigold in 1920, and in 1932 foliage injury was noticed in West Haven on hemlock, Japanese barberry, California privet, and lilac. The hemlocks had been moved from a nursey in Westville, where the insect was first found, about 1922, and Britton (*60*) stated that apparently this was the source of the West Haven infestation. Some of the trees had died and others were severly injured by the defoliation. In 1934 injury was reported chiefly on rhododendron, mountain laurel, and deutzia. This weevil is about 5 mm. long, stout, and light to dark brown mottled with transverse bands of brown and black. The elytra are striate, with white lines in the grooves and whitish spots on the apical half. The elytra are apparently fused, thereby preventing flight, so natural dissemination will be slow. There is no information available on the immature stages.

Polydrusus impressifrons Gyll., a European species, has been taken in New York and Connecticut on a variety of trees, chiefly willow, poplar, birch, and plum. The adult is about 5 mm. long, and is light metallic green. The eggs are laid in May or June under loosened bark on dead stubs or scars. The larva is white, slender, and legless. It goes into the soil and eats the roots. Pupation takes place in the spring. The young adults eat the developing buds and the unfolding leaves. *P. americanus* Gyll., a native species, is common on beech.

Thylacites incanus L., is a rather recent European introduction, and has been reported from Massachusetts and Long Island. Barbey (*22*) stated in 1925 that it is 8 to 11 mm. long, brown in general color, the brownish-gray scales having a metallic reflection. The antennae are reddish-brown, and the elytra are finely striated and punctured. The larva is at times a serious pest of pines and spruces in Europe. It attacks the roots, and the adult chews the needles of pines. This weevil hibernates as an adult and in the spring deposits its eggs in the root systems of young trees. As a rule, the injury is of little importance.

Two species of *Brachyrhinus* are at times pests in nurseries. The larvae of **the black vine weevil** (*B. sulcatus* (F.)), and **the strawberry root weevil** (*B. ovatus* (L.)) were reported in recent years to have done considerable damage to the roots of young yew plants in New Hampshire, Massachusetts, New York, and Ohio. Britton (*61*) stated that in 1934 the larvae of *B. ovatus* destroyed the roots of 75,000 young hemlock and several hundred thousand blue spruce seedlings near Hartford, Conn. Occasionally damage also occurs in nurseries in Michigan, Wisconsin, and Minnesota.

Gambrell (*180*) obtained good results with poisoned baits. Smearing the sides of bed boards in nurseries with a sticky material will prevent attack, as the adults are wingless and spread to new areas by crawling. Clean cultivation and the rotation of seedbeds and transplant beds, allowing the infested areas to lie fallow and be thoroughly cultivated in alternate years, provide the most satisfactory and logical control measures.

The New York weevil (*Ithycerus noveboracensis* (Forst.)) is the largest species of the group Ithycerinae found in the Northeastern States. The adult is black, modified by ash-gray and pale-brown prostrate hairs, which give it a mottled appearance. The individuals range in length from 12 to 18 mm. The adult beetles may be found from May to July gnawing the tender bark on the twigs and eating into the buds of various hardwoods, such as oak, hickory, and beech. This may cause the twigs to die back, or they may break at the wound through wind action. The larvae are reported to breed in the twigs of hardwoods. Control measures in the forest are not practicable, but on young shade trees and fruit trees the beetles may be jarred into a net and destroyed.

Phyllobius oblongus (L.), **the European snout beetle** was first collected in the United States in 1923 at Rochester, N. Y., when it was found injuring elm leaves. It was not again mentioned from the United States until 1934, when it was found in the same area feeding on the foliage of pear, apple, plum, and chokecherry. In 1936 adults were collected in this same area on the foliage of apple, pear, and plum. Apparently it is most common in neglected orchards. In 1935 adults were found feeding at Painesville, northern Ohio, on the leaves of maple and elm, and in 1937 damage was extensive near this area, especially on the young shoots of willow, maple, and cottonwood. In Europe it is not usually a serious pest in forests, but Carruth (*81*) reported it as being at times a serious pest in orchards.

Rhynchophorus cruentatus (F.), **the palmetto bill bug** is at times a common insect on weakened trees in Florida, being common on the cabbage palmetto and other palms. It is found from North Carolina to Louisiana. It breeds in the trunks of decadent trees, and Chittenden (*87*) stated that the adult fed on bruised terminal buds and the sap which exudes from recently felled or wounded trees. The adult is from 20 to 31 mm. long and has shiny, black elytra, with deep but not punctured striae. The thorax is red, fringed with black margins, and the legs are fringed with long yellowish hairs.

The flea weevils, *Rhynchaenus* spp., are somewhat important from a forestry point of view. They are found mostly on the poplars, willows, and birches. The adults eat holes in the leaves, and the larvae are leaf miners. They are rather broad weevils, with large eyes that almost meet in front, the antennae are elbowed, and the hind femora are very thick and fitted for jumping. **The willow flea weevil** (*Rhynchaenus rufipes* (Lec.)) is at times very abundant on willow in the East according to Nash (*315*). A closely related species of *Rhynchaenus* is common on birch in northern Wisconsin, and in some stands paper birch has been weakened sufficiently from defoliation to allow successful attack by the bronze birch borer.

Subfamily ATTELABINAE

The Leaf-Rolling Weevils

The leaf-rolling weevils are not very important from a forest insect viewpoint, but are discussed because of their rather peculiar habits. Some of the species roll leaves, depositing an egg in each roll, others deposit their eggs in young fruit, the kernel being eaten by the larvae, and still others place their eggs in buds, which are destroyed by the larvae. The oaks, walnuts, butternuts, hickories, sumacs, hazelnuts, and alders are all listed as hosts. Four species of *Attelabus*, namely *analis* Ill., *nigripes* Lec., *bipustulatus* F., and *rhois* Boh., are found on oaks, walnuts, and hickories from Canada to Florida, but they do little damage. The females roll the leaves. These rolls are often hanging by a narrow strip of the leaf, and later fall to the ground. Blatchley and Leng (*49*) stated that the larvae chew the inner part of the rolls, and when mature, leave them and pupate in the ground. *Eugnamptus collaris* (F.) and other species of this genus are found on the leaves of various hardwoods. **The rose curculio** (*Rhynchites bicolor* (F.)) is probably the most important species in this family. The pine-flower snout beetles of the genera *Cimberis* (*Rhinomacer*) and *Diodyrhynchus* feed on the staminate flowers of various pines and other conifers from Canada to Florida. The eggs are laid in the flowers also. The adults of this family are small to medium-sized, very few being over 5 mm. in length. They are robust, and usually dull red or black. They have flat snouts, which are about as long as the thorax.

Subfamily COSSONINAE

The Broad-Nosed Bark Weevils

The adults of the subfamily Cossoninae are small, oblong or elongate, black or brown weevils, with eyes small, or sometimes lacking entirely. The beak is often short and broad at the apex. Several species of the genus *Cossonus* frequently inhabit the sapwood of hardwoods and conifers killed by bark beetles. *C. impressus* Boh., a dull black species, is found in Florida, and *C. corticola* Say, a shining piceous or black species is found all over the eastern part of the United States. Both species are generally common beneath the bark of dying pine trees. *C. platalea* Say and *C. impressifrons* Boh. are commonly found beneath the bark of various broadleaved trees.

The species of the genus *Rhyncolus* are similar to those of *Cossonus*, but smaller and more cylindrical. *R. brunneus* Mann., which is dark red, is common in dying coniferous wood. A closely related, dark-brown species, *Hexarthrum ulkei* Horn, is found in manufactured coniferous wood products in the eastern part of the United States. This species is sometimes destructive to the woodwork of old buildings and occasionally reduces the wood to powder, necessitating the removal of much material. This beetle is often associated in wood infested with the anobiid *Xyletinus peltatus* (Harr.). Another black, shining species, *Tomolips quercicola* Boh., also has been found causing damage in buildings to seasoned coniferous woods such as pine floorings and pecky cyprus paneling. *Pselactus spadix* (Hbst.) has been taken from salt water piling just above the high-water mark in railroad piers at East Boston, Mass. Occasionally it is found in the damp woodwork beneath buildings. *Dryophthorus americanus* Bedel has been reported from both hardwoods and softwoods, and is very common in hickory killed by the hickory bark beetle. *Stenoscelis brevis* (Boh.) is very common in dead, dying, and rotten hardwoods.

The larvae of all the species cut meandering galleries across the grain of the wood and pack them tightly with granular frass except for that portion immediately behind them. The adults may be found in the wood, or, more usually under the bark about a year after the tree is killed. The subfamily is not very important economically, except for the occasional attack on wood utilized in buildings and the fact that the galleries frequently interfere with the utilization of the sapwood of trees killed by bark beetles.

Family SCOLYTIDAE

THE BARK BEETLES

By M. W. Blackman

The bark beetles (Scolytidae) are small cylindrical beetles ranging from less than 2 mm. to about 9 mm. in length. Mature specimens range from brown or reddish brown to black, depending on the species. A few species are marked with contrasting colors, which may be due either to actual color differences in the body wall or elytra, as in certain species of *Trypodendron* and *Monarthrum*, or may be produced by the grouping of scales or setae of different colors, as in *Leperisinus* and *Pseudohylesinus*. The individuals of most species, however, are usually more or less uniform in color.

Technically, the Scolytidae belong to the suborder Rhynchophora of the order Coleoptera, as they possess undivided maxillae and rigid palpi of not more than three joints, and the larvae are legless. They differ, however, from the Curculionoidea and other Rhynchophora in that the head is never produced into a prominent rostrum or snout and the submentum lacks a gular peduncle. The characteristic elbowed antennae serve to distinguish them readily from the Bostrichidae, some forms of which bear a superficially strong resemblance to bark beetles. In all but a few species the antenna has a compact club.

The larvae are small, soft, white or yellowish-white, legless grubs, usually strongly curved and dorsally plicate with a prominent and strongly sclerotized head. They have triangular mandibles of the biting type, without molar structure, and the ventral mouth parts are joined in a trapezoidal unit by fusion of stipes and labium. The mesothoracic spiracle is apparently pushed forward into the prothorax. The true bark-inhabiting forms are much thicker through the thoracic segments than elsewhere and are strongly curved. In many species of ambrosia beetles, the larvae are more elongate and more uniformly cylindrical. Although considerable work on scolytid larvae has been attempted, no entirely satisfactory larval characters separating the family from the Curculionidae or capable of being used in a key to the genera and species have been found.

THE HABITS OF BARK BEETLES

The Scolytidae differ from other beetles even more sharply in habits than in structure, and a species often may be recognized by its burrow as readily as by its body structure. Nearly all scolytids are borers, both as larvae and as adults, in the bark or wood of living or dead trees or shrubs, and all but a few hours of their existence is passed within their burrows. The most outstanding biological characteristic of the family is the secluded life of all stages; even the adults of most species are in the open only long enough to leave the old burrows and find new hosts in the proper condition for attack.

The family may be separated into the three following groups as regards the location of their burrows and the character of the food of the larvae and adults: (1) The true bark beetles, which construct their burrows either entirely in the inner bark or at the juncture of the bark and sapwood; (2) the xylophagous, or wood-eating scolytids, which excavate burrows through the sapwood and heartwood and feed on the ligneous tissues at all stages of their active life; and (3) the ambrosia beetles, which construct their burrows in the sapwood and feed both in the larval and adult stages on fungi, known as ambrosia, which they cultivate within their tunnels.

Forest trees serve as the breeding place of most species of bark beetles, but fruit trees and even herbaceous plants are subject to the attacks of a few species. Ornamental trees, which are usually forest trees growing under unnatural conditions, are often affected, and this is especially so in the case of conifers. In tropical countries, and to a much less extent in temperate regions, a number of species attack seeds and nuts, and in some cases casks containing water, wine, or other liquids may be damaged by the burrows. But for the most part, both adults and larvae live in the bark or wood of trees.

Bark beetles usually show a rather close discrimination in their choice of a breeding place. Usually a certain species has adopted as its host either a single species of tree or any one of several closely allied species. Many species confine their attacks to pines, whereas others may breed in either pine, spruce, or larch. A few species, however, show little discrimination between several genera of trees not closely related botanically, as in the case of *Dryocoetes betulae* Hopk., which breeds not only in several species of birch, but also in beech, wild cherry, and red gum.

The part of the tree chosen for attack by bark beetles also is often indicative of rigid discrimination by certain species. Some are found only in the lower trunk, others only in the upper trunk, some in the larger limbs, others in the smaller limbs, still others in the small twigs, and some only in the cones. In the southern pines the cones are attacked by *Conophthorus taedae* Hopk.; the terminal twigs by *Pityophthorus pulicarius* Zimm.; the smaller smooth-barked limbs by *P. consimilis* Lec. and *P. nudus* Sw.; the medium-sized limbs by *Pityogenes meridianus* Blkm.; *P. plagiatus* Lec., and *Ips avulsus* Eichh.; the upper trunk by *Ips grandicollis* Eichh., and *I. calligraphus* Germ.; the middle trunk by *Dendroctonus frontalis* Zimm.; and the lower trunk by *D. terebrans* Oliv., *D. valens* Lec., and *Orthotomicus caelatus* Eichh.

Bark beetles also show discrimination as regards the physiological condition of the host. Some will breed only in dead or decaying bark or wood, others only in dying or recently felled timber, while a few prefer trees that appear to be perfectly healthy or are at most only slightly weakened. Species that are habitually found in trees or in limbs that are slowly dying from suppression are seldom found in slash or in vigorous tree tissue. Forms that breed characteristically in fresh slash will seldom attack living trees when their favorite material is available. If such forms do attack vigorous trees they suffer a high mortality and, although they may eventually kill a few trees, their losses are so great that they are unable to continue an epidemic in the absence of slash.

The larvae and adults of the same species usually have similar food habits. The ambrosia beetles and their larvae both feed on the fungi which invariably grow in their burrows. The wood-eating forms, such as *Hylocurus*, *Lymantor*, and *Micracis* in both stages get their food from the woody tissues of the sapwood, which may contain considerable fungous material. The true bark beetles generally construct their galleries at the dividing line of bark and sapwood, and their food is often derived from both; however, the phloem and cambium usually seem to be the main sources of food.

Young bark beetles, when they have just transformed from the pupal stage, are nearly colorless, except for the eyes and mandibles and a slight pigmentation at some of the principal leg joints. They take little or no food for a day or so, until their chitinous structures have hardened somewhat, but then begin to feed actively. It is usually from one to several weeks before they attain their mature coloration and are ready to leave their original host. When transformation takes place late in the summer or in the fall, most species usually remain throughout the winter in the host in which they developed, and emerge the following spring after several days of feeding. If emergence occurs late in the season, some species, such as *Ips*, and *Pityophthorus*, will not attack new hosts, but will seek hibernation quarters in bark crevices, under loose bark, or even in the forest duff.

Most species on emergence are sexually mature and will attack the first suitable material they encounter. Some species, however, must feed elsewhere for a time before they are ready to construct their brood burrows. The newly emerged adults of species of *Scolytus* and *Phloeosinus* feed for several days by boring in the bark and sapwood of twigs or in the petioles of the leaves of their host plants. Another departure from the usual habit is shown by species of *Phthorophloeus* and *Leperisinus* and by the native elm bark beetle (*Hylurgopinus rufipes* Eichh.) and others, which emerge from their old hosts in the fall, bore into the outer bark of living trees, feed on the sap and tissues of the outer part of the phloem, and hibernate in this location. The following spring they emerge and seek material suitable for breeding purposes.

Some of the most interesting habits of the family are those concerned with their construction of brood burrows in the bark or wood of trees and shrubs. The adults lay their eggs in their burrows where most of them spend the remainder of their lives and die. Some beetles, after laying a number of eggs, emerge and reattack the same or other host material, producing new burrows and another group of progeny. This may even be repeated several times.

While the brood burrows are of a variety of different types, those made by the same species are usually so characteristic as to be readily identified, and often the insect responsible for certain injuries can be identified by the brood burrows more readily than in any other way.

True bark beetles construct the entrance gallery diagonally through the bark to the surface of the sapwood. There it is either widened to form an irregular cavity or it is continued as one, two, or several egg galleries which may extend longitudinally, transversely, or diagonally in the cambium. Eggs are laid either loosely in a heap in the irregular cavity, placed singly in small conical niches in the sides of the egg gallery, in groups of several in larger cuplike cavities, or in larger groups in long egg grooves.

Usually each larva excavates a separate mine through the bark, roughly at a right angle to the egg gallery, but sometimes the larvae work together in a common chamber. Pupation takes place in a slightly widened chamber at the end of the larval mine. The young adult beetles often feed in the inner bark for some time before emerging, the feeding tunnels frequently merging to form larger, irregular cavities. Where a number of young adults thus feed in a group, one emergence hole may serve as an exit for all. Where young adults, as those of the hickory bark beetle and others, do not feed to any great extent in the old host, each emerges through a separate exit hole and produces the "shot-hole" effect frequently seen. The new adults of ambrosia beetles, however, leave by the same opening through which their parents originally entered the wood.

In all the studies of emerging young beetles the two sexes have been found in approximately equal numbers. This is by no means always true of the beetles found later in the newly established brood burrows, where, in many species, the females considerably outnumber the males. In other species only females are present in the new burrows, while in still others the two sexes are equally represented. In explanation of these differences, some discussion of the reproductive habits is necessary.

Fertilization of the female may take place in the old host in which the beetle has passed its immature stages, but usually in the new host. With certain ambrosia beetles, such as *Anisandrus* and *Xyleborus*, the males are much smaller and weaker than the females and their wings are not sufficiently developed for flight. In such species the females must be fertilized before leaving their parent burrows.

Bark beetles may be either monogamous or polygamous, and in some cases where several males and several females are associated in the formation of one brood burrow, the relations might be described as promiscuous polygamy. The character of the brood burrow and the behaviour of the beetles while constructing it differ according to whether they are monogamic or polygamic.

In the monogamic forms the female begins the burrow and does all or nearly all the construction work. The male may enter the new burrow and may assist in constructing the nuptial chamber and aid in the disposal of the frass from the egg gallery, but in other cases the only real duty he performs is fertilizing the female. The burrows of monogamic species have a variety of forms—simple cavities, regular or irregular longitudinal or transverse galleries, or forked galleries—and they may occur in the inner bark, in the wood, or in the pith.

In the polygamous beetles the male begins the burrow and does all the early work in its preparation. Most of the males begin to leave the old host several days earlier than the females. They find suitable host material and each begins a new burrow by constructing an entrance gallery diagonally through the bark to the sapwood. Here he excavates an irregular cavity, the nuptial chamber, and the burrow is then ready for the reception of one or several females, which have taken no part in this early work.

On entering the new burrow, each female begins the construction of a separate egg gallery leading off from the central nuptial chamber. The directions of the galleries, with regard to the grain of the wood, depend on the species of beetle. In some species the galleries have a general longitudinal direction, in some they may be transverse, and in others they may bear any relation whatever to the grain of the wood or bark. The completed burrow is thus more or less radiate or stellate in general form. The egg galleries are of uniform bore and are just large enough to allow the passage of the beetles. When they are unusually long, they may have at varying distances small alcoves, known as turning niches, into which the beetle may back up and reverse its direction. In many galleries no such provision is made, and the female must back into the nuptial chamber in order to turn around.

Polygamous beetles most commonly live in burrows of the radiate type but may also live in the cave type, and either type may be excavated in the bark, the wood, or the pith. Ambrosial galleries may contain only females that have been fertilized before leaving the parent burrows, or they may contain several males and many females.

An interesting habit shown by many monogamous species, and almost universal with the polygamous forms, is that of the males in blocking the entrance to their burrows with their own bodies, thus preventing the entrance of both predators and parasites. The entrance of the burrows is thus rendered invulnerable to any ordinary attack. Many of the males die in this position, and even after death their bodies afford some protection to the brood within.

From the foregoing discussion, it is apparent that the reproductive habits of each species are largely responsible for the type of burrow or engraving made by it. The burrows may be grouped in about 10 general types, with considerable variation in each type, due to size, direction, and position of the component parts.

(1) Cave Burrows.—These consist of an entrance gallery leading directly into an irregular cavity made by the parent beetles. In this the eggs are laid either in irregular masses at any part of the cave or in egg niches or grooves at its periphery. All the larvae may work together in enlarging the original cavity, or they may excavate

radiating mines. The cave burrow is the simplest and probably the most primitive type. Beetles making such burrows may be either monogamous, polygamous, or promiscuous. Examples of such insects are *Cryphalus mainensis* Blkm., *Pityophthorus* spp., and *Erineosinus squamosus* Blkm.

(2) Irregular Elongate Burrows.—In this type the entrance gallery is continued at the juncture of wood and bark for a variable distance, and then irregularly widened to provide a place for the deposit of eggs. The burrow ranges in length from several inches to a foot, or even several feet. The eggs are deposited in masses in the wider areas on one or both sides of the main gallery and are protected by a wall of frass. This type of burrow is made by monogamous forms, such as *Dendroctonus valens* Lec. and *D. terebrans* (Oliv.).

(3) Simple Longitudinal or Transverse Burrows.—These differ from the foregoing in that they are uniform in diameter throughout, and may be either longitudinal or transverse, straight or winding. Each burrow may or may not have a turning niche, or nuptial recess, at the juncture of entrance gallery and egg gallery. The eggs may be laid in egg niches arranged symmetrically or irregularly and there may be one or more egg grooves in which all the eggs are placed. The simplest burrows of this type, which contain no nuptial recess, are made by species of *Scolytus* and others. In *Phloeosinus*, *Chramesus*, and some other beetles the rather short galleries are similar, but each has a nuptial niche. In *Dendroctonus frontalis* Zimm. the burrows are much longer and are winding. Species making this type of burrow are monogamic.

(4) Forked Longitudinal of Transverse Burrows.—In this type the entrance gallery leads into a more or less enlarged chamber, from which the two egg galleries either extend in opposite directions or diverge at a very wide angle. Typical galleries of this type are those of species of *Phthorophloeus*, *Hylurgopinus*, and *Leperisinus*, which are transverse in direction, and those of *Scolytus piceae* Sw., which are longitudinal. Burrows of *Cryptocleptes dislocatus* Blkm. are also longitudinal but differ from the typical in that the eggs are not placed in niches but packed in the sawdustlike frass in the main bore of the gallery. In one species, *Pseudothysanoes drakei* Blkm., there is a double-forked transverse burrow, appearing as if two forked burrows were joined together by a short longitudinal gallery connecting with a common entrance. Beetles making the forked burrows are usually bigamous, but some are monogamous.

(5) Radiate or Star-Shaped Burrows.—In the radiate burrows the entrance gallery leads directly into an irregular chamber, known as the nuptial chamber, from which radiate the egg galleries, each made by a separate female. The egg galleries may be symmetrically arranged as in those made by *Pityogenes* spp., *Ips pini* Say and some species of *Pityophthorus;* they may be chiefly longitudinal, as those by *Ips calligraphus* Germ.; principally transverse as those by *Pityophthorus liquidambarus* Blkm.; or they may be irregular, as in *Dryocoetes betulae* Hopk. Radiate burrows are inhabited exclusively by polygamous forms.

(6) Pith Burrows.—Several bark beetles such as *Micracis opacicollis* Lec., *Pityophthorus pulicarius* Zimm., and several species of *Myeloborus* bore through the bark and wood and construct one or more

egg galleries in the pith. They occur only in twigs or very small limbs, and in the case of the last two genera, are found in the leaf-bearing portion of living pines. The larvae feed on the pith, the wood, or the inner bark. Forms making pith burrows are usually polygamous.

(7) Wood Burrows.—These are excavated from the sapwood and in general chracteristics are similar to burrows occurring in the bark. The entrance gallery leads directly through the bark into the wood, where it may be continued as a simple egg gallery, may be branched, or may be expanded into a nuptial chamber from which several egg galleries arise. Various species of *Hylocurus*, *Micracis*, and *Thysanoes* and *Lymantor decipiens* Lec. construct wood burrows. The beetles producing these burrows may be either monogamous or polygamous.

(8) Simple Ambrosial Burrows (Pinhole Burrows).—The burrows of ambrosia beetles are always cut in the wood and are stained black by the action of the ambrosial fungi, which grow upon their walls and which serve as food for both larvae and adults. The simplest type of burrow, made by *Xyleborus saxeseni* Ratz. and *X. pecanis* Hopk., usually consists of an unbranched gallery extending into the sapwood, where it is slightly widened to form a space for the eggs. The adults and larvae work together, enlarging this cavity, thus forming a wide flat room of varying area. This type of gallery is somewhat similar to Types 1 and 2 in the bark.

(9) Branched Ambrosia Burrows (Pinhole Burrows).—In this type the entrance gallery, after entering the sapwood, breaks up into several branches extending in various directions in the same general plane. The eggs are laid free in certain of the galleries and the larvae live there, feeding on the ambrosial fungi. The burrows of *Xyleborus celsus* Eichh. have many branches, but those of *Anisandrus* spp. have fewer.

(10) Compound Ambrosial Burrows (Pinhole Burrows).—The burrows of this type resemble those last described in that several egg galleries arise from the entrance gallery. They differ, however, in that the parent beetles make niches in the upper and lower sides of the galleries. In these niches the eggs are deposited and the young remain throughout their larval and pupal lives, the larvae being fed by ambrosia brought to them by the adults. As they grow, the larvae enlarge the niches more and more to form the characteristic larval cradles produced by species of *Trypodendron*, *Xyloterinus*, *Gnathotrichus, and Monarthrum.*

ECONOMIC IMPORTANCE OF BARK BEETLES

The family Scolytidae contains several of the most destructive forest insects found in the United States. Although more trees are killed by them than by any other group of insects, only a comparatively small number of species of bark beetles ordinarily attack and kill vigorous trees. Other forms, however, can breed successfully in twigs, cones, or other portions of living trees but in so doing destroy only the parts infested. By far the great majority of species, however, breed in recently cut trees, stumps, broken limbs, or in decadent, dying, or dead trees or portions of trees. Thus a number of species are economically neutral and some are even mildly beneficial. As a family, however, the injuries done by scolytids greatly outweigh the benefits they confer.

Although losses due to bark beetles are by no means as severe in the

East as in the West, a number of them are serious pests. One reason why the losses are not so great is that the East no longer contains many large tracts of overmature trees in which an extensive outbreak can develop. In the West vast forest tracts, consisting largely of one kind of tree and often containing many mature, overmature, and decadent trees, offer ideal habitats for certain bark beetles. Under proper climatic conditions these beetles may rapidly increase to outbreak proportions.

All stages of the tree, from the origin of the seed to the utilization of the lumber, are subject to injury by scolytid beetles. Injuries may be considered under several headings as follows: (1) Damage to forest reproduction; (2) impairment of the health and growth of trees; (3) actual killing of trees; (4) injury to timber during the process of lumbering and manufacture; and (5) damage to utilized timber.

Injuries to utilized timber by bark beetles is of much less importance than that by other groups of insects, such as lyctids and termites. Aside from damage by tropical ambrosia beetles of the genus *Xyleborus* to barrels and other wooden containers of water, wine, or other liquids, bark-beetle damage is practically confined to timber from which the bark has not been removed. Fence posts, poles, and round structural timbers more or less in contact with the soil, from which they can obtain moisture, are subject to injury by ambrosia beetles during the first year of this use—especially if used without previous seasoning. The burrows extend in through the sapwood, and those of *Platypus* even into the heartwood, thus reducing the strength of post or pole and allowing ready entrance to decay-causing fungi. At least one wood-eating scolytid, *Hylocurus langstoni* Blkm., is capable of doing considerable damage to unbarked timbers, its injuries being somewhat similar to those of the powder-post beetles.

A host of bark beetles and ambrosia beetles prefer to breed in recently cut trees. Therefore in the warmer seasons many trees become infested within a few days after they are cut. The injury to such material by the true bark beetles is not great, since they merely destroy the inner bark; but, unfortunately, many species of bark beetles introduce into the tree the spores of wood-staining fungi, such as the blue stains. The hyphae of these penetrate the sapwood and discolor it, rendering it unfit for many purposes and reducing its sales value. The bark beetles, by loosening the bark, permit more ready entrance for fungi.

The burrows of ambrosia beetles, however, are extended directly through the bark and into the sapwood, where they are branched or variously elaborated, according to the species concerned. The ambrosial fungi, on which both larvae and adults feed, grow in the burrows and impart a black stain to the surrounding wood. The burrows of most ambrosial beetles are confined to the sapwood, but species of *Platypus* extend theirs also into the heartwood. Unless it is promptly sawed up, timber cut during the warmer months will invariably suffer from ambrosia beetle attack. In the Southern States lumbermen know from experience that it is wise to work up oak, gum, and cypress cut during the warmer months within 2 or 3 weeks from the time it is felled. Within that time many burrows may already have been started, but they will penetrate only a short distance and most of them will come off in the slab when the logs are sawed into lumber.

The most important enemies to forest reproduction—the flower, seed, seedling, or young tree—belong to other groups. There are, however, some scolytid enemies of reproduction. Several species of the genus *Conophthorus* attack the growing cones of eastern pines and prevent the development of the seeds. Of these, *C. coniperda* (Sz.) kills the immature cones of northern white pine and often destroys a considerable portion of the seed crop in certain localities, and other species of *Conophthorus* attack the cones of other pines. Other scolytids, such as species of *Ips*, *Pityogenes*, and *Pityophthorus*, work in the bark of the stems and twigs, and species of *Hylastes* attack the root collar of young pines that have recently been transplanted or are growing under adverse conditions. Thus trees are killed which, although weakened, would otherwise have survived. When these beetles are excessively numerous, healthy young trees may be killed by a massed attack, although the beetles suffer heavy mortality in such material.

A number of bark beetles and ambrosia beetles attack, and sometimes breed in, healthy trees without necessarily killing them, although the tree is always more or less affected. It may be so weakened as to become easy prey for other insects or disease, its growth may be affected, or its timber value may be reduced.

Dendroctonus valens Lec. and *D. terebrans* (Oliv.), while preferring stumps or sickly trees, often attack healthy pines near the base of the trunk and kill areas of bark near the ground level. The young beetles of various species of *Scolytus* and *Phloeosinus*, after emerging from their larval host, feed for some time on the young twigs or leaf petioles of healthy trees, killing many twigs and weakening the trees. *Phthorophloeus frontalis* Zimm., the **native elm bark beetle** (*Hylurgopinus rufipes*, and similar species emerge from their larval host in the fall, bore into the bark of the trunks of living trees, and feed on the tissues and juices of the outer phloem.

Ambrosia beetles usually breed only in dying, cut, or recently dead trees, but a few species, such as **the Columbian timber beetle** (*Corthylus columbianus* Hopk.) attack living trees and breed for generations in the living wood. Such a tree often survives and may show but little outward evidence of the attack; but, when converted into lumber, the heartwood and sapwood may be riddled by old and recent burrows and the timber value destroyed or much reduced.

The greatest amount of damage, however, is done by forms that kill forest trees. Such bark beetles vary considerably in their aggressiveness in attacking living trees. Some breed by preference in cut, injured, or decadent trees, and attack vigorous ones only when they are very numerous or when inferior material is lacking. Other species, even when present in only moderate numbers, will attack living trees in preference to cut or decadent material, provided enough beetles are at hand to overcome the tree's resistance.

The less aggressive forms find ideal conditions for increase in localities where lumbering has been carried on for several years, or where timber has been broken by a tornado or injured by a fire or a flood. Such conditions often provide suitable breeding material long enough for several generations of bark beetles to develop. The insects may thus increase to nearly incredible numbers, and then, when their favorite breeding material is lacking, they attack living trees. A few trees may be killed, but the mortality of the beetles entering vigorous trees is so great that the infestation rapidly dies out. Concerned in these incipient outbreaks are such eastern species as *Ips calligraphus*, *I. grandicollis*, *I. pini*, and, more rarely, species of *Pityogenes*. Sporadic outbreaks of this character are very easily controlled; but, since most of them soon die out with only light injury, control is hardly justifiable.

The more aggressive forms, such as certain species of *Dendroctonus*, do not usually produce heavy broods in felled or dying trees, although these serve as breeding places. Therefore great populations of such beetles are not built up in areas devastated by lumbering, tornadoes, fires, or floods.

KEYS TO BARK BEETLES

In the following pages will be found a key by which men untrained in forest entomology should be able to identify the work of many of the eastern bark beetles, after making a field examination of the injured material. An attempt has been made to avoid the use of technical terms, and, insofar as possible, the key is based on the character of the burrows, the species of tree affected, and the part of the tree attacked. Insect characters are used very sparingly, and when used are described in nontechnical terms.

It is hoped that such a key will prove to be useful. The ordinary technical key to the insects, while much easier to prepare, could be used only by a trained entomologist, and perhaps only by one who has specialized on a certain group.

Technical keys to most of the Scolytidae and Platypodidae will be found in Swaine (*401*), Blackman (*38*), and Chamberlin.[22]

KEY TO INSECT INJURIES BY SCOLYTIDAE AND PLATYPODIDAE

1.	Entrance gallery leading directly through the bark to the surface of the wood, where it is elaborated into one of the various types of bark burrows	2
	Entrance gallery proceeding through bark into the wood or even into the pith	23
2.	Occurring in the inner bark of coniferous trees	3
	Occurring in the inner bark of deciduous trees	20
3.	Attacking exposed roots or basal part of trunk	4
	Attacking the main trunk or thick barked primary branches	6
	Attacking the medium to small branches	11
	Attacking the twigs	16
	Attacking the cones	19
4.	Attacking fresh stumps or the bases of living pines and spruces; the entrance often marked by large pitch tubes; the egg gallery of irregular elongate type, extending downward from entrance	5
	Attacking older stumps or the bases and roots of dying trees; preferring fermenting bark *Hylastes* spp., *Hylurgops pinifex* Fitch, p. 324.	
5.	The beetles reddish brown, 5 to 9 mm. long, common in all parts of the United States *Dendroctonus valens* Lec., p. 319.	
	The beetles nearly black, slightly smaller; Southern States, rarer in Northeast *Dendroctonus terebrans* Oliv., p. 320.	

[22] Chamberlin, W. J. THE BARK AND TIMBER BEETLES OF NORTH AMERICA, NORTH OF MEXICO. THE TAXONOMY, BIOLOGY AND CONTROL OF 575 SPECIES BELONGING TO 72 GENERA OF THE SUPERFAMILY SCOLYTOIDEA. Oreg. State Col. Coop. Assoc. 513 pp. 1939. [Processed.]

KEY TO INSECT INJURIES BY SCOLYTIDAE AND PLATYPODIDAE—Continued

6. Attacking the thicker bark of pines........ 7
Attacking the thicker bark of spruces..... 8
Attacking the thicker bark of larch........ 10
Attacking the thicker bark of standing and felled balsam fir, causing the death of decadent trees; burrows radiate; beetle reddish brown, 2.5 mm. long..........*Pityokteines sparsus* Lec., p. 336.
Attacking the thicker bark of decadent and felled juniper, arborvitae, cypress, etc.; also causing injury by feeding on the twigs:
On arborvitae, Northeastern States
Phloeosinus canadensis Sw., p. 321.
On juniper, Eastern and Southern States
Phloeosinus dentatus Lec., p. 321.
On cypress, Southern States..*Phloeosinus taxodii* Blkm., p. 321.

7. Brown to black beetles about 3.6 mm. long, killing healthy southern pines by making S-shaped egg galleries in the inner bark
Dendroctonus frontalis Zimm., p. 315.
Reddish brown to black beetles, 3.5 to 6.5 mm. long, sometimes killing smaller trees or the tops of larger trees, but usually breeding in dying or cut trees; burrows radiate:
Ips calligraphus Germ., p. 334
Ips grandicollis Eichh., p. 334
Ips pini Say, p. 335
Ips chagnoni Sw., p. 335
Beetles 3 to 6.5 mm. long, reddish brown to black; in radiate burrows in the inner bark of trunks of dying or cut pines; rarely or never killing healthy trees; burrows radiate:
Ips longidens Sw., p. 335
Orthotomicus caelatus Eichh., p. 335
Dryocoetes americanus Hopk., p. 336

8. Brown to black beetles, 5 to 6 mm. long, making longitudinal egg galleries in mature, living spruce and killing the trees
Dendroctonus piceaperda Hopk., p. 318
Reddish brown to black beetles, 2 to 4 mm. long, making radiate or forked burrows in the bark of the trunk or larger limbs of dying or cut spruce.. 9

9. Beetles shining black, 3 mm. long; forked burrows
Scolytus piceae Sw., p. 313
Beetles reddish brown, 4 mm. long; radiate burrows
Dryocoetes americanus Hopk., p. 336
Beetles reddish brown, 2.5 mm. long; radiate burrows
Dryocoetes piceae Hopk., p. 336
Beetles dull black or brown, 2.4 mm. long; burrows radiate, the 4-eyed dark beetle.........*Polygraphus rufipennis* Kby., p. 313
Beetles dull brown, 2.2 mm. long; eyes normal; burrows radiate
Xylechinus americanus Blkm., p. 321
Beetles reddish brown, 3 mm. long; 3 teeth each side at rear end; radiate burrows............*Orthotomicus caelatus* Eichh., p. 335

10. Dark reddish-brown beetles, 3.5 to 5 mm. long; making straight or wavy egg galleries in the bark of living, felled, or decadent larch trees..........................*Dendroctonus simplex* Lec., p. 319
Small bark beetles in decadent or felled larch:
Scolytus piceae Sw., p. 313
Polygraphus rufipennis Kby., p. 313
Orthotomicus caelatus Eichh., p. 335
Dryocoetes americanus Hopk., p. 336

11. Attacking the medium to small branches of pine................ 12
Attacking the branches of spruce.............................. 16
Attacking the branches of larch:
Scolytus piceae Sw., p. 313
Polygraphus rufipennis Kby., p. 313
Attacking the branches of balsam fir:
Pityokteines sparsus Lec., p. 336
Cryphalus balsameus Hopk., p. 329

KEY TO INSECT INJURIES BY SCOLYTIDAE AND PLATYPODIDAE—Continued

12. Breeding in slash by choice but also breeding in decadent and weakened branches and tops ---------- 13
Breeding by preference in slowly dying, shaded-out limbs, less commonly in slash ---------- 15
13. In smooth, thin bark of white pine, less common in other pines:
Pityogenes hopkinsi Sw., p. 330. *Pityogenes lecontei* Sw., p. 330. *Ips pini* Say, p. 335. *Pityophthorus cariniceps* Lec., p. 332.
In rougher bark of pine slash ---------- 14
14. In southern pines:
Ips grandicollis Eichh., p. 334. *Ips avulsus* Eichh., p. 335. *Pityogenes plagiatus* Lec., p. 330. *Pityophthorus pulchellus* Eichh., p. 332. *Pityophthorus pullus* Zimm., p. 332.
In northern pines:
Ips grandicollis Eichh., p. 334. *Ips pini* Say, p. 335.
15. Found only in southern pines:
Pityogenes meridianus Blkm., p. 330. *Pityoborus comatus* Zimm., p. 330.
Found most commonly in white pine but also in others, including southern pines:
Pityophthorus consimilis Lec., p. 333. *Pityophthorus nudus* Sw., p. 333.
16. Found in medium-sized branches of spruce:
In longitudinal forked burrows *Scolytus piceae* Sw., p. 313.
In radiate burrows --- *Polygraphus rufipennis* Kby., p. 313.
In transverse forked burrows *Phthorophloeus piceae* Sw., p. 315.
In irregular radiate burrows; larger *Dryocoetes americanus* Hopk., p. 336.
In irregular radiate burrows; smaller *Dryocoetes piceae* Hopk., p. 336.
Found in the smaller branches of spruce:
Cryphalus mainensis Blkm., p. 329. *Pityophthorus cascoensis* Blkm., p. 332. *P. shepardi* Blkm., *P. tonsus* Blkm., p. 332. *P. pulchellus* Eichh., *P. consimilis* Lec., p. 332. *P. nudus* Sw., p. 333.
17. Attacking the twigs of pines ---------- 18
Attacking the twigs of spruce:
Various species of *Pityophthorus*, p. 331. *Cryphalus* spp., p. 329.
Attacking the twigs of larch -------- *Pityophthorus* spp., p. 331.
Attacking the twigs of balsam fir:
Pityophthorus spp., p. 331. *Cryphalus* spp., p. 329.
Attacking the twigs of juniper, arborvitae, cypress, etc.; young adults eating out the bases of twigs causing them to wilt or to break off ---------- *Phloeosinus* spp., p. 321.
18. Attacking living pine twigs, boring through the bark and wood to the pith:
In red pine ---------- *Myeloborus fivazi* Blkm., p. 331.
In white pine ---------- *Myeloborus ramiperda* Sw., p. 331.
In various pines ---- *Pityophthorus pulicarius* Zimm., p. 331.
Attacking the twigs of decadent or severed branches; breeding principally in the inner bark but often affecting the wood:
Carphoborus bicristatus Chap., p. 314.
Carphoborus bifurcus Eichh., p. 314.
Pityophthorus spp., p. 331.
19. Small brown to black beetles causing the death of growing pine cones:
Destroying white pine cones *Conophthorus coniperda* (Sz.), p. 328.
Destroying red pine cones *Conophthorus resinosae* Hopk., p. 328.
Affecting cones of loblolly pine *Conophthorus taedae* Hopk., p. 328.
Affecting cones of Virginia pine *Conophthorus virginianae* Hopk., p. 328.

KEY TO INSECT INJURIES BY SCOLYTIDAE AND PLATYPODIDAE—Continued

20. Attacking the bark of the main trunk and larger branches of hardwood trees 21
Attacking the smaller limbs and twigs of hardwood trees 22

21. Entering the bark of the trunk and larger branches of living hickory; forming centipedelike engravings on the inner bark, killing the trees. Young adults injuring the small twigs in feeding .... *Scolytus quadrispinosus* Say, p. 308.
Breeding in the inner bark of decadent or felled elms; not killing healthy trees but dangerous as vectors of Dutch elm disease
Making short, simple, longitudinal egg galleries; young adults injuring small twigs in feeding:
Scolytus multistriatus (Marsh), p. 310.
Scolytus sulcatus Lec., p. 312.
Making branched, tranverse burrows; young adults often hibernating in bark of healthy elms
Hylurgopinus rufipes Eichh., p. 323.
Breeding in the inner bark of decadent and felled ash; making regular, transverse, branched engravings:
Leperisinus aculeatus Say, p. 323.
Leperisinus fasciatus Lec., p. 323.
Breeding in the trunk and larger branches of decadent or felled birch, beech, red gum, and wild cherry; in irregular radiate burrows in the inner bark
Dryocoetes betulae Hopk., p. 336.
Engraving the inner bark and sapwood of decadent and felled mulberry with regular, transverse, branched engravings; adults hibernating in inner bark of living trees, injuring them
Phthorophloeus frontalis Zimm., p. 315.
Breeding in the inner bark of injured wild plum and wild cherry:
In short, unbranched, longitudinal galleries:
Scolytus rugulosus Ratz., p. 310.
In forked, tranverse burrows:
Phthorophloeus liminaris Harr., p. 315.
Phthorophloeus mississippiensis Blkm. p. 315.
Breeding in the thin bark of the trunks of sumac; making radiate burrows:
Pityophthorus rhois Sw., p. 331.
Pityophthorus crinalis Blkm., p. 331.
Pityophthorus scriptor Blkm., p. 331.

22. Breeding in the smaller limbs and twigs of hickory:
Making short, unbranched burrows in the smaller limbs
Chramesus hicoriae Lec., p. 314.
Making very slender, branched longitudinal burrows in hickory twigs ...... *Cryptocleptes dislocatus* Blkm., p. 326.
Young beetles causing injury to green twigs and leaf petioles of hickory by feeding, causing them to wilt or break
Scolytus quadrispinosus Say, p. 308.
Breeding in the small branches of hackberry
In unbranched, longitudinal burrows:
Scolytus muticus Say, p. 310.
Chramesus chapuisii Lec., p. 314.
In transverse branched burrows
Phthorophloeus dentifrons Blkm., p. 315.
Breeding in the small branches of oaks and chestnut:
Pseudothysanoes lecontei Blkm., p. 326.
Pseudopityophthorus spp., p. 327.
Breeding in the small branches of basswood:
Pseudothysanoes rigidus Lec., p. 326.
Pseudothysanoes drakeii Blkm., p. 326.
Breeding in the small branches of redbud
Pityophthorus natalis Blkm., p. 331.
Breeding in the small branches of red gum
Pityophthorus liquidambarus Blkm., p. 331.

KEY TO INSECT INJURIES BY SCOLYTIDAE AND PLATYPODIDAE—Continued

Occurring in the bark, wood, or pith of the small branches and twigs of various hardwoods, with little regard to species
Species of *Hypothenemus* and *Stephanoderes*, p. 327.

23. Pinhole burrows in the wood not stained dark by ambrosial fungi__ 24
Pinhole burrows extending into the wood and stained dark by ambrosial fungi__ 28

24. Very small pinhole burrows in the living leaf-bearing twigs of pines, extending through the wood to the pith and continued there as egg galleries; entrance usually covered by pitch tube:
In red pine twigs, Northern States
Myeloborus fivazi Blkm, p. 331.
In white pine twigs, Northern States
Myeloborus ramiperda Sw.. p. 331.
In twigs of various eastern and southern pines
Pityophthorus pulicarius Zimm., p. 331.
Pinhole burrows in the wood or pith of dying or dead hardwoods, branching into several egg galleries in the sapwood or pith__ 25

25. Small beetles with the rear end tapering to a point__ 26
Small beetles with the rear end rounded__ 27

26. Small beetles with the basal joint of the antenna flattened, expanded, and ornamented with long hairs:
Breeding in the wood of willow and redbud; Maryland to California *Micracis swainei* Blkm., p. 325.
Breeding in poplar shoots; central New York
Micracis populi Sw., p. 325.
Breeding in redbud and other hardwoods; Maryland to Illinois *Micracis suturalis* Lec., p. 325.
Breeding in willow and redbud; Virginia to Mississippi
Micracis meridianus Blkm., p. 325.
Breeding in pith of oaks, maple, etc.; Massachusetts to Kansas and south to Texas and Florida
Micracis opacicollis Lec., p. 325.
Breeding in pith of oaks, etc.; South Carolina to Texas
Micracis nanula Lec., p. 325.
Small beetles with the rear end acute and first joint of antenna normal:
In wood of honeylocust, hackberry, and other hardwoods; Maryland to Texas__*Hylocurus langstoni* Blkm., p. 325.
In wood of hickory, maple, etc.; Michigan to Georgia
Hylocurus rudis Lec., p. 325.
Known only from hickory wood:
New York to North Carolina
Hylocurus biorbis Blkm., p. 325.
Mississippi__*Hylocurus bicornis* Blkm., p. 325.
Hylocurus harnedi Blkm., p. 325.
Pennsylvania to North Carolina
Hylocurus spadix Blkm., p. 325.

27. Small dull yellowish-brown to black beetles; the basal joint of the antenna club-shaped with long hairs:
Yellowish brown; from Pennsylvania to Florida and Texas, in oaks, hickory, and other hardwoods
Thysanoes fimbricornis Lec., p. 326.
Dark brown; in oaks and maples in Mississippi and Georgia
Thysanoes lobdelli Blkm., p. 326.
Dark brown; in elm and rattan vine from Virginia to Texas
Thysanoes berschemiae Blkm., p. 326.
Small, shining, reddish-brown beetles; wing covers coarsely, irregularly punctured; Massachusetts to Iowa and Mississippi in maple and hickory__*Lymantor decipiens* Lec., p. 326.

28. In stained ambrosial burrows usually confined entirely to the sapwood; common in wood of both coniferous and broadleaved trees__ 29

KEY TO INSECT INJURIES BY SCOLYTIDAE AND PLATYPODIDAE—Continued

In stained ambrosial burrows, in both sapwood and heartwood; beetles longer, slender, cylindrical, with wide heads flat in front; the wing covers of the males with spinelike projections behind; in conifers and hardwoods -- 36

29. In the wood of broadleaved trees; the burrows of various types --- 30

Compound ambrosial burrows in the wood of decadent or felled conifers -- 35

30. Breeding in living broadleaved trees, not killing them but affecting the value of the wood; compound burrows in tulip, maple, oak, etc ------------- *Corthylus columbianus* Hopk., pp. 301, 338.

Breeding in dying or dead broadleaved trees, especially in recently cut timber -- 31

31. Constructing simple, unbranched, ambrosial burrows (see page 299 for description) in various hardwoods.

In sapwood of various hardwoods, such as elm, maple, hickory, birch, etc.; beetles 2 mm. or less in length; Europe and eastern part of the United States *Xyleborus saxeseni* Ratz., p. 340.

In southern hardwoods, especially in pecan, hickories, birch, sweet gum, etc.; beetle very similar to above, Southeastern States ---------------- *Xyleborus pecanis* Hopk., p. 340.

Constructing branched ambrosial burrows (see p. 229 for description) in various hardwoods -- 32

Constructing compound ambrosial burrows (see p. 229 for description) in various hardwoods -- 33

32. In branched ambrosial burrows in the sapwood of dying and recently dead hickories; cylindrical beetles 4 mm. or more in length ---------------------- *Xyleborus celsus* Eichh., p. 341.

In branched ambrosial burrows in the sapwood of various species of dying and dead hardwoods; beetles from 1 to 4 mm. long:

In beech, birch, maple, oak, etc.; Northeastern States *Anisandrus obesus* Lec., p. 341.

In branches of apple, maple, etc.; Eastern States *Anisandrus pyri* Peck, p. 341.

In small branches and twigs of maples and beech; Northeastern States ----------- *Anisandrus minor* Sw., p. 341.

Attacking stumps and logs of hardwoods in New Jersey, New York, Connecticut, and the upper Ohio Valley; introduced from the Orient *Xylosandrus germanus* Bldfd., p. 341.

33. In narrow black-stained burrows in various hardwoods; beetles small and slender -- 34

In notably coarser, black-stained burrows in hardwoods; beetles larger and much stouter:

In birch, beech, maple, etc.; beetle brown to black in color *Xyloterinus politus* Say, p. 339.

In poplars; Northeastern States; beetle with smoky yellow stripe on each wing cover *Trypodendron retusus* Lec., p. 339.

In various birches; Northeastern States; stripe of yellow on each wing cover ------ *Trypodendron betulae* Sw., p. 339.

34. Beetles very slender, more than 3 times as long as wide; antennal funicle 2-jointed:

Beetle reddish brown, wing covers all one color; smaller; in many hardwoods ------- *Monarthrum mali* Fitch, p. 339.

Beetle dark brown, wing covers with cross band of yellow; larger; infests many southern hardwoods *Monarthrum fasciatum* Say, p. 339.

Beetles less than 3 times as long as wide; antennal funicle 5-jointed; in various hardwoods:

Xyleborus affinis Eichh., p. 340.
Xyleborus xylographus Say, p. 340.
Xyleborus fuscatus Eichh., p. 340.
Xyleborus confusus Eichh., p. 341.

KEY TO INSECT INJURIES BY SCOLYTIDAE AND PLATYPODIDAE—Continued

35. In rather narrow compound ambrosial burrows in the wood of decadent or felled conifers:
In pine; Pennsylvania and New York
Xyleborus fitchi Hopk., p. 340.
In pine; South Dakota
Gnathotrichus aciculatus Blkm., p. 340.
In pine, spruce, larch, balsam, etc.; in Eastern and Southeastern States____*Gnathotrichus materiarius* Fitch, p. 340.
In notably coarser compound ambrosial burrows in decadent and felled conifers; beetles stout, dark brown to black, marked with lighter brown or yellow:
Known from pine, wing covers often with indistinct stripe of smoky brown on black
Trypodendron scabricollis Lec., p. 339.
Common in pine, spruce, larch, hemlock, balsam, arborvitae; wing covers of beetles with distinct yellow stripes
Trypodendron bivittatum Kby., p. 339.

36. Flatheaded ambrosia beetles making compound ambrosial burrows in southern hardwoods; beetles less than 5 mm. long:
Beetles in hickories, oaks, gums, cypress, etc.
Platypus compositus Say, p. 342.
In southern oaks and chestnut
Platypus quadridentatus Oliv., p. 343.
Flatheaded ambrosial beetles making compound ambrosial burrows in southern conifers, especially in pines; larger, more than 5.5 mm. long______________________*Platypus flavicornis* F., p. 342.

DISCUSSION OF THE SPECIES OF SCOLYTUS

The genus *Scolytus* Geoff. is readily distinguished from other bark beetles by the short, thick, brown or black body, by the outer angle of the fore tibia being produced into a curved hook, and by the contour of the abdomen—the ventral surface ascending abruptly behind, and in some cases being concave or excavated and ornamented by spines, tubercles, etc.

Blackman (*43*) considered all the species of *Scolytus* as true bark beetles, all but one of the eastern species breeding in deciduous trees. Most of the species are monogamic, the egg galleries being of the simple longitudinal variety, but a few produce burrows of the forked or the radiate type. The genus contains several species of well-known economic importance, one of these, the hickory bark beetle (*Scolytus quadrispinosus*) being decidely injurious on its own account; whereas another, the smaller European elm bark beetle (*S. multistriatus*), is important as the chief insect vector of the destructive Dutch elm disease. Several species of importance in the Western States are treated by Keen (*262*).

The hickory bark beetle (*Scolytus quadrispinosus*) is black, 3 to 5 mm. in length, and about twice as long as wide, with the upper surface nearly devoid of hairs. In the female the ventral surface of the abdomen is strongly ascending and is only slightly concave, whereas in that of the male the second segment is very deeply excavated with the anterior margin strongly extended, the third segment bears three large spines, and the fourth segment a single spine. The armature on the male is likely to be more strongly developed in specimens from the South, and some specimens have additional spines. This scolytid breeds in all species of hickory, including native and cultivated pecans, and has been observed constructing burrows in butternut. It is found from Quebec to Georgia, Alabama, and Mississippi and westward to Texas, Oklahoma, Kansas, and Minnesota. It has been reported, perhaps erroneously, from Utah, and is likely to be found wherever the various species of hickory grow naturally.

Often the first indication of the presence of the hickory bark beetle is seen in wilting leaves and hanging broken twigs on an otherwise normal hickory tree. These appear during early midsummer and are due to the activities of the recently emerged adults, which feed voraciously by boring into the petioles of the leaves and the young growth of the twigs. The cavities made in feeding may extend nearly through twigs and petioles, causing the leaves to wither and the twigs to break and either fall to the ground or remain hanging by a few shreds of bark or woody tissue. The feeding of the young adults often does considerable damage to a tree, but does not kill it.

Fatal injuries to hickory by these bark beetles are due to their breeding habits. The young beetles, after feeding for some time as previously described, fly to the trunk and branches of living trees, bore through the bark to the surface of the sapwood, and there construct rather short, longitudinal egg galleries and deposit their eggs. The entrance to the burrow is nearly perpendicular to the surface of the wood, but with a slightly upward angle, and the egg gallery extends directly upward, with the grain of wood, at the contacting surfaces of wood and bark. In thick-barked hickory the wood is scarcely etched by the gallery, but in thin-barked limbs as much as half of the diameter of the burrow may be gouged from the wood. The egg galleries range from 1 inch to 3½ inches in length, depending largely on the vigor of the tree attacked, the burrows being longer in dying bark.

Usually from 20 to 60 eggs are placed in small pockets or niches at each side of the egg gallery, but in unusually long galleries as many as 140 have been observed. Upon hatching, the larvae burrow in the phloem, starting in at right angles to the gallery. At first the larval mines are very narrow and straight, but as they increase in diameter they diverge more and more, finally producing a centipede-like engraving.

When nearly full grown, the larvae leave the phloem and bore into the outer part of the inner bark. If they reach full growth in the fall, which they normally do in the Northern States, they remain in the bark over winter, and transform to pupae and later to adults the following spring or early in the summer.

In the Northern States the hickory bark beetle has a single generation a year, the adults being in flight during June and the early part of July. The foliage of trees attacked usually begins to fade and fall by the middle of August, but in some cases fatally attacked trees retain nearly their full foliage until time for normal fall shedding. Farther south, e. g., in northern Mississippi, there are apparently two generations in each year, the first attacks taking place early in May.

The hickory bark beetle has caused the death of thousands of trees in New York, Pennsylvania, and other regions of the North, and also in Maryland and Virginia, and is by all odds the most deadly enemy of various hickories. When the beetles in an area are not very numerous, they breed in broken or cut material or in decadent or dying trees; but, when present in sufficient numbers, they attack trees that are apparently in good health, killing hundreds of them in a single season.

Such killings have taken place in eastern and central New York, in Michigan, and elsewhere in the Northern States. Such outbreaks seem to occur during years in which precipitation is deficient during the summer months, and the increase in bark beetle numbers appears to be due to the direct beneficial effect on the insects of a deficiency of moisture and an abundance of sunshine, rather than indirectly because of lessened vigor in the trees. An excess of precipitation and a dearth of sunshine while the adults are feeding on the new growth and establishing their burrows in the bark, and later when the larvae are young, results in a very high mortality and greatly reduces infestation in the following years. Control methods are discussed on pages 47–51.

Further information on this species may be found in Swaine (*401*); Blackman (*38*, *39*, *43*) and Chamberlin.[23]

The hackberry engraver (*Scolytus muticus*) is black, 3 to 4.5 mm. long, and about half as wide. It is readily distinguished from other species by the rather long ashen hairs on the elytra and the sides of the pronotum. It breeds in the limbs of several species of hackberry (*Celtis*) and is known from New Jersey to Florida and westward to Kansas and Texas. It is not a serious enemy, as it breeds in dying and dead limbs of hackberry and is not known to attack vigorous material. The egg galleries are quite similar to those of the hickory bark beetle. The larvae on hatching begin their mines at the contacting surfaces of the bark and sapwood, but as they become nearly full grown, the burrow is continued downward into the sapwood. Transformation to pupa and adult occurs beneath the surface of the wood. As the hackberry engraver seldom or never attacks living trees, control is not necessary, but could readily be accomplished by burning infested material. The reader is referred to Blackman (*38*, *43*) for further information on the hackberry engraver.

The shot-hole borer (*Scolytus rugulosus*), or **fruit tree bark beetle,** is reddish brown to black, averages about 2.5 mm. in length, and is distinctly more than twice as long as wide. The elytra are closely striate and well supplied with evenly distributed short hairs. The ventral abdominal outline is strongly ascending and slightly convex. This species, originally introduced from Europe, has been known in the United States since 1878 and at present is to be found in most of the States east of the Continental Divide, as well as in New Mexico, California, and Oregon. Trees serving as hosts for the shot-hole borers include our common cultivated fruit trees and also the wild plums and cherries.

The habits of the shot-hole borer are similar to those of other species of *Scolytus*. They are not serious enemies of trees, because for breeding purposes they choose broken, cut, or dying material, and seldom or never attack healthy bark. Damage is usually confined to orchards where sanitation has been neglected and the vigor of the fruit trees has been allowed to deteriorate, or in natural growths that have been injured by ground fires or in some other way. On at least one occasion, specimens were taken from beneath the bark of sickly elm. Gossard (*189*) and Blackman (*38*, *43*) have discussed this species.

The smaller European elm bark beetle (*Scolytus multistriatus* (fig. 61, *A*) is brownish to black in color, 2.5 to 3.5 mm. long, and about

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[23] See footnote 22, p. 302.

half as wide. It is readily recognized by the presence of a rather long subcapitate spine arising from the anterior third of the second abdominal sternite and extending backward, and by the fact that the elytra are rounded at the top.

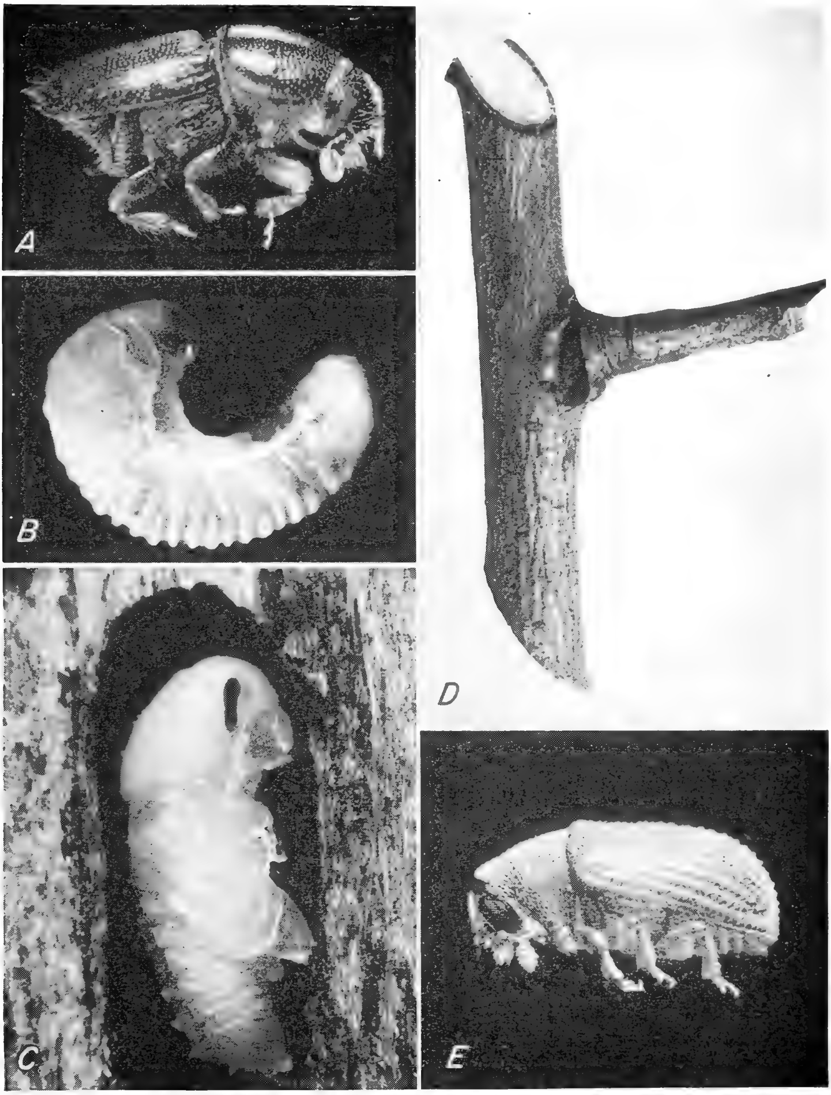

FIGURE 61.—The smaller European elm bark beetle (*Scolytus multistriatus*): *A*, Adult, × 15; *B*, larva, × 13; *C*, pupa; *D*, feeding scar made by adult in small elm crotch; *E*, adult of the native elm bark beetle (*Hylurgopinus rufipes*).

This species is widely distributed in Europe and was accidentally introduced into this country sometime prior to 1909, when it was found to be firmly established in the vicinity of Boston, Mass. It is also known to occur in New Hampshire, western Connecticut and Massachusetts, eastern New York, Delaware, Pennsylvania, northern New Jersey, Indiana, Kentucky, Ohio, Maryland, Virginia, and West Virginia. After the flood of the Ohio River early in 1937, elm driftwood containing *Scolytus multistriatus* was found at several points on the lower Ohio River. There is strong evidence that the beetles have been introduced at several different points.

The smaller European elm bark beetle seems to confine its attacks to the various species of elm. The beetles show a decided preference for recently cut, broken, or dying material, and although they sometimes attack living elm bark, they are not successful. The simple unforked egg galleries follow the grain of the wood and are usually straight. The small nearly spherical eggs are deposited in niches in the sides of the egg gallery, and average about 73 per gallery. Emergence of young adults from infested material varies according to the density of the initial attack and the conditions surrounding development. Less than 100 beetles per square foot were obtained from material overwintering in the field, whereas an emergence of over 600 per square foot was obtained from the most favorable sticks in an outdoor rearing cage.

In northern New Jersey, the length of the life cycle ranges from 45 to 60 days under favorable conditions. In this area there are two full generations and a partial third each year, whereas in the Boston area there is said to be only one generation per year. Beetles are in flight at all times during the summer and early part of the fall in the New Jersey area, with two periods of greater abundance—early in June and about 2 months later. Usually this introduced elm bark beetle passes the winter in the larval stage, and late in May or early in June the young adults emerge and fly to healthy elm trees, where they feed for some time on the bark of young twigs before they are ready to deposit their eggs. This habit of the beetles makes them very dangerous as disease vectors. In the areas where the very serious Dutch elm disease is present, trees suffering from this disease offer very favorable breeding material for the beetles. Young adults emerging from the infected bark carry the disease spores on their bodies, and in feeding later on the twigs of a healthy tree they often introduce these spores and the tree becomes inoculated with the disease.

Earlier work conducted in Europe proved that both of the common European elm bark beetles are efficient carriers of the spores of the fungus, and later work at Morristown, N. J., has shown that the smaller European elm bark beetle is the most important vector in this country. Control of bark beetles is discussed on pages 47–51, and further information on this particular species may be found by consulting Collins (*99*) and Collins *et al.* (*100*).

Scolytus sulcatus ranges in color from shining brown to black. It is from 3.4 to 4.4 mm. long and about twice as long as wide. The elytra have the punctures arranged in regular strial and interstrial rows of nearly equal size, the striae weakly impressed. The abdomen is weakly concave on the ventral side, the fifth sternite longer than the preceding two combined and lacking a posterior margin in the male. Comparatively little is known of this species, except that it occurs in Connecticut, New York, and New Jersey and has been taken from the bark of plum, apple, and elm. Special interest attaches to the fact that it has been taken near New York City from dying or dead elm infected with the Dutch elm disease. This suggests the possibility of its acting as a disease vector, as its habits are well adapted to such a role. Up to the present, however, it has not been found in sufficient abundance to cause great alarm.

Scolytus fagi Walsh, **the beech bark beetle**, is somewhat similar to *S. sulcatus*, but is larger, 4.5 to 5 mm. long, and the elytra have the striae distinctly impressed, and the strial punctures are much coarser than those of the interspaces. The recorded hosts are beech and hackberry, and this beetle occurs in the Mississippi Valley from Illinois to Texas. Very little is known of its habits, and its economic importance is doubtful.

Scolytus piceae, **the spruce scolytus,** is readily distinguished from other eastern species by the presence of a tubercle or spine extending backward from the center of the second ventral abdominal segment, and distinguished from *S. multistriatus* in having the elytra subtruncate. It occurs from Quebec and Maine westward to Colorado, Montana, and Manitoba. It seems to be confined to the northern forests and is known to breed in white spruce, red spruce, Englemann spruce, eastern larch, and eastern balsam fir. Its burrows differ from those of other eastern forms in consisting typically of two, or sometimes three, egg galleries extending longitudinally from a central nuptial chamber. It breeds by preference in broken limbs or tops of its host trees and is not notably injurious.

Three species of small beetles of the genus *Crypturgus* Erichson are often common in the Eastern States. They are very small brown or black beetles, about 1 mm. long, and are found in the inner bark of dying or dead coniferous trees. Their burrows usually originate from the burrows of larger bark beetles, such as those of species of *Dendroctonus Polygraphus*, and *Ips*, but sometimes the so-called ventilation openings made by *Monochamus* spp. are utilized for access to the inner bark. Species of *Crypturgus* are not injurious and are here mentioned merely because they often occur in infested material killed by other more destructive species and may be found under suspicious circumstances after the real aggressors have left the dead bark. *C. atomus* Lec. occurs from Maine and northern New York to West Virginia and westward. *C. corruguatus* Sw. is known from Maine, New York, and Pennsylvania, and *C. alutaceus* Sz. from New Jersey to Florida.

Polygraphus rufipennis, **the four-eyed spruce bark beetle,** is slightly less than 2.5 mm. long and is black with the elytra brownish black. It can readily be distinguished from any similar form by the fact that the eyes are completely divided and the antennal club is unsegmented. The favorite host for this *Polygraphus* is spruce, and all species of the genus *Picea* are readily infested. Larch is also commonly attacked, but pine is less common as a host. The burrows are of the radiate type, with from 2 to 6 egg galleries, each made by a separate female. The beetle is not aggressive, and therefore the burrows are nearly always found in either dying, broken, or recently cut material. Occasionally green, standing trees are attacked and killed, but it is doubtful that really vigorous trees ever succumb to this beetle.

Trees left in cutting operations are sometimes killed, but in such cases conditions are abnormal, owing to the emergence of myriads of the beetles from the slash and the weakening of the residual stand by the removal of the merchantable timber. It is therefore very questionable whether the insects do more than hasten the death of trees which, in any event, would succumb to the drastic changes in their surroundings. It therefore is probably unnecessary to consider control of the four-eyed bark beetle, but in lumbering operations where it is numerous the larger slash and cull logs should be treated if the cutting is discontinued suddenly.

The genus *Carphoborus* Eichh. contains small, dark-brown to black beetles which have numerous small cinereous scales and the elytral declivity with the first interspace slightly and the third strongly elevated. Only two species have been reported in the East, and both are quite small, being less than 2 mm. long. They breed in broken, cut, and dying twigs of the various southern pines, and are not responsible for any damage. The burrows are of the true radiate type, having from three to eight egg galleries in each engraving. There are two or more generations a year. The two species, *C. bicristatus* Chapuis and *C. bifurcus Eichh.*, are fairly common throughout the Southern States and occasional specimens may be taken as far north as New York. Additional information on this beetle may be found in publications by Blackman (*38*) and Chamberlin.[24]

The genus *Chramesus* Lec. is represented in the East by two species of small, stout, strongly convex, **"humpbacked beetles,"** less than 2 mm. long. They are readily distinguished by the form and also by the antenna, the club of which is large, long-oval, and unsegmented, and is attached to the funicle at one side. Neither of these species is injurious, as they breed in broken or dying twigs and small limbs. They are both monogamic forms, the adults making longitudinal, unbranched egg galleries, partly in the bark and partly in the sapwood, with the eggs evenly spaced in niches at each side. *C. hicoriae* Lec. breeds in cut or badly injured twigs and small branches of various species of hickory. It occurs generally throughout the eastern half of the United States. *C. chapuisii* Lec. breeds in cut or injured small limbs and twigs of hackberry. It is found from Pennsylvania to Mississippi and Louisiana. More detailed information is to be found in Blackman (*38*, *44*).

The species of *Phthorophloeus* Rey. may be readily distinguished from other bark beetles by the loosely jointed antennal club, each of the three parts of which are extended on the inner side into a leaflike process. Several species of this genus occur in the eastern half of the United States, and all but one of these breed in broad-leaved trees. The burrows are of the transverse forked type, but appear to be made by a single pair of beetles. The species are either unaggressive, attacking only dead or cut material, or only moderately aggressive, attacking material which is still capable of some resistance.

One habit well known for several of the species is perhaps the cause of more injury than that produced by their ordinary breeding habits. The young adults emerge from their larval hosts in the fall, burrow into the bark of living trees, and spend the winter and early spring at the contact of the outer bark and the phloem. Their burrows often extend into the outer part of the living bark and cause an irritation resulting in an abnormal growth, which may show as a swelling on the trunk of a tree badly affected. While this habit of the beetles causes

[24] See footnote 22, p. 302.

considerable damage, the trees are not directly killed, but may be so weakened as to make them susceptible to the brood attacks of this or other boring insects.

The peach bark beetle (*Phthorophloeus liminaris*), also known as **the peach-tree bark beetle,** attacks not only peach and other cultivated fruit trees, such as plum and cherry, but also breeds in wild cherry, wild plum, and mountain-ash. The fall brood of young adults emerge and hibernate in the bark of living peach, cherry, or plum trees, often causing a flow of gum. It occurs from New York and Michigan southward to Maryland and Tennessee. *P. mississipiensis* Blkm. and *P. scabricollis* Hopk. are closely allied forms and have similar hosts and habits. *P. frontalis* is widely distributed in the East, comparable to the range of its favorite host trees, the several species of mulberry. It is also said to breed in hackberry, but these records should perhaps refer to *P. dentifrons*. It is common throughout the Southern States, where the black knots caused on living mulberry trees by the hibernating adults, and also the beautiful regular engravings on the wood of dead trees, are often seen. *P. dentifrons* is found principally in the dying and broken limbs of hackberry. It is probably rather widely distributed, as it is common in both eastern Kansas and northern Mississippi. Many of the young adults of the fall generation of this species remain in their burrows over winter, but it is possible that others may bore into the bark of living trees to hibernate. *P. piceae* differs from most of the genus in that it breeds in coniferous trees. It is common in white spruce in eastern Canada, in both white and red spruce in Maine, and in red spruce in northern New York. It often breeds in the rather dry bark of branches, as well as in fresher material, and is not destructive. The beetles of this genus have been discussed by Gossard (*189*), Blackman (*38*), and Chamberlin.[25]

The genus *Dendroctonus* Erichson contains a number of species more destructive to coniferous trees than any other group of insects. The most destructive species occur in the West, but at least two eastern species would probably be capable of comparable devastation if climatic and silvicultural conditions were equally favorable. Members of the genus are rather stout beetles, the species ranging in color from reddish brown to black, and in size from 2 to 9 mm. The eyes are oval, without emargination, and the antenna has a five-jointed funicle and a stout compact club, thickened at the base. Hopkins (*234*) published results of a special study of this genus.

The southern pine beetle (*Dendroctonus frontalis*) is a native insect occurring from Pennsylvania southward to Florida and westward to eastern Texas and Oklahoma. It is the most serious insect enemy of pine within its range, as it attacks and kills healthy pines of practically all species and practically all sizes except the smallest. A conservative estimate of its damages in the Southern States since 1891, when it was first studied carefully, exceeds $50,000,000.

In most years the southern pine beetle is difficult to find, but periodically it increases very rapidly under favorable climatic conditions, and an epidemic outbreak is soon under way. A number of such outbreaks have occurred during the last 50 years, the most recent of

[25] See footnote 22, p. 302.

which was in 1945–47, in the northern part of its range. The known hosts, according to Hopkins, include *Pinus strobus* L., *P. taeda* L., *P. rigida* Miller, *P. virginiana* Miller, *P. pungens* Lambert, *P. echinata* Miller, *P. glabra* Walter, *P. palustris* Miller, *Picea rubra* Link., and *Picea excelsa* (?).

Often the first indication of the presence of the beetle in a forest is the appearance of groups of dying or dead pines whose death cannot be explained as the result of fire or other destructive agencies. Usually such trees show pitch tubes on the surface of the bark of the middle and upper trunk. If such trees are examined by removing some of the bark in this region, it will be found that the inner bark, next to the wood, is riddled by characteristic winding or **S**-shaped galleries (fig. 62). These are the egg galleries made by the adult beetles. In recent infestations small brownish or black beetles one-eighth of an inch long will be seen in these burrows (fig. 63). At the sides of the egg gallery the beetle gouges out small niches and in each places a small pearly white egg. The larvae hatching from these eggs bore through the living phloem and after extending their mines only a short distance attain full larval growth. Each larva then carries its burrow outward into the bark and makes an enlarged oval chamber in which it passes into the quiescent pupal stage and later transforms to the adult.

The development is unusually rapid, as under favorable conditions a brood can develop from egg to adult in 30 to 40 days. From 3 to

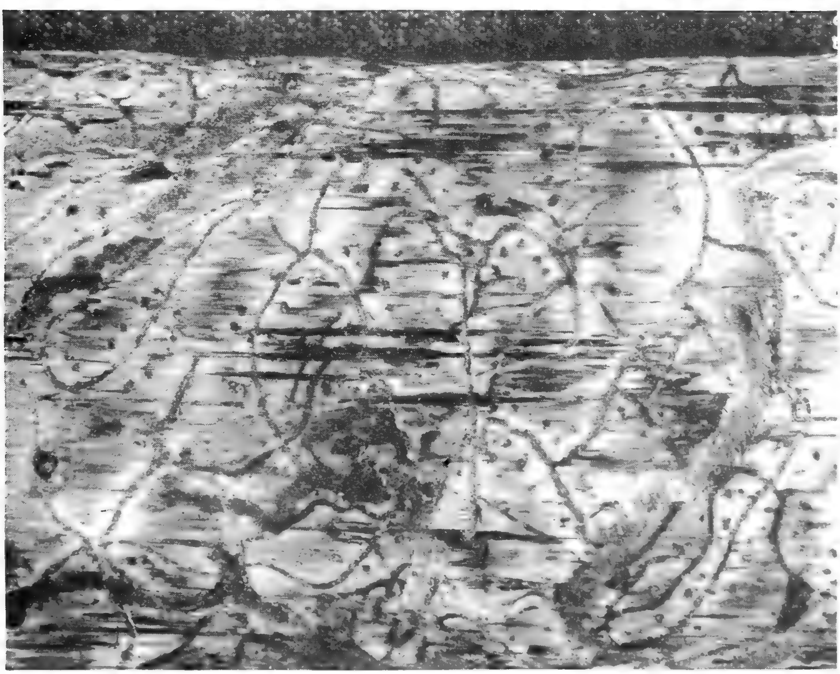

FIGURE 62.—Winding galleries made by adults of the southern pine beetle (*Dendroctonus frontalis*). (The larger ones are those of the southern pine sawyer (*Monochamus* titillator), which often destroys many broods of the former.) Slightly reduced.

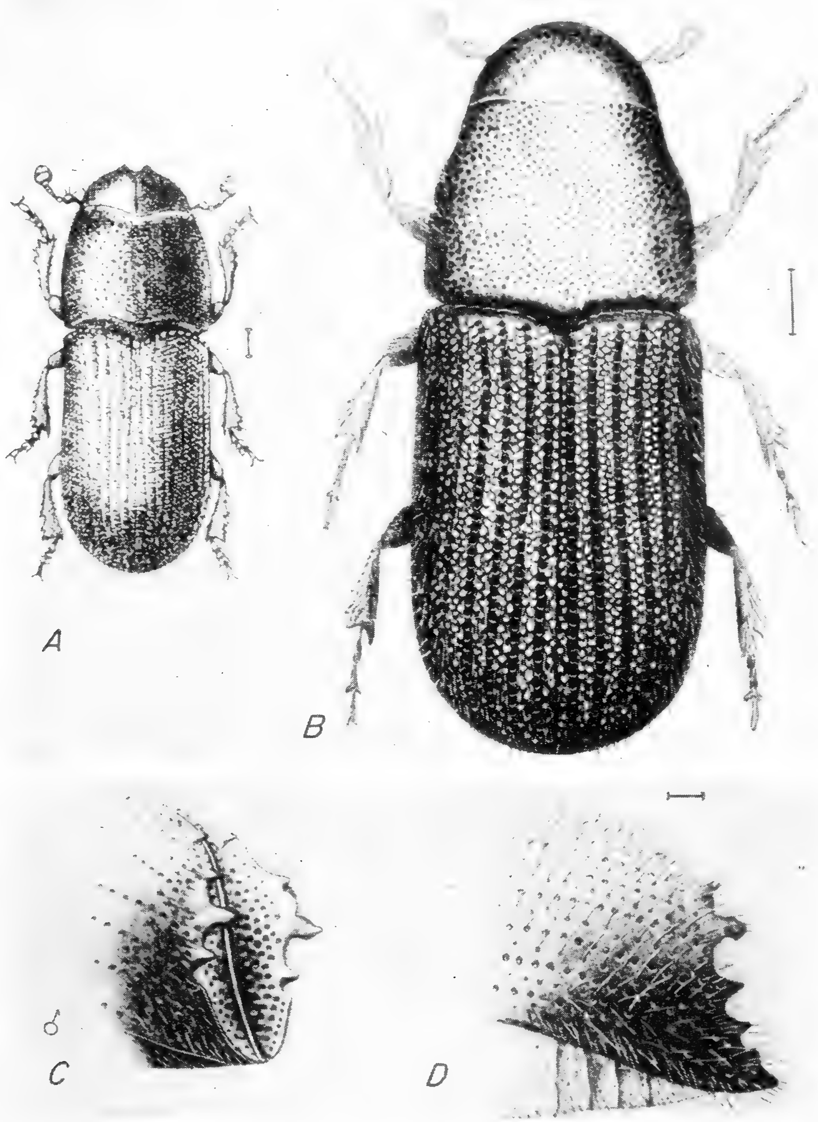

FIGURE 63.—Adult bark beetles: *A*, The southern pine beetle; *B*, one of the turpentine beetles similar in shape but larger. (In both insects note the end of the abdomen rounded out in a convex manner. *C*, and *D*, ends of abdomens of *Ips* spp. showing end concave and armed with toothlike projections.

5 or more generations occur each season, the exact number being dependent on the length of the summer season and on weather conditions. Under optimum conditions it is not unusual to obtain a 10-fold increase in a single generation. With 5 generations a year, the application of elementary arithmetic will explain the sudden outbreaks and extremely rapid increases known to take place.

The most striking fact regarding the southern pine beetle is the rapidity with which populations of the beetle both increase and decrease, because of only slight variations from normal or average climatic conditions. Craighead (*111*) correlated the appearance of incipient epidemics with deficiencies in rainfall. A drop of 1 inch or more below the normal monthly precipitation for several months is likely to be followed by a marked increase in infestation, which may or may not develop to epidemic proportions, depending on whether or not the moisture deficiency is continued. When an incipient outbreak seems well under way, a return to normal or excess rainfall is promptly followed by a marked reduction in beetle survival. This beetle is readily controlled by temperatures around zero Fahrenheit (p. 12).

The following measures have been suggested to prevent serious outbreaks: Encourage a mixture of the better hardwoods in pine stands. Prevent fires, as these weaken trees and attract bark beetles. Watch for infestations in decadent pines and in trees injured by lightning or windstorms. During drought periods watch for the first evidence of the southern pine beetles and treat the trees harboring them.

Discussion of methods of controlling outbreaks of pine beetles will be found on pages 47–51.

The eastern spruce beetle (*Dendroctonus piceaperda*) is considerably larger than the southern pine beetle, being usually between 5 and 6 mm. long. The head, pronotum, and abdomen are black and the wing covers reddish brown. It is a native insect, found from central Pennsylvania northward through New York, northern New England, and the Maritime Provinces of Canada and Newfoundland, and westward to Michigan and Manitoba. It attacks and kills the native red, white, and black spruces.

Adults of the eastern spruce beetle are in flight at all times throughout the summer from June to September, but the heaviest attack occurs late in June and early in July. The seasonal history of the beetles is greatly complicated by the fact that the parent beetles after laying one complement of eggs, emerge from the first tree attacked by them, and enter and lay their eggs in a second tree. The beetles are monogamous, and the egg gallery consists of an unbranched, longitudinal burrow about 6 inches long, at the line of the inner bark and wood, but almost entirely in the former. The eggs are deposited in large groups in grooves along alternate sides of the egg gallery, where they are packed in boring dust and walled off from the bore of the gallery. On hatching, the larvae from each egg group feed together in a common chamber, but soon each begins an individual mine and these mines, at first subparallel, diverge more and more as the larvae grow and extend their burrows.

In a heavy infestation the beetle attack may extend from the base up into the crown of a tree, but more often only the lowermost 30 feet or so is affected, while the top of the tree is filled in with secondary forms. Swain (*402*) established by actual count that an 18-inch red spruce in eastern Canada contained 750 egg galleries, and he estimated the number of eggs deposited in this tree at more than 100,000. Signs of attack by the eastern spruce beetle are the presence of red boring dust and pitch tubes on the bark, the fading and dropping of the foliage, and the reddish appearance of the twigs after the needles have dropped. Often the needles fall while still green, and the tree may be nearly bare of foliage within a few weeks after attack. The reddish appearance of its twigs is characteristic of such recently infested trees. Woodpecker work is often conspicuous and serves to draw attention to trees still infested.

The eastern spruce beetle is one of the most serious bark-beetle enemies of trees in the East. Several outbreaks took place in the last century, but the first to be studied occurred in eastern Canada and northern New England in 1897–1901, causing a loss estimated by Hopkins (*234*) at more than a billion feet of fine spruce. After this outbreak the beetle appeared to be very rare until about 1915, but in the next few years extensive outbreaks took place in Quebec and Ontario, and lesser infestations in New Brunswick and Newfoundland, and as far west as Manitoba. In 1936 and 1937 serious infestations existed in the Green Mountain National Forest in Vermont and less serious ones in other parts of New England and northern New York.

No infestation of the eastern spruce beetle has been investigated with sufficient thoroughness to reveal the underlying factors that cause it to reach outbreak proportions. It is well known, however, that severe damages occur only in spruce stands containing a considerable proportion of mature or overmature spruce. Swaine's (*402*) work has indicated that piles of slash responsible for an unusual increase in beetle populations in a mature spruce forest may produce a serious outbreak. It is possible that climatic factors are very important in building up such infestations (Nash *316*).

Control of bark beetles under forest conditions is discussed on pages 47–51.

The eastern larch beetle (*Dendroctonus simplex*) is dark reddish brown, 3.5 to 5 mm. long, with the front of the head convex and the epistomal process with the sides subparallel and reaching but not extending beyond the epistomal margin. This species is found throughout eastern Canada and the eastern part of the United States from the Atlantic coast westward to Minnesota and Manitoba and southward to New York, and with a southern extension through the mountains of Pennsylvania to northern West Virginia. Its host is the eastern larch or tamarack (*Larix laricina* (Du Roi) (Koch.) (Simpson, *380*)).

The galleries of *Dendroctonus simplex* are longitudinal, wavy or winding, often branched, and sometimes anastomosing. The eggs are deposited in niches, often arranged in alternate groups in the sides of the egg galleries. The larval mines are in the inner bark and are usually quite short (Hopkins, *234*). This beetle breeds in dying, felled, and injured but living, eastern larch. It is not particularly aggressive, and living trees killed by it have usually been weakened through defoliation by the larch sawfly or from other causes. Control work is seldom necessary, but when it is justifiable it can be readily accomplished by barking infested trees, or by bark-penetrating sprays, pages 49–51.

The red turpentine beetle (*Dendroctonus valens*) is the largest species of the genus and is usually from 7 to 8 mm. long. Its color ranges from light reddish brown to dark brown, but the reddish color is more characteristic. It readily attacks all species of pine and per-

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haps all species of spruce. It is more widely distributed in pine forests than any other American scolytid, being found from the Atlantic to the Pacific and from Alaska to Guatemala. Attacks by this beetle are made principally on stumps and at the bases of standing trees. The egg galleries are longitudinal, extending downward from the point of entrance, which is usually marked by a large pitch tube. The gallery is often extended down to, or even below the surface of the mineral soil, and may range from less than a foot to several feet in length. The eggs are laid in irregular masses in grooves in the sides of the egg gallery, from which they are separated by a wall of frass, thus allowing free passage of the beetles without injury to the eggs.

Upon hatching, the larvae feed together and destroy considerable areas of the inner bark. When approaching full growth, however, many of them bore short individual mines in which they pupate and transform to adults, while others surround themselves with a wall of frass in the common feeding chamber and there complete their transformation. In most parts of the country the beetle completes only one generation a year, but in warmer areas two generations may be completed in a single season.

The favorite breeding place for this insect is in the bark of recently cut stumps or in the bases of standing trees dying from other causes. The odor of newly sawed lumber and fresh pitch exerts a powerful attraction, however, and in the presence of such an odor the beetles often attack healthy, living trees. Such attacks are usually unsuccessful in vigorous bark, and while the beetles may persist in their efforts for several weeks and may form a large pitch tube, eventually they either abandon their burrows or succumb to the flow of resin. Many trees affected by disease or by the attack of other insects, or weakened by fire, flooding, or drought, die after being attacked by the red turpentine beetle.

In areas where lumbering is continued for a number of years this insect often breeds up to countless thousands. If such operations are suddenly discontinued these beetles, lacking the usual breeding material, will attack healthy trees, causing catfaces, and will kill decadent trees in the residual stand. They often leave such an area in swarms of thousands of individuals. Such swarms are attracted to new buildings that are being erected or to buildings being painted, and create a nuisance for a few days. Control of bark beetles is discussed on pages 47–51. If lumbering is to be suddenly discontinued the bark of stumps and cull logs should be removed.

The black turpentine beetle (*Dendroctonus terebrans*) is very similar to the red turpentine beetle, except that it averages slightly smaller and is darker, its color ranging from piceous to black. It is much more limited in its distribution, being found only in the Eastern States from New Hampshire to Florida and Texas. Its habits are very similar to those of *D. valens*.

Members of the genus *Phloeosinus*, known as the cedar bark beetles, are characterized by their rather stout form. They range from reddish brown to black in color, and from 2 to 3.5 mm. in length. The eyes are deeply emarginate on the inner border, the antennae have five-jointed funicles and elongate clubs with oblique sutures, and the rear of the elytra have the first, third, and alternate interspaces elevated and more strongly tuberculate.

Species of the genus breed principally in the cupressine branch of the pine family, but a few forms are found in pine and in spruce. The eastern species infest such native trees as arbovitae, juniper, and cypress, but may also attack allied introduced trees.

All the species of *Phloeosinus* are true bark beetles and all are monogamous in their breeding habits, constructing rather short, unbranched, longitudinal egg galleries between the bark and wood of the limbs or trunk of their host tree. The eastern species are not notably injurious, because they prefer to attack cut, broken, or decadent bark. Occasionally trees that would otherwise continue to live are killed, but this is unusual.

One habit of the insect is moderately injurious to ornamental hedges or specimen trees of arborvitae or juniper. The young adults on emerging from their parent hosts feed for a time on the twigs of living trees in a manner very similar to that of the species of *Scolytus*. They bore into these small twigs and feed on the sapwood, causing the twigs to wilt and break. This injury is seldom serious enough greatly to affect the vigor of the trees, but the wilting and hanging twigs are unsightly and disconcerting to the owner, and, if sufficiently abundant, may affect somewhat the symmetry of the tree. However, the beetles never occur in numbers sufficient to cause any considerable damage, except in localities where carelessness has been shown by allowing breeding material to remain untreated. A prompt burning of all limbs and the barking of the trunks of dying or cut cedar or cypress will keep down the beetle population to a point where it can do little or no damage.

Of the several species in the eastern half of the country only three will be mentioned. All these have the general habits discussed above and for the purposes of this publication differ principally in their hosts and distribution. *Phloeosinus canadensis*, **the northern cedar bark beetle,** breeds principally in the northern white cedar or arborvitae. It occurs throughout eastern Canada and the northeastern part of the United States. *P. dentatus*, **the eastern juniper bark beetle,** occurs from Massachusetts to Florida and westward to Texas. Its principal host is the eastern red cedar, *Juniperus virginiana* L., although other allied trees are also attacked. *P. taxodii*, **the southern cypress bark beetle,** is known only from the Southern States. The host is *Taxodium distichum* (L.) Richard.

Xylechinus americanus, **the suppressed spruce bark beetle,** is dark brown with the legs lighter in color. It is about 2.2 mm. long and moderately slender. The eyes have the inner margin nearly straight, the antennal funicle is five-jointed, and the club is ovate, compact, and very slightly flattened. The pubescence consists of ashen scalelike hairs. This species was described from specimens found in the bark of white spruce and white pine in Maine and in red spruce in the Adirondacks, but it is doubtless more widely distributed. A closely related species, as yet undescribed, occurs in the forests of the West. The burrows of *X. americanus* are of the transverse radiate type and were found only in the bark of trees weakened and dying from suppression. It is not commonly met with in either of the localities in which it was found, and even if numerous would probably not be really injurious. No control is indicated as necessary.

Species of the genus *Leperisinus* differ from most other bark beetles in their possession of a variegated coloration. The color markings are produced by spots or bands of light-colored scales alternating with areas of dark scales, producing a rather definite color pattern for each species. The body form is rather stout, with the elytra gradually descending behind, and the antenna has a seven-jointed funicle, with the club elongate, fusiform, and compressed. Apparently all the eastern species of *Leperisinus* breed by preference in various species of ash, and are known as **ash bark beetles.** They are all true bark beetles, constructing their regular, transverse, forked burrows between the bark and sapwood, and grooving the latter rather deeply. The engravings in ash are very similar in appearance to those of *Phthorophloeus frontalis* in mulberry (p. 315), except that they are larger and coarser, especially the larger species, such as the very common *L. aculeatus* Say (fig. 64). The species have been discussed by Blackman (*38*).

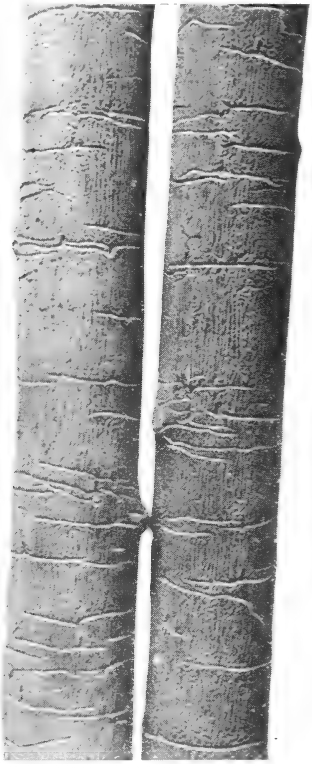

FIGURE 64.—Tunnels of the adults and larval galleries of *Leperisinus aculeatus* beneath the bark of ash. (Natural size.)

The ash bark beetles seldom or never do any real damage. They do enter trees already weakened by mechanical injury, disease, or fire, and they certainly hasten the death of such trees, but no cases have been observed where vigorous trees were attacked. The adults often pass the winter in the inner part of the outer bark of the trunk of living ash trees. The favorite breeding places are in recently cut or broken ash trees, in which both trunk and limbs are attacked. In wood intended for rustic work the bark will become loosened; however, if the logs are evenly attacked, and the bark is later removed, the result may be pleasing, evenly engraved material, which can be utilized in very attractive rustic pieces.

Usually the ash bark beetles are kept down to moderate numbers by the combined effects of various natural factors, among which may be mentioned both parasitic and predaceous insects. The clerid *Enoclerus quadriguttatus* Oliv. and others are often seen in considerable numbers on the surface of the bark that is being attacked by the scolytids, and they destroy many of the beetles. Swaine (*402*) pointed out the efficiency of hymenopterous parasites. The writer has also observed cases where sometimes as high as 90 percent of the pupal cells of *Leperisinus aculeatus* were occupied by parasitic cocoons.

Leperisinus aculeatus, the common **eastern ash bark beetle, is** from 2.5 to 3 mm. long. It is dark brown, variegated with lighter tan or ashy scales. It is the most common and widely spread species of the genus, occurring in Canada from the eastern coast to Manitoba and in the United States from Maine to Kansas and southward to the Gulf of Mexico. It attacks various species of ash. *L. fasciatus* Lec., **the white-banded ash bark beetle,** is smaller, ranging from 1.5 to 2 mm. in length, and is black with white markings. It is not so common as the former but is widely distributed, specimens having been collected in New York, New Jersey, Pennsylvania, Maryland, the District of Columbia, West Virginia, and Indiana.

The native elm bark beetle (*Hylurgopinus rufipes*) is a moderately stout, brown beetle, from 2.25 to 2.75 mm. long. The eyes are long and oval, without emargination; the antennal funicle is seven-jointed, and the club is elongate oval, with three distinct sutures. The pronotum is closely punctured, and the elytral striae are impressed and coarsely punctured (fig. 61, *E*).

This species is widely distributed throughout the Eastern States and is notably more common in the more northern States than in those farther south. Because this insect is associated with the Dutch elm disease fungus in the infected areas near New York City and elsewhere, and is known to be a vector, the information on its distribution is more complete than it was a few years ago. It is now known to occur in eastern Canada, New Hampshire, Vermont, Massachusetts, Connecticut, Rhode Island, New York, New Jersey, Pennsylvania, Delaware, Maryland, Virginia, West Virginia, Ohio, Indiana, Minnesota, Missouri, Kansas, Kentucky, Tennessee, Alabama, and Mississippi. The beetle is recorded from various species of elm and from basswood.

The native elm bark beetle is not an agressive insect, as it successfully attacks only diseased, dying, broken, or cut material. The burrows are of the transverse, forked type and can readily be distinguished from those of the **smaller European elm bark beetle** (*Scolytus multistriatus*) which are longitudinal. The beetles complete one or more generations a year, depending on the climate, and pass the winter either as larvae or adults. Many of the young adults emerge in the fall and burrow into the bark of either the trunks or limbs of living elm trees, especially in the lower trunk, where they hibernate during cold weather. They often bore through the bark to the wood and doubtless obtain nourishment during warmer periods from the living inner bark.

Experiments at the Forest Insect laboratory at Morristown, N. J., indicate that if such hibernating young adults have emerged from bark infected with the Dutch elm disease fungus, they carry the fungus with them, and if these spores are deposited in the wood of healthy trees, such wood often becomes infected. When confined in cages, *Hylurgopinus rufipes* will also feed in the crotches of young twigs, but it is not known that they do this in nature. Since they often breed in infected elm, the beetles carry the disease to uninfected, cut, or broken elm, which thus acts as an additional reservoir of the fungus. Knull (*268*) and Collins (*99*) have described the scouting and control work in connection with the Dutch elm disease campaign.

These elm bark beetles may be controlled by spraying with heavy dosages of DDT. (See pp. 53–54.)

ROOT AND BARK BEETLES OF THE GENERA HYLASTES AND HYLURGOPS

In the genus *Hylastes* the antennal funicle is seven-jointed, the club oval, not compressed, distinctly segmented, with the first segment nearly as long as the others combined. In color the species range from brown to black, and in form from moderately slender to slender. The head has a short stout beak, which is better developed than in most other scolytids.

The several eastern species of this genus breed principally in the bark of decadent trees and the stumps of felled trees, and are usually to be found in the inner bark at the bases of trees, near or below the surface of the soil. They choose bark which is quite moist or even wet, with an abundance of fermenting sap. Occasionally the adults will injure or even kill pine transplants or young plantation trees by chewing the bases of the stems. Usually, however, they are of little economic importance and may be ignored. In cases where they are damaging young trees, their breeding places should be discovered and treated.

The more common eastern species are described as follows: *Hylastes porculus* Er. is black, moderately slender, more than 5 mm. long, and occurs from Maine to Michigan and southward to Virginia. *H. salebrosus* Eichh. is slightly shorter and stouter than *H. porculus*, dark brown or black, and is more common in the South Atlantic States. *H. scaber* Sw. is closely related to *H. porculus* and is reported from Virginia, the District of Columbia, and Tennessee. *H. tenuis* Eichh. and *H. exilis* Chap. are two small, slender, brown species about 3 mm. long, found from Virginia to Arkansas and southward to Florida. Several undescribed species are also known.

The genus *Hylurgops* is closely related to *Hylastes*, but the eastern species, *Hylurgops pinifex*, is considerably stouter, and the elytral declivity is covered with small ashy-gray scales and a few long erect hairs. The habits are similar to those of *Hylastes*, the base of the tree trunk being the preferred point of attack. *H. pinifex* is a secondary enemy of pines, spruce, and larch, and no control is necessary. It is widely distributed and common in eastern Canada and the northeastern part of the United States.

Wood-Eating Bark Beetles

Two closely allied genera of wood-eating beetles, *Hylocurus* Eichh. and *Micracis* Lec., contain a number of species that rear their brood not in the inner bark but in the wood or pith of their hosts. These two genera are similar in several respects. In both, the head is concealed from above by the pronotum, which is strongly roughened in front; the antennal club is compressed; the tibiae of the forelegs have the sides nearly parallel, with the outer edge not serrate; and the elytra are elongated posteriorly to form an acuminate apex. In

Hylocurus the first joint of the antenna is club-shaped, and the eyes are short, oval, and widely separated both above and below, whereas in *Micracis* the basal joint of the antenna is flattened and ornamented with long hairs, the eyes are large, elongate, and either contiguous, or narrowly or moderately separated beneath.

The burrows made by the species of these two genera are rather similar in form to those of other scolytids, but differ in being in the sapwood (Type 7) or in the pith (Type 6) (see pp. 298–299). The entrance gallery proceeds directly through the bark into the sapwood, or farther, into the pith. Here a slightly enlarged nuptial chamber is constructed, and from this, one or several egg galleries arise. In the wood the galleries extend obliquely with little regard either to growth rings or the grain of the wood. In the pith one or more egg galleries extend in each direction through the pith. The larvae feed on the wood or pith and doubtless on the hyphae of fungi growing in this material. Usually species of *Hylocurus* and *Micracis* are of little economic importance, as with one exception they occur most commonly in small or moderate-sized branches. Species of *Hylocurus* especially favor the recently cut, dying, or dead limbs of hickory as host material, and all but one of the eastern species have been taken from such material. One species, *H. langstoni*, is more commonly found in larger material and in other hosts. Species of *Micrasis* are found in a variety of hardwoods, particularly in twigs and smaller branches.

Hylocurus langstoni has been taken in Mississippi, Texas, Maryland, and Virginia, and the known hosts include honeylocust, hackberry, mulberry, and elm. This species attacks the trunks of dying or recently dead trees and often enters poles and fence posts utilized while still green. The larvae bore through the sapwood, producing an injury very similar to that caused by powder-post beetles, as the larval mines are often closely crowded together, are packed with a fine, powdery frass, and may riddle the entire sapwood. Removal of the bark or thorough seasoning of posts and poles before setting in the soil will probably prevent damage.

Hylocurus rudis has been taken from hickory, maple, chestnut, and hackberry, and is widely distributed, though not common, having been collected in Michigan, Maryland, North Carolina, Georgia, and Mississippi. *H. biorbis* is known from New York, Pennsylvania, Maryland, District of Columbia, and North Carolina. Hickory is the only known host. *H. bicornis* and *H. harnedi* have been found only in hickory in Mississippi. *H. spadix* occurs in hickory in Pennsylvania and North Carolina.

Micracis swainei is widely distributed, having been taken in willow or redbud in Maryland, West Virginia, Mississippi, Louisiana, Texas, Arizona, and California. *M. populi* is known only from New York, where it was taken in poplar shoots. *M. suturalis* infests redbud, walnut, and papaw in Illinois, Michigan, Ohio, Pennsylvania, Maryland, Virginia, West Virginia, and the District of Columbia. *M. meridianus* is found in willow and redbud in Mississippi, the District of Columbia, and Virginia. *M. opacicollis* is a pith borer in dead sprouts or shoots of oak, maple, redbud, and cypress. It is common and widely distributed from Massachusetts to Michigan and Kansas and south to Florida and Texas. *M. nanula* is closely related to *opacicollis* but is more southern in its distribution, having been taken in South Carolina, Georgia, Florida, and Texas. The known hosts are oak and red bay.

The genus *Thysanoes* Lec. is closely allied to *Micrasis* and *Hylocurus*, but differs in the absence of the acuminate apex to the elytra. It is similar in habits to the two last-named genera in that the brood burrows are in the wood. This insect is only mildly injurious, and no control is necessary. *Thysanoes fimbricornis* occurs from Pennsylvania southward to Florida and westward to Texas. The known hosts are oak, hickory, redbud, and acacia. *T. lobdelli* is known only from Mississippi and Georgia, breeding in oak and maple. *T. berschemiae* breeds principally in rattan vine, but has been taken from elm. Its range is from Virginia to Florida and westward to Mississippi and Texas.

Pseudothysanoes Blkm. is a genus closely allied to *Thysanoes*, and although the eastern species breed in the bark rather than the wood, they should be mentioned here. Two of the eastern species occur in bark of basswood, whereas the third is found in several other hardwoods. These insects are not known to cause any real injury. *P. rigidus* breeds in basswood from Canada to Michigan, Ohio, and West Virginia. *P. drakeii* is found in basswood bark in central New York. *P. lecontei* has been taken from chestnut, oak, hackberry, walnut, and hornbeam from Maryland and West Virginia to North Carolina.

Cryptocleptes Blkm. is a genus of very small, rather slender, brown beetles, found in forked, longitudinal burrows in the bark of dying and recently cut hickory twigs. Insofar as is known, the single species is not responsible for any real injury, and no control is necessary. *Cryptocleptes dislocatus* was described from Mississippi and is also known in Texas, North Carolina, South Carolina, and West Virginia. Hickory is the common host, but in Texas it was found in acacia.

Another species that burrows in the wood is *Lymantor decipiens*. Structurally it is not at all closely related to *Micrasis* and its relatives, but more closely to *Dryocoetes*. It is reddish brown, less than 2 mm. long, rather slender, with the posterior pronotum and wing covers deeply and coarsely punctured. It is known throughout the Eastern States from Massachusetts to Iowa and south to Mississippi. Known hosts include hickory, pear, and maple. In maple the egg galleries and larval mines are both in the outer sapwood of twigs that have already begun to decay.

Further information on these beetles may be found in the writings of Blackman (*37*, *38*).

The Dead-Twig Borers

Various species of two closely related genera of small bark beetles are found in dying and dead twigs, dead bark, seeds, and dead hulls, such as cotton bolls. Nearly all are of little economic importance, being mildly beneficial as promoters of decay, but a few become injurious when they attack seeds and other stored vegetable products. Numerous species of *Hypothenemus* Westw. are very common in the Southern States. They are very small brown or black beetles from less than 1 to nearly 1.5 mm. in length. The species are difficult to distinguish, and as they have little economic importance will not be discussed further than to state that they may be found either in the bark or wood of dead twigs and in other dead vegetable matter.

The genus *Stephanoderes* Eichh. contains larger species, ranging from 1.5 to nearly 2.5 mm. in length. They are similar to *Hypothenemus* in habits, but are more often found in dying bark or the undecayed wood of twigs. Some species breed in the bark, others in the wood, and still others in the pith of shoots. They are usually of little or no economic importance in this country, but in tropical countries a few species are destructive. An excellent example is *S. hampei* Ferr., which destroys coffee beans and which has been distributed by commerce to nearly every part of the world, although it has become established only in coffee-raising countries. Often the American species are not confined to any particular species of tree but may be found in almost any dead vegetable matter.

The Oak-Bark Beetles

Nearly all species of *Pseudopityophthorus* Sw. prefer to breed in the inner bark of the various species of oak, although several species may also be found in other trees. The eastern species of this genus range from slightly more than 1 to about 2 mm. long. They are dark brown to black and slender to moderately slender. The wing covers are finely punctured and not striate, and the males have the front of the head ornamented with a brush of long yellowish or ashen hairs. In habits the beetles are not particularly aggressive, preferring to breed in recently cut or dying limbs, but in some cases apparently healthy limbs are attacked and killed. On the whole, however, they should not be considered notably injurious. The burrows are of the transverse, forked type.

Pseudopityophthorus asperulus (Lec.) ranges from 1.1 to 1.4 mm. long. It is found from Maine to Florida and westward to Texas, and has been taken from various oaks, chestnuts, and birch. *P. fagi* Blkm. is similar in size and is known only from six specimens taken from beech in West Virginia. *P. pubescens* Blkm., 1.8 mm. long, occurs in Virginia and North Carolina, breeding in oak and chestnut. *P. minutissimus* (Zimm.), 1.5 to 1.9 mm. long, is common and is widely distributed from Massachusetts to Colorado and southward to Georgia and Mississippi in oaks and a considerable variety of other hardwoods. *P. pruintosus* (Eichh.), about 2 mm. long, occurs from New York to Michigan and southward to Florida and Texas. Oaks are the favored host, but chestnut, beech, hickory, blue beech, hornbeam, and maple are also attacked.

Many of these beetles have been fully discussed by Chamberlin[26] and the genus was revised in 1931 by Blackman (*41*).

The Cone Beetles

The cone beetles belonging to the genus *Conophthorus* Hopk. are small, stout, dark-brown to black, shining beetles, commonly 2.5 to 3.25 mm. long, which bore into the stem and up through the axis of the young cones and there deposit their eggs, causing the cones

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[26] See footnote 22, p. 302.

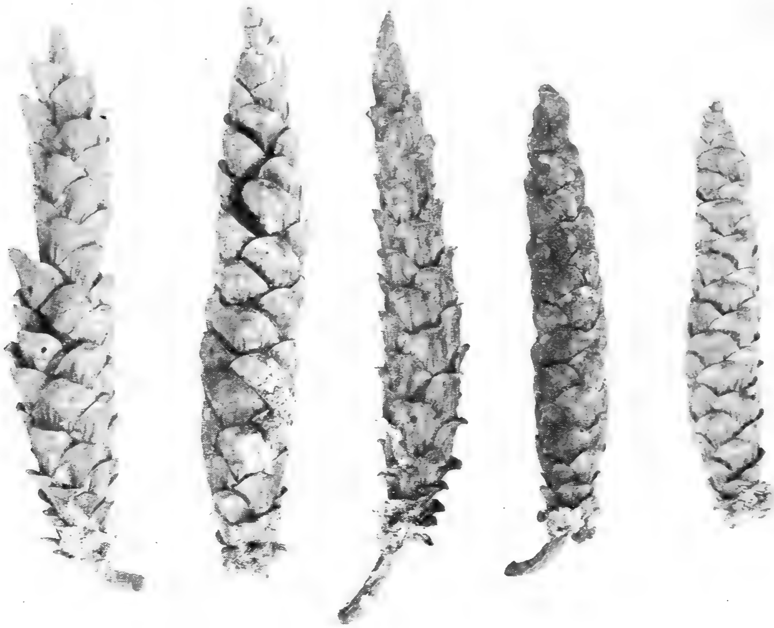

FIGURE 65.—White pine cones killed by *Conopthorus coniperda*.

to wither and die when hardly half grown (fig. 65). The larvae feed on the scales, the developing seeds, and other tissues of the wilting cones. The cones usually fall to the ground, and the young beetles emerge the following season. The damage to white pine cones is frequently severe. Some years 50 percent or more of the seed crop over large areas is destroyed, and in limited areas the destruction may approach 100 percent. Where the infested cones fall to the ground, control by gathering and burning them can be readily practiced, but this measure is scarcely applicable over a large area.

The white-pine cone beetle (*Conophthorus coniperda*) averages slightly more than 2.5 mm. in length, is shining black when fully mature, and is often very destructive to the cones of white pine (*Pinus strobus* L.). It occurs in eastern Canada and as far south as North Carolina. **The red-pine cone beetle** (*C. resinosae*) breeds in the cones of red pine (*Pinus resinosa* Ait.) and is known from Ontario, Maine, New Hampshire, and New York. *C. taedae* breeds in the cones of loblolly pine (*Pinus taeda* L.) in Virginia. *C. virginianae* breeds in Virginia pine (*Pinus virginiana* Mill.) in West Virginia. These beetles were discussed by Hopkins (*236*).

Bark Beetles of Twigs and Small Limbs

Small bark beetles belonging to numerous species of several genera are grouped together under this general heading as a matter of convenience. A number of the forms mentioned are not twig beetles in the stricter sense, since they may be found in the smaller or even larger branches or stems, but these belong to groups of which the larger number of species are true twig-inhabiting beetles.

Most of the species breed in decadent, broken, or cut material. Many of them inhabit the lower limbs of coniferous trees, and in so doing are a beneficial factor, as they aid in and speed up natural pruning, thus contributing to the production of timber clear of knots. A few species, however, attack vigorous twigs, as is indicated by the appearance of a pitch tube at the point of attack.

The burrows made by the twig borers are of several types. Most of them are constructed just beneath the bark, but several species of *Myeloborus* and *Pityophthorus* penetrate both the bark and the sapwood, and the egg galleries are excavated in the pith. The burrows of the twig borers are of several types—cave, radiate, or pith type.

The genus *Cryphalus* Erich. contains small, dull, dark-brown to black beetles about 2 mm. or slightly less in length. They occur in spruce and fir, either in twigs or small limbs. They are not particularly aggressive and usually breed in decadent bark. The burrows may be of either the cave or the radiate type. *Cryphalus balsameus* breeds in balsam fir and is widely distributed in eastern Canada and the eastern part of the United States, probably throughout the range of its host. *C. frazeri* Hopk. was described from specimens taken from Fraser fir in North Carolina. *C. rubentis* Hopk. was described from specimens taken from red spruce in West Virginia. *C. mainensis* is common in both red and white spruce in Maine and northern New York.

The genus *Pityogenes* Bedel contains four eastern species, all of which breed in the twigs and thin-barked limbs of several species of pine. The genus is characterized as follows: Body form usually moderately stout, pubescence scanty, pronotum asperate in front, not margined behind, elytra with rows of punctures, the posterior end excavated and ornamented with teeth which are much stronger in the males. The front of the head in the female may be excavated or otherwise modified. The burrows in the inner bark are typically radiate and often quite regular.

Some of the species breed by preference in pine slash, whereas others are found most commonly in the decadent lower limbs of growing pines. Usually vigorous trees are not attacked, but in some cases where the previous presence of slash in an area has bred up an immense population, the beetles on emerging find little suitable host material and are forced to attack young pine trees. In such cases many beetles are killed by the resistance of the trees, but if numerous enough they eventually succeed in killing some trees. They are unable, however, to maintain their numbers under such conditions, and such killing of advanced reproduction in a cut-over area soon ceases, except where these young trees are in poor condition. Trees weakened by drought or transplanting, or injured by ground fires or mechanical means, which might otherwise survive, are frequently killed by *Pityogenes*.

Control measures against *Pityogenes* are seldom necessary. The upbuilding of large populations in slash should be prevented by proper treatment of slash near areas of advanced reproduction, especially in years of drought.

Pityogenes hopkinsi is a small reddish-brown beetle about 2 mm. long, with the pronotum projectile-shaped, and the elytra armed with three teeth at each side, those on the male being larger. The female has a circular pit in the front of the head. This beetle is widely distributed in eastern Canada, and in the United States extends from Maine to Wisconsin and southward to North Carolina. Its distribution conforms to that of its favorite host tree, white pine. This insect is more abundant in the northern tier of States than farther south. Other species of pine and occasionally spruce are also attacked, though more sparsely (Blackman, *35*).

Pityogenes lecontei is similar to *P. hopkinsi*, but the females are easily recognized by the frontal pit, which is divided into two parts by a median carina. Aside from the type in the Leconte collection, *P. lecontei* is known from specimens collected in three localities in Pennsylvania. *P. plagiatus* is similar in size, but the frontal pit of the female is replaced by a triangular pubescent area, and in the males the dorsal tooth of the elytral declivity is enlarged and hooked at the end. It occurs in the Atlantic States and is especially common in West Virginia and southern Pennsylvania. Various species of pine are attacked by it. *P. meridianus* is similar in structure but is considerably longer (2.8 mm. long) and more slender. The front of the female lacks both pit and pubescent area, and in the male the declivital teeth are similar to those in *P. plagiatus* but longer and more slender. It has been taken from shortleaf pine and loblolly pine at five localities in Mississippi and is not known from elsewhere (Blackman, *38*).

The genus *Pityoborus* Blkm. contains only a single eastern species, *P. comatus* (Blackman, *38*). It is readily distinguished from *Pityophthorus*, the most closely related genus, and from all other North American genera by a patch of fine, dense, yellow, silky hair on each side of the pronotum of the female. *P. comatus* breeds in pine bark, preferring the lower branches, which are still alive but weakened from being shaded. The insects may be occasicnally injurious, but are most often of little economic importance. They may even be considered mildly beneficial, as they hasten natural pruning of the lower branches. The species is fairly common in Mississippi, is known from Florida and South Carolina, and is widely distributed. The known hosts include shortleaf pine, slash pine, and longleaf pine.

The genus *Myeloborus* Blkm. contains two eastern species which construct their burrows in the pith of the needle-bearing portion of living pine twigs. They are small, black bark beetles, very similar in general appearance to *Pityophthorus* (p. 331), but differ in the structure of the antennal club, which is not septate. Both species breed in and kill the leaf-bearing twigs of pine. The entrance gallery passes directly through the thin bark and sapwood, into the pith. Here it is enlarged to form a nuptial chamber, from which two egg galleries proceed in opposite directions. The larvae feed on wood, pith, and bark, killing the twigs. The place of entrance is marked by a small but conspicuous white or cream-colored pitch tube. Only a few eggs are laid in each burrow, the adults emerging and attacking a new twig. Attacks occur most frequently on the lower branches of the sides of the tree most exposed to sunlight. The dying of twigs on these lower branches is conducive to the production of clear lumber.

Smaller trees are, however, sometimes more or less severely injured. Pruning and burning of the wilting twigs will aid in reducing the numbers of the beetle.

Myeloborus ramiperda Sw. is about 2 mm. long. It breeds in the twigs of white pine. It is rather widely distributed in eastern Canada, and in the United States from Maine to Michigan. *M. fivazi* Blkm. is larger (2.65 mm.) and is known only from two localities, one at Cranberry Lake in northern New York and a single specimen taken in Wisconsin. They breed in the leaf-bearing twigs of red pine.

The genus *Pityophthorus* Eichh. contains more species than any other North American genus of bark beetles. There are numerous eastern species ranging from 1.3 to 2.75 mm. in length and in proportions from 2.6 to over 3 times as long as wide. Their color ranges from light brown to black. The pronotum is asperate in front and margined behind, the elytral declivity is more or less sulcate, and the front of the head in the female is often ornamented with longer or more abundant hairs than in the male. This genus and the preceding were discussed by Blackman (*36*, *38*, *40*) and by Swaine (*401*).

Most of the species breed in twigs or small branches, but a few may also be found in larger material. All but a few live in the inner bark, but several species of the genus, such as *Pityophthorus pulicarius*, are pith borers and may also riddle the wood of the twigs, as does *P. puberulus*. The typical bark burrow is of the radiate type with from two to nine egg galleries, but a few species lay their eggs in a cave burrow. Most of the species are entirely secondary in that they attack limbs that are broken, cut, decadent, or dying from other causes. A few, however, are more aggressive and may attack and kill apparently healthy twigs.

Most of the species of *Pityophthorus* breed in conifers, but a few are found only in deciduous trees. *P. rhois* breeds in several species of *Rhus*, including not only the ordinary sumac but also poison ivy. It occurs from Maine to Michigan and southward to South Carolina and Mississippi. A variety is found in witch-hazel and maple. *P. natalis* Blkm. has been taken from redbud in Mississippi and West Virginia. *P. liquidambarus* also occurs in Mississippi and West Virginia and breeds in red gum. *P. crinalis* occurs in various species of *Rhus* from Maryland to Florida. *P. scriptor* is common in sumac in Mississippi and ranges from Texas to Georgia and North Carolina.

All the other eastern species live in coniferous trees. The various species of pine most frequently serve as hosts, but spruce, fir, and larch also are attacked by several kinds. A few species may be found in any one of these eastern conifers growing in the area in which they occur. *Pityophthorus puberulus* Lec. is common in eastern Canada and from Maine westward to Wisconsin and Kansas and southward to North Carolina. It has been taken from white, red, jack, and Virginia pines, red spruce, and balsam fir. In pine it is most commonly found in the twigs of broken or cut limbs, but it occasionally attacks and kills living twigs, riddling the pith and wood as do the species of *Myeloborus*. *P. opaculus* Lec. occurs from Maine to South Dakota and south to West Virginia. It breeds in the twigs of all species of spruce in its range and is also found in white pine, larch, and balsam fir. *P. pulicarius* Zimm. is a widely distributed and aggressive species often attacking the leaf-bearing part of the living twigs of several species of pine, much after the manner of *Myeloborus*. The egg galleries are in the pith, and the twigs are killed and the wood riddled by the larval burrows. It is known from Quebec and Maine to Georgia and westward to Texas and Wisconsin. Known hosts include longleaf, shortleaf, loblolly, white, pitch, Virginia, and slash pines, and deodar cedar. Cutting and burning the wilted twigs will destroy the brood.

Pityophthorus cognatus Blkm. is one of the largest of the eastern species, being stout and more than 2.5 mm. long. It has been taken from white, red, and Virginia pines in North Carolina. *P. cariniceps* is similar in size and proportions to *P. cognatus* and is widely distributed and common in eastern Canada and in the northern tier of States from Maine to Minnesota. It commonly breeds in the smaller branches of white and red pines. It has also been taken from balsam fir. *P. dentifrons* Blkm., about 2.2 mm. long and moderately stout, breeds in red spruce in Maine, New York, West Virginia, and North Carolina.

A number of small, slender, closely related species are found in the twigs of pine, spruce, and fir. They are all about 2 mm. long and nearly exactly three times as long as wide. While they are very similar in structure the several species can be separated by the character of the front of the head of the females. Some of them are found in twigs, which appear to have been healthy when attacked, but are found principally on lower limbs, and are not numerous enough to cause much injury. *Pityophthorus patchi* Blkm. breeds in the twigs of pine, spruce, and fir in Maine. *P. augustus* Blkm. is known from red spruce and balsam fir in northern New York. *P. briscoei* Blkm. breeds in the twigs of red spruce in Maine. *P. biovalis* Blkm. is found in Maine and New York in red spruce twigs. *P. concavus* Blkm. has been taken in New York and Michigan in twigs of red spruce and red pine. *P. mundus* Blkm. breeds in red spruce in New York, New Hampshire, and Minnesota. *P. balsameus* Blkm. is known from Maine and West Virginia in balsam fir, red spruce, and red pine.

The following four species are somewhat similar in general structure. They are 2 mm. or less in length, are slightly stouter than the group of species just discussed, and are found either in twigs or small to medium-sized limbs of conifers. *Pityophthorus cascoensis* has been taken only from red spruce in Maine. *P. shepardi* is known from white spruce in northern Maine and from red spruce in northern New York. *P. tonsus* has been taken from spruce and red pine in New Hampshire and Michigan. *P. pulchellus* ranges in distribution from Maine to Wisconsin and southward to North Carolina and Texas. The known hosts include Virginia, pitch, jack, and red pines, red spruce, and balsam fir.

All the remaining species of *Pityophthorus* to be mentioned agree in having the apex of the elytra drawn out into a more or less sharp point. The species range in size from 1.3 to 2.7 mm. long. Some of the species attack limbs or stems several inches in diameter, while others are found in small limbs or twigs. *P. pullus* is a very common species, but is seldom injurious. It ranges from 1.8 to 2.7 mm. in length and is slightly more than three times as long as wide. It is often found in material several inches in diameter. It occurs from Massachusetts to Michigan and southward to South Carolina and Texas. White, longleaf, shortleaf, loblolly, pitch, and Virginia pines are known hosts.

Pityophthorus bellus Blkm. is somewhat similar in size and general appearance to the foregoing, but the female has the front of the head flattened and ornamented with long hairs. Its distribution ranges from West Virginia to Florida and westward to Texas. Several species of pine are known hosts. *P. consimilis* is a small reddish-brown species, 1.6 mm. long. It breeds both in twigs and small branches and is often found in the lower, suppressed branches of pine. It is common and widely distributed, occurring from Nova Scotia to Manitoba in Canada, and in the United States from Maine to Wisconsin and southward to Georgia and Mississippi. Known hosts include white, jack, red, pitch, Virginia, shortleaf, loblolly, longleaf, and slash pines, red spruce, and balsam fir. *P. nudus* is very similar to *P. consimilis* in structure, habits, distribution, and hosts, but is not so common. *P. annectens* Lec. varies considerably in size but averages about 1.5 mm. long, and three times as long as wide. Its distribution ranges from West Virginia to Florida and westward to Texas. The hosts are Virginia, pitch, loblolly, shortleaf, longleaf, and slash pines.

Bark Beetles of the Stem and Larger Limbs

Several genera of the subfamily Ipinae are often found breeding in the trunks and large branches of trees of sapling, pole, and larger sizes. Some species may also breed in smaller branches, but they are more often characteristic of larger material. Nearly all the forms here discussed choose conifers as their host, but one eastern species of *Dryocoetes* is found in broad-leaved trees. Species of *Pityogenes* and a few species of *Pityophthorus*, already discussed under twig beetles, may also be found in medium-sized limbs and stems.

Most of the forms here discussed prefer to breed in cut or broken trunks or branches of medium size, but a few will attack growing trees, and if numerous enough, will kill them. However, none of the species are able to continue depredations on healthy trees, because in attacks on vigorous bark their numbers are depleted with each generation. The burrows made by the species here discussed are all of the radiate type, but those of most species have distinguishing characteristics having to do with the host, the diameter, length, and direction of the egg galleries, and the manner of placing the eggs.

The genus *Ips* contains bark beetles ranging in size from 2.6 to 6.5 mm. in length, and in color from reddish-brown to black. The rear end of the body is diagonally truncate and concave, with the margins at each side ornamented with three to six teeth, variously developed and differently arranged for each species. The posterior end of this concavity ends in a shelf distinct from the margin of the elytra.

Most of the species breed by preference in pine slash or in recently cut or broken trees, and attack living trees only when immense numbers have bred up in slash and upon emergence do not find suitable material in which to breed. In living trees, beetle mortality is so great that unless the young trees have been weakened by drought, fire injury, or other causes, the infestation continues for only one or two generations of the beetles; however, if the young stand is decadent because of drought or other injury, the infestation may kill many trees that otherwise would have survived. Tops of larger trees may also be attacked and killed.

The point of attack on living pines is usually indicated by a pitch tube or an exudation of pitch, but where the tree is decadent or the attacks are numerous, the only indication may be the extrusion of red boring dust or "sawdust," which collects in the bark crevices. A later indication of successful attack is the fading of the foliage, which first becomes yellowish green and later sorrel.

The seasonal history of the *Ips* beetles varies greatly according to the species and the climatic conditions. In northern Maine and New York a single generation occurs, but farther south the same species may pass through two or more generations in a single season. The species in the Southern States may complete five generations, or even more, per year. Under the most favorable conditions of host and climate a generation may be completed in less than 40 days. Other discussions of the *Ips* beetles will be found in Swaine (*401*) and Blackman (*38*).

Ordinarily these beetles can be ignored in the forest, but under certain conditions their attacks must be guarded against. About lumbering operations the beetles breed up to immense numbers, but as each generation emerges it is absorbed by the new slash. Overcrowding in this material tends to keep down the numbers to such as can be accommodated in the new slash constantly being added. A sudden discontinuance of lumbering, however, may result in the destruction of advanced forest reproduction, the loss depending on the health of the young trees. Thus, while burning of slash is not considered necessary during active lumbering, it is advisable to clean up the debris when the cutting is to be discontinued. This is especially true during a drought period or when the residual stand is not in the best condition. The laying down of slash from thinnings and road construction should also be avoided during drought, though under normal conditions there is little danger of any noteworthy injury.

Dying trees in the forest infested with *Ips* may be ignored unless they occur in groups. Single, infested trees are nearly always decadent or dying when attacked by the beetles and need cause no apprehension. If control measures are to be undertaken against *Ips* beetles, a discussion of the methods recommended will be found on pages 47–51.

Ips calligraphus is the largest species of the genus in the Eastern States. It is from 4 to 6.5 mm. long, ranges from reddish brown to black, and may be distinguished from all other eastern species by the presence of six teeth at each side of the diagonally truncate rear end. This species occurs in eastern Canada and the Eastern States, but in the Northern States it is not so common and is not usually found at the higher elevations. It breeds in the various species of pine in its range. It is one of the more aggressive species of *Ips* and in the Southern States is the one first attacking trees suffering from drought. It breeds in the trunks of pines. *I. grandicollis* is smaller than *I. calligraphus*, ranging from 3 to 3.8 mm. long. It is readily recognized by the presence of five teeth at each side of its rear end. This species prefers the trunk of saplings or the upper trunk and larger limbs of more mature trees. It occurs throughout the Southern States and as far north as Massachusetts and New York. Any of the pines in its range may be attacked.

Ips avulsus is the smallest of the eastern species of *Ips*, ranging from 2.1 to 2.8 mm. in length. It is brown to black, and has four small teeth at each side of its rear end. It breeds from Pennsylvania to Florida and westward. Various species of pine are affected, the parts attacked being branches from 1 to 6 inches in diameter. This species is less aggressive than the other southern forms.

Ips pini ranges in length from 3.5 to 4.2 mm. and in color from brown to black. It has four teeth at each side of the rear end, these being considerably coarser than in *I. avulsus*. It is found in the

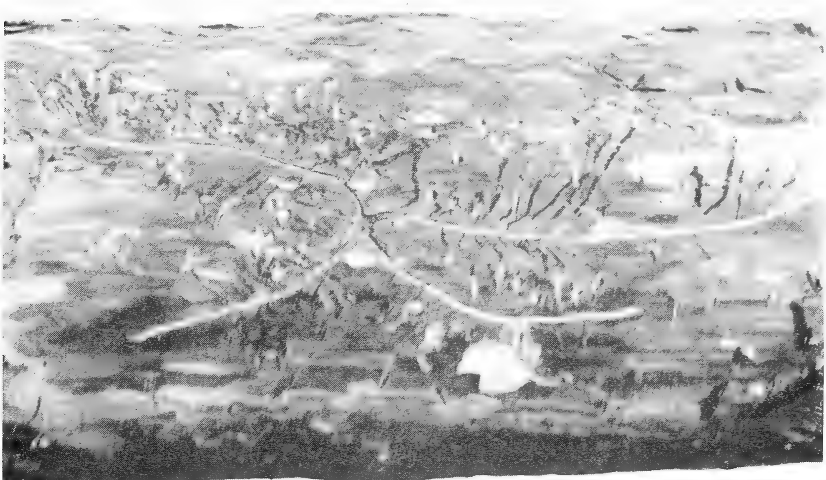

FIGURE 66.—Galleries of *Ips pini* on white pine.

Northern States from Maine to Minnesota. The favorite host is white pine (fig. 66), but other pines in its range, and occasionally spruces, are also attacked. It is less aggressive than *I. calligraphus* but when present in great numbers will attack living trees, especially if these are decadent. *I. chagnoni*, like *I. grandicollis*, has five pairs of teeth on its rear end, but it is larger (4 to 4.8 mm. long) and stouter. It attacks white pine, red pine, and white spruce, and is known from eastern Canada and the northern part of New York, New England, and Minnesota. *I. longidens* is slightly more than 3 mm. long and is reddish brown. It differs from all other eastern species by having the body nearly squarely truncate behind, and by having only three teeth on each side, of which the third is the longest. It is fairly common in central New York in the lower trunks of white pine and has been reported as infesting hemlock in Nova Scotia.

The genus *Orthotomicus* Ferrari contains only one eastern species, *O. caelatus* Eichh. In general form the genus resembles *Ips* in that the rear end is truncate, with the sides armed with teeth, but the shelflike structure at the posterior end of the concavity is much reduced. *O. caelatus* is usually about 3 mm. long, with three teeth at each side of the concavity at the rear end, with the second and third slightly within the margin. This species occurs in eastern Canada and in the United States as far south as Florida. It breeds in the thicker bark at the bases of pines of all species, and in spruce and larch. It is less aggressive than most of the eastern species of *Ips* and is distinctly a secondary species. The brood galleries are radiate, but the egg galleries are shorter than in *Ips*, the egg niches are larger and fewer in number, and in each from two to six eggs are deposited.

The genus *Pityokteines* Fuchs. is also represented in the Eastern States by only one species, *P. sparsus.* It is of the same general type of structure as *Ips*, but here the shelf at the rear end of the posterior concavity is even more reduced than in *Orthotomicus*. The three teeth at each side are strongly developed in the males, but weakly developed in the females, and these are further distinguished by the long, yellow hairs arising from the front of the head and from the apical margin of the pronotum.

The single eastern species, *Pityokteines sparsus*, **the balsam fir beetle,** is slightly less than 2.5 mm. long. Its distribution corresponds closely with that of its usual host, the eastern balsam fir. It breeds in balsam fir slash, and is also often found in the bark of the trunk and limbs of firs that have died suddenly, as indicated by rapidly fading foliage. It has, therefore, often been classed as a primary enemy of eastern balsam. This is doubtful, however, because a thorough examination will usually reveal that such trees were in a very decadent condition when attacked by the beetles. It is also reported from eastern larch.

The genus *Dryocoetes* Eichh. is not very closely related to *Ips*, but is discussed here because of similarity of habit. In *Dryocoetes* the pronotum is more feebly arched than in *Ips* and is more or less granulate over the entire surface. The rear end is not truncate, or excavated, but convex or slightly flattened, and weakly granulate. *Dryocoetes* breeds in several species of conifers and hardwood trees. Logs or decadent trees are preferred, and the eastern species are not known as killers of trees. The burrows are of the radiate type, but in some species are often very irregular. These species have been included in those discussed by Swaine (*401*) in 1918, Blackman (*38*) in 1922, and Chamberlin [27] in 1939.

Dryocoetes americanus is 3 to 4 mm. in length and occurs in the Northeastern States and as far west as the Rocky Mountains. It breeds in species of pine, spruce, and larch. It is a secondary species, breeding by preference in cut or broken material. *D. piceae* is much smaller, averaging about 2.5 mm. in length, and is very closely related to a western species, *D. affaber* Mannh., which is slightly larger but otherwise similar. It breeds in pines and spruces in its range from Maine to Colorado. It is not aggressive and favors dying or cut material. *D. betulae* ranges in length from 2.5 to 4.5 mm. and breeds in the bark of birches, beech, and occasionally wild cherry when these are decadent. The southern variety, known as *D. liquidambarus* Hopk., is found in red gum in the Southern States.

[27] See footnote 22, p. 302.

The Ambrosia Beetles

The ambrosia beetles are not a compact group distinguished by anatomical differences from the true bark beetles. Although similarities in the structure of certain organs set most of them apart from bark-eating forms, these differences have apparently been brought about as adaptations, associated with their different mode of life and different food habits. Their true taxonomic affinities to various groups of bark-eating forms are plainly indicated by the structural similarities of such body parts as would not be greatly affected by peculiarities in their habits. The mode of life of the ambrosia beetles has been discussed in the general portion dealing with the entire group (pp. 294–299) and needs only to be briefly summarized here. The burrows extend directly through the bark into the sapwood and are there elaborated into simple, branched, or compound ambrosial burrows, depending on the species. Not all the species of each genus of ambrosia beetles necessarily construct the same type of burrows. The fact is illustrated by the work of *Xyleborus*, where ambrosial burrows of all three general types are made by different species of the group.

The food of both larvae and adults consists of the tender shoots of ambrosial fungi grown on the walls of the galleries. In both the simple and branched galleries the larvae move about freely in at least a portion of the burrow and feed on these fungi directly. In the compound type of burrow each larva has its own special niche, branching from the main gallery, in which it spends its entire larval, pupal, and callow adult stages. It is here tended by the adults, who supply each larva with ambrosial food and remove the debris. Most of the ambrosia beetles breed in decadent or recently cut trees, often entering the wood of otherwise healthy trees through some injured or dying area of the bark. Since they require considerable moisture, seasoned wood is not suitable. In the tropics, especially, a few species will enter the wood of casks containing water, wine, or other liquids, causing leakage and loss. A few species breed in living trees, with apparently little effect on their health.

The chief damage by ambrosia beetles is due to the black-stained galleries made by them in the sapwood of trees felled for lumber. Timber cut during the time the beetles are active will almost invariably suffer injury unless utilized at once. This is especially true in the Southern States, and there lumbermen know from experience that it is a good practice to saw up their cypress, oak, gum, and other logs, felled during the warmer months, within 2 weeks. Even within that period, the timber will usually have been attacked, but if sawed promptly all or most of the injury will be removed in the slabs and edgings.

Aside from prompt sawing, other methods of preventing excessive injury to logs felled in the warmer months, are rapid seasoning of such material, storage in water, or removal of the bark. Rapid seasoning can be accomplished in some areas and some seasons by placing the logs in full sunlight, and free of the ground. Turning the logs after about 2 weeks will aid in drying out the under side and will often kill any beetles that have entered. Storage in water will render the wood too moist to be attractive to ambrosia beetles and will cause a gradual leaching out of the fermenting sap so attractive to them. Removal of the bark is effective, but the checking caused by too rapid seasoning renders the wood unfit for many uses. Other notes on control have been given on pages 38–40. Hubbard (*247*) wrote on the biology of the ambrosia beetles in 1897, and general discussions will be found in Swaine (*401*), Blackman (*38*), and Chamberlain.[28]

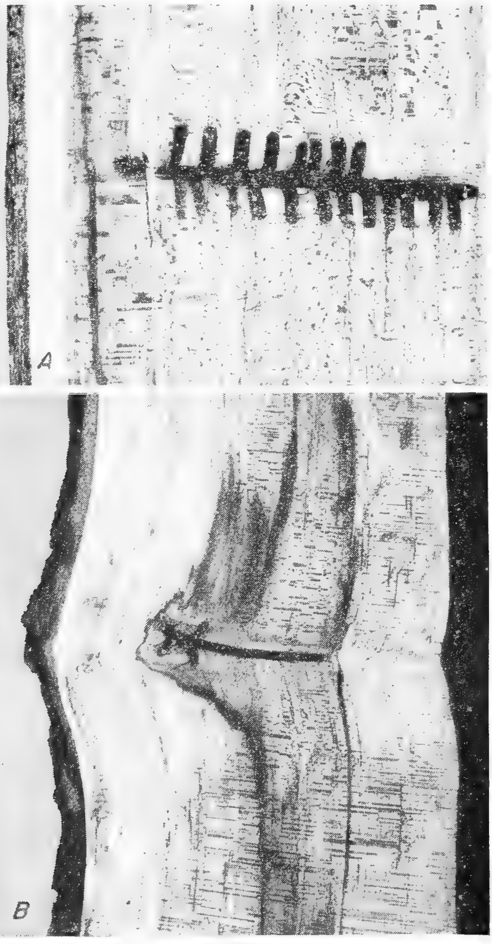

FIGURE 67.—Black holes in white oak made by *Corthylus columbianus*: *A*, slightly enlarged, *B*, slightly reduced.

The genus *Corthylus* Erich. contains several eastern species of shining, dark-brown to black beetles 3 to 4 mm. long. The antennal funicle has only 1 segment and the club is very large and flat. **The Columbian timber beetle** (*Corthylus columbianus* Hopk.) is one of the most aggressive species of ambrosia beetles, as it enters the sapwood of living hardwood trees and there breeds successfully. The trees are not killed, although the beetles may continue to breed in them for many years. The burrows, however, remain in the wood as a permanent defect and record.

In a living tree, Hopkins found the burrows extending back to the year 1479. The defects consist not only of the black-stained burrows (fig. 67) but also of discolorations extending above and below the galleries for a considerable distance, varying with the species of wood. In yellow poplar these stains are responsible for the condition known as "calico-poplar." Various hardwood trees are affected, including yellow poplar, various oaks, beech, birch, maple, and boxelder. The insect has been reported from Massachusetts and Michigan and is common in Maryland, Virginia, and West Virginia. *C. punctatissimus* Zimm. is smaller than *C. columbianus*, being little more than 3 mm. long. Its range is from

[28] See footnote 22, p. 302.

Massachusetts to Colorado and southward. The hosts include blueberry, rhododendron, and mountain mahogany.

The genus *Monarthrum* Kirsch contains two eastern species, one slightly less than and the other slightly more than 2.5 mm. long, and a third as wide. The antenna has a two-jointed funicle. Both species breed in the sapwood of eastern hardwoods, making very slender black-stained galleries of the compound ambrosial types. They attack only dying, injured, or recently cut trees, and their burrows in logs left unsawed too long reduce the value of the product. *M. mali* Fitch is of a nearly uniform brown color, and averages about 2.3 mm. long. It is common throughout the eastern half of the country as far south as Florida and injures the wood of all species of deciduous trees, including fruit trees. *M. fasciatum* Say is slightly larger than *M. mali* and is readily recognized by a pale yellow band across the middle of the wing covers. It occurs throughout the eastern part of the United States, but is much more common in the South and lacking or rare in the extreme North. It infests most of the eastern hardwoods.

The genus *Xyloterinus* Swaine is represented by a single species, *X. politus* Say. Specimens average slightly more than 3 mm. long, 2.6 times as long as wide, and are dark brown to black with the wing covers paler. This species ranges throughout the Eastern States and Canada. It occurs in many of the common eastern hardwoods and has been taken in hemlock. The burrows are of the compound ambrosial type.

The genus *Trypodendron* Steph. contains four eastern species, two of which injure hardwoods and two coniferous wood. They are small, stout beetles from 3 to 4 mm. long, dark brown or black, usually marked with bands or stripes of yellow. All prefer dying or recently cut wood in which to breed, and all construct the compound ambrosial type of galleries. *T. scabricollis* ranges from 3.1 to 3.6 mm. in length, and is dark brown or black, sometimes with indistinct stripes on the wing covers and a similar band on the pronotum behind. It occurs from New York to Mississippi and westward to New Mexico. It breeds in pines and is also said to attack hemlock and witch-hazel.

Trypodendron retusus is the largest eastern species, being 3.5 to 4 mm. in length, with a broad stripe of smoky yellow on each wing cover. The males have the pronotum broadly emarginate in front. It is rather common in species of *Populus* in the northern tier of States, and its range extends from eastern Canada to West Virginia. *T. betulae* ranges from 3 to 3.5 mm. in length, and has a broad stripe of yellow on each wing cover and an indefinite yellow band on the pronotum behind. Several species of birch serve as hosts, and the range of the beetle comprises eastern Canada and the Northeastern States, and also Minnesota. *T. bivittatum* is about 3 mm. long with color markings similar to those of *T. betulae* but is readily distinguished in the field by its hosts, which consist of pines, spruces, arborvitae, fir, larch, and hemlock. Its range includes eastern Canada and the eastern part of the United States, and it is doubtfully distinct from western forms.

The genus *Gnathotrichus* Eichh. contains two species of very slender reddish-brown beetles which are true ambrosia beetles, although structurally they are more closely related to *Pityophthorus* than to any group of ambrosia beetles. They are elongate, 3¼ times as long as wide, the surface very smooth with fine punctures. The galleries in the sapwood are of the compound ambrosial type, similar to, but considerably smaller in diameter than those of *Trypodendron*. With the exception of a single western species the genus in this country is confined to coniferous trees. Decadent or dying trees and the stumps and trunks of felled trees are the favorite breeding places. *Gnathotrichus* do not injure living trees, but may do considerable damage to logs left unsawed too long. In a beetle-killed tree the trunk is usually attacked soon after the bark beetles have overcome the tree's resistance. Blackman (*42*) published on a revisional study of this genus.

Gnathotrichus materiarius is almost exactly 3 mm. long. The species is widely distributed over eastern Canada and in the United States is known from Maine to Minnesota and Nebraska and south to Florida and Texas. Its hosts include various species of pine, spruce, larch, balsam fir, and arborvitae. Other conifers used in plantations or as ornamentals are also subject to attack. *G. aciculatus* is really a western form, being common in New Mexico and Arizona, but is found as far east as Colorado and South Dakota in ponderosa pine. It is larger than *G. materiarius*, being 3.5 mm. long.

The genus *Xyleborus* Eichh. is distributed around the world in the tropical and temperate zones. It probably contains more species than any other genus of the family, but in the United States the species of *Pityophthorus* outnumbered those of *Xyleborus*. Many of the species of *Xyleborus* are very closely related and difficult to identify, and as it is probable that a number of species reported from our territory have been incorrectly named, only those of which the authors feel reasonably certain will be included here.

The galleries made by different species of *Xyleborus* illustrate all three of the general types of ambrosial burrows. Those of *X. saxeseni* and *X. pecanis* are of the simple ambrosial type; those made by *X. celsus* are of the branched type; while several species, exemplified by *X. fuscatus*, make compound ambrosial burrows. Some species of *Xyleborus* are rather more aggressive than most ambrosia beetles in that they attack decadent, but still living, tissue and sometimes apparently contribute to the death of the tree. Most species, however, prefer dying or freshly broken or cut material, thus affecting only the timber value of the tree. A few species, especially in the tropics and subtropics, cause considerable damage to casks containing water, wine, or liquor.

Xyleborus saxeseni is common to both Europe and the Eastern States, being found in a large number of hardwood species. *X. pecanis* was described from Mississippi in pecan, but also breeds in various hardwoods in the Southeastern States. It is very closely related to *X. saxeseni* and might better be considered as a variety of that species. *X. affinis*, originally described from Cuba, breeds from New Jersey southward to Florida and Mississippi. It has been taken from hickory and other hardwoods. *X. xylographus* is similar to, but distinct from *X. affinis*. It breeds in various hardwoods from New York to Minnesota and southward to Florida, and apparently authentic specimens have also been taken from pine. *X. fitchi* was described from Long Island and was also found in southern Pennsylvania in pitch pine. *X. fuscatus*, described from South Carolina, breeds in oaks and other hardwoods as far north as New York and west to Texas. The closely allied species, *X. confusus*, is known from Mississippi and other Southern States. *X. celsus*, the largest of our eastern species, is 4 to 4.5 mm. long. It breeds on various species of hickory from New York westward to Minnesota and Indiana and southward to South Carolina and Mississippi.

The genus *Anisandrus* Ferrari is closely allied to *Xyleborus*, but can be readily distinguished by the short, very stout body form, with the pronotum globose. The burrows are branched or compound, and various deciduous trees serve as hosts. *A. obesus* is the largest species of this genus, being 3.3 to 3.7 mm. in length, and stout and black. It breeds in birches, maples, oaks, and beech in eastern Canada and in the Northeastern States south to Virginia and west to Minnesota. The burrows are found both in trunk and limbs. *A. populi* Sw. breeds in poplars and is definitely known only from eastern Canada, but may occur in the Northeastern States. *A. minor* is much smaller than the foregoing, being slightly less than 2.5 mm. long. It attacks the branches of maples and beech in eastern Canada and New York. *A. sayi* Hopk. is slightly larger and attacks sassafras in West Virginia and spice bush (*Benzoin*) in Pennsylvania. *A. pyri* is nearly identical with the European species *A. dispar* F. It breeds principally in fruit trees, but also attacks other hardwoods. It ranges from Maine to Florida and westward to Michigan, and is also found on the Pacific coast.

The genus *Xylosandrus* Reitter is similar to *Anisandrus* but differs in the shining pronotum, the strongly margined sides of the elytral declivity, and the wide separation of the bases of the forelegs. This group of insects is largely confined to the Orient, but two species are now known to be present in the United States. One of these, *X. zimmermanni* Hopk., was described from specimens taken by Hubbard and Schwarz at Biscayne, Fla. Nothing of its habits is known at present, and it may easily have been introduced from the Orient. *X. germanus* originally lived in Japan and Formosa, but has been reported for several years from Connecticut, New York, Long Island, and northern New Jersey. Specimens have been taken in the upper Ohio Valley. Branches, peeled and unpeeled logs, and stumps are attacked. These beetles have become extremely numerous in the area infected by the Dutch elm disease fungus near New York, where a small percentage of them carry the disease organism on their bodies.

Family PLATYPODIDAE

The Flatfooted Ambrosia Beetles

The *Platypodidae* are almost exclusively tropical and subtropical beetles, and only a few species occur normally within the United States. These all belong to the genus *Platypus* Herbst. Of the half dozen or so species, three are common in the Southern States, and along the Atlantic coast they may be found as far north as southern New York. Numerous other species have been imported in tropical woods, but they are unable to withstand climatic conditions and soon succumb. All the *Platypodidae* are ambrosia beetles. In general they are not found exclusively in one kind of tree, but the same species may breed in a variety of hosts. The beetles are readily distinguished from the other ambrosia beetles by their larger size; their slender, cylindrical bodies; their large prominent heads, flattened in front; the very long, slender tarsus, with the basal joint longer than the others combined; the slender thorax, constricted about midway at the sides; and in the males by the spinelike projections of the elytra behind.

The *Platypus* beetles are more destructive than ordinary ambrosia beetles because their burrows are more extensive and often penetrate deep into the heartwood of the trees attacked, thus destroying more of the valuable timber. The eggs are laid in small clusters, loose in the burrows, each female depositing from 100 to 200. The larvae at first live freely in the tunnels along with the adults and, like the latter, feed on a minute fungus which forms a coating over the walls of the burrow, producing the black stain characteristic of the burrows. After about 5 or 6 weeks, when the larvae are nearly full grown, each excavates a small cell at one side of the main burrow. These cells are usually placed in groups of 8 or 10, or more, and always extend with the grain of the wood. In these cells the larvae transform to pupae and later to adults. The beetles seldom or never attack vigorous, healthy trees, for, although the tree attacked may be in full foliage, the insects enter through some dead or dying area of the bark.

Apparently a fermenting condition of the sap is necessary for the proper development of the ambrosial fungi on which the young depend entirely and the adults largely for their food. Thus the *Platypus* beetles are perhaps never the primary cause of the death of trees, but their activities may result in hastening the death of injured or sickly trees. More important still, their burrows often ruin the timber value of girdled trees or large trees recently felled in the course of lumbering operations. There are only three species of *Platypus* commonly found in the Eastern States and of these only two are often of real importance. For control measures against these beetles see pages 38–40. Additional information may be obtained by referring to Blackman (*38*).

Platypus flavicornis is dark reddish brown, more than 5.5 mm. long; the pronotum with an unmargined, shallow fovea at each side of the anterior end of the longitudinal groove in the female only; the posterior end of the female elytra is prolonged at each outer third to form a blunt process, which in the male is much longer and sharper. *P. flavicornis* is common throughout the Southeastern States and is found as far north as New Jersey. It is most common in various species of pine, but also breeds in other conifers and has been reported from several deciduous trees. However, throughout the South the chief damage is done to pine trees, and as the beetles are energetic burrowers and often attack in considerable numbers, the wood is soon rendered worthless as saw timber and its value as cordwood is much decreased. Trees or logs attacked should be utilized at once.

Platypus compositus is rather light reddish brown and less than 5 mm. in length. The pronotum is finely, shallowly, and sparsely punctured, with a distinct longitudinal groove on the posterior third, and with a small margined pit at each side, near the anterior end of the groove in both sexes. The males have the wing covers each prolonged into a heavy process, tridentate at the end, while in the females the elytra are somewhat truncate and unarmed. *P. compositus* is found throughout the Southern States and has been taken as far north as southern New York and southern Illinois. It attacks a wide variety of trees including hickory, pecan, birch, poplars, willows, oaks (fig. 68), maple, chestnut, basswood, elm, beech, wild cherry, sweetgum, sourgum, magnolia, and cypress. The greatest injuries from this ambrosia beetle are those suffered by girdled cypress and by recently felled hardwoods. Injury to logs can be largely prevented by sawing the felled trees within 2 or 3 weeks after they are felled. Many southern mills make it a rule during the warmer months to saw all hardwoods within 2 weeks after felling. *Platypus quadridentatus* Oliv. is a closely related species found on oak and chestnut.

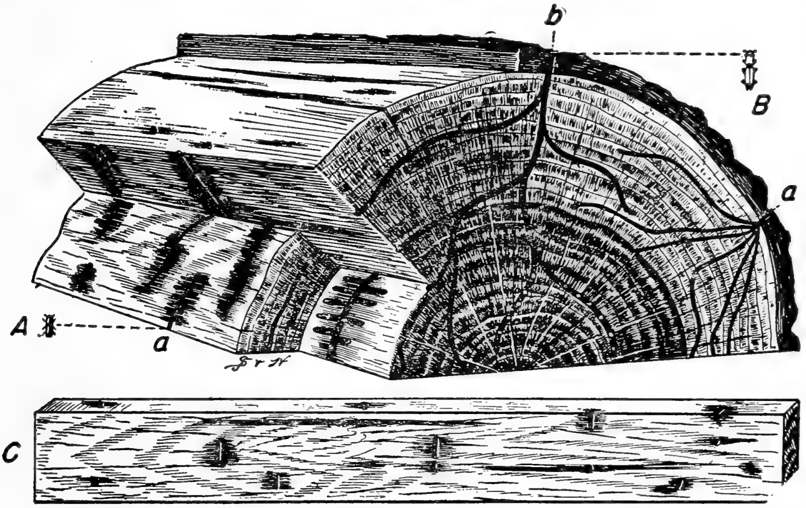

FIGURE 68.—Work of ambrosia beetles in oak: *A, Monarthrum mali, a,* its work; *B, Platypus compositus, b,* its work; *C,* lumber showing pinholes made by ambrosia beetle larvae.

BUTTERFLIES AND MOTHS

ORDER LEPIDOPTERA

BY J. V. SCHAFFNER, JR.[29]

The butterflies and moths belong to the order Lepidoptera, the word meaning scaly-winged. They have four membranous, more or less triangular wings. The body and wings are clothed with overlapping scales, or modified hairs, arranged in definite patterns, and are often of brilliant colors. In admiring the colors and beauty of the butterflies and moths too few people realize the havoc the larvae of these insects may cause when abundant. It is also probable that few are aware of the part nature plays in keeping thousands of species more or less constantly under control, so that they cause little or no injury.

The order Lepidoptera includes many of the most serious insect pests of our forests and shade trees, not to mention the thousands of other plants and products attacked by them. A few species, like the silkworm (*Bombyx mori* L.) and *Feniseca tarquinius* (F.), whose

[29] Mr. Schaffner acknowledges his indebtedness to Carl Heinrich, of the Division of Insect Identification, for review of this part of the manuscript.

larvae are predaceous on the woolly alder aphid (*Prociphilus tessellatus* (Fitch)) are beneficial.

The feeding habits of the lepidopterous larvae vary greatly, but by far the greater number are plant feeders. They may attack the foliage of forest and shade trees as miners or skeletonizers, or devour it completely, or act as miners or borers of buds, stems, twigs, bark, or wood. Some stage of these insects is present at all times, but the injury may pass unnoticed unless an outbreak occurs. Various factors affect their economic importance, particularly the nature and extent of injury, whether they are general feeders or are restricted to certain food plants, and the value of the plants or products attacked.

In the eastern part of the United States there are more than 5,000 species representing more than 60 families of Lepidoptera. Comparatively few of these species, however, attract attention as serious pests of forest and shade trees and shrubs; therefore only the families and species that are generally most common are discussed herein. The species are grouped systematically under their respective families, the arrangement following that used in the United States National Museum.

The wealth of material at the New Haven, Conn., laboratory of the Bureau of Entomology and Plant Quarantine has aided materially in the preparation of this section of the manual. This material, both in records and specimens accumulated from many years of collecting and rearing of lepidopterous larvae, resulted from studies begun in 1915 at Melrose Highlands, Mass. Various publications, not all of which are listed in Literature Cited, p. 637, have been consulted freely for further information on many of the families, genera, and species.

In their life cycle, Lepidoptera undergo a complete change, or perfect metamorphosis, passing through four stages as follows: Egg, larva or caterpillar, pupa or chrysalis, and adult. These various stages have been discussed by Comstock (*103*), Forbes (*165*), and Holland (*228*, *229*).

ADULTS

The minute scales covering the wings and body of the adults are a distinctive feature of this order. These scales overlap like shingles on a roof and are of many shapes, ranging from hairlike structures to short and broad scales. The mouth parts are formed for sucking, as the food consists only of liquids, such as nectar from flowers, juices of overripe fruit, or honeydew. The adults of many species, however, do not take any nourishment, and their mouth parts are poorly developed, probably from disuse through countless generations.

Although the order Lepidoptera is popularly divided into the two groups of butterflies and moths, this division is not based on a natural classification. In general, it may be said that the butterflies have antennae which are alike in both sexes, being long and threadlike and usually with a club at the tip. They fly during the daytime, and when at rest the wings are folded together in a vertical position over the body, except for some of the "skippers," whose forewings are held in a vertical position while the hind wings are folded horizontally. The moths differ from the butterflies in that the antennae are usually threadlike or featherlike and without a club at the tip. They have a tendency to fly by night, and most species are attracted to lights. The wings of moths are folded rooflike, held in a horizontal position, or wrapped around the abdomen when at rest. The females of some species of moths are heavy bodied and cannot fly, even though they are equipped with wings, and those of a few species are wingless. The adults vary greatly in size. In the eastern part of the United States they range from the tiniest of the family Nepticulidae, which has a wing expanse of about 1/8 of an inch, to the largest of the family Saturniidae, which has a wing expanse of nearly 6 inches. A number of these moths are shown in figure 69.

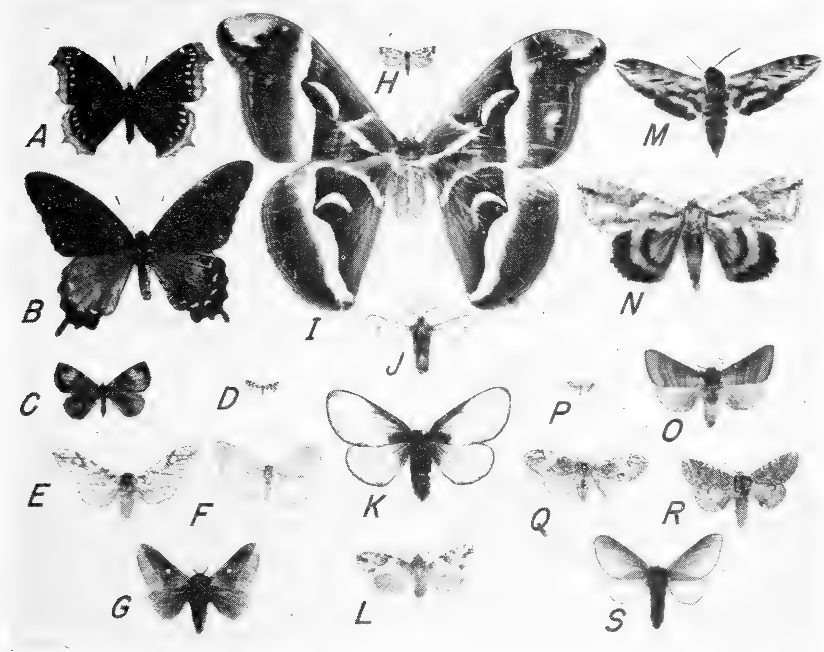

FIGURE 69.—Representative adults of Lepidoptera (butterflies and moths): *A*, *Nymphalis antiopa*; *B*, *Battus philenor*; *C*, *Feniseca tarquinius*; *D*, *Taniva albolineana*; *E*, *Halisidota caryae*; *F*, *Lambdina pellucidaria*; *G*, *Anisota stigma*; *H*, *Rhyacionia buoliana*; *I*, *Philosamia cynthia*; *J*, *Aegeria apiformis*; *K*, *Hemileuca lucina*; *L*, *Polia latex*; *M*, *Sphinx gordius*; *N*, *Catocala parta*; *O*, *Datana angusii*; *P*, *Epinotia nanana*; *Q*, *Olene basiflava*; *R*, *Heterocampa guttivitta*; *S*, *Anisota senatoria*.

EGGS

The eggs are of various shapes, often with intricate ornamentation. Some species deposit their eggs singly, and others lay them in one or more groups or clusters which may be entirely naked, packed and coated with a cement or gelatinlike substance, or packed in hairs which the female removes from her body.

LARVAE

Lepidopterous pests cause injury during the larval stage, and it is at this time that they are usually observed, so a general description of the external larval structure will aid in distinguishing them from larvae of other orders.

The larvae vary greatly in appearance but are usually more or less cylindrical. Each has a well-developed head, thorax, and abdomen. The head is equipped with biting mouth parts. The thorax has three segments, each bearing a pair of 5-jointed legs. The first segment, or prothorax, bears two spiracles, one on each side, and on the top surface a sclerite, known as the cervical, or thoracic, shield. The abdomen is composed of 10 segments, each of the first 8 bearing a pair of spiracles. There may be from 2 to 5 pairs of abdominal legs or prolegs, which are fleshy, without joints, and are cast off with the last larval skin. On forms that feed externally prolegs are never present on the first or second abdominal segments. This distinguishes them from sawfly larvae, which have prolegs on the second abdominal segment. The larva may appear as naked; sparsely or densely clothed with hairs, bristles, or spines; or equipped with fleshy or horny warts and tubercles. The fact is, however, that the body bears a regular arrangement of setae on each segment, which are of great value in identifying the different species.

From time to time as the larva increases in size, its outer skin, or epidermis, becomes too tight to admit further growth, so a new and more flexible skin is formed underneath the old one, and the old skin then splits back of the head along the dorsal line and is molted, or shed. The number of molts ranges from 3 to 10 in the different species. Prior to the first molt the larva is said to be a first instar, between the first and second molt, a second instar, and so on until it becomes full-grown.

PUPAE

When the larvae are full grown they cease to feed, usually seek a sheltered place, and then void the contents of their digestive tract. Most species pupate within cocoons constructed by the larvae. A cocoon may be composed entirely of silk, of a folded leaf or several leaves drawn together with silk, a mixture of silk and hairs from the body of the larva, particles of wood or other substances, a combination of silk and fluid secretion, which dries and forms a hard-shelled cocoon, or an earthen cell made from particles of soil cemented together. A few species have naked pupae, usually protectively colored, which are attached by the caudal extremity to some object by silk and often with a silken girdle to hold them in place. Cocoons may be formed on any part of a tree, in the soil, or in any conceivable place that offers protection. The pupae, or "chrysalids," of some species of the butterflies are ornamented with gold- or silver-colored spots.

Preparatory to pupation, the larva decreases in length but increases in girth, and finally the action and pressure from within causes the skin to split along the dorsal line of the thorax, and the freshly formed pupa forces itself out. Considerable transformation from the larval stage has taken place. The divisions of the head, thorax, and abdomen are easily recognized, and the appendages characteristic of the adult, closely bound to the body, are plainly marked on the pupa. Many of the internal organs undergo extensive changes during the pupal period.

The method of escape by the adult from the pupa and cocoon varies greatly with the different species. Immediately prior to the emergence of the adult, some pupae develop a considerable power of motion by the use of hooks or other processes and the freeing of some of the segments and appendages. In many species before the adult emerges the pupa is thus able to work its way out of the cocoon, and to the surface of the ground or to the entrance of the larval gallery. Many species use a process on the posterior end of the pupa, known as the cremaster, which is often provided with hooks to hold the pupal shell in place while the adult emerges from it. A softening fluid from the emerging insect also aids in its escape from the cocoon.

FEEDING HABITS OF LEPIDOPTERA AND CHARACTER OF INJURY

Brief reference has already been made to the characteristic feeding habits of the larvae. Fortunately most of our native species are held down more or less by the natural control factors, so that the feeding they do seldom attracts attention. The control of those species that increase enough to cause serious injury is one of the big problems of the forest entomologist, the forester, and others responsible for the care of trees and shrubs. Knowledge of the biology of the insect concerned and the character of its work is necessary before one can decide intelligently if and when control measures are advisable or practical.

The external structure of the larva, its habits, the food plant, and the character of its work can be used in the identification of the pest. Although many species are borers of buds, stems, twigs, bark, or wood, most of them are leaf eaters, or defoliators. The latter group may mine, skeletonize, or completely devour the leaves, and when the larvae are abundant their feeding may completely defoliate the food plant. It is therefore important to point out some of the characteristics of these insects and to give the common names used in identifying various species or groups.

The **leaf miners** are found among the beetles (Coleoptera), true flies (Diptera), and sawflies (Hymenoptera), but by far the greatest number of species having this habit is found among the Lepidoptera, and here are also found the best developed leaf-mining habits. One or more species of these tiniest of moths may be found inhabiting the foliage of practically every species of plant. All have at least one generation annually, but some species have several. The mines, in general, are of two principal kinds—linear and blotch. The linear mines may take a straight or serpentine course and the blotch mines may be circular, oblong, or of other shapes. There are many intergradations between the two types.

Some species of leaf miners are sap feeders, removing very little of the parenchyma; some are adapted for sap feeding in the early instars but when partly grown acquire tissue-feeding mouth parts; and others are entirely tissue feeders. The mining habits differ, depending on the extent of the life cycle spent in the mines. The larvae of *Paraclemensia acerifoliella* (Fitch) (family Incurvariidae) are leaf miners only during their early larval life, later becoming leaf cutters and casebearers. The larvae of *Bucculatrix* (family Lyonetiidae) vacate the mine when young and feed openly, skeletonizing the foliage, and are commonly considered skeletonizers. Those of the Nepticulidae and some species of other families vacate the mines only when they are full grown. The larvae of Coleophoridae, commonly called casebearers, mine portions of the food plant and from the material they construct portable cases which they carry around on the body, and enlarge as they grow.

In the Gracilariidae, the largest family of leaf miners, the larvae of species in the genus *Gracilaria* become external, but concealed, feeders when partly grown. They spin silken threads across the loosened epidermis, forming tentiform mines, or they make a shelter by folding over a part of the leaf. Those in the genera *Cameraria* and *Phyllonorycter* feed continuously in the mines and pupate there. The families Gelechiidae, Heliozelidae, Olethreutidae, Yponomeutidae, and Tortricidae each include species with leaf-mining habits, and some of these species are important pests of evergreens.

There are some 18 families of Lepidoptera represented among the leaf miners, but the 10 noted above include most of the species of economic importance. Their identification is often difficult, and the name of the host plant, the form and color of the mine, the frass, the silk, the larva, the pupa, and the molt skins, particularly the head capsules, are used in the specific determination of these insects.

The **skeletonizers,** as the name implies, eat the parenchyma of the leaves, usually leaving only the tougher veins and midribs. This common name applies to species of *Bucculatrix*, and is also used for such species as *Anthophila pariana* Clerck, and others.

The **bagworms** and **casebearers** include species the larvae of which construct and inhabit portable baglike structures, or cases, such as members of the families Psychidae, Coleophoridae, and Lacosomidae.

The **leaf rollers** or **leaf tiers** conceal themselves in leaves folded, or rolled, or fastened by silk. Species having these habits are found in the families Tortricidae, Gelechiidae, Pyraustidae, Pyralididae, Oecophoridae, Hesperiidae, and others. In general, the species are solitary in habit.

The **webworms** or **tentmakers** for the most part are gregarious, and either spin silk over several leaves to form a web, or spin a silken tent in a crotch of a tree or shrub. Some species feed within the web, enlarging it so as to enclose more foliage when necessary, and other species leave the tent to feed but return for their resting periods. These habits are found among species of the families Tortricidae, Epipaschiidae, Lasiocampidae, Arctiidae, and others.

The larvae that live mostly in the open without larval cases or webs for protection are called **free feeders.** Certain structural characters and the vestiture, as well as the habits, permit the division of these larvae into many groups that will aid in identifying them.

The **sluglike larvae** include the "puss" caterpillars, or "possum-bugs," of the family Megalopygidae and the slug and saddle-back larvae of the family Limacodidae.

The **hairy caterpillars** of the free feeders include the "woolly-bears" of the Arctiidae, which are densely clothed with clusters of hairs arising from tubercles. The "tussocks" of the family Lymantriidae have conspicuous tufts of hairs on the backs of some of the segments, and long pencils of hairs at each end of the body; the "*Datanas*" of the family Notodontidae are gregarious and have a peculiar habit of clinging to the twigs or foliage with their middle prolegs and holding the head and anal end of the body in a more or less perpendicular position. Some species of the genus *Acronicta*, family Phalaenidae, are densely clothed with hairs.

The **spiny caterpillars** include species of the family Nymphalidae and some of the Saturniidae, Citheroniidae, and others. These are heavily armed with coarse branched or barbed spines.

The **giant silkworms** of the family Saturniidae are more or less armed with tubercles and spines and are conspicuous because of their large size. The larvae of Citheroniidae are also armed with spines or horny tubercles, of which those on the second thoracic segment, and also sometimes those on the third, are rather long and curved.

The **free-feeding naked larvae** include the sphinx caterpillars or hornworms of the family Sphingidae, which have either a horn or an eyelike tubercle on the eighth abdominal segment; the loopers, measuring worms, cankerworms, or geometers of the family Geometridae, so-called because of their manner of locomotion; the cutworms of the family Phalaenidae, and others.

The **bark and wood-boring larvae** infest the trunk and larger branches and roots of trees, and in some cases the food plant aids in the identification of the species. These insects belong to families Aegeridae, Cossidae, Phycitidae, Hepialidae, and others.

The **bud, shoot, and twig borers** belong to the families Tortricidae, Phycitidae, Olethreutidae, and Nepticulidae. The **leaf-stem borers** are found in the Nepticulidae, Lavernidae, Tortricidae, and Oleuthreutidae. The **fruit, nut, cone, and seed borers** are members of the families Tortricidae, Blastobasidae, Phycitidae, and others.

At least six families (Incurvariidae, Psychidae, Gelechiidae, Amatidae, Arctiidae, and Zygaenidae) are represented by one or more **species whose larvae feed on lichens** on trees or rocks. Among these species are found casebearers, bagworms, and hairy, and naked larvae. Occasionally some are more or less common locally. The larvae of several species in the family Tineidae, particularly in the genera *Scardia* and *Tinea*, are **external feeders or borers in fungus growths,** and many are scavengers. They are generally casebearers. The moths are small, most species having a wing expanse of less than 1 inch.

PARASITIC AND PREDACEOUS HABITS

In the United States there is only one species in the Lepidoptera which is known to be an internal parasite, and very few species are truly carnivorous in their habits. Two widely distributed species, whose habits have been studied, are mentioned here because they both attack important forest insect pests.

The larva of *Euclemensia bassettella* (Clem.) (family Heliodinidae) is an internal parasite of the oak soft scale, *Kermes* sp. It is a stout larva with a brown head and white body. The moth has a wing expanse of about 3/5 inch and is active in July and August. It ranges from Ontario to Texas.

The larva of the butterfly *Feniseca tarquinius* (F.) (family Lycaenidae) feeds on woolly aphids. It is found most often in colonies of the woolly alder aphid (*Prociphilus tessellatus* (Fitch)). When fully grown it is about 5/8 inch in length. The head is brown, the body sluglike and clothed with short black-and-white bristles. The larva is usually well concealed as the white exudations of the host adhere to the bristles on the body of the larva. The winter is passed as a chrysalis, and the adult of the first brood emerges late in May. There may be two or three generations a year, and larvae are found until early in October.

Because of the large number of Lepidoptera which may from time to time be found in considerable abundance in the eastern part of the United States, it is practically impossible to construct a key to the larvae of all the common species by using nontechnical terminology.

An examination of the external structure or vestiture of the full-grown larvae, however, and observations on their habits and the character of their work will show that most of the more important species will fall within one or another of the groups just described. Often additional important clues to their identity will be discovered by considering the region or locality in which they were collected, the food plants, the solitary or gregarious habits of the larvae, and the seasonal history.

The following key, therefore, is erected by using these groupings as a basis. The larval descriptions given in the key are of full-grown specimens unless otherwise stated. Although necessarily incomplete, the key should aid materially in the identification of many of the more common species that inhabit the forest. It seems advisable, however, to point out that larvae of hundreds of species not mentioned here will also fit into one or another of the couplets in the key and, too, that many species whose larvae are not strikingly marked cannot be specifically determined in the field. In many cases it is necessary to obtain the adults for identification.

A FIELD KEY TO SOME OF THE MORE COMMON LEPIDOPTEROUS LARVAE THAT ATTACK FOREST AND SHADE TREES, SHRUBS, AND VINES

1. Leaf feeders ---- 2
 Not leaf feeders (borers of buds, stem, bark, wood, roots, or fruit) - 34
2. Leaf miners, casebearers, or bagworms ---- 3
 Skeletonizers (leaves not webbed together with silk) ---- 9
 Leaf rollers or leaf tiers (some species skeletonize the leaves) ---- 10
 Webworms or tent makers ---- 11
 Free feeders ---- 12
3. Noncasebearing leaf miners ---- 4
 Casebearing leaf miners, or other casebearers, and bagworms ---- 7
4. Blotch, serpentine, or tentiform mines in foliage of deciduous plants - 5
 Miners in the foliage of Pinaceae ---- 6
5. Families Gracilariidae, Heliozelidae, and others. Some common species listed below:
 Lilac (tentiform mine) ---- *Gracilaria syringella* (F.), p. 492.
 Oak (blotch mine, larvae solitary)
 Cameraria hamadryadella (Clem.), p. 492.
 Oak (blotch mine, larvae gregarious)
 Cameraria cincinnatiella (Chamb.), p. 492.
 Tupelo (blotch mine) - *Antispila nyssaefoliella* Clem., p. 485.
6. Families Gelechiidae, Olethreutidae, Yponomeutidae. Some common species are listed as follows:
 Arborvitae ---- *Argyresthia thuiella* (Pack.), p. 487.
 Argyresthia freyella Wlsm., p. 487. *Recurvaria thujaella* Kearf., p. 457.
 Juniper ---- *Argyresthia freyella*, p. 487.
 Recurvaria juniperella Kearf., p. 458.
 Hemlock ---- *Recurvaria apicitripunctella* (Clem.), p. 457.
 Pitch pine and other hard pines
 Exoteleia pinifoliella (Chamb.), p. 458.
 Spruce:
 Head, shields, and true legs blackish; body dirty white to reddish; length 3/16 inch
 Epinotia nanana (Tr.), p. 471.
 Head and cervical shield light brown; body reddish to light cinnamon brown; length about 5/16 inch
 Recurvaria piceaella Kearf., p. 457.
 Head yellowish brown; shields pale greenish; body greenish brown; length about 3/8 inch
 Taniva albolineana (Kearf.), p. 475.

KEY TO LEPIDOPTEROUS LARVAE—Continued

7. Larva in a case which is composed of a part or parts of a leaf 8
Larva when nearly full grown in a tough, oval, silken case *Acrobasis* spp., p. 449.
Larva in a baglike case of silk and covered with bits of the food plant ..... Psychidae, p. 438.

8. Larva in a flat case on sugar maple *Paraclemensia acerifoliella* (Fitch), p. 502.
Larva in an ellipsoidal case with circular opening at each end; on oak ..... Lacosomidae, p. 437.
Larva in a cigar- or pistol-shaped case ..... Coleophoridae
Some common species are listed as follows:
Apple, cherry, hawthorn, plum, and quince *Coleophora fletcherella* Fern., p. 489.
Birch, alder ..... *Coleophora salmani* Heinr., p. 491.
Elm ..... *Coleophora limosipennella* (Dup.), p. 490.
Hickory and pecan *Coleophora caryaefoliella* Clem., p. 489.
Larch ..... *Coleophora laricella* (Hbn.), p. 490.

9. Skeletonizers; leaves not webbed together with silk. Some common species are listed:
Apple and hawthorn .. *Bucculatrix pomifoliella* Clem., p. 495.
Anthophila pariana (Clerck), p. 485.
Birch ..... *Bucculatrix canadensisella* Chamb., p. 495.
Oak ..... *Bucculatrix ainsliella* Murt., p. 496.

10. Leaf rollers and leaf tiers. Some species skeletonize, but in each case the larva is in a rolled leaf or between leaves webbed together:
Apple—See general feeders.
Barberry—black, dotted with white; venter brown. Each between leaves webbed together. August–September *Omphalocera dentosa* (Grote), p. 446.
Basswood—green; head and shield black; in rolled leaf, July–September ..... *Pantographa limata* G. & R., p. 445.
Beech—pinkish white; head brown; leaf tier, August–September ..... *Psilocorsis faginella* (Chamb.), p. 461.
Birch, poplar, ash, wild cherry, etc.—dark green; body largest at third thoracic segment, which bears on each side a large yellow spot edged with black and enclosing a purple spot encircled with black *Papilio glaucus* L. and the form *turnus* L., p. 368.
Cherry (wild)—See general feeders.
Elm—green, with margins of segments tinged with yellow. June–October ... *Canarsia ulmiarrosorella* (Clem.), p. 454.
Fir—See spruce.
Grape—head and cervical shield light brown; body glossy translucent yellow green; length about 1 inch. May to October ..... *Desmia funeralis* (Hbn.), p. 444.
Greenish white, hairy; length about ½ inch. May–June *Pterophorus periscelidactylus* Fitch, p. 456.
Hickory—dull green; head, shield, and tubercles black. May–June ..... *Archips infumatana* (Zell.), p. 477.
Head pale green tinged with brown; body pale, translucent; length about ¾ inch. May and June *Argyrotaenia juglandana* (Fern.), p. 483.
Honeysuckle (bush)—yellowish green; reddish dorsal stripe; head mottled; May–June *Harpipteryx xylostella* (L.), p. 487.
Locust (black), and wisteria—green with yellowish lines; head and shield blackish. June–September *Salebria subcaesiella* (Clem.), p. 453.
Light green, head light brown; June–September *Salebria virgatella* (Clem.), p. 453.
Greenish yellow with fine black rings; head dull red with two yellow spots on face. May–October *Proteides clarus* (Cram.), p. 371.

KEY TO LEPIDOPTEROUS LARVAE—Continued

10. Leaf rollers and leaf tiers, etc.—Continued

Dull pale green; head large, dull brownish or reddish brown; July–October
Erynnis icelus (Scud. and Burg.), p. 371.

Maple—light green; head yellowish; in trumpetlike frass tube; July–September *Epinotia aceriella* (Clem.), p. 473.

Dull yellowish green; head reddish brown, cervical shield brown, shaded to black posteriorly and on sides. May and June
Sparganothis pettitana (Rob.), p. 477.

Oak—light green; head and shield dark brown to black. April–June *Archips argyrospila* (Wlkr.), p. 478.

Light green; head amber yellow. May–June
Argyrotaenia quercifoliana (Fitch), p. 482.

Pale greenish; between two leaves fastened with silk; August–September
Psilocorsis quercicella Clem., p. 461. *Psilocorsis reflexella* Clem., p. 461.

See also General feeders p. 353.

Pine (white)—greenish yellow; head greenish brown with dark patch on sides; in tube made of needles and silk: May–June, August–October
Argyrotaenia pinatubana (Kearf.), p. 483.

Poplar—translucent; head and shield brown; legs and tubercles black. May-June
Anacampsis innocuella (Zell.), p. 459.

Dull olive green; head blackish; shields mostly black. July to spring *Archips conflictana* (Wlkr.), p. 480.

Dull pale green; head large, dull brownish to reddish brown. July-October
Erynnis icelus (Scud. and Burg.), p. 371.

Light green with light brown head. July to September
Amorbia humerosana Clem., p. 476.

Privet and bush fruits—dull green; head light to dark brown; May-June *Archips rosana* (L.), p. 477.

Redbud—white with black markings in a folded leaf or between leaves webbed with silk
Fascista cercerisella (Chamb.), p. 460.

Sassafras and spicebush—body largest at third thoracic segment; dorsum pea green, sides yellowish; a transverse black line on prothorax; eyelike spots with blackish centers on enlarged segment; also two spots on the first abdominal segment *Papilio troilus* L., p. 368.

Spiraea—dark green; tubercles light; sparsely hairy; head light brown. May–July *Evora hemidesma* (Zell.), p. 470.

Spruce, fir, and jack pine—dark brown; tubercles pale, conspicuous; head black; in opening buds or on twigs webbed with silk. April–June *Archips fumiferana* (Clem.), p. 480.

Bright green; head brownish, or black; also on fir and hemlock. May–July *Peronea variana* (Fern.), p. 484.

Head brownish yellow, body yellowish to grayish green; spinning the opening buds and terminal needles together in spring.
Zeiraphera ratzeburgiana (Sax.), p. 471.

Sumac—larva in silken gallery in flower spikes. May–June
Anacampsis rhoifructella (Clem.), p. 459.

Yellow and brown head; body yellow green with brick red lines; in rolled leaves. July–September
Salebria semiobscurella Hulst, p. 454.

Light green, more or less tinged with red; ½ inch long. June–September *Episimus argutanus* (Clem.), p. 471.

Sycamore—light green; body tapering toward ends; ¾ inch long. May and June
Adoxophyes furcatana (Wlkr.), p. 476.

Tupelo—black with yellowish head. July–August
Tacoma nyssaecolella Dyar, p. 453.

KEY TO LEPIDOPTEROUS LARVAE—Continued

10. Leaf rollers and leaf tiers, etc.—Continued
   Viburnum—larva in folded leaf. May–June
   Anacampsis rhoifructella (Clem.), p. 459.
   Virginia creeper—head and cervical shield light brown; body glossy, translucent yellow green; length about 1 inch. May–October ------- *Desmia funeralis* (Hbn.), p. 444.
   Willow—dull pale green; head large, dull brownish or reddish brown. July–October
   Erynnis icelus (Scud. & Burg.), p. 371.
   Light green with light-brown head. July — September
   Amorbia humerosana Clem., p. 476.
   Witch-hazel—light green, more or less tinged with red; ½ inch long. June–September
   Episimus argutanus (Clem.), p. 471.
   General feeders:
   Light green; head and shield dark brown to black. April–June --- *Archips argyrospila* (Wlkr.), p. 478.
   Pale green; head brownish. April–June
   Archips rosaceana (Harr.), p. 479.
   Dull green; head light to dark brown. May–June
   Archips rosana (L.), p. 477.
   Greenish, translucent, with 4 whitish, longitudinal lines; head and shield yellow brown. May–June
   Dichomeris ligulella (Hbn.), p. 460.
   Green; body tapering; head large; in web along midrib of leaf. July–August
   Machimia tentoriferella Clem., p. 461.
   Dark brown; head black. May–June, in opening buds and unfolding leaves
   Spilonota ocellana (D. and S.), p. 471.
   Light green with light-brown head, on apple, poplar, willow, and others. July–September
   Amorbia humerosana Clem., p. 476.
   Dull yellowish green; head reddish brown, cervical shield brown and black; length ½ to ¾ inch. May and June ---------- *Sparganothis pettitana* (Rob.), p. 477.
   Head pale green tinged with brown: body pale grass green; length about ¾ inch. April–September
   Argyrotaenia velutinana (Wlkr.), p. 483.
   Quite similar to *A. velutinana;* apple apparently most favored food plant
   Argyrotaenia quadrifasciana (Fern.), p. 483.
11. Webworms and tent makers:
   Ailanthus—gregarious; dark olive brown with white lines; living in web --------------- *Atteva aurea* (Fitch), p. 487.
   Apple, cherry; etc.—gregarious, dark with white stripe on back; at rest in silken tent in fork of branches. April–June -------------- *Malacosoma americana* (F.), p. 416.
   Apple, cherry, plum, oak, etc.—small, brown, hairy, gregarious; early instars in a web of two or more leaves fastened securely with silk near the tip of twig. August–May
   Nygmia phaeorrhoea (Don.), p. 412.
   Apple, cherry, elm, hickory, willow, etc.—gregarious, light, hairy; feeding in loose silken web spun over foliage. June–October --------- *Hyphantria cunea* (Drury), p. 387.
   Beech—gregarious; yellowish green, with faint stripes; feeding in small nest of leaves webbed together. July–September ----- *Tetralopha* sp. near *asperatella* Clem., p. 447.
   Birch, sweetfern, sweet gale, and willow—gregarious; in a nest of webbed leaves; head black; body dark brown to black with a series of black dots on sides, below which are spots varying from white to brick red; length about 1 inch. June–September ------------ *Eulype hastata* (L.), p. 428.
   Cherry (wild)—gregarious; black and yellow loopers in nest of leaves toward end of branch, feeding upon upper epidermis. June–October ----- *Calocalpe undulata* (L.), p. 426.

KEY TO LEPIDOPTEROUS LARVAE—Continued

11. Webworms and tent makers—Continued

Cherry (wild and choke)—gregarious; yellow with black head; in dense web in which they feed, enlarging it when necessary. May–July
Archips cerasivorana (Fitch), p. 477.

Elder (*Sambucus*)—between leaves webbed together; light green; sparsely hairy; 2 white stripes on dorsum. Full-grown larva pinkish to dull white. June–September
Phlyctaenia tertialis (Guen.), p. 445.

Juniper—gregarious; brown and black; feeding in web; April–June; September
Dichomeris marginella (F.), p. 460.

Juniper (common)—gregarious; brownish yellow; head and shield darker; in webs. May–June
Phalonia rutilana (Hbn.), p. 485.

Maple (sugar)—gregarious; brown, yellow and black striped; in small nest of leaves webbed together. July–September
Tetralopha sp., p. 446.

Oak—gregarious; gray green; head and shield black; in nest of densely webbed leaves, common on scrub oak. May–July _Archips fervidana_ (Clem.), p. 478.

Oak—gregarious; brown and yellow striped; spiracles and legs black; in nest of leaves. July–October
Tetralopha asperatella (Clem.), p. 447.

Pine—gregarious; yellowish brown with darker stripes; in silken tubes in globular masses of excrement and silk. August–October *Tetralopha robustella* Zell., p. 446.

Poplar—gregarious; dark brown with yellowish lines; head black; at rest in nest of leaves drawn together and lined with silk. May–October *Ichthyura inclusa* Hbn., p. 396.

Poplar—gregarious; brown and yellow striped; spiracles and legs black; length ¾ inch; in nest of leaves. July–October
Tetralopha sp. near *asperatella* Clem., p. 447

12. Larvae sluglike — 13
Not sluglike, but typical caterpillars — 14

13. Sluglike, densely hairy (puss caterpillars) Megalopygidae, p. 442.
Sluglike, of various forms; smooth or armed with spines
Limacodidae, p. 439.

14. Typical caterpillars:

Body distinctly clothed with hairs or bristles — 15
Each segment of body prominently armed with a transverse row of branched spines — 20
Body naked or sparsely hairy, bearing prominent horny or wartlike tubercles or spines on some of the segments, usually uneven in size and shape — 21
Body naked, abdomen unarmed except for the eighth abdominal segment which bears a prominent horn or eyelike tubercle — 26
Body naked, but bearing long fleshy filaments — 29
Body naked, abdominal segments with one or more prominent dorsal humps, Notodontidae (*Schizura* and others), Phalaenidae (Acronictinae) — 30
Body naked, and having 2 anal projections or ending in a pair of stemapoda or modified filamentous anal legs. Some species have the head armed with antlers — 31
Body naked, usually slender, abdominal legs except those on the sixth and tenth segments more or less rudimentary or obsolete; when walking body forms a loop — 32
Body naked, without prominent tubercles or filaments on dorsum; some species of Phalaenidae, Notodontidae, Agaristidae, and others — 33

15. Hairy; gregarious; when disturbed have a habit of raising head and anal end in an upright position, clinging to twig or branch with their middle prolegs; usually strip one branch before migrating to another; full-grown caterpillars 2 inches in length. July–October *Datana* spp., — 16
Hairy; gregarious or solitary; but not with habit as above — 17

KEY TO LEPIDOPTEROUS LARVAE—Continued

16. Head black; neck narrowly ringed with yellow, cervical shield waxy-yellow; body black with narrow pale yellow stripes
Datana ministra (Drury), p. 398.
Similar to *D. ministra,* but its cervical shield is entirely black; most commonly found on oak ----- *Datana angusii* G. & R., p. 398.
Head black; neck, cervical shield and most of anal segment yellow; other segments black with prominent yellow stripes; on blueberry, basswood, sassafras, etc.
Datana drexelii Hy. Edw., p. 398.
Head and neck black; cervical shield transversely oblong and waxy orange yellow; body black with white or yellowish stripes; clothed with long hairs; on oak or sycamore
Datana contracta Wlkr., p. 400.
Head and body black; clothed in long, dirty white hairs; on butternut, hickory, or walnut ----- *Datana integerrima* G. & R., p. 399.
Head, shield, and legs mahogany red; body black with broken white lines; on apple, blueberry, azalea, etc.
Datana major G. & R., p. 398.
Head dark red or black; shield reddish brown; anal plate blackish; body yellow with reddish to blackish stripes; on sumac
Datana perspicua G. & R., p. 399.

17. Hairy or bristly; without long hair pencils, brushlike tufts or "tussocks," usually with prominent markings ---------------- 18
Hairy or bristly with long hair pencils, brushlike tufts or "tussocks" -- 19

18. Head yellow and black; body dusky with 5 pairs of blue spots followed by 6 pairs of red spots on dorsum; 2 inches long; general feeder. May–July -------------- *Porthetria dispar* (L.), p. 408.
Head brown; body dark brown, with a broken white line on each side; two conspicuous reddish spots on dorsum near posterior end; on apple, cherry, oak, etc. May–June
Nygmia phaeorrhoea (Don.), p. 412.
Head black with bluish tinge; body blackish on dorsum with a row of white blotches; a narrow broken white subdorsal line; sides mottled with black and white; on poplar and willow. May–June ---------------------------- *Stilpnotia salicis* (L.), p. 414.
Head and body pale bluish; a row of keyhole-shaped white spots on dorsum; 2 inches long; on ash, birch, sugar maple, oak, poplar, etc. May–June ------------- *Malacosoma disstria* Hbn., p. 418.
Gray with faint longitudinal lines; body flattened with lateral lappets; metathorax with a pair of warts and a velvety black band; 2½ inches long; deciduous growth. June–August
Tolype velleda (Stoll.), p. 419.
Bluish gray, somewhat mottled; flattened; 2 transverse scarlet bands on thorax; 2½ inches long; on deciduous growth. May–August
Epicnaptera americana (Harr.), p. 419.
Head orange brown; neck, venter of body, legs, and anal segment light; dorsum of other segments black, and each crossed by 2 yellowish stripes and a row of orange warts; hairs brownish at base and black at tip; Southern States. March–May
Seirarctia echo (A. & S.), p. 388.
Head dark reddish or black; body velvety black dotted with yellow; usually a broken subdorsal yellow stripe; a broad yellow stigmatal stripe notched above so the white spiracles are surrounded by black; tubercles black or reddish and bearing bristly reddish hairs; on alder, poplar, willow, etc. June–September
Acronicta oblinita (A. & S.), p. 393.
Head shiny black; body velvety black; usually with a faint reddish substigmatal stripe; venter sometimes reddish; tubercles pale; the hairs on second and third thoracic, first, eighth, and ninth abdominal segments somewhat bristly and reddish brown or black, elsewhere the hairs are soft and pale yellowish; on alder, apple, cherry, poplar, etc. June–October
Acronicta impressa Wlkr., p. 392.
Head shiny black, hairy, and with a yellow spot on clypeus and one on each side; body greenish white, clothed with long, silky, white hairs arising from small wartlike tubercles; on oak, maple, etc. July–October ---------- *Charadra deridens* (Guen.), p. 395.

KEY TO LEPIDOPTEROUS LARVAE—Continued

19. Caterpillars with long hair pencils, and with brushlike tufts of hairs or "tussocks" on dorsum of some of the segments.

Head red; a pair of long upright black hair pencils on prothorax, another one on the eighth abdominal segment; tufts whitish; a reddish dot on dorsum of the 6th and 7th abdominal segments. May–October ------- *Hemerocampa leucostigma* (A. & S.), p. 406.

Head and body yellow; a pale dorsal stripe; tufts yellow; a black spot behind each of second and third tufts on abdomen *Hemerocampa definita* (Pack), p. 407.

Head black; body dark gray; tufts whitish; a pair of prominent black hair pencils on prothorax, and one on each side of the second abdominal segment ------------ *Notolophus antiqua* (L.), p. 407.

Head black; body densely clothed in brown, gray, and blackish hairs; a pair of prominent hair pencils on prothorax and usually a dark tuft and 2 or 3 long pencils at anal end-*Olene* spp., p. 407.

Head yellowish brown; body yellowish; clothed in whitish to yellowish hairs; long pencils orange and white; on sycamore *Halisidota harrisii* (Walsh), p. 387.

Head black; body blackish, clothed in gray to yellowish hairs with an olive tinge; pencils brownish to black with some white; on deciduous growth. August–October *Halisidota tessellaris* (A. & S.), p. 386.

Head black; body grayish white with black markings, clothed in grayish-white hairs; a row of black tufts on dorsum; the first and seventh abdominal segments each with a pair of long black pencils; on butternut, hickory, walnut, apple, etc. June–October *Halisidota caryae* (Harr.), p. 385.

Head shiny black; body blackish; a row of tufts on dorsum mostly black, those on sides of abdominal segments 2 to 6 yellow, others black; tufts on thoracic and eighth abdominal segments longer and with some yellow or white hairs intermixed with the black; on deciduous growths. July–October *Halisidota maculata* (Harr.), p. 386.

Head shiny black; body greenish white above, ventor blackish; clothed in fine yellowish hairs, a pair of long black pencils on first and third abdominal segments and a single one on the eighth; 2 inches long; on apple, maple, and other deciduous growths. June–October --------------- *Acronicta americana* Harr., p. 392.

Head, cervical shield, and true legs jet black; body dull whitish; clothed in long yellowish hairs; single, long black hair pencils on abdominal segments 1, 3, 4, 5, and 8; on poplar and willow. July–October ------------ *Acronicta lepusculina* (Guen.), p. 391.

Head greenish white or marked with black; body densely clothed in long fine curved white or yellow hairs, with a few bristly black ones on ends of body, turns darker just prior to pupation; on poplar, etc. August–September *Acronicta leporina vulpina* (Grt.), p. 391.

Head rounded, yellowish; body white or yellow with venter black; a dorsal and a lateral row of black spots; densely clothed in long fine white or yellow hairs; a long black tipped hair pencil on the second and third thoracic and eighth abdominal segments; length about 1¾ inches. June–September *Apatelodes torrefacta* (A. & S.), p. 420.

Head brownish, mottled; thorax with 2 black transverse bands and long brown and white hairs projecting forward over the head; abdomen gray with wavy black lines and yellowish green spots, sparsely hairy; length about 2¼ inches. August and September *Apatelodes angelica* (Grt.), p. 421.

20. Caterpillars bearing transverse rows of prominent branched spines.

Head dark red; body brownish, mottled with yellow; spines light colored, some tipped with black; on elm. May–September *Polygonia interrogationis* (F.), p. 369.

Head grayish in front and black on sides; body yellowish white; spines light, tipped with black; on elm and hop. May–September *Polygonia comma* (Harr.), p. 369.

KEY TO LEPIDOPTEROUS LARVAE—Continued

20. Caterpillars bearing transverse rows of prominent branched spines—Continued
    Head black; body reddish to blackish on dorsum, dotted with light green; spines below spiracles usually light and those above are black; on birch. May–July
    Nymphalis j-album (Bdv. and Lec.), p. 369.
    Head bilobed, black; body black sprinkled with whitish dots; a black dorsal line interrupted by a row of 7 or 8 reddish spots; spines black; abdominal legs reddish; on elm, poplar, and willow. May–September *Nymphalis antiopa* (L.), p. 369.
    Head pea green, glossy, ocelli black; body pea green; a broad reddish spiracular stripe, below which is a white stripe and another reddish line; spiracles yellowish narrowly ringed with black; most of spines yellowish tipped with black; on deciduous growth. July–September ___ *Automeris io* (F.), p. 380.
    Head reddish brown; body dull brown to blackish, covered with small, pale yellowish dots; spiracles pale; narrowly oval; clothed with bristles and compound spines; bristles rusty brown tipped with black; compound spines black or banded with white; on oak. May–August
    Hemileuca maia (Drury), p. 380.
    Similar to *H. maia*, but with a broken yellowish subspiracular stripe and spines shorter; on spiraea
    Hemileuca lucina Hy. Edw., p. 380.

21. Thorax bearing long prominent spines ______ 22
    Spines short and blunt, some merely enlarged tubercles ______ 25

22. A single pair of long spines on thorax ______ 23
    Two or more pairs of prominent spines on thorax ______ 24

23. Spines on second thoracic segment large, barbed and club-shaped; dorsum of some of segments angular; length about 1½ inches; head bilobed and covered with small sharp tubercles
    Basilarchia spp., p. 370.
    Spines on second thoracic segment stiff, slender and about as long as body is thick; other spines short ______ *Anisota* spp., p. 381.
    Head cherry red; body pale tawny red with white granulations; on hazelnut and oak. July–September
    Anisota stigma (F.), p. 381.
    Head jet black; body with black and yellow or orange stripes; on oak. July–October __ *Anisota senatoria* (A. & S.), p. 381.
    Head greenish to light brown; body greenish to grayish with white granulations; a subdorsal and a lateral pink stripe; anal plate and anal legs amber colored; on oak. July–October
    Anisota virginiensis (Drury), p. 382.
    Head cherry red; body pale yellowish green with 7 dark green or blackish longitudianl lines; on maple. June–October
    Anisota rubicunda (F.), p. 383.

24. All spines stout and black; the largest pair situated on the first abdominal segment; the head and a dorsal hump on the first abdominal segment red; length about 1 inch. Head black in the earlier instars ______ *Schizura concinna* (A. & S.), p. 404.
    Two pairs on thorax and the caudal horn much larger than others and yellow with black prickles; body green; secondary hairs conspicuous; caterpillars large _ *Eacles imperialis* (Drury), p. 384.
    Five pairs on thorax and the caudal horn long and spiny; others smaller; body bluish green to brownish; caterpillars large
    Citheronia regalis (F.), p. 383.

25. Thorax bearing one or more pairs of short and blunt tubercles or spines.
    Spines short and blunt, but prominent, subequal in length.
    Two pairs of tubercles on thorax and one on eighth abdominal segment yellow or reddish, others rudimentary. Body bluish white; length about 2 inches
    Callosamia promethea (Drury), p. 379.
    Two pairs of tubercles on thorax modified into knobs, others more or less rounded; those on dorsum red and yellow, others bluish; all bearing short black spines; body bluish green; large ___ *Samia cecropia* (L.), p. 377.

KEY TO LEPIDOPTEROUS LARVAE—Continued

25. Thorax bearing one or more pairs of short and blunt tubercles or spines—Continued

Those on all segments nearly equal; bluish; bearing small setae; body green dotted with black; large *Philosamia cynthia* (Drury), p. 377.

Spines reduced to mere tubercles, surmounted with long setae.

Two pairs on thorax and one on eighth abdominal segment larger than others. Tubercles pink, body green; anal plate amber colored edged in front with yellow *Tropaea luna* (L.), p. 379.

Dorsum of body segments convex to angular; tubercles orange or golden, some with silver base; anal shield edged with purple *Telea polyphemus* (Cram.), p. 379.

Tubercles without spines or setae.

Bluish green; second thoracic segment bearing 2 reddish tubercles; abdominal segments 1, 5, and 8 marked with transverse yellowish bands, edged in front with red; length 1¼ inches *Raphia frater* Grt., p. 395.

26. Glossy, leaden or with a purplish tinge; eighth abdominal segment swollen dorsally and bearing a well-developed horn; on poplar and willow. July–October *Pheosia rimosa* Pack., p. 400.

Not glossy, but smooth or granulated Sphingidae,

Eighth abdominal segment bearing a well-developed horn 27

Eighth abdominal segment bearing an eyelike tubercle 28

27. Larvae with 7 oblique stripes on each side of body.

Apple, wild black cherry, plum—July–September; yellowish green; head with a reddish band on each side; body stripes carmine, broad; horn and thoracic feet dark reddish to blackish; length 3 inches. *Sphinx drupiferarum* A. & S., p. 374.

Ash and lilac—June–October; bluish green; head with a broad pale band; stripes light yellow; horn reddish and curved downward at tip; anal plate and anal legs dotted with elevated black points; length 2½ inches *Ceratomia undulosa* (Wlkr.), p. 372.

Ash and lilac—June–September; light green; head bluish with a pale band on each side; body stripes light yellowish edged above with bluish-green; horn pale blue; length about 3 inches *Sphinx chersis* (Hbn.), p. 374.

Ash, laurel, lilac, rhododendron, etc.—June–October; yellowish green; head with a black band; body stripes black edged below with yellow; anal plate dotted with black points; horn blue with black raised markings; length 3 inches *Sphinx kalmiae* A. & S., p. 374.

Bayberry, sweet fern, wild rose, etc.—August–October; apple green with small whitish dots; head with a yellowish or brownish stripe on each side; body stripes carmine edged below with white; horn black on sides and at tip; green above and below; length nearly 3 inches *Sphinx gordius* Cram., p. 374.

Cherry (wild)—July–October; green with yellowish granulations; head conical, a faint yellowish line on each side; the last stripe on the body widest and most distinct; horn short and green, sometimes reddish above; spiracles rose colored; thoracic legs reddish. Some specimens have the spiracles set in small red patches; also subdorsal patches of red; length 2¼ inches *Paonias myops* (A. & S.) p. 375.

Elm, basswood, and birch—July–October; pale green to reddish brown; thorax with 4 tuberculated horns; stripes composed of whitish granulations; length 3 inches *Ceratomia amyntor* (Hbn.), p. 372.

Poplar, willow, and birch—July–October; light green, granulated; head apple green, conical, a pale stripe on each side; body stripes yellowish; the last one wider than others; spiracles deep lilac or black; thoracic legs reddish or lilac; length 2½ inches *Paonias excaecatus* (A. & S.), p. 375.

KEY TO LEPIDOPTEROUS LARVAE—Continued

27. Larvae with 7 oblique stripes on each side of body—Continued

Poplar and willow—August–October; similar to *S. gordius* but smaller .... *Sphinx luscitiosa* Clem., p. 374.

Poplar, willow, and birch—July–October; similar to *P. excaecatus*, but may be recognized by the rose-colored spiracles; horn bluish purple; thoracic legs violet; and sometimes there is a subdorsal row of reddish spots; length 2½ inches .... *Smerinthus jamaicensis* (Drury), p. 375.

Walnut (black), butternut, hickory, pecan, etc.—May–September; light green to reddish, coarsely granulated with white; head truncate in front, triangular, apex bearing 2 brownish projections, a yellow stripe on each side; body stripes yellowish, sometimes bordered above with reddish; horn brownish, granulated; length about 2 inches *Cressonia juglandis* (A. & S.), p. 376.

Larvae without 7 oblique stripes on each side of body.

Catalpa—spring to early fall; yellow and black; both light and dark forms; head and horn black; length 2½ to 3 inches .... *Ceratomia catalpae* (Bdv.), p. 373.

Grape and Virginia creeper—July–September; pea green with numerous yellow dots; body with a cream-colored lateral band rising posteriorly and extending onto sides of caudal horn. Some specimens with yellowish triangular spots on the dorsum of some of the abdominal segments, each containing a smaller lilac spot; length about 2 inches .... *Ampeloeca myron* (Cram.), p. 377.

Grape and Virginia creeper—July and August; chocolate brown, with numerous minute dots of a darker color; horn black; length about 2½ inches *Amphion nessus* (Cram.), p. 377.

Grape and Virginia creeper—July–September; green with pale yellow dots; a subdorsal cream-colored stripe on each side extending to base of horn; horn green; length about 2 inches .... *Deidamia inscriptum* (Harr.), p. 377.

Honeysuckle (bush) and snowberry—June–October; bluish green above, green on sides and brownish beneath; head bluish green; head and plates coarsely granulated; horn blackish and prickly; length nearly 2 inches *Hemaris diffinis* (Bdv.), p. 376.

Viburnum—June–October; yellowish green; sometimes purplish; head rounded, bluish green; head and shields coarsely granulated; body with green dorsal stripe bordered with whitish; horn bluish with black granulations; length 2 inches .... *Hemaris thysbe* (F.), p. 376.

28. Grape and Virginia creeper—June–September; chocolate brown with numerous transverse blackish lines and 2 dark longitudinal dorsal stripes, and a lateral one on each side. Another form is reddish brown with large light-green patches on the dorsum and along sides of body. Length 3 inches *Sphecodina abbottii* (Swain), p. 376.

Grape and Virginia creeper—July–September; pinkish on dorsum; sides darker; head dull reddish brown; on abdominal segments 2 to 7 the spiracles are set in cream-yellow, oval spots which are outlined with black; numerous small black dots on second and third thoracic and first to third abdominal segments; length about 3 inches .... *Pholus pandorus* (Hbn.), p. 377.

Grape and Virginia creeper—July and August; greenish to reddish brown; head, thoracic segments, and spiracles flesh colored; the spiracles on abdominal segments 2 to 7 situated in elongated oval cream-colored scalloped spots; length 3 to 3½ inches *Pholus achemon* (Drury), p. 377.

KEY TO LEPIDOPTEROUS LARVAE—Continued

29. Body bearing fleshy filaments:

Apple, birch, wild cherry, chestnut, maple, oak, etc.—May–July; greenish brown; head rust red; body with a pair of tubercles on the first and eighth abdominal segments, and a pair of long, fleshy, brownish filaments on the second and the third abdominal segments; a white stripe on dorsum from prothorax to first pair of filaments; length ¾ inch............*Nematocampa limbata* (Haw.), p. 433.

Pipevine (Dutchman's)—June–October; velvety black with a brownish tint, covered with long, fleshy, blackish tubercles and shorter ones orange in color; length about 2 inches *Battus philenor* (L.), p. 367.

30. Body naked; abdomen with one or more dorsal humps

Elm—June–September; polished bluish green; thoracic segments unarmed; first 8 abdominal segments each with a large anteriorly directed prominence ending in a bifid ridge; length about 1¼ inches *Nerice bidentata* (Wlkr.), p. 401.

Oak, beech, elm, and maple—June–October; head orange red; body smooth, shining; orange-red enlargement on eighth abdominal segment; a yellow subdorsal and a yellow stigmatal stripe, and several fine blackish lines; length about 1¾ inches.........*Symmerista* spp., p. 401.

Oak and beech—August–October; head bilobed, pale, with a dark brownish irregular branched band on each side outlining whitish patches on the face; first abdominal segment with a large dorsal tubercle, slightly cleft; eighth abdominal segment with a smaller brownish tubercle; the colors are pea green and shades of brown; length about 1½ inches............*Dicentria lignicolor* (Wlkr.), p. 404.

Poplar and willow—June–October; a conical tubercle directed posteriorly on the second and one on the third abdominal segments; a prominent hump on the eighth; pearly gray marbled with brownish; a pinkish stigmatal line; length about 1½ inches *Hyperaeschra stragula* (Grt.), p. 400.

Viburnum.................*Schizura badia* (Pack.), p. 405.

Willow, apple, wild cherry, etc. *Schizura unicornis* (A. & S.), p. 405.

Others may be found in families Notodontidae and Phalaenidae.

31. Prothorax with its lateral tubercles wider than the head; body tapers to the end; caudal appendages filamental, extensile, and up to ⅔ inch in length; the color is green and brown tinged with red or purplish; on poplar, willow, wild cherry *Cerura* spp. (4 more or less common), p. 405.

Pale green; head with vertex high, conical, pinkish on sides; body thickest in the middle, a yellowish dorsal stripe, and occasionally pinkish spots; caudal appendages filamental, held outstretched and not quite as long as body is thick. Length about 2 inches; on beech, maple, poplar, oak, etc. July–October *Fentonia marthesia* (Cram.), p. 405.

Head armed with antlers; body green and having two anal projections; length about 1¼ inches; on hackberry from spring to fall.................................*Asterocampa* spp., p. 370.

32. Geometers, loopers, measuring worms—not over 1 inch in length.

Birch (gray and paper)—May–July; green to yellowish brown; body with fine yellowish lines and a broad subspiracular stripe; the prolegs on abdominal segments 3, 4, and 5 are rudimentary; length 1 inch *Brephos infans* Moesch., p. 422.

Cherry (wild)—June–August; head brown, body light green; length about ¾ inch...*Bapta semiclarata* (Wlkr.), p. 428.

Currant—May–early in July; light yellow, dotted with black; length about 1 inch.......*Itame ribearia* (Fitch), p. 429.

Elm, apple, etc.—May and June; color varies from light green to dark brownish green; a darker dorsal stripe; prolegs on fifth abdominal segment rudimentary; length 1 inch...............*Alsophila pometaria* (Harr.), p. 422.

KEY TO LEPIDOPTEROUS LARVAE—Continued

32. Geometers, loopers, measuring worms—not over 1 inch in length—Continued

Elm, apple, etc.—May and June; color varies from reddish or yellowish brown to greenish; body lines irregular, numerous, somewhat broken, distinct in some specimens and nearly obsolete in others; prolegs only on the sixth and anal segments; length about 1 inch
Paleacrita vernata (Peck), p. 424.

Hemlock—May–July; head broader than thorax, brown, bilobed; body greenish tinged with reddish brown, the second abdominal segment usually with a swelling on each side; length ⅞ inch
Anacamptodes ephyraria (Wlkr.), p. 430.

Hemlock, fir, larch, and spruce—June–August; whitish with yellowish or reddish tinge; marked with black dots, and yellowish lateral stripe below which are 4 dark wavy hair lines; length about 1 inch
Nepytia canosaria (Wlkr.), p. 434.

Locust (black)—June and July; green with many obscure red wavy lines; length about 1 inch
Semiothisa ocellinata (Guen.), p. 429.

Maple (sugar), poplar, beech, etc.—May–June; bright green with 3 narrow yellowish white stripes on each side of body; only 2 pairs of prolegs; length about ¾ inch
Operophtera bruceata (Hulst), p. 426.

Maple (red), etc.—May and June; green, skin wrinkled; head slightly bilobed; body with a double whitish dorsal line bordering which are yellowish-white lines; spaces between segments yellowish; length about ⅝ inch
Physostegania pustularia (Guen.), p. 429.

Pine (white)—July–September; head with brownish tinge, body deep green with a narrow subdorsal and stigmatal white stripe and a greenish-white line on dorsum; length about 1 inch........*Eufidonia notataria* (Wlkr.), p. 429.

Pine (white), spruce, fir, and larch—July–September; head brownish, body light green, sometimes a brownish tinge above, light stripe each side between which are 2 finer lines; length ⅞ inch.......*Semiothisa granitata* (Guen.), p. 429.

Sweetfern—June, July, September, and October; head brown; body slender, light green, sometimes tinged with brown; length about ⅞ inch
Cosymbia pendulinaria (Guen.), p. 426.

Sweetfern—July–September; green with a reddish tinge, body with curved lateral appendages; length about ⅞ inch
Synchlora rubrifrontaria Pack., p. 424.

Willow and apple—June–September; brownish with curved lateral appendages; length about ⅞ inch
Synchlora aerata (F.), p. 424.

Geometers from 1 to nearly 2 inches in length when full grown.

Alder, beech, yellow birch, etc.—July–September; green to brownish; head rather small, flattened in front, whitish spots on dorsum; spiracles black; length 1¼ inches
Hyperitis amicaria (H.-S.), p. 433.

Birch, maple, oak, walnut, etc.—April–October; head brownish; body reddish to chocolate brown; a pair of blunt tubercles on dorsum of eighth abdominal segment; length about 1¼ inches...*Ectropis crepuscularia* (Schiff.), p. 430.

Birch (yellow) and maple—June–August; dull brown; head bilobed; body with blotches of lighter and darker shades, and a prominent swollen area on sixth abdominal segment; length 1½ inches.......*Plagodis serinaria* (H.-S.), p. 433.

Cherry (wild)—July–September; head grayish, square in front; body dull reddish brown with white markings; a black median line from fifth abdominal segment to supra-anal plate; length 1½ inches.*Tetracis lorata* Grote, p. 437.

KEY TO LEPIDOPTEROUS LARVAE—Continued

32. Geometers from 1 to nearly 2 inches in length when full grown—Continued

Cherry (wild), blueberry, huckleberry, sweet fern, etc.—June–August; pale yellow; head dotted with black; body with black markings on sides presenting a chain-dotted effect; length about 2 inches *Cingilia catenaria* (Drury), p. 436.

Cherry (wild), basswood, oak, etc.—June–early August; green, head rather flat, oblique; body with a broad subdorsal stripe on each side, a broken purplish brown line on the dorsum, and a yellowish stigmatal stripe; length 1¼ inches *Melanolophia canadaria* (Guen.), p. 429.

Cherry (wild), chestnut, maple, oak, poplar, willow, etc.—spring and summer; gray or brown; somewhat mottled or marked with dark brown or black; 1½ to 2 inches *Euchlaena* spp., p. 433.

Cherry (wild), larch, and black locust—July–October; head quadrate, brown; body increasing in girth toward anal end, brown, with lighter and darker markings; length 1½ inches *Pero honestarius* (Wlkr.), p. 426.

Cherry (wild), maple, willow, blueberry, sweetfern, etc.—June–September; purplish brown to light brown; head rounded, flattened in front; the second thoracic segment swollen and streaked with reddish; the hinder part of the fourth abdominal segment swollen above and marked with white; dorsum of eighth segment bearing a pair of tubercles; length about 2 inches *Prochoerodes transversata* (Drury), p. 437.

Elm, basswood, red maple, etc.—May and June; dark brown to black; its large head and anal segment reddish; length about 1½ inches *Ennomos subsiqnarius* (Hbn.), p. 434.

Grape and Virginia creeper—May–July; pale green with reddish markings; head flattened in front, bilobed; slender, about 1½ inches in length *Lygris diversilineata* (Hbn.), p. 428.

Hemlock and balsam fir—June–August; yellowish green; head and body flecked with black; length about 1¼ inches *Lambdina fiscellaria fiscellaria* (Guen.), p. 434.

Hemlock—July–September; yellowish; head with brown or blackish spots; body obscurely marked, darkest on sides, the sides and venter with dark brown wavy lines; length about 1¼ inches *Lambdina athasaria athasaria* (Wlkr.), p. 435.

Oak and other deciduous forest trees—May–July; flesh colored with many fine, wavy blackish lines giving it a drab appearance; head flat, quadrangular, mottled with black; body bearing small piliferous tubercles; length 1½ inches *Phigalia titea* (Cram.), p. 431.

Oak and other deciduous forest trees—late April to early July; head rust brown; body yellow with ten wavy black lines on dorsum; legs yellow; length about 1½ inches *Erannis tiliaria* (Harr.), p. 432.

Oak—June–September; slate gray; head angular, bilobed; first two thoracic segments marked with reddish brown and black; body stout, many wartlike tubercles; some segments swollen; length about 2 inches *Nacophora quernaria* (A. & S.), p. 430.

Pine (pitch)—June–September; straw to greenish yellow; head freckled; body marked with blackish dots and wavy lines, blackest on sides. Some are darker with dorsum tinged by reddish brown; length about 1¼ inches *Lambdina athasaria pellucidaria* (G. & R.), p. 435.

Poplar—July–September; head brown, quadrate; body yellowish green, a reddish band on second abdominal segment. reddish blotches on dorsum, and a pair of blunt tubercles on eighth abdominal segment; length 1⅛ inches *Anacamptodes larvaria* (Guen.), p. 430.

KEY TO LEPIDOPTEROUS LARVAE—Continued

32. Geometers from 1 to nearly 2 inches in length when full grown—Continued

Poplar and willow—July–September; light green; red stripe each side of head; body with a more or less broken red stripe on each side; and diffuse reddish patches on dorsum; length 1⅛ inches____*Deilinea erythremaria* (Guen.), p. 428.

Sassafras and tulip poplar—June and July; possibly a second generation in the South; head small, reddish brown; body stout, yellowish to dark brown; marked with many fine irregular wavy lines; length about 1½ inches *Epimecis virginaria* (Cram.), p. 430.

Geometers 2 or more inches in length when full grown.

Ash, birch, etc.—July–August; yellowish green tinged with red; head small, bilobed; abdomen has a swollen area on dorsum of segments 2 to 5, and venter of third, 2 conical tubercles on dorsum of eighth; length 2 to 2¼ inches *Deuteronomos magnarius* (Guen.), p. 436.

Cherry (wild), maple, poplar, etc.—June–August; purplish brown; head rounded; second thoracic and fourth abdominal segments swollen above, and tubercles on the dorsum of fifth and ninth abdominal segments rather prominent; length about 2½ inches *Abbottana clemataria* (A. & S.), p. 437.

Willow, poplar, wild cherry, sweetfern, locust, etc.—July–October; head deeply cleft, flat in front, granulated; body greenish to reddish brown; front of cervical shield angular; anal claspers large___*Amphidasis cognataria* Guen., p. 432.

Willow, elm, maple, poplar, etc.—May–July; vinous in color; prothorax has four whitish spots; body marked with many wavy lines and creamy-white spots *Lycia ursaria* (Wlkr.), p. 432.

33. Some common species are naked and without prominent tubercles on body, but each bears five pairs of abdominal legs:

Ash, apple, oak, rhodendron, willow, etc.—April to early in July; head pale, mottled with brown; body light green, with five whitish lines; the median line narrow, subdorsal ones somewhat broken, and stigmatal broad and extending downward onto anal prolegs; skin with minute white dots; length 1½ inches__________*Orthosia hibisci* (Guen.), p. 394.

Beech, sugar maple, and apple—June–August; light green, sometimes with a bluish cast; head large, banded with red; body smooth, usually with saddle-shaped patch of reddish brown; markings variable; length 1½ inches *Heterocampa guttivitta* (Wlkr.), p. 403.

Beech, oak, basswood, elm, etc.—July–October; head large, a blackish and a whitish band on each side; body smooth yellowish green; a pale median line with more or less red-brown on each side; markings variable; length about 1½ inches *Heterocampa manteo* (Dbldy.). p. 404.

Greenbrier—August–October; black with broken white lines and blotches; venter grayish green; length about 1¼ inches *Phosphila turbulenta* Hbn., p. 395.

Hemlock, larch, and spruce—May–July; head yellowish; body light green, a pale median stripe, also a subdorsal and stigmatal stripe on each side; the stigmatal stripe bordered above with red; length 1¼ inches *Feralia jocosa* (Guen.), p. 394.

Maple, ash, apple, etc.—May–July; pale green; head with yellowish tint; body has a broad whitish dorsal stripe, each side a narrower subdorsal and a broad irregular stigmatal stripe; skin minutely dotted with white; length about 1½ inches____________*Graptolitha antennata* (Wlkr.), p. 394.

Oak, etc—May to October; pale pea green; head large, rounded; body with a yellowish subdorsal stripe; spiracles red; length about 1¾ inches *Nadata gibbosa* (A. & S.), p. 400.

KEY TO LEPIDOPTEROUS LARVAE—Continued

33. Some common species are naked and without prominent tubercles on body, but each bears five pairs of abdominal legs—Continued

Oak, etc.—May to October; somewhat similar to *N. gibbosa;* a faint double median whitish line, a lateral reddish stripe edged below with white
Lophodonta angulosa (A. & S.), p. 401.

Pine (white, pitch, and jack)—July–September; grass green; head triangular, conical; yellowish stripe on each side; body with a median brick-red stripe and three white stripes on each side; length 2 inches
Lapara bombycoides Wlkr., p. 375.

Poplar—June–September; pale green; yellow subdorsal line on each side, between which are usually reddish blotches on thorax and abdominal segments 3 to 9; length about 1¼ inches ______________ *Gluphisia septentrionis* Wlkr., p. 405.

Spruce—late summer, winter and spring; dull brown, spiracles and tubercles black; length about ¾ inch
Epizeuxis spp., p. 395.

Tender roots, stems, and foliage of various species of tree and shrub growth—stout, dull grayish or brownish, with darker markings; normally concealing themselves during the day ______________ Cutworms (Phalaenidae), p. 390.

Virginia creeper, grape, and Boston ivy—June to September; head and cervical shield orange, dotted with black; body white, each segment crossed by 8 black lines and an orange band; all bands with black elevated spots; length about 1½ inches ______________ *Alypia octomaculata* (F.), p. 390.

34. Borers

Infesting bud, stem, shoot, or twig ______________ 35
Infesting fruit, nut, cone, or seeds ______________ 36
Infesting bark, wood, or roots ______________ 37
Infesting dead and decaying sapwood ______________ 38

35. Borers in buds, shoots, or twigs of conifers. Some common species:

Pine (red, mugho, Scotch, Austrian, etc.)—head and cervical shield black; body brownish; length about 7/16 inch. Bores into buds and expanding shoots; late summer to first of June ______________ *Rhyacionia buoliana* (Schiff.), p. 466.

Pine (red, mugho, etc.)—head, cervical shield and anal plate brown to dark brown; body yellowish; length about ¼ inch. Bores in buds and cones __ *Battaristis vittella* (Busck), p. 458.

Pine (pitch and other hard pines)—yellowish to pale brown; head and cervical shield blackish; length about ⅜ inch. Bores into buds and succulent growth at tips of twigs
Rhyacionia frustrana (Com.), p. 467.

Pine, (red, pitch, Jersey, etc.)—similar to *R. frustrana;* bores into buds ______________ *Rhyacionia rigidana* (Fern.), p. 468.

Pine (white)—dirty white; head yellowish brown; cervical and anal shields yellowish. Bores into side shoots in June and July, killing shoot ___ *Eucosma gloriola* Heinr., p. 470.

Pine (pitch and other hard pines)—pale brownish; head and cervical shield dark brown; length about ½ inch. Bores into twig and pitch mass forms over entrance hole; winters in tunnel and attains full growth in May
Petrova comstockiana (Fern.), p. 469.

Pine (jack, lodge pole, ponderosa)—reddish with small and shiny tubercles; head and cervical shield light brown. Bores into young branches, usually at juncture of smaller twigs, and pitch mass forms over entrance hole
Petrova albicapitana (Busck), p. 469.

Pine (Virginia)—similar to *P. comstockiana,* but bores into older twigs and small branches
Petrova virginiana (Busck), p. 470.

Pine (various species)—varies from dirty white to reddish-brown or greenish; head chestnut brown; body with a series of black dots; length about ¾ inch. Bores into terminal shoots, branches, and trunk
Dioryctria zimmermani (Grt.), p. 452.

KEY TO LEPIDOPTEROUS LARVAE—Continued

35. Borers in buds, shoots, or twigs of conifers—Continued

Pine, Douglas fir, and spruce—dull with a purplish tinge and ornamented with piliferous warts; head and anal shield brown, and cervical shield blackish; length ¾ inch. Bores in cones, shoots, branches, and trunk
Dioryctria abietella (D. & S.), p. 451.

Spruce—reddish brown to amber; head and cervical shield reddish brown; body ornamented with piliferous warts; length about ⅝ inch. Bores into cones and terminals, attaining full growth in May or June
Dioryctria reniculella (Grt.), p. 451.

Borers in buds, and twigs of deciduous growths. Some common species:

Chestnut—larva in cylindrical gall encircling young twig
Ectoedemia castaneae (Busck), p. 502.

Horse chestnut and maple—larva bores in seeds, stems, and terminal twigs; May and June
Proteoieras aesculana Riley, p. 470.

Box elder and maple—larva bores in stems and twigs
Proteoteras willingana Kearf., p. 470.
Proteoteras crescentana Kearf., p. 470.

Locust (black)—bores in new twig growth forming galls 1 to 3 inches in length; larva reddish to straw yellow; head dark brown; cervical shield honey yellow. Late May to early November in vicinity of Washington, D. C.
Ecdytolopha insiticiana Zell., p. 474.

Poplar—larva in globular gall, about the size of a pea on petiole of leaf______*Ectoedemia populella* (Busck), p. 502.

36. Infesting cones, fruit, nuts, and seeds. Some common species:

Acorn borer—pink or whitish; larva about ¾ inch in length
Melissopus latiferreanus (Wlsm.), p. 474.

Acorns, chestnuts, hickory nuts—grayish white or yellowish with blackish dorsal marks, cervical and anal shields brownish__________*Valentinia glandulella* (Riley), p. 461.

Blueberry, cranberry, and huckleberry—bores into berries; July–September; green, often tinged with reddish on the dorsum; head yellowish; length about ½ inch
Mineola vaccinii (Riley), p. 451.

Hickory and pecan—small green or nearly mature nuts may be attacked; head light brown; body creamy white length about ⅜ inch__*Laspeyresia caryana* (Fitch), p. 473.

Pine (Austrian, longleaf, Scotch, Virginia, etc.)—head, cervical shield, and anal plate brown to dark brown; body yellowish; length about ¼ inch. Bores in buds and cones________________*Battaristis vittella* (Busck), p. 458.

Pine (various species)—bores into cones, shoots, and branches; dirty white, reddish brown to greenish; head chestnut brown; body with a series of black dots; length about ¾ inch______*Dioryctria zimmermani* (Grt.), p. 452.

Pine—similar to *D. reniculella*, but bores into cones and terminals of pine____*Dioryctria abietella* (D. & S.), p. 451.

Pine (yellow)—bores in cones, terminals, and in wounds of pine in Gulf States_____*Dioryctria amatella* Hulst, p. 452.

Spruce—bores into cones and feeds upon the seeds; hibernates in the cones__*Laspeyresia youngana* (Kearf.), p. 473.

Spruce—bores into cones and terminals; head and cervical shield reddish brown; body reddish brown to amber, ornamented with piliferous warts
Dioryctria reniculella (Grt.), p. 451.

37. Borers in branches, trunk, or roots of deciduous trees and shrubs. Some common species are listed as follows:

Alder trunk and roots—head long; body cylindrical, five pairs of prolegs. Life cycle probably 2 years
Sthenopis argenteomaculatus (Harr.), p. 505.

Ash, lilac, and privet—bores into main stem, causing it to wilt or break. Larva white; attains full growth early in summer ____________*Podosesia syringae* (Harr.), p. 465.

KEY TO LEPIDOPTEROUS LARVAE—Continued

37. Borers in branches, trunk, or roots of deciduous trees and shrubs. Some common species are listed as follows—Continued

Ash (white, red, European, and sometimes mountain-ash)—bores into trunk and branches, more commonly in trunk below surface of soil_____ *Podosesia fraxini* (Lug.), p. 464.

Chestnut—larva in serpentine mine in the bark *Ectoedemia phleophaga* Busck, p. 502.

Flowering dogwood—enters through rough bark or a wound. Larva white with pale-brown head. Life cycle similar to that of *C. rhododendri*____ *Conopia scitula* (Harr.), p. 463.

Elm, locust, maple, oak, poplar, green ash, etc.—in branches and trunks; reddish brown with brown head; length 2 to 3 inches; life cycle probably 3 years *Prionoxystus robiniae* (Peck), p. 497.

Elm, maple, etc.—in twigs, branches, or trunk; pale yellow; head, thoracic and anal plates brownish black; body sparsely hairy and dotted with black tubercles; length about 2 inches; nearly 2 years in larval stage *Zeuzera pyrina* (L.), p. 499.

Hickory, oak, and pecan—in twigs, branches or trunk; head, cervical shield, and anal plate shiny dark brown; body pinkish, and sparsely clothed in fine hairs; length about 1½ inches_____________ *Cossula magnifica* (Stkr.), p. 501.

Linden (European)—bores into corky and green portions of bark of trunk and branches. Head brown; body whitish; length about ¼ inch_ *Chrysoclista linneella* Clerck, p. 456.

Locust (black)—gall-like injury to lower stem in nurseries; head and cervical shield brown; body greenish white with somewhat broken dark brown stripes; length about ⅝ inch_____________ *Elasmopalpus lignosellus* (Zell.), p. 454

Maple (hard and soft)—bores into bark and sapwood, usually entering wounds on trunk; head brownish, body white; length about ½ inch______ *Conopia acerni* (Clem.), p. 462.

Maple (red and silver)—bores into small branches causing gall-like swellings_______ *Conopia corni* (H. Edw.), p. 463.

Oak (pin)—larva in flattened-oval, spiral mine in bark of young branches______ *Ectoedemia heinrichi* Busck, p. 502.

Oak—similar to *P. robiniae* and often confused with it *Prionoxystus macmurtrei* (Guer.), p. 497.

Persimmon—bores into solid wood of taproot and main stem. Sometimes a serious pest in nurseries, boring in roots 16 to 18 inches under ground *Sannina uroceriformis* Wlkr., p. 464.

Poplar and willow—in roots and base of trunk; head reddish and body white; length about 1½ inches. It has a 2-year life cycle_____________ *Aegeria apiformis* (Clerck), p. 462.

Rhododendron—bores into stems and branches, causing them to wilt; larva attains full growth in fall; pupates in burrow in spring____ *Conopia rhododendri* (Beut.), p. 463.

Willow roots—head long; body cylindrical, 5 pairs of prolegs. Life cycle probably 2 years *Sthenopis thule* (Stkr.), p. 505.

Borers in branches and trunks of conifers

Pine (white and pitch), and spruce—bores into inner bark and sapwood, entering a wound or beneath a branch. Life cycle 2 or 3 years__ *Parharmonia pini* (Kell.), p. 464.

Pine (various species)—bores into branches, shoots, and cones; larva dirty white, reddish brown to greenish; head chestnut brown; body with a series of black dots *Dioryctria zimmermani* (Grt.), p. 452.

38. Borers in dead and decaying wood

Oak, chestnut, hickory, etc.—larva feeds in decaying sapwood; head black; body whitish with brown spots; length about 1⅜ inches. August through to spring *Scolecocampa liburna* (Geyer), p. 395.

DISCUSSION OF FAMILIES AND SPECIES

In the following pages most of the species are treated individually but are grouped by families. An attempt has been made to include all species of importance as pests in the forests of the Eastern States. In addition many others are included, the larvae of which occasionally become abundant locally in this region and cause considerable concern when attacking trees, shrubs, or vines in the forest or those grown for shade and ornamental purposes. In some families consisting of species generally of little economic importance, a discussion is given for only one or two representatives.

Whenever possible a brief description of the full-grown larva is given for each species, but generally the adults of only the more important species are described. Information is also given on the distribution, the food plants, the life history, and the habits, as far as they are known, and any other data considered important.

The control of forest and shade tree insects is discussed elsewhere in this manual (see section on The Control of Forest Insects). When artificial control measures are considered necessary to protect the foliage of trees, shrubs, and vines against the ravages of lepidopterous larvae, the timely application of a stomach poison such as lead arsenate or DDT, will control the species that feed externally. For cautions in the use of these materials see pp. 25 and 34. Therefore, in the discussion of such species, no reference is made to artificial control unless other methods are also recommended.

For species such as leaf miners and various types of borers, which need special treatment when control practices are necessary, the proper measure is given under the discussion of the insect, or reference is made as to where it can be found.

Family PAPILIONIDAE

Among the species included in the family Papilionidae are our well-known swallowtail butterflies, so-called because of the wavy margin and taillike prolongation of the hind wings. Their larvae are not hairy or spiny, but in some species the body bears fleshy filaments. The first thoracic segment of each bears a protrusive bright-colored, forked process, capable of emitting a disagreeable odor, which undoubtedly is used as an organ of defense.

Although some species are generally quite common, only occasionally do any of them become abundant enough to necessitate artificial control.

The adult of **the pipe-vine swallowtail** (*Battus philenor* (L.)) has a wing expanse of about 4 inches; the forewings are black with greenish-metallic reflections, and the hind wings are brilliant steel blue with greenish reflections. The full-grown larva is about 2 inches long, velvety black with a brownish tint, and covered with long fleshy tubercles of the same color, and shorter ones of orange (fig. 70, *A*).

It is distributed through the Eastern States, north to Massachusetts and occasionally in Vermont, and is also recorded from Arizona, Mexico, and southern California. The larvae feed on species of *Aristolochia* and often seriously defoliate dutchmans-pipe, both in nurseries and when grown as an ornamental vine out of doors. There are usually two generations. The adults emerge in May and June and

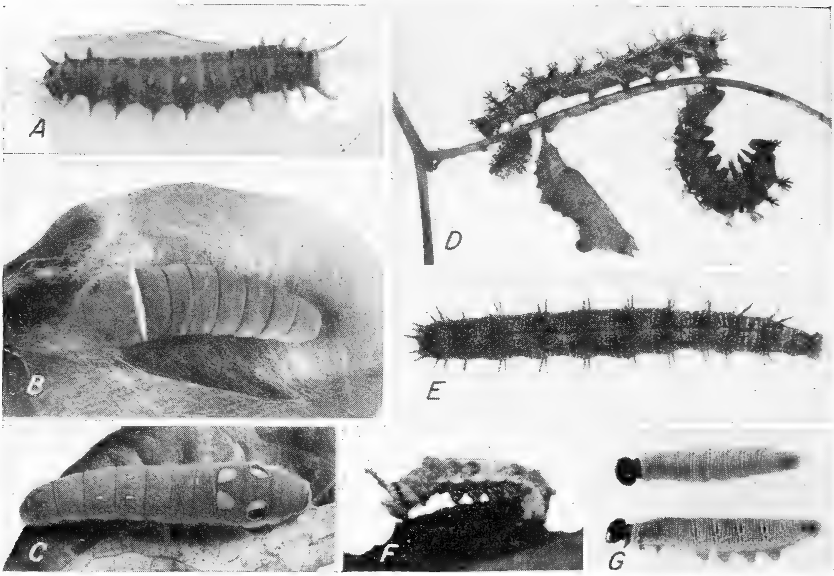

FIGURE 70.—Larvae of butterflies: *A*, ***Battus philenor*** (the pipe-vine swallowtail); *B*, ***B. glaucus turnus*** (the tiger swallowtail); *C*, ***B. troilus*** (the spicebush swallowtail); *D*, ***Pologonia interrogationis*** (the question sign); *E*, ***Nymphalis antiopa*** (the spiny elm caterpillar); *F*, ***Basilarchia archippus*** (the viceroy); *G*, ***Proteides clarus*** (the silver-spotted skipper). (*A*, *B*, *C*, and *F*, courtesy Conn. Agr. Expt. Sta.)

from July to September, possibly earlier in the more southern States. The larvae are found from June to October. The winter is passed as a chrysalis fastened to some object, usually above the ground.

The tiger swallowtail (*Papilio glaucus* L. and the form *turnus* L.) is very common in the eastern part of North America, the dark form in the South and the light one (*turnus*) more common to the North, and they need no description here. The full-grown larva is about 1½ inches long and dark green. The third thoracic segment is enlarged and is marked on each side by a large yellow spot edged with black and enclosing a small purple spot bordered with black, and on the posterior part of the first abdominal segment is a transverse yellowish ridge edged posteriorly with black (fig. 70, *B*). Although not important as a pest its larvae commonly feed on apple, ash, birch, cherry, lilac, poplar, and other trees. The adults are active from spring until late summer, there being one generation in the North and at least two farther south. The larva spins a silken carpet upon the upper surface of a leaf usually causing the leaf to fold lengthwise, thus providing the larva a shelter when at rest. The transformation to the chrysalis usually takes place upon some object above the ground, and the winter is passed in this stage.

The spicebush swallowtail (*Papilio troilus* (L.)) is found throughout most of the eastern part of the United States. The full-grown larva is about 1½ inches long, and the body is largest at the third thoracic segment. The head and under side are pink, the top pea green, and the sides yellowish. It is marked with a transverse black line on the prothorax, two orange spots on the third thoracic segment, and two on the first abdominal segment, the first two with black centers. There are six small spots on abdominal segments 2 to 7, and four on the eighth (fig. 70, *C*). Its principal food plants are spicebush (*Benzoin*) and sassafras, and although sometimes very common it probably never is a serious pest. The life history and habits are similar to those of *P. turnus*.

Family NYMPHALIDAE

The Nymphalidae is the largest family of butterflies, most of its species being of medium to large size and of a great variety of striking forms. They may be distinguished from all other butterflies by their small or rudimentary forelegs, which are folded on the breast and cannot be used in walking. Many of our most common species are included in this family. The larvae are spiny or have fleshy warts covered with hair. The head is usually more or less bilobed, the tips of the lobes often supporting branched spines. The chrysalids are naked and are suspended by the cremaster. Holland (*228*) described the stages of many species of the family Nymphalides.

Although many species of this family are at times very common, few ever become abundant enough to warrant the practice of artificial control measures. A few species are discussed briefly.

Polygonia interrogationis (F.), **the question-sign,** as a full-grown larva is about 1½ inches long. The head is dark red, the body brownish, mottled with yellow, and each segment bears a transverse row of light-colored branched spines, some of which may be tipped with black (fig. 70, *D*). This species is distributed throughout the United States east of the Rocky Mountains, and in Canada and Nova Scotia. The larvae are often very common on elm, particularly on seedling and sprout growth along roadsides, feeding on the tender leaves of the terminal twigs. They also feed on hackberry and hop. In most of its range there are two generations, the adults hibernate during the winter, and the larvae may be found from May to September.

The full-grown larva of *Polygonia comma* (Harr.), **the hop merchant** or **comma butterfly,** is about 1¼ inches long. The head is grayish in front and black on the sides, the body is yellowish white, and each segment has a transverse row of light-colored, branched spines, tipped with black. It ranges from the Carolinas to Texas and north into Canada. The larvae feed on elm, nettle, and hop, and are sometimes abundant on the latter. The life history and habits are very similar to those of the preceding species.

The full-grown larva of *Nymphalis j-album* (B. & L.) is about 1½ inches long. The head is black, the body reddish to blackish on top dotted with light green, each segment with a transverse row of branched spines, those below the spiracles usually of a light color and those above black. This species has been reported from Pennsylvania and northward from Labrador to Alaska. The larvae feed on gray birch and paper birch, and are also reported on poplar and willow. Apparently it is never important as a pest. The adults hibernate, and the larvae may be found from May to July.

The mourning cloak butterfly (*Nymphalis antiopa* (L.)) is dark brownish purple with the outer edge of the wings banded with creamy yellow, inside of which is a row of blue spots. The wing expanse ranges from 2 to nearly 3 inches. The full-grown larva, or spiny elm caterpillar, is about 2 inches long; the head bilobed and black, and the body black thickly sprinkled with whitish dots. The back has a black longitudinal line interrupted by a row of seven or eight reddish spots, and each segment has a transverse row of black, branched spines. The abdominal legs are reddish (fig. 70, *E*).

This species is widely distributed throughout the subarctic regions of North America, and also in Europe and Asia. Elm, willow, and poplar are its food plants, and sometimes it is abundant locally, principally on shade and ornamental trees and along fence rows. The adults hibernate during the winter and leave their hiding places during the first warm days of spring. The eggs are deposited in clusters around the smaller twigs at the time the foliage is nearly full grown, or later. There are two generations a year, and the larvae may be found from May to September. They are gregarious until nearly full grown and usually defoliate one branch before moving to another.

The full-grown larva of **the viceroy** (*Basilarchia archippus* (Cram.)) is about 1½ inches long. The head is large, bilobed, and pale green, and the face grooved vertically. The body has segments 1 and 2 pinkish to brownish, segments 3 to 6 and sides of 7 brownish or greenish, top of segments 7 and 9 and nearly all of 8 pale pinkish or whitish, the sides of 9 and nearly all of the last three segments brownish or greenish. There is a pale flesh-colored or whitish stigmatal stripe. On the top of the second thoracic segment are two barbed, club-shaped, brown tubercles, and on the top of other segments are pairs of smaller tubercles armed with blunt spines. The shading is somewhat variable (fig. 70, *F*).

The species occurs from the Gulf States to Canada and British Columbia. Its larvae feed on poplar and willow and, although common, probably are never serious pests. The adults are found from June to September, and the larvae are active from spring until fall. The partly grown larvae hibernate individually, each in a rolled leaf attached to a twig of the food plant. There are probably at least two generations in the United States.

Basilarchia arthemis (Drury) and *B. astyanax* (F.) resemble very closely *B. archippus* in the larval stage. They commonly feed on apple, basswood, and wild black cherry. *B. arthemis* occurs through the Northeastern States, Quebec, and Ontario, and *B. astyanax* is generally distributed from southern Canada south through the United States. Like *B. archippus* they are sometimes very common locally, and they have a similar life history.

The full-grown larva of *Asterocampa celtis* (B. & L.) is bright pea green and about 1⅕ inches in length. The head is broad, varying in color, and armed above with two prominent branched horns or antlers. The body tapers toward both extremities, the anal end with two slightly elevated projections. The top of the body is marked with a longitudinal row of yellow spots, and on each side there are three yellow lines.

The full-grown larva of *Asterocampa clyton* (B. & L.) is bright green and about 1¼ inches in length. The head is shiny bluish green and armed with broad branched antlers. The body is marked with a yellowish dorsal stripe, and a deep blue stripe on each side of it bordered with yellow. The anal end has two projections as in the preceding species. The larvae of both species feed on hackberry and are distributed practically throughout the entire range of their food plant. Sometimes these insects become locally abundant and cause considerable concern, especially where hackberry trees have been planted for shade or ornament. There are two generations a year, and the immature larvae of the second generation pass the winter among the fallen leaves. The butterflies are found from June to September, and the larvae may be found on the under side of the leaves from spring until fall. They change to chrysalids on the under sides of leaves or in one or more leaves drawn together with silk. The leaves beneath infested trees may be raked up and burned late in the fall, thus destroying the hibernating larvae, or the trees may be sprayed with an arsenical during the growing season.

Family **HESPERIIDAE**

The adults of the family Hesperiidae dart from place to place in the daytime and because of this manner of flight are commonly called "skippers." The distinguishing characters are as follows: The head is nearly as wide or wider than the thorax, the clubs on the antennae are usually drawn out at the tips, and the hind tibiae usually have two pairs of spurs. The larvae of the common skippers are characteristic in appearance, all having large heads, and strongly constricted necks. The larvae are usually solitary, and when young, each conceals itself under a part of a leaf cut and folded over, constructing a larger nest when necessary, sometimes fastening two or more leaves together.

Several species are common in the eastern part of the United States, but are seldom, if ever, of much economic importance. The larvae of *Erynnis icelus* (Scudd. and Burg.) and *E. juvenalis* (F.) are found commonly on black oak, red oak, and scrub oak in the northeastern part of the United States. Sometimes they are common along roadsides and fence rows, but they have never been reported as abundant. These species hibernate as full-grown larvae in loose cocoons in the leaves on the ground.

The adult of **the silver-spotted skipper** (*Proteides clarus* (Cram.)), also described by Fabricius and discussed in publications as *Epargyreus tityrus*, is dark chocolate brown with a row of yellow spots extending across the forewings, and on the under side of the hind wings is a broad irregular silvery spot. The wing expanse is 1¾ to 2 inches. The full-grown larva is nearly 2 inches long with a large head, which is dull red with two yellow spots on the lower part of the face. The neck and the sides of the first thoracic segment are red, the cervical shield is black, and the body pale greenish yellow marked with fine, black rings (fig. 70, *G*). The species is widely distributed throughout the United States and southern Canada. The larvae feed on black locust, clammy locust, ground nut, and wisteria, and occasionally cause serious defoliation locally. The adults of the first generation emerge from March to July, depending on the climatic range, and those of the second generation may be found as late as September. In the northern regions there may be only one generation, or a partial second. The larval habits are as described under the family. The larvae leave their nests to feed and are rather voracious feeders. Pupation takes place in a loose cocoon spun among the leaves, usually on the ground.

Family SPHINGIDAE

The sphinx moths, or hawk moths, as they are commonly known, are moderate sized to very large and are strong flyers. Most species of this family fly during the night, although some are active during the day or in twilight, and these may often be seen hovering over flowers and extracting the nectar while on the wing, holding themselves in position by a rapid motion of the wings. The moths of this family are easily recognized by their elongate, strong forewings with very oblique outer margin, the stout spindle-shaped body, and the antennae more or less thickened toward or beyond the middle and usually pointed at the apex. The proboscis is usually very long and when not in use is coiled like a watch spring. The larvae are cylindrical, and smooth or with a granulated skin, and naked. The eighth abdominal segment bears a prominent horn or eyelike tubercle, and many species have the abdomen marked with oblique stripes. When at rest these insects generally cling to the twig or foliage by their abdominal legs and hold the front part of the body aloft. Pupation usually takes place in a cell in the ground.

Although many species inhabit the eastern part of the United States, few ever become abundant enough in the forest or on shade trees and ornamentals to necessitate artificial control. The larval descriptions, food plants, and life histories are given for some of the more common and injurious species.

The larva of *Ceratomia amyntor* (Hbn.) varies from pale green to reddish brown. The body is marked on each side with seven oblique stripes of whitish granulations, each stripe extending from the lower part of one segment backward across another and reaching the third near the top, the last stripe extending to the caudal horn. On each of the second and third thoracic segments is a pair of tuberculated horns, and a strong caudal horn arises from the eighth abdominal segment. The full-grown larva is about 3 inches in length (fig. 71, *H*). This species is distributed through the Atlantic States and west to the Mississippi Valley. Its larvae feed on basswood, birch, and elm. The moths emerge in June and July, the larvae may be found from July to early October, pupation takes place in the soil, and the winter is passed in the pupal stage.

The larva of *Ceratomia undulosa* (Wlkr.) has a bluish-green head marked by a broad pale band; the body, tapering toward the head, is pea green and marked by seven oblique light yellow stripes on each side, the last extending to the base of the caudal horn. The spiracles are orange, the caudal horn is reddish and curved downward at the tip, and the anal plate and anal legs are dotted with elevated black points. The thoracic legs are green or reddish. The full-grown larva is about 2½ inches in length (fig. 71, *I*). This species occurs in eastern Canada and Maine, south to the Carolinas, and west into the Mississippi Valley. The larvae feed on white ash and lilac. The moths emerge from late in May to July, the larvae may be found from June to October depending on the locality, and the winter is passed in the pupal stage in the soil.

The larva of **the catalpa sphinx** (*Ceratomia catalpae* (Bdv.)) is about 3 inches in length when full grown. The head and caudal horn are always black, but the body is variable in color. Howard and Chittenden (*245*) described two forms, a light and a dark one (fig. 71 *C*, *D*.). The dark form is black on top, pale yellow somewhat speckled with black on the sides, and has a more-or-less broken stripe of black near the base of the legs. It is pale yellow underneath, and the thoracic legs are black. The light form is pale yellow with markings and patches of black on the back.

This species, which occurs from New Jersey to Florida and west to Illinois and Texas, feeds on our native species of catalpa. Its injury

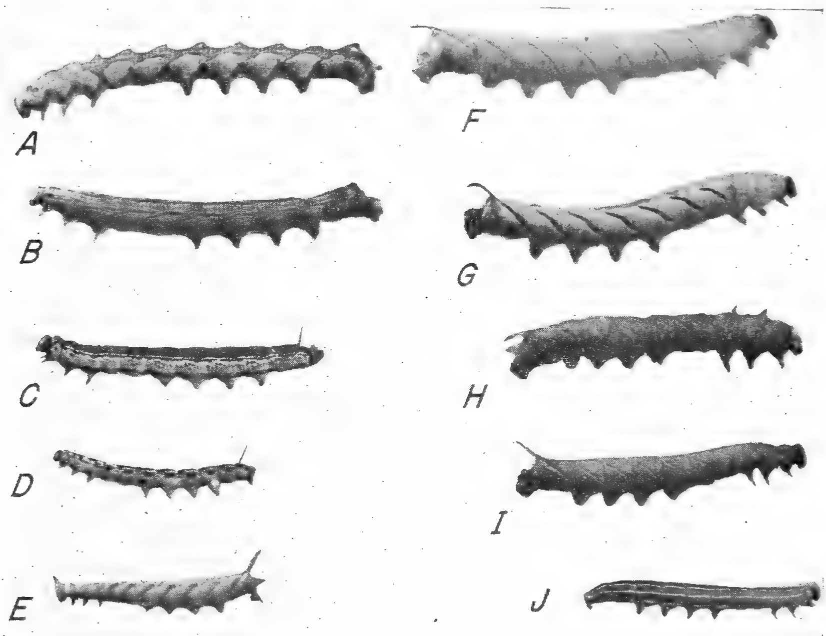

FIGURE 71.—Representative larvae of the Sphingidae: *A*, *B*, *Sphecodina abbottii*; *C*, *D*, *Ceratomia catalpae*; *E*, *Cressonia juglandis*; *F*, *Sphinx chersis*; *G*, *Sphinx kalmiae*; *H*, *Ceratomia amyntor*; *I*, *Ceratomia undulosa*; *J*, *Lapara bombycoides*.

has been more widespread in recent years, undoubtedly because of the increased planting of catalpa outside of the natural range of the tree and in pure stands. Outbreaks sometimes extend over a period of 3 or more years, causing severe defoliation and a great retardation of growth and sometimes a heavy mortality of the trees. There are at least two generations in its northern range, but in the South there may be three or four. In the South the moths emerge in March and later, and the larvae may be found throughout the spring and summer. In its northern range the moths emerge from early in June to September, and larvae may be found from the middle of June to early in October. The eggs are pale yellowish green and are usually deposited in masses on the under sides of the leaves. For some time after hatching the larvae are gregarious, later separating. Pupation takes place in the soil, and the winter is passed in the pupal stage.

The larva of *Sphinx chersis* (Hbn.) has a bluish head marked by a pale band on each side. The body is generally light green with seven oblique, light yellowish stripes edged above with bluish green, the last stripe extending to the base of the caudal horn. The caudal horn is pale blue and rather erect in the early instars but curved downward when the larva is nearly full-grown. The anal plate is triangular, the spiracles are bordered with white, and the thoracic legs are rose colored. The full-grown larva is about 3 inches long (fig. 71, *F.*) This species occurs from Canada to Florida and west to the Pacific. Its food plants are ash and lilac. It is often common locally on ash saplings and sprout growth, sometimes defoliating the terminal shoots. In the Middle States there are two generations annually, and the moths are active in May and August. Farther north there is only one generation, the moths emerge in June and July, the larvae are active from July to late in September, and the winter is passed in the pupal stage in the ground.

The larva of *Sphinx kalmiae* A. & S. is yellowish green, the head has a black band, and the body is marked by seven oblique, black stripes edged below with yellow. The spiracles are orange, the caudal horn is arcuate and blue with black raised markings. The anal plate is dotted with elevated black points, and the thoracic and abdominal legs are black, each with a yellowish-green band. The full-grown larva is about 3 inches in length (fig. 71 *G.*). This species ranges from southern Canada through the Atlantic States to Georgia. The larvae feed on ash, fringetree, mountain-laurel, lilac, and rhododendron. Its life history is similar to that of *Ceratomia undulosa.*

The full-grown larva of *Sphinx gordius* Cram. is nearly 3 inches in length, the head is green with a yellowish or brownish stripe on each side in front, the body is bright apple green with numerous small yellowish or whitish dots some of which are encircled with black. Along each side of the body are seven oblique carmine stripes, the lower side of each edged with white. The caudal horn is black on the sides and at the tip and green at the middle above and beneath. The spiracles are orange, the thoracic legs pink, greenish at base, and the abdominal and anal legs are green. This species is distributed throughout the Atlantic States and west to the Mississippi Valley. The larvae feed on apple, bayberry, cranberry, wild rose, and sweet-fern. The moths emerge in June and July, the larvae are found from August to October, and the winter is passed as pupae in the ground.

The full-grown larva of *Sphinx luscitiosa* Clem. is very similar to that of *S. gordius* and may be confused with it. It ranges through the Atlantic States, and the larvae feed on poplar and willow. The life history is similar to that of *S. gordius.*

The larva of *Sphinx drupiferarum* A. & S. is yellowish green with each side of the head marked with a reddish stripe edged in front with yellow. The sides of the body have seven oblique mauve stripes edged posteriorly with white. The spiracles are yellowish, the caudal horn is long and arcuate, black above and yellowish beneath, and the thoracic legs and abdominal feet are reddish to blackish. The full-grown larva is about 3 inches in length. This species is apparently widely distributed in the United States and the southern part of Canada. The larvae feed on apple, beach plum, wild cherry, cranberry, hackberry, plum, and peach. The moths emerge in June and July, the larvae are found from late in June to September, and the winter is passed in the pupal stage in the ground.

The larva of *Lapara bombycoides* Wlkr. is grass green and without a caudal horn; the head is triangular, conical, with a pale, yellowish stripe on each side, and the face sometimes reddish. The body has three longitudinal white stripes on each side, the lower one rather broad. The full-grown larva has a broad, brick-red, median, dorsal stripe, sometimes wanting on the thoracic segments or represented by patches. The abdomen has a reddish stripe underneath, and sometimes brick-red patches enclose the spiracles on the abdomen. The length of the full-grown larva is about 2 inches (fig. 71, *J*). This species ranges from Canada through the Atlantic States and west into the Mississippi Valley. The larvae feed on white pine, pitch pine, and jack pine. The moths emerge in June and July, the larvae are found from July to September, and the winter is passed in the pupal stage in the ground. *Lapara coniferarum* (A. & S.) also feeds on pine and its range is reported as similar to that of *L. bombycoides*.

The full-grown larva of *Paonias excaecatus* (A. & S.) is about 2½ inches long. The head is apple green, conical, and granulated, and with a white or pale-yellow stripe on each side, meeting at the apex. The body is light green studded with pointed granulations. Seven oblique yellowish stripes run back on each side of the body; the last, the widest and most distinct, reaches the base of the caudal horn. The spiracles are deep lilac or black, the caudal horn is nearly straight, and usually green and the thoracic legs are lilac or reddish. This species ranges through the Atlantic States. Its larvae feed on poplar, willow, and sometimes on apple and birch. The moths emerge in May and June, the larvae are found from July to October, and the winter is passed in the pupal stage in the ground.

The full-grown larva of *Paonias myops* (A. & S.) is green with yellowish granulations and is about 2¼ inches in length. The head is conical, and has a faint yellowish line on each side. The body has seven yellowish, oblique stripes on each side, the last wider and more distinct than the others and extending onto the caudal horn. The caudal horn is short and green, sometimes reddish above and green beneath, the thoracic legs are reddish, the abdominal legs green, and the spiracles rose colored. Some specimens have the spiracles set in small, red patches and some have subdorsal patches of red. The young larva is pale yellowish green with a pointed head. This species occurs through the Atlantic States and west into the Mississippi Valley, and it has also been recorded from Colorado. The larvae feed on wild cherry. The life cycle is very similar to that of *P. excaecatus*.

The larva of *Smerinthus jamaicensis* (Drury) (=*geminatus* Say) is very similar to that of *Paonias excaecatus* and is very often confused with it, but may be recognized by the rose-colored spiracles, the bluish-purple caudal horn, the violet thoracic legs, and sometimes a subdorsal row of reddish spots on each side of the body. Its distribution, food plants, and life history are very similar to those of *P. excaecatus*.

The full-grown larva of **the walnut sphinx** (*Cressonia juglandis* (A. & S.)) is about 2 inches long, ranges in color from light green to reddish, coarsely granulated with white. The head is truncate in front and triangular, the apex bearing two rough, brownish projections, and on each side of the head there is a yellowish stripe. The body has seven light yellowish oblique stripes, sometimes bordered above with reddish, and often very indistinct. The caudal horn is brownish and very granulated (fig. 71, *E*). The young larva is yellowish green.

This species occurs from Canada to Florida and westward to the eastern boundary of the Great Plains. The larvae feed on butternut, black walnut, the hickories (including pecan), and hop hornbeam. There is one generation in the North and at least a partial second in the South. The moths emerge in June and July in the North but much earlier in the Southern States. In the two-generation zone the larvae may be found from May to September, and farther north from July to September. The pupae pass the winter in the ground. This species is sometimes rather common in pecan orchards.

The full-grown larva of *Hemaris thysbe* (F.), **the hummingbird clearwing,** is about 2 inches long. The head is rounded and bluish green, the body yellowish green, with a green dorsal line bordered with whitish, sometimes a vinous tint. There is a subdorsal, longitudinal, whitish line on each side, sometimes nearly obsolete, the spiracles are reddish and white, the caudal horn bluish with black granulations, the thoracic legs brownish with black at base, and the abdominal legs blackish toward tip on the outer side. The head and the cervical and anal shields are coarsely granulated, and the body is rather finely granulated. Some specimens have a purplish tint. This species is found in Canada and Nova Scotia, southward to Florida and west to the Mississippi Valley. The larvae feed on the viburnums, and sometimes they have been very common in nursery rows. There may be two generations or at least a partial second, the moths emerging from May to August, and the larvae being found from June to October. The winter is passed in the pupal stage on the ground.

Hemaris diffinis (Bdv.), **the snowberry clearwing**, is distributed from New England to Georgia and westward to the eastern boundaries of the Great Plains. The larvae feed on snowberry and bush honeysuckle. There are two generations a year.

The full-grown larva of *Sphecodina abbottii* (Swaine), **the abbott's sphinx**, is fully 3 inches in length and has a polished eyelike tubercle in place of a caudal horn. The color and markings are variable; one form is chocolate brown with numerous transverse, blackish lines, also two dark-brown, longitudinal, dorsal stripes and another on each side of the body; the second form is reddish brown with large, light-green patches on the back and along the sides of the body (fig. 71, *A*, *B*). The partly grown larva is bluish green with transverse, blackish lines and the caudal horn is aborted and of an orange color. This species ranges from southern Canada through the Eastern States and west to Iowa and Kansas. Its larvae feed on Virginia creeper and grape. Although rarely if ever abundant they sometimes cause concern to owners of vines. The moths emerge in May and June, larvae are found from June to September, and the winter is passed as pupae in the ground.

The larvae of the following sphingids also feed on grape and Virginia creeper: *Pholus pandorus* (Hbn.), **the achemon sphinx** (*P. achemon* (Drury)), *Ampeloeca myron* (Cram.), *Deidamia inscriptum* (Harr.), and *Amphion nessus* (Cram.).

Family SATURNIIDAE

The largest moths inhabiting the eastern part of the United States belong to the family Saturniidae. They have a small head which is deeply sunken in the thorax, and the antennae are bipectinate, those of the males much broader than those of the females. The thorax is densely hairy, the body is stout, and the wings are strong and broad, some with transparent windowlike spots. They are nocturnal and are attracted to lights. The larvae are large, and most species spin dense silken cocoons in which they transform, and therefore are commonly known as giant silkworms. They are more or less armed with tubercles and spines, and most species live exposed on the foliage of trees and shrubs. They have been described by Packard (*324*).

The species of this family are usually held in check by natural control factors, and although most species are quite common in their natural habitat, it is rarely necessary to use artificial control measures to prevent serious injury by them. Because of the large size of the larvae they often attract attention, and therefore brief descriptions of the larvae and the habits of the more common species are given here.

The full-grown larva of **the cynthia moth** (*Philosamia cynthia* (Drury)) is about 3 inches in length; the head yellowish green and about one-half as wide as the body is thick, and the prothoracic segment is lemon yellow, as is also the anal plate, the dorsal region of the ninth abdominal segment, and the thoracic and abdominal legs. The rest of the body is light bluish green to yellowish dotted with black. Each segment except the last has four dorsal and two lateral, long, bluish tubercles, with short radiating bristles. The tubercles on the last segment are much reduced, and the lateral tubercles are ringed with black at the base (fig. 72, *A*).

This species was introduced into this country from Asia about 1861, and its present known distribution in the United States is from southern Connecticut to Virginia. Its preferred food plant is ailanthus, but it is also recorded as feeding on wild black cherry and plum. The moths emerge between June and early September, the larvae are found from July to early October, and the pupae in their cocoons, fastened to twigs on the food plant or among the dried leaves on the ground, from August until the following summer. The cocoons are similar to those of *Callosamia promethea* and may be mistaken for them. Occasionally some pupae remain dormant until the second summer. This species is often abundant locally, and apparently ailanthus, its preferred food, is an important factor in limiting its dispersal.

The full-grown larva of **the cecropia moth** (*Samia cecropia* (L.)) is 3 to 4 inches in length. The head is green with 2 black spots on each side, the body pea green with a bluish tinge. On the top of the second and third thoracic segments are 4 large, coral-red tubercles, and on the first to eighth abdominal segments 15 yellow tubercles. All tubercles on the prothorax and a double row on the sides of all other segments are blue. The tubercles are armed with short, black spines, the spiracles are white with a narrow black ring, and the thoracic feet are yellowish green, but black at the end (fig. 72, *B*). This species

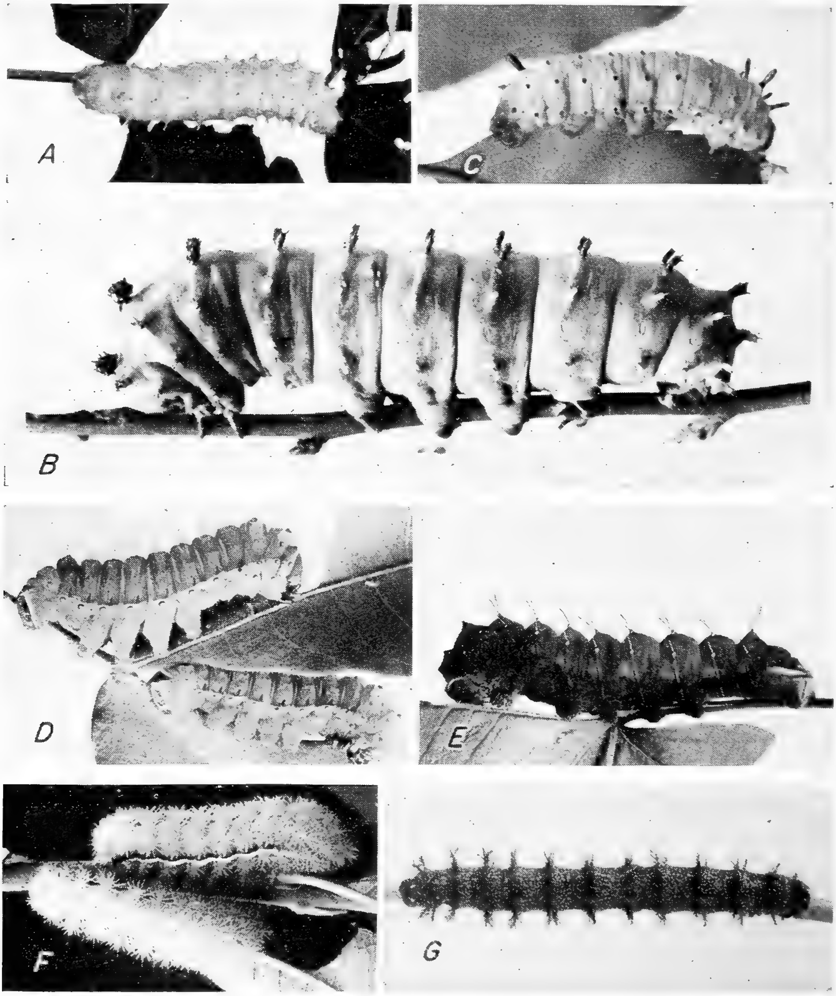

FIGURE 72.—Larvae of some Saturniidae: *A*, *Philosamia cynthia* (the cynthia moth); *B*, *Samia cecropia* (the cecropia moth); *C*, *Callosamia promethea* (the promethea moth); *D*, *Tropaea luna* (the luna moth); *E*, *Telea polyphemus* (the polyphemus moth); *F*, *Automeris io* (the io moth); *G*, *Hemileuca maia* (the buck moth).

is distributed throughout the eastern part of the United States and eastern Canada. It has a long list of food plants including apple, ash, birch, cherry, elderberry, grape, hawthorn, maple, rose, sassafras, and willow. The moths emerge from May to July, larvae are found from June to October and they transform to pupae within dense, silken cocoons. The cocoons are spun on a branch of the food plant or fastened lengthwise to some other nearby object. The winter is passed in the pupal stage.

The full-grown larva of **the promethea moth** (*Callosamia promethea* (Drury)) is about 2 inches in length. The head is small and yellow; the body is bluish or greenish white, on the top of the second and third thoracic segments are four large coral-red tubercles, and on the eighth abdominal segment is a large yellow one. Those on the top of the other segments and two rows of tubercles on each side of the body are black, much reduced in size, some merely raised dots. All the legs are yellowish, and each of the middle abdominal legs has a black dot in the middle of the outer side (fig. 72, *C*). The larvae in the first and second instars are yellowish with black bands, and from the third to the next-to-the-last instars, inclusive, the large tubercles on the back are yellow, and the bands have disappeared.

This species ranges throughout most of the eastern part of the United States and southern Canada. Its food plants include ash, cherry, lilac, sassafras, spicebush, and yellow poplar. The moths emerge from June to August, the eggs are deposited more or less in small groups on the under sides of the leaves. The larvae feed gregariously for some time and may be found from late in June to September. They change to pupae within elongated cocoons, each enclosed in a leaf, the petiole of which is fastened to the branch by silk, and, thus securely fastened, the cocoon hangs from the tree throughout the winter. This is probably the most common of our native species of Saturniidae.

The full-grown larva of **the luna moth** (*Tropaea luna* (L.)) is about 3 inches long. The head is bluish-green shaded with brown above and on the sides, the body is apple green to yellowish green, each segment with six pinkish or greenish tubercles from which arise yellowish bristles. The backs of the second and third thoracic segments are swollen under the tubercles, and these segments are more angular than the abdominal segments. The anal plate is amber colored, edged in front with yellow, and has a yellow stripe below the spiracles. The spiracles are reddish brown, and the true legs brown (fig. 72, *D*). This species is found from southern Canada south to Florida and west into the Mississippi Valley, also in Nebraska and Texas. Its principal food plants are hickory and walnut, but it is also found on beech, birch, persimmon, sweetgum, and willow. The moths emerge in June and July, the larvae are found from July to September, pupation takes place in a rather thin cocoon which resembles that of *Telea polyphemus*, and the insect passes the winter as a pupa in the cocoon, usually on the ground.

The full-grown larva of **the polyphemus moth** (*Telea polyphemus* (Cram.)) is about 3 inches in length. The head is reddish brown, the front margin of the prothoracic segment yellow, the body apple green, and the segments convex to angular on the back, each segment with six orange or golden tubercles, some with a silvery tint, from which arise one to three straw-colored bristles. The spiracles are orange brown, the anal segment edged with purple, the thoracic legs yellowish to brown, and the middle abdominal legs greenish. The young larva is yellowish green, becoming greener as it increases in size, and the tubercles vary from green to orange red (fig. 72, *E*). This species is widely distributed throughout the United States and Canada. It has a long list of food plants which include basswood, beech, birch, elm, hawthorn, hickory, maple, oak, sassafras, yellow poplar, and willow. The moths emerge from May to early in August, larvae are found from June to October, and pupation takes place within a dense cocoon, which is generally enclosed in a leaf. The winter is passed in the pupal stage in the cocoon, which usually drops to the ground.

The larva of **the io moth** (*Automeris io* (F.)) is spiny and is about 2 inches long when full grown. The head is pea green, glossy, and with black ocelli, and the body is cylindrical and pea green with a broad reddish spiracular stripe on each side edged below with a white stripe and another reddish line below the white stripe. The spiracles are yellowish, narrowly ringed with black. Each segment of the body has branched spines arising in whorls from small conical tubercles as follows: 8 on segments 1 to 5 and 10, 6 on segments 6 to 9, 5 on the eleventh, and 7 on the twelfth. These spines cause a nettling effect when in contact with the human skin. Most of the spines are yellowish tipped with black. The thoracic legs and the ends of the abdominal legs are reddish brown (fig. 72, *F*).

This species is distributed from the Atlantic coast west to Colorado and New Mexico, and from Canada south to Florida and Mexico. Its larvae feed on various deciduous growths, including birch, blackberry, wild black cherry, currant, cotton, black locust, poplars, and willows. The moths emerge in June and July, the larvae are gregarious during the early instars, and are found from July to September, pupation takes place within a rather tough oval cocoon often enclosed in leaves, and the winter is passed in the pupal stage, usually on the ground. It is sometimes abundant locally.

The full-grown larva of **the buck moth** (*Hemileuca maia* (Drury)) is about 2½ inches in length. The head is deep, reddish brown, the body dull brownish to black covered with small, pale, yellowish dots and without stripes, and the spiracles are pale, narrowly oval. Each segment has tufts of bristles or compound spines arising from tubercles as follows: 8 on segments 1 to 5 and 10, 6 on segments 6 to 9, 5 on the eleventh, and 7 on the twelfth; the two tufts of bristles on the top of each of segments 2 to 10 and one on segment 11 are rusty brown tipped with black, and those on segment 2 also have a compound black spine. The compound spines are tubular and black at the base with branches sharply pointed and black at tip, many with white bands. The thoracic legs are reddish brown, and the abdominal legs dull reddish (fig. 72, *G*). This species ranges from southern New Hampshire south to Georgia and west to Oklahoma, and its larvae feed gregariously on oak. The moths emerge in September and October, the eggs are deposited in clusters, usually encircling a twig, and the larvae may be found from May to August.

Hemileuca lucina Hy. Edw. is closely related to *H. maia* and the two species are often confused. The larvae of *H. lucina* have a broken, pale-yellowish stigmatal stripe, and the spines are shorter. The principal food plant is *Spiraea salicifolia*, but they are also found on wild black cherry, gray birch, and oak. Often they are abundant locally in swampy areas in the Northeastern States.

Hemileuca nevadensis Stretch, **the Nevada buck moth,** is a western species ranging eastward into the Great Plains, and its larvae commonly feed on poplar and willow. It was reported as abundant and injurious to poplar (cottonwood) in Nebraska in 1922. The biology and appearance are very similar to those of *H. maia.*

Family CITHERONIIDAE

The Citheroniidae is a small family of stout-bodied, hairy moths, medium to large in size, and with strong wings. The head is generally sunken in the prothorax, and the antennae of the males are strongly bipectinate on the basal half or two-thirds.

The larvae are armed with horns, or spines, and some are thinly hairy. The horns, or spines, on the second thoracic segment and sometimes those on the third are long and usually curved. These larvae feed on the foliage of forest trees and shrubs, and two species are often pests of considerable importance. The members of this family do not spin cocoons but transform to pupae in the ground (Packard *324*). The more common species of the eastern part of the United States will be discussed.

There are four species of *Anisota* which are often common to abundant in the eastern part of the United States. The moths are dark yellow or brownish with a lilac or purplish tinge. All species have the forewings marked with a white discal dot, and the wing expanse ranges from 1½ to 2½ inches. The sexes differ considerably in appearance and size. The males in general are smaller and can be distinguished by their pectinate antennae. The larva has a cylindrical body with two recurved, slender, smooth horns on the second thoracic segment, the prothoracic spines being reduced to tubercles, and all the other dorsal and lateral spines of the body being small. The anal plate has from three to four lateral and two stout, conical, terminal spines. The body is marked with conspicuous stripes.

The moth of **the spiny oak worm** (*Anisota stigma* (F.)) has a wing expanse of from 1¾ to 2½ inches. The wings and body are dark, reddish ochre, the base of the wings and the outer portion often tinged with lilac, and all more or less speckled. The male resembles the female in coloration. The female closely resembles that of *A. senatoria*, and they may be often confused. The full-grown larva is 1½ to 2 inches in length. The head is cherry-red, the body pale, tawny red and densely covered with white granulations of uneven size with a faint dusky spiracular line. The second thoracic segment bears two spines about as long as the body is thick, the other spines are curved backward, the upper surface is smooth, and the under side marked with spinules. The anal plate is reddish with a rough surface, the spiracles and legs are black, but the sides of the anal legs are reddish (fig. 73, *A*). This species occurs in southern Canada and New England, south to Georgia, and westward to Kansas. Its larvae feed on hazelnut and the oaks. The moths emerge in June and July, the larvae may be found from July to September, and pupation takes place in the ground, the insect remaining in the pupal stage from fall until early summer.

The moths of **the orange-striped oak worm** (*Anisota senatoria* (A. & S.)) may be distinguished from those of *A. stigma* by the following characters: The male differs in that the hind wings are distinctly triangular, the apex less rounded, and the wings reach only about two-thirds the length of the abdomen, which is less than in *A. stigma*. The wings of the female are paler, thinner, and less speckled than in *A. stigma*, and the extradiscal line in the hind wings is obsolete above, but fairly distinct below. The full-grown larva is about 1¾ inches long. The head is large and jet black, the body jet black with two longitudinal dorsal stripes of yellow or orange and on each side a narrow subdorsal line and two wavy lateral lines of the same color, also a median ventral stripe of yellowish. On the second thoracic segment is a pair of black, slender, stiff, erect, blunt spines nearly as long as the body is thick, and on each succeeding segment is a series of small, sharp, black spines (fig. 73, *B*).

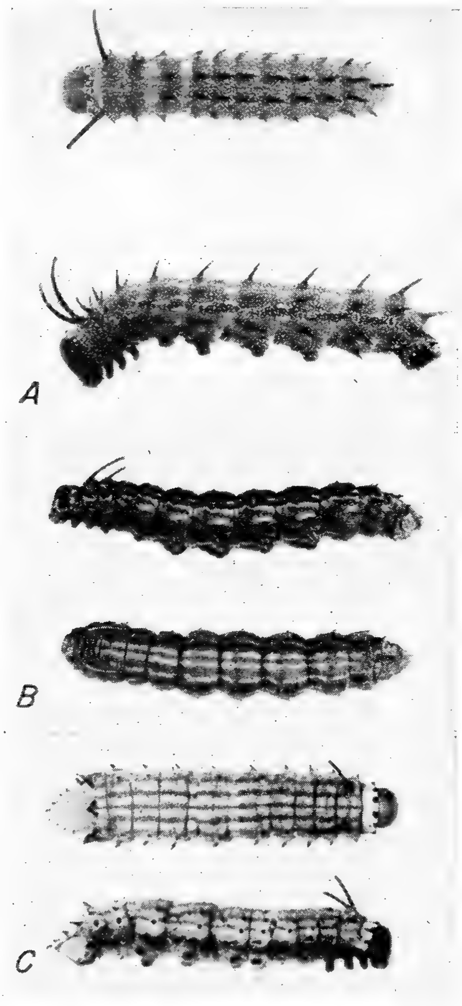

FIGURE 73.—Larvae of Citheroniidae: *A*, *Anisota stigma* (F.); *B*, *A*, *senatoria* (A. & S.); *C*, *A. rubicunda* (F.)

This species ranges from eastern Canada southward to Georgia and westward to Iowa and Minnesota. The larvae feed on the various species of oak. Each year they are usually reported as common to abundant in one or more localities, and, although the infestations in general are extremely local, often serious defoliation results. The moths emerge from June to August, the eggs are deposited in clusters on the under sides of leaves, the larvae are gregarious during the early instars and may be found from July to October, and the winter is passed in the pupal stage in the ground.

Anisota virginiensis (Drury), **the brown Anisota,** differs from the two preceding species in the thinness and transparency of the forewings beyond the discal dot, the stronger lilac hues, and in the absence of the speckling. In the males the wings are triangular, but the costa of the hind wing is much rounded, the inner angle produced almost into a lobe, and the transparent area in the forewing is larger than in *A. senatoria.* The full-grown larva is about 2 inches in length. The head is greenish to light brown, the prothoracic shield bears four blackish, flattened tubercles near the front, the second thoracic segment bears two long, slender horns varying in thickness, and the body is greenish, or grayish, densely granulated with white, marked by a subdorsal longitudinal stripe and a lateral stripe of pink, and armed with short spines, shorter than those on *A. stigma.* The anal plate and anal legs are amber colored, the other legs pale, and those of the midabdomen have a dark spot on the outside. The life history and habits are similar to those of *A. senatoria*. This species ranges from Maine to Georgia and westward to Missouri and Minnesota. The larvae feed on various species of oak. Although sometimes common there are no records which indicate that it is ever important as a pest.

The moth of **the green-striped maple worm** (*Anisota rubicunda* (F.)) has a wing expanse of 1½ to 2 inches. The body is yellowish above and pinkish beneath, the forewings are rose-colored and crossed by a broad yellowish band, the width of the band varying in different specimens. The hind wings are pale yellow, and the legs pink. The full-grown larva is about 1½ inches long. The head is cherry red, and the body is pale yellowish green with seven dark green or blackish longitudinal lines. There are two long slender horns on the second thoracic segment, two rows of short spines on each side of the body, one above and one below the spiracles, and four prominent, dorsal spines on the eighth and ninth abdominal segments (fig. 73, *C*).

This species is distributed throughout the eastern half of the United States and southern Canada. The larvae feed on the maples, often causing severe defoliation of forest and shade trees. This species is sometimes associated with *Heterocampa guttivitta* during severe outbreaks in the New England States. The moths emerge from May to August, and in August and September, there being one, a partial second, or two complete generations depending on the climatic range. The eggs are deposited in clusters on the under sides of the leaves, and hatching takes place in about 10 days. The larvae may be found from June to October, and transformation to the pupal stage takes place in the ground, the winter being passed in this stage.

The regal moth (*Citheronia regalis* (F.)), also called **the royal walnut moth,** has a wing expanse of 4½ to 6 inches. The head and body are orange red marked with pale yellow, the forewings olive-gray with reddish-brown veins and spotted with pale yellow, and the hind wings orange red, somewhat redder on the veins, with the costa and inner margin marked with pale yellow. The full-grown larva is called **the hickory horned devil.** It is 4 to 5 inches long and about ¾ inch thick. The body is smooth, green or bluish, or sometimes reddish brown. Each segment is armed with a transverse row of spines; some are hornlike, especially two on the first, four on the second, and four on the third thoracic segments, and the caudal horn. These are much longer and stouter than the others and are orange with the apex of each black; the other spines are black. There are two large, black patches between the horns of the second and third thoracic segments, and the sides of the abdomen are shaded with oblique blackish patches (fig. 74, *A*).

This species ranges from Massachusetts to Illinois and south to Texas and Florida. The larvae feed on hickory, butternut, cotton, black walnut, persimmon, sumac, and other deciduous growths. Although its size and appearance attract attention, it is not important as a pest. The moths emerge in June, the larvae are found from July to September, and the winter is passed in the pupal stage in the ground.

The moth of *Citheronia sepulchralis* G. & R. has a wing expanse of about 3 to 4 inches. The body, wings, and legs are dark brownish gray with a lilac tinge, and the forewings have a dusky discal spot. The full-grown larva is about 4 inches long; dull brown, more obscurely colored than that of *C. regalis*, and with rather short, orange horns.

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This species ranges from southern Maine to Florida. The larvae feed on various species of pine. It is rare in the Northeastern States, but not uncommon in the Southeastern States. Its life history is similar to that of *C. regalis*.

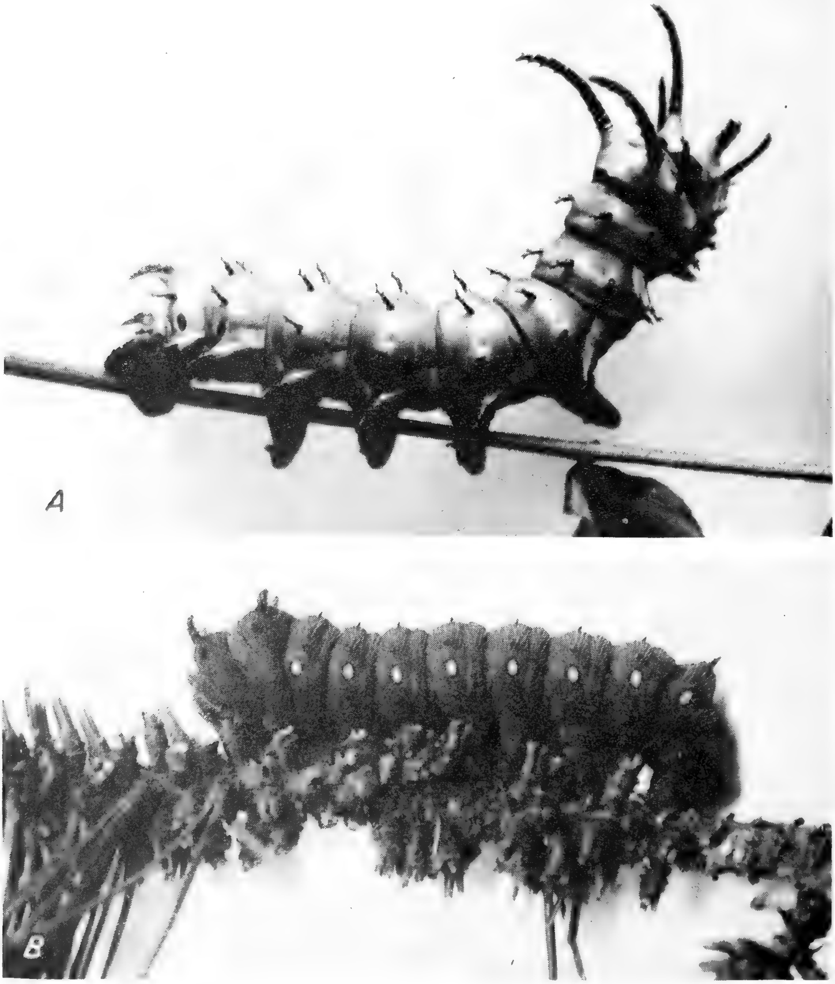

FIGURE 74.—*A*, Larva of *Citheronia regalis; B*, larva of *Eacles imperialis*. (*A*, *Courtesy Conn. Agr. Expt. Sta.*)

The imperial moth (*Eacles imperialis* (Drury)) has a wing expanse of 4 to 6 inches. The head is yellow, and the thorax, body, and wings bright yellow with pale, lilac markings. The full-grown larva is about 4 inches long, the head is about one-half as wide as the body, orange yellow with the sides green, and the body is generally green, sometimes tinged with red or brown, and thinly clothed in long whitish hairs. Each segment has five or six thorny, yellow tubercles, or warts, and two on the top of the second and two on the third thoracic segments and the caudal horn are longer than the others. Those on the top of the thoracic segments are curved backward like horns. The spiracles are large and white, and the anal shield and a triangular plate on the outer side of the anal claspers are brown or black with yellow margins and covered with raised orange-colored dots (fig. 74, *B*). This species is distributed through the eastern half of the United States and southern Canada, and its larvae are general feeders on foliage of forest and shade trees, but records indicate it is never an important defoliator. The moths emerge in June and July, the larvae may be found from July to October, and pupation takes place in the ground. There is one generation annually, and the winter is passed in the pupal stage.

Family **ARCTIIDAE**

The Tiger Moths or Arctiids

The Arctiidae are a large family of stout-bodied moths with moderately broad wings. Many species are marked with spots or stripes of bright colors, which apparently suggested the common name "tiger moths." In general they are moderate in size, with broad head, ocelli present, antennae pectinate or ciliate, and the proboscis often weak. They are night fliers, are attracted to lights, and when at rest usually fold their wings rooflike upon the abdomen.

The larvae of most species are clothed with dense clusters of hairs. In some species certain of these clusters are larger and longer than others, causing the larvae to resemble those of the tussock moths of the family Lymantriidae, and for this reason the larvae of the genus *Halisidota* are also commonly called tussocks. The woolly bears also belong to this family. Most species prefer the foliage of low-growing plants as food, but a few feed on the foliage of trees and shrubs. A great many species pupate in cocoons constructed of silk intermixed with hairs from the body of the larva. The species of most importance as feeders on the foliage of trees and shrubs are discussed in the following paragraphs.

The hickory tussock moth (*Halisidota caryae* (Harr.)) has a wing expanse of about 2 inches. The head and body are light brown or buff, the forewings light brown marked with many silvery white spots, and the hind wings pale yellowish and translucent. The full-grown larva is nearly 1½ inches long. The head is black, and the body grayish white clothed with short spreading tufts of grayish-white hairs. There is a row of black tufts on the tops of the first eight abdominal segments, a pair of long black pencils arising from the first abdominal segment, and another pair on the seventh abdominal segment. The hairs arising from the thoracic segments are longer than those on other segments (fig. 75, *A*).

This species ranges from Quebec south through North Carolina and west to Saskatchewan and Missouri. The larvae are rather general feeders on the foliage of deciduous trees and shrubs, but show a preference for walnut, butternut, apple, pear, and hickory. They are frequently abundant locally, but apparently have never been recorded as causing any extensive defoliation. The moths emerge from late in May to early in July, and the eggs are deposited in batches of 50 to 400 in a single layer on the under sides of the leaves. The larvae are gregarious until nearly full grown and may be found from June until October, as the duration of the feeding period varies considerably. The winter is passed in the pupal stage in a gray, hairy cocoon constructed of silk and hairs from the body of the larva.

The spotted tussock moth (*Halisidota maculata* (Harr.)) is pale yellow, and has a wing expanse of about 1¾ inches. The forewings are marked with brown spots, the outer one of which forms an irregular subterminal band. The full-grown larva is about 1¼ inches in length with a large and shiny black head. The body is dull black above, thickly clothed with tufts of black and bright yellow to whitish hairs, with a row of short tufts down the middle of the back, mostly black.

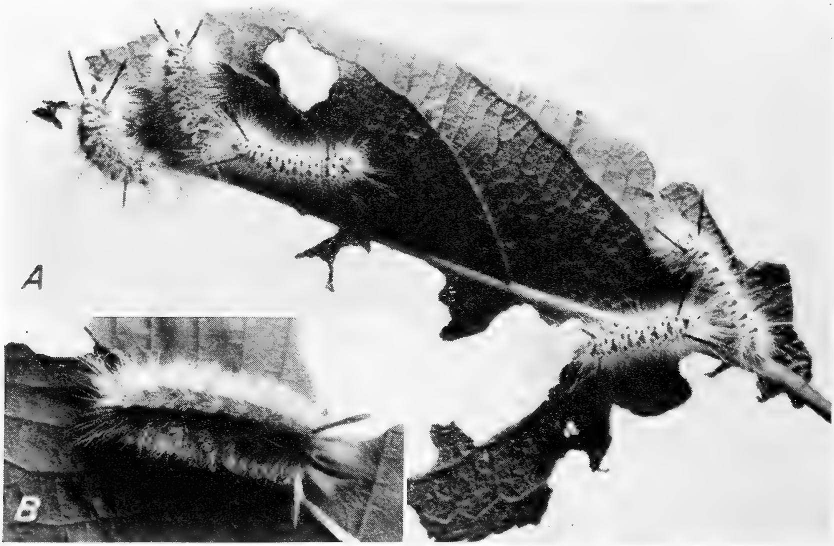

FIGURE 75.—*A*, Larva of the hickory tussock moth (*Halisidota caryae*); *B*, larva of the pale tussock moth (*H. tessellaris*). (Courtesy Conn. Agr. Expt. Sta.).

The hairs on the sides of the second to sixth abdominal segments, inclusive, are yellow, but others are black, the tufts on the second and third thoracic and the eighth abdominal segments are longer than those on the others and have some yellowish or white hairs intermixed with black; those of the thoracic segments overhang the head. Prior to the last instar the larva has been much lighter in color.

According to Holland (*229*), the species in 1903 ranged from the northern portions of the Atlantic coast region westward to California. It is sometimes very common in the northern portions of the Northeastern States, but has not been recorded as a serious defoliator. The larvae are solitary in habit and feed on alder, apple, aspen, birch, boxelder, wild black cherry, maple, oak, and willow. The moths emerge from late in May to July, larvae are found from July to October, and the winter is passed in the pupal stage in a hairy cocoon.

The pale tussock moth (*Halisidota tessellaris* (A. & S.)) has a wing expanse of 1½ to 2 inches. The head and body are pale buff yellow, the collar and inner margins of the shoulder lappets tinged with bluish green, and the forewings translucent and crossed by five broad, irregular, slightly darker bands edged with fine, dark lines. The third band reaches only from the costal margin to the median vein. The hind wings are translucent, pale, and yellowish. The full-grown larva is about 1¼ inches long. The head is black, the body blackish and clothed in compact tufts of fine hairs varying from gray to yellowish with an olive tinge. Arising from each of the second and third thoracic segments is a pair of long, brownish to black pencils and just beneath each is a somewhat white pencil; also from the eighth abdominal segment projects a pair of blackish pencils (fig. 75, *B*).

This species ranges throughout the eastern part of the United States and southern Canada. The larvae are general feeders on the foliage of deciduous trees, and usually are found singly. Frequently they are very common in forests and along roadsides. The moths emerge in June and July, the larvae are prevalent from August to October, and the winter is passed in the pupal stage in a brownish, hairy cocoon made of silk and hairs from the body of the larva.

The sycamore tussock moth (*Halisidota harrisii* (Walsh)) cannot be distinguished from *H. tessellaris*, and the larva apparently differs only in color. The full-grown larva has a yellowish-brown head, and yellowish body clothed in whitish to yellow hairs, and the long hair pencils are orange. This species feed on sycamore and probably is found throughout the range of its food plant. The life history is similar to that of *H. tessellaris*. It has been noted in abundance on shade and ornamental trees in the Northeastern States.

The moth of **the fall webworm** (*Hyphantria cunea* (Drury)) is pure white with a wing expanse of about 1¼ inches, the forewing sometimes marked with blackish dots. The full-grown larva is about 1 inch long, generally pale yellowish or greenish with a broad, dusky, longitudinal stripe on the back and a yellowish stripe along the sides. The body is covered with whitish to reddish hairs, which arise from black and orange warts (fig. 76). This species is distributed throughout the greater part of the United States and Canada. It is a rather general feeder, and a well-known pest of deciduous shade trees, ornamental trees and shrubs, and those along roadsides. It affects the esthetic value of the trees rather than causing actual injury from defoliation, except in periods of extreme abundance (fig. 77).

There is one generation in the northern range of the insect, usually one and a partial second in the latitude of southern Connecticut and New Jersey, and two complete generations farther south. The moths emerge from May to early July, depending on the climatic range, and those of the second generation in July and August. The eggs are laid in white masses of 400 to 500 on the under sides of the leaves. Soon after they have hatched the larvae begin to spin a silken web over the foliage, enlarging it to enclose more food as they grow. They are gregarious until the last larval instar, by which time 2 or 3 feet of one or more branches are enclosed with a dirty web which contains excrement, molt skins, and bits of dried leaf clippings. The larvae may be found from June to October, the dates varying in the different regions. In general, the larvae of the first generation are active in June and July, the larvae of the second generation and those in the region of the single generation may be found from July to October. Pupation takes place in a thin cocoon usually spun in the duff on the

FIGURE 76.—The fall webworm (*Hyphantria cunea*), nearly full-grown larvae.

ground. When the outbreak is not widespread, the most practical method is to remove and destroy all webs as soon as they are discovered. A protective spray (p. 52) applied at the proper time will prevent injury.

The moth of *Seirarctia echo* (A. & S.) is white with the veins of the wings edged with dark brown or black. The wing expanse is about $2\frac{1}{4}$ inches. The full-grown larva is about 2 inches in length, and has a broad, slightly bilobed, orange-brown head. The body with the venter, legs, front of prothorax, and the anal segment is yellowish green to orange. The backs of the other segments are black, and each of them is crossed by two yellowish stripes and a row of orange-colored warts. The body is clothed in coarse hairs which, in general, are orange brown at the base and black at the tip.

This species has been recorded from Alabama, Florida, Georgia, and Mississippi, and its food plants include sabol palmetto, persimmon, and ground oak. An outbreak of this insect was observed by G. W. Barber [30] in April 1933 about 15 miles north of Daytona, Fla. The highway was literally covered with larvae for more than a mile, with stragglers extending about $\frac{1}{4}$ mile north and 2 miles south of the heavy

[30] Unpublished notes.

FIGURE 77.—Trees defoliated by the fall webworm, showing webs at the end of the branches.

infestation. The larvae became full grown the latter part of April and pupated in hairy cocoons, and the moths emerged in May.

FAMILY AGARISTIDAE

The members of a small family, the Agaristidae, are like the Phalaenidae, but are distinguished in the adult stage by the antennae, which are more or less thickened toward the tip instead of having the shaft taper regularly, as in the Phalaenidae.

There is one species, **the eight-spotted forester** (*Alypia octomaculata* (F.)), of considerable importance as a pest in the Northeastern States. The moth is velvety black and has a wing expanse of 1 to 1½ inches. The forewing has two large sulfur-yellow spots, the hind wing two white spots, and the thorax has sulfur-yellow spots on each side. The full-grown larva is about 1¼ inches long. The head and cervical shield are orange dotted with black, the body ground color is white, and each segment is marked with eight black transverse lines and a band of orange. The orange is most conspicuous on segments 4 and 11, and all the bands are marked by black, conical, elevated spots. This species is found from New England westerly and southerly to South Dakota, Colorado, and Texas. Its food plants include grape, Virginia creeper, and Boston ivy. There may be two generations or only a partial second generation each year. The moths emerge from May to July, and from July to August. Occasionally pupae remain in a dormant state through 1 year or more. The larvae are found from June to September, and sometimes they cause serious defoliation, particularly of vines used for ornamental purposes.

Family PHALAENIDAE (NOCTUIDAE)

The Noctuid or Owlet Moths

The noctuids make up the largest of all the families of Lepidoptera in North America. This group has been divided into many subfamilies and these, in turn, into many genera. Nearly 2,700 species are known to exist north of Mexico. The nocturnal habits of the moths and the fact that in the darkness their eyes often shine brightly, have suggested the names noctuids and owlet moths. There is considerable variation in form, size, and coloring; the majority, however, are medium in size and dull colored. In general, the thorax and body of the moths are stout, the forewings strong, with the outer margin shorter than the inner margin, and when at rest the wings are folded upon the abdomen so that the insects are triangular in outline. The antennae of most species are threadlike, fringed with hairs or brushlike, or in the males sometimes pectinate.

Taxonomists have found it very difficult to classify properly the species of this family. In some genera it is often necessary to study the genital structures to definitely determine the species. The larvae of most species are foliage feeders, but some are borers, and others gnaw into fruits. The majority of the larvae are naked, but some are distinctly hairy. They are provided with five pairs of prolegs. In most species the larvae are dull colored, but some are brightly marked.

Space does not permit a discussion of each genus and of all the species common in the eastern part of the United States. There are many publications in which the authors have given excellent descriptions of the stages of one or more species, together with data on the life history, food plants, and the distribution. Therefore, to conserve space here, only a few representatives are discussed in detail and others are listed with one or more references.

In the genus *Catocala* many of the moths are rather large, some having a wing expanse of over 3 inches. The forewings usually are gray or brown and marked with darker wavy or zigzag lines. The hind wings in most species are more or less black and conspicuously and broadly banded with shades of red, yellow, or white, which suggested the common name "underwings." When at rest the hind wings are entirely covered by the forewings. Barnes and McDunnough (*23*) published a paper on the life histories of these moths. The full-grown larvae range from about 1½ to 3 inches in length, and in color from light to dark shades of gray and brown, mottled, dotted, or streaked with darker shades. They may or may not have lateral filaments and a dorsal wart on the fifth abdominal segment. When they are at rest during the day, the colors of both larvae and the moths blend with those of the tree trunk or other objects which they select as resting places. The larvae of most species feed on the foliage of forest and shade trees or shrubs, but are not considered as serious defoliators. Present knowledge of this genus indicates that all species have one generation a year and pass the winter in the egg stage.

The genus *Acronicta* has nearly 100 species, many of which are indigenous to the eastern part of the United States. The larvae of most species feed on the foliage of forest and shade trees and, although some are very common, they seldom if ever become abundant enough to cause serious defoliation. In general, the adults are remarkably similar to one another, most species being moderately robust, gray and white with black markings, head somewhat retracted, thorax and abdomen untufted, legs unarmed, and antennae simple in both sexes. Many species have a daggerlike mark near the anal angle of the forewing, hence the common name **"dagger moths."** The larvae, however, exhibit a wide diversity in their external characters. Smith and Dyar (*384*) classified many of the species into five groups and gave adult and larval descriptions. Although some species have two generations a year, the majority probably have only one, and apparently in all cases the winter is passed in the pupal stage. A few of the more common species are discussed in the following paragraphs.

The cottonwood dagger moth (*Acronicta lepusculina* Guen.) has been the center of considerable confusion because of the diversity among the adults in this species and as a consequence many names have been added to the synonymy. The full-grown larva (fig. 78) is about 1½ inches long, rather densely clothed with long, soft, yellowish hairs, and on the backs of abdominal segments 1, 3, 4, 5, and 8 are single, long, black, hair pencils. The head, cervical shield, and thoracic feet are jet black, the skin of the body is dull whitish, and the venter has a brownish tint. The spiracles are black rimmed. In earlier instars the body has a greenish tint, the hairs are long and white, and the pencils black. This species is distributed through southern Canada and the northern part of the United States from the Atlantic to the Pacific. Poplar is the food plant, though occasionally it is found on willow. The moths emerge late in May to early in July, larvae are found from July to October, and the winter is passed in the pupal stage in cocoons composed of silk and bits of wood.

Acronicta leporina vulpina (Grote) is the American form of *leporina.* The full-grown larva is about 1½ inches long, and is densely clothed in long, fine, curved, white or yellow hairs, with a few bristly, black ones on the ends of the body. The head is greenish white, sometimes with black markings, the body greenish white, often with black dorsal spots patterned as the hair pencils in other species. Just prior to pupation the larva becomes much darker, varying from brown to blackish. This species is recorded from Canada, northern New England, New York, and northern Illinois. The favored food plant is poplar. Other authors also list willow and birch. The moths emerge in June and July, the larvae are found in August and September, and the winter is passed in the pupal stage in a frail cocoon on the ground.

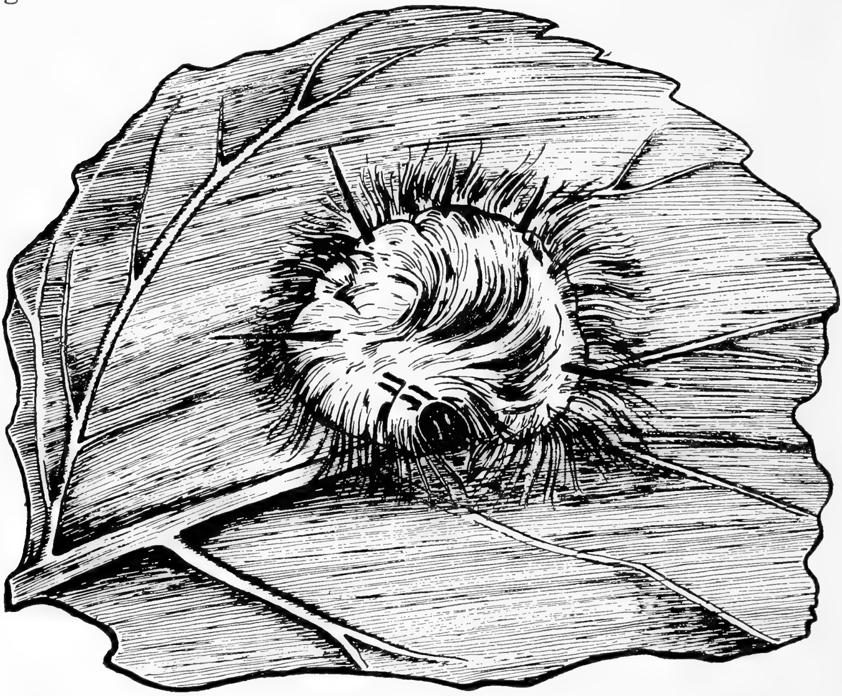

FIGURE 78.—Larva of the cottonwood dagger moth (*Acronicta lepusculina*).

The American dagger moth (*Acronicta americana* Harr.) is the largest species of the group. The full-grown larva is about 2 inches in length, clothed in fine, yellowish hairs, and bears a pair of long, black hair pencils on the backs of the first and third abdominal segments and a single one on the eighth. The head is shining black; the body greenish white above with a broad, black stripe on the top of the ninth and tenth abdominal segments, and a broken stigmatal, black stripe and traces of a subdorsal one. The body is blackish underneath.

This species occurs throughout the eastern part of the United States and Canada. In the Northeastern States it is often very common. Its food plants include apple, basswood, boxelder, chestnut, elm, maple, oak, willow, and other deciduous growths. The moths emerge from May to July, the larvae are found from June to October, and the winter is passed in the pupal stage in a cocoon composed of silk and hairs.

Acronicta impressa Wlkr. and *A. distans* (Grote) are possibly a single species. The full-grown larvae are somewhat variable. The head is shining black, the body velvety black, usually with a broad, diffuse, faint, reddish substigmatal stripe. The venter is sometimes reddish brown. There are pale tubercles from which arise short hairs, those on the second and third thoracic, and first, eighth, and ninth abdominal segments are somewhat bristly and either reddish brown or black; elsewhere the hairs are soft and pale yellowish. The larva is about 1¼ inches long. This species is distributed through the eastern part of the United States and Canada, west to the Rocky Mountains. Its food plants include speckled alder, apple, azalea, birch, cherry, poplar, sweetfern, strawberry, and willow. The moths emerge in May and June, and July to September, the larvae are found from June to October, and the winter is passed in the pupal stage in a silken cocoon spun tightly among the leaves on the ground.

The full-grown larva of **the smeared dagger moth** (*Acronicta oblinita* (A. & S.)) is about 1½ inches long. The head is black, sometimes tinged with red, the body velvety black dotted with yellow, usually with a somewhat broken subdorsal yellow stripe and a broad yellow stigmatal band notched above so that the white spiracles are surrounded by black. The tubercles vary from black to reddish, and each bears short, bristly, reddish hairs. Some specimens have transverse reddish bands reaching across the back to the spiracles. This species is distributed from Nova Scotia to Florida and west to the Rocky Mountains. Reports indicate that it is sometimes very common locally. Its food plants include speckled alder, apple, boxelder, wild cherry, poplar, and willow. The moths emerge from May to July, the larvae may be found from June to September, and the winter is passed in the pupal stage in a thin cocoon spun among the leaves on the ground.

The species of most economic importance in the family Phalaenidae are those commonly known as **cutworms.** They include a large number of species representing many genera. Several species confine their feeding to tender roots or stems and foliage close to the surface of the ground, and some of these occasionally cause considerable injury in forest nurseries. In addition to being pests in nurseries, in vegetable and flower gardens, and of field crops on the farm, many species climb shrubs and trees, and cause serious injury by feeding on the buds, foliage, flowers, green fruits, and succulent growths.

The cutworms, in general, are stout, hairless, and dull grayish or brownish in color. They normally conceal themselves during the day on the ground, or in some cases, beneath bark and in holes in the trees. They will also gather beneath burlap bands attached to trees. Because of the habit of concealing themselves during the day, serious damage often is done before the insects are discovered. Many species have long lists of food plants. The life histories of the various species differ considerably, and there may be one or more generations a year depending on the species and the climate. Some species hibernate in the egg stage, some in the larval stage, some in the pupal stage, and a few in the adult stage.

For control measures, clean cultivation, keeping the ground free of weeds, is recommended for the nursery and garden. If artificial control is necessary poisoned baits (p. 32) should be used for the ground-feeding species, and poison sprays or dusts (p. 52) should be used for those feeding on the trees and shrubs.

Since there are so many species that may be termed **"climbing cutworms,"** all cannot be discussed here. Those most commonly found injuring forest and shade trees and shrubs are species belonging to the following genera: *Euxoa*, *Chorizagrotis*, *Feltia*, *Agrotis*, *Peridroma*, *Lampra*, *Polia*, *Morrisonia*, *Sideridis*, *Ceramica*, *Homohadena*, *Graptolitha*, *Conistra*, *Amphipyra*, *Prodenia*, *Laphygma*, and *Drasteria*. Crumb (*123*) listed 30 species, together with descriptions of the larvae, their distribution and food plants. Phipps (*352*) listed 25 species, together with information on their seasonal history, importance, and for some species a description of the stages, and Schaffner and Griswold (*375*) listed many species, together with data on their food plants, seasonal history, and parasites.

Many species, about which little is known, undoubtedly are of more economic importance than is generally realized. *Polia latex* (Guen.) and several species of *Graptolitha* are sometimes locally abundant in the woodlands in the Northeastern States, and, although no complete defoliation by them has ever been recorded, their feeding during these periods of abundance must affect the vitality of their food plants.

The full-grown larva of **the green fruitworm** (*Graptolitha antennata* (Wlkr.)) is about 1½ inches in length, and pale green with a yellowish-green head. The body has a rather broad white or yellowish-white, longitudinal, dorsal stripe and on each side a narrower broken subdorsal and a broad irregular stigmatal stripe of the same color. The skin is smooth and minutely dotted with white, but the white, slightly raised tubercles give it a roughened appearance. This species is distributed through the eastern part of the United States and Canada. The larvae feed on apple, ash, maple, and other deciduous growths. Maple and ash trees were defoliated in local outbreaks in New York and Vermont a few years ago. It also causes serious injury to the green fruit of apple, pear, and cherry. The moths emerge during the fall, hibernate, and lay their eggs early in spring. The larvae feed from May to July and pupate in the ground.

The full-grown larva of *Orthosia hibisci* (Guen.) (=*Graphiphora alia* auct.) is about 1½ inches long. The head is pale, mottled with brown, the body light green with five longitudinal, white or cream-colored lines, the median line narrow, the subdorsal line somewhat broken and the stigmatal line generally rather broad and extending downward onto the anal proleg. The skin is smooth, and the upper part of the body is speckled with minute white dots. This species ranges from Maine through the Eastern, Northern, and Middle States, and is sometimes abundant locally. The larvae feed on the opening buds and foliage of apple, ash, birch, horsechestnut, oak, rhododendron, willow, and other trees and shrubs. Sometimes they cause considerable injury by chewing holes in the small, green fruit of apple and pear. The larvae are sometimes mistaken for those of *Graptolitha antennata*, but can be readily distinguished from them by their smooth skin and somewhat smaller head. The moths emerge in March and April, the larvae may be found from April until early in July, and the winter is passed in the pupal stage in the ground.

The full-grown larva of *Feralia jocosa* (Guen.) is about 1¼ inches in length. The head is yellowish to light brown, the body light green with pale dorsal, subdorsal, and stigmatal stripes, the latter bordered above with a red stripe. This species occurs in the southeastern part of Canada and the Atlantic States. The larvae feed on hemlock, larch, and spruce. The moths emerge in April and May, the larvae are found from May to July (later in Canada), and the winter is passed in the pupal stage in the ground.

The full-grown larva of *Phosphila turbulenta* (Hbn.) is about 1¼ inches in length. The head and cervical shield are black, the body above the spiracles is black with the prothoracic and last 3 abdominal segments marked with irregular white blotches, and the other segments have 12 broken white lines. The body below the spiracles is grayish green with 2 broken white stripes on each side. The legs are black. This species occurs in the Atlantic States, and the larvae feed on *Smilax* (greenbrier). The larvae are gregarious and often abundant locally. The moths emerge from June to August, the larvae are found from August to October, and the winter is passed in the pupal stage in the ground.

The full-grown larva of *Charadra deridens* (Guen.) is about 1½ inches in length. The head is shining black and hairy, and has three yellow spots, one on the clypeus and one on each side. The body is dull white tinged with greenish and clothed with long, silky, white hairs arising from small wartlike tubercles. This species ranges from Canada to Florida and Texas, and west to Colorado. Oak, maple, elm, and birch are the preferred food plants. The moths emerge in June and July, larvae are found from July to October, and the winter is passed in the pupal stage in a rather loosely spun cocoon in leaves on the ground.

The full-grown larva of *Raphia frater* Grote is about 1¼ inches in length. The head is pale, and the body bright green or tinged with blue and dotted with yellow. The back of the second thoracic segment bears two reddish protuberances, and on abdominal segments 1, 5, and 8 are transverse, somewhat crescent-shaped, yellowish bands edged in front with red. This common species is found in the Atlantic States, and its food plants include poplar and willow. The moths emerge in June and July, the larvae are found from July to September, and the winter is passed in the pupal stage in cocoons spun on the bark of trees or on the ground.

The full-grown larva of *Scolecocampa liburna* (Geyer) is about 1⅜ inches in length. The head is black and the body whitish with brown spots. This species occurred through the Atlantic States in 1902, according to Dyar (*141a*). It is common, and the larvae feed in the decaying sapwood of various species of trees, particularly the oaks, chestnut, and hickories. The moths emerge during Juy. The larvae are active during the late summer and fall, hibernate when partly grown, and complete their growth in the spring. Each pupates in the burrow in a loose cocoon composed of silk mixed with chips and frass.

The full-grown larva of *Epizeuxis aemula* (Hbn.) is dull brown and about ⅝ inch in length. The head is somewhat mottled and the body has a dark dorsal stripe. The spiracles and tubercles are black. This species was recorded in Dyar's list (*141a*) as occurring in the Atlantic States. It is common in the Northeastern States on spruce, particularly in ornamental plantings. The larvae are commonly found in webbed masses of dried needles and excrement on the branches. They feed on the older needles. The moths emerge in

June and July, the eggs hatch late in the summer, and the larvae feed for a few weeks, hibernate as partly grown larvae, and resume feeding again in the spring.

The full-grown larva of *Epizeuxis americalis* (Guen.) is about ¾ inch in length and dull brown with the tubercles black, slightly raised and rather prominent. This species probably has about the same range as *E. aemula*, and its seasonal history is very similar. The larvae feed on dried leaves and have been found in the nests of squirrels and ants.

Family NOTODONTIDAE

The moths of the Notodontidae are of moderate size, few having a wing expanse of more than 2 inches, and in appearance they resemble the Phalaenidae. In general they have a stout body densely clothed with hair, and the legs, especially the femora, are clothed in long hairs. The wings are strong but not very broad, the front wings in some species have prominent projecting lobes on the inner margins, and the anal angle of the hind wings rarely reaches the end of the abdomen. They are nocturnal and are often attracted to lights.

The larvae feed on the foliage of trees and shrubs, and most species live exposed, although a few species, such as *Ichthyura inclusa*, conceal themselves in tents or webs composed of silk and leaves. In this family, there is a wide variation in larval characters; they are either naked or clothed in hairs and some species have spines, fleshy tubercles, or prominent dorsal humps, and many are brightly colored. The transformation takes place in a thin silken or parchmentlike cocoon or in the ground. A monograph of the Notodontidae of North America was published by Packard (*324*) in 1895.

A few species are important as defoliators of forest and shade trees.

The moths in the species of *Ichthyura* have a wing expanse ranging from ¾ to 1¼ inches, and in general are grayish to light brown, with the head rather broad in front, eyes hairy, antennae short and well pectinated to the tip, and the thorax usually with a dark-brown median crest. The forewings are short and broad, apex slightly upturned, the outer edge a little bent, and usually marked by four cross lines, two of them forming a V. The hind wing has a rounded apex, and the legs are densely scaled. The thorax and inner margin of hind wings are densely hairy, and the abdomen in the male is long and slender with a spreading dark tuft at the end.

The poplar tentmaker (*Ichthyura inclusa*) is about 1¾ inches in length. The head is black with white hairs scattered over it, the body brownish to nearly black with four dorsal lines of light yellow, one bright and several indistinct lateral lines and yellowish marks. The back of the first abdominal segment bears a bifid black tubercle, and there is also a similar one on the eighth abdominal segment. The thoracic legs and anal shield are black, and the abdominal legs yellowish brown (fig. 79). This species is distributed through the Atlantic States and westward into the Mississippi Valley, and also reported from southern Canada, Nebraska, and Colorado. The larvae are gregarious, feeding on poplar, and when at rest live in a tent or web constructed by drawing together the edges of one or more leaves and lining them with silk. They are often abundant locally, causing severe defoliation on small groups of trees, particularly those growing more or less in the open. There are two generations or one and a partial second in most of its natural range.

The moths emerge from April to early July, and July to August, the eggs are deposited in clusters on the under side of leaves, the larvae are found from May to October, pupation takes place in a loose cocoon formed by drawing leaves together, and the winter is passed in this cocoon on the ground. The old webs hanging on the trees are sometimes mistaken for those of the browntail moth. *Ichthyura albosigma* Fitch also feeds on poplar, and *I. apicalis* Wlkr., *I. brucei* Hy. Edw., and *I. strigosa* Grote feed on poplar and willow, but they are generally held in check by natural factors.

FIGURE 79.—Nest of the poplar tentmaker (*Ichthyura inclusa*) torn open to show the larvae.

The species in the genus *Datana* closely resemble one another in both the adult and larval stages. The moths are rather attractive and are of various shades of brown, the fore part of the thorax having a conspicuous patch of a darker shade. The wing expanse in each species ranges from about 1½ to 2 inches. The forewings are crossed with bars of darker shades, most species have a discal dot, the hind wings are of a lighter color and without lines, and the body is rather heavy. The moths, in general, emerge between May and August. The eggs are deposited in a cluster on a leaf of the food plant. The larvae are gregarious in habits, all from one egg cluster feed in a colony and usually strip all the foliage from one small branch before moving to another. When disturbed they have a peculiar habit of raising their heads and anal ends in an upright position and clinging to a twig or branch by their abdominal legs. The larvae may be found from June to October. Pupation takes place in the ground late in the summer or fall, and the winter is passed in the pupal stage. There is generally one generation a year in the Northeastern States, but farther south some species may have two generations, or at least one and a partial second.

As all species of *Datana* are gregarious, the simplest method of control in light infestations is to remove and destroy each colony. In heavier infestations spray with an arsenical or DDT (p. 52). **For cautions in the use of these materials see pp. 25 and 34.**

One species is of particular importance as a pest of forest and shade trees, and several others are of lesser importance. A description of the larvae of those species that most commonly attract attention as pests, together with the food plants and general distribution of each are given here.

The full-grown larva of **the yellow-necked caterpillar** (*Datana ministra* (Drury)) is black and about 2 inches long, moderately clothed with white hairs. The neck is narrowly ringed with yellow, the cervical shield is waxy yellow, and the body has four narrow, pale-yellow, longitudinal stripes on the sides, narrower than the intervening spaces. The venter has a pale-yellow median line, and a line on each side interrupted by the bases of the legs. All legs are yellowish at base, the rest of the true legs and a band on the prolegs are black. The partly grown larva has the head and cervical shield black and the body reddish brown with yellowish stripes.

This species occurs throughout most of the Eastern States west to Missouri and in southern Canada. Its food plants include apple, birch, blueberry, basswood, cherry, elm, hawthorn, oak, and other deciduous growth. Often it is abundant locally, particularly on unsprayed apple trees.

The full-grown larva of *Datana angusii* G. & R. is black with pale-yellow lines and is quite similar to *D. ministra*, but can be distinguished from that species by its cervical shield being entirely black. This species is found in the Atlantic States west to Illinois and north into southern Canada. Its larvae feed on beech, gray birch, butternut, hickory, and the oaks.

The full-grown larva of *Datana drexeli* Hy. Edw. is about 2 inches long and moderately hairy. The head and body are black, with the cervical shield and anterior portion of the prothoracic segment honey yellow, and the tenth abdominal segment yellow except for the black anal plate and anal legs. The body has 11 longitudinal, yellow stripes, narrower than the intervening spaces, and the bases of the legs and corresponding spots on legless segments are dark yellow. The partly grown larva has the head, cervical shield, anal plate, thoracic and anal feet, and the abdominal feet outwardly black, and the body brownish with yellow stripes. This species is found in the Atlantic States, west to Ohio, and its larvae feed on blueberry, basswood, sassafras, and witch-hazel.

The full-grown larva of *Datana major* G. & R. has the head, cervical shield, the legs and corresponding spots on the legless segments of a mahogany red. The body is about 2 inches long, black, sparsely clothed with whitish hairs, and has four longitudinal rows of whitish (occasionally yellowish) spots on each side, and also three rows on the venter. The earlier instars vary in color and markings, but in general the head is blackish or dark red, the cervical shield and anal plate black or partly brown, the body varies from reddish to brownish black with white or yellowish stripes, and the bases of the legs are reddish. This species occurs throughout the Atlantic States and west, at least to Illinois. Its food plants include andromeda, apple, azalea, blueberry, and huckleberry.

The full-grown larva of *Datana perspicua* G. & R., **the sumac datana,** is moderately hairy and about 2 inches long. The head is dark reddish to black, the cervical shield reddish brown, and the anal plate blackish. The body is deep straw or lemon yellow with 11 longitudinal dark reddish-brown to blackish stripes, the median dorsal stripe and

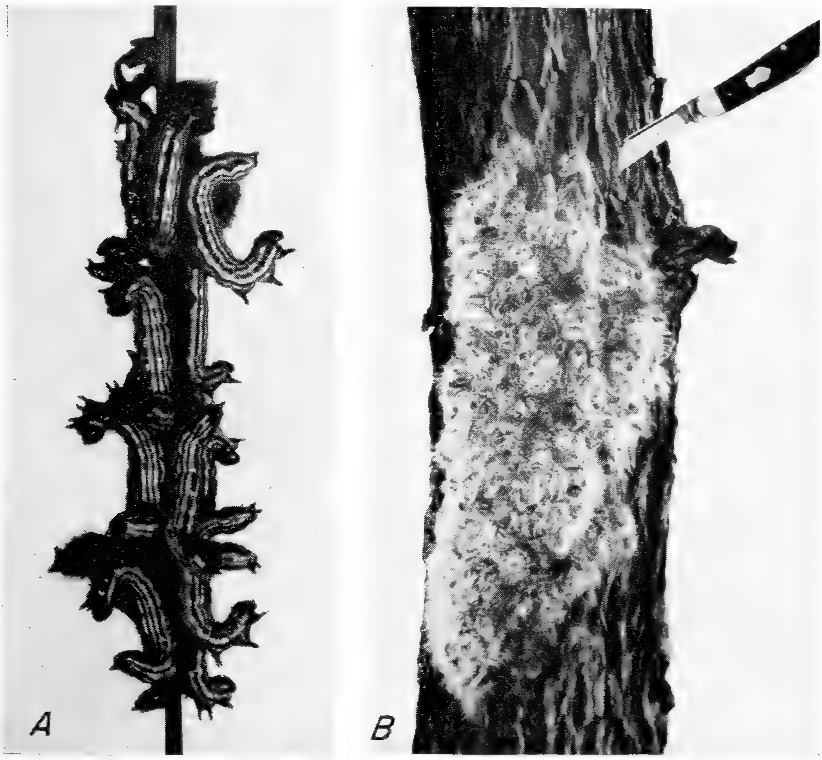

FIGURE 80.—Datana larvae: *A*, The sumac datana (*Datana perspicua*); *B*, the walnut caterpillar (*D. integerrima*).

the stigmatal stripes wider than the others. The legs are black with reddish-brown bases (fig. 80, *A*). The partly grown larva has a black head, a blackish cervical shield, and the body is lemon yellow with dull, reddish stripes. This species has been recorded from New England south to Virginia and west to Colorado and Montana. Its larvae feed on sumac (*Rhus glabra*, *R. typhina*, and *R. copallina*).

The full-grown larva of **the walnut caterpillar** (*Datana integerrima* G. & R.) is nearly 2 inches long and clothed in long, dirty-white or grayish hairs. The head and body are black and the abdominal legs are black outside and reddish inside (fig. 80, *B*). The partly grown larva varies from brick red to dark reddish brown, with yellowish to grayish longitudinal stripes. The head and cervical

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shield are black. This species is distributed through most of the eastern part of the United States, west to Kansas. Its food plants are butternut, black walnut, hickory, and pecan. The larvae are often abundant locally in parts of Massachusetts and more numerous farther south, causing serious defoliation. In the Northeastern States there is one generation annually, but Leiby (*272*) found two generations in North Carolina, the larvae of the first in June and July and those of the second in the latter part of August and in September.

The full-grown larva of *Datana contracta* Wlkr. is about 2 inches long and clothed in long, white hairs. The head is black, the cervical shield transversely oblong and waxy orange yellow, and the anterior portion of the prothoracic segment is blackish. The body is black with 11 longitudinal, yellowish-white stripes, the one just below the stigmatal line much wider than the others. The thoracic legs are black with orange-yellow fleshy bases, the middle abdominal legs orange yellow, each with a black patch on the outer side, and the anal legs and anal plate are black. This species is distributed from Massachusetts west to Wisconsin and south to Arkansas. Its food plants are oak and sycamore.

The full-grown larva of *Hyperaeschra stragula* Grote is about 1½ inches in length, the head is oval, flattened in front, and the vertex slightly bilobed. The body is thickest on the second and third abdominal segments, on each of which is a thick, fleshy, conical tubercle directed posteriorly, the anterior one the larger. The back of the eighth abdominal segment is raised into a prominent hump and the anal plate is smooth and rounded. The general color is pearly gray, somewhat marbled with brown and marked with a reddish-brown, dorsal line between the head and the second tubercle. The hump on the eighth abdominal segment is pale rust color, yellowish red on the sides, and has a stigmatal line of pink. This species has been recorded from Canada to New Jersey, Ohio, and Wisconsin. Its food plants are poplar and willow. There is at least a partial second generation in some localities, the moths emerging in May and June, and July to August. The larvae may be found from June to October, and the winter is passed in the pupal stage in the ground.

The larva of *Pheosia rimosa* Pack. with its caudal horn, resembles those of some of the Sphingidae. When full grown it is about 1¾ inches long, glossy, and of a lead color with a purplish tinge. The head is rounded and bilobed, all segments of the body are slightly swollen in the middle, the eighth abdominal segment swollen dorsally and bearing a well-developed horn. The anal plate is coarsely granulated and rust red, and the spiracles are black and ringed with yellowish white. This species is distributed from the Atlantic to the Pacific in Canada and the Northern States, extending southward into the Middle States. The larvae feed on poplar and willow. There may be two complete generations in some parts of the United States, the moths emerging in June and July, and in August. The larvae may be found from July to October, and the winter is passed in the pupal stage in frail cocoons in the leaves on the ground.

The moth of *Nadata gibbosa* (A. & S.) is light buff with a rusty tinge and a high pointed tuft on the front of the thorax which is very hairy beneath. It has a wing expanse of 1½ to 2 inches, the forewings with a slightly curved brownish line beyond the discal cell and parallel with the outer margin. There are two small silvery discal dots and an inner, rusty line crossing the wing. The hind wings are paler and the legs hairy. The full-grown larva is pale pea green and about 1¾ inches in length. The head is large and rounded, the mandibles yellow and tipped with black, making them conspicuous, and the body is cylindrical, tapering toward the end, naked, and without tubercles, humps, or spots, but with a yellowish longitudinal subdorsal stripe on each side. The spiracles are deep red, and the anal plate has the apex rounded and edged with yellow. All the legs are pale pea green.

This species ranges throughout the United States and Canada. The larvae feed on various species of oak and occasionally on maple, beech, and birch. Although common generally, the natural control factors apparently prevent outbreaks. There may be two generations or one and a partial second as far north as the New England States; the moths emerge from May to July and August to September, the larvae are solitary and may be found from May to October; and the winter is passed as a pupa in the ground.

The full-grown larva of *Lophodonta angulosa* (A. & S.) is pea green in color and somewhat similar to that of *Nadata gibbosa*. The head is rounded, the body cylindrical, smooth, and tapering posteriorly. A faint, double, median, whitish line, and a distinct, lateral, reddish stripe edged below with white extends from the head to and on the edge of the anal plate. The body is about 1½ inches long. This species is distributed from Maine to Florida, and west into the Mississippi Valley and Texas. Its food plants are the various oaks. Apparently there are two generations in the South and only one in the Northern States. The moths emerge from April to July and in July and August, the larvae may be found from May to October, and the winter is passed in the pupal stage on the ground in cocoons composed of silk mixed with grains of dirt.

The full-grown larva of *Nerice bidentata* Wlkr. is a polished bluish green and about 1¼ inches in length. The head is narrow but high and slightly bilobed, pale green with four broad white bands in front and on the sides, the lateral ones edged by a blackish line. The thoracic segments are all of nearly the same size and width, and unarmed. The abdominal segments 1 to 8, inclusive, have each a large anteriorly directed prominence ending in a bifid ridge, the incision being transverse, and the tip of each tubercle brownish red. The ninth abdominal segment bears a pair of small dorsal tubercles, and the anal plate is quite smooth and has four longitudinal, white bands. This species ranges from Canada and the Northeastern States west to Wisconsin and Kansas. The larvae feed on elm. Apparently there is at least a partial second generation in some localities. The moths emerge in May and June, and in August. The larvae may be found from June to September, and the winter is passed in the pupal stage in silken cocoons on the ground.

The moth of *Symmerista albicosta* (Hbn.), **the red-humped oak worm,** is ashen gray and has a wing expanse of 1½ to 2 inches. The head and prothorax are tawny and whitish in front, the forewings have a long white area near the outer two-thirds of the costal margin, and the region below the white portion is usually dark ash tinged more or less with fuscous. The submarginal region is a little lighter and marked with a series of inwardly oblique, black, linear, lunate spots, and the hind wings are smoky. The full-grown larva is about 1¾ inches in length, the head rounded, orange red, and wider than the

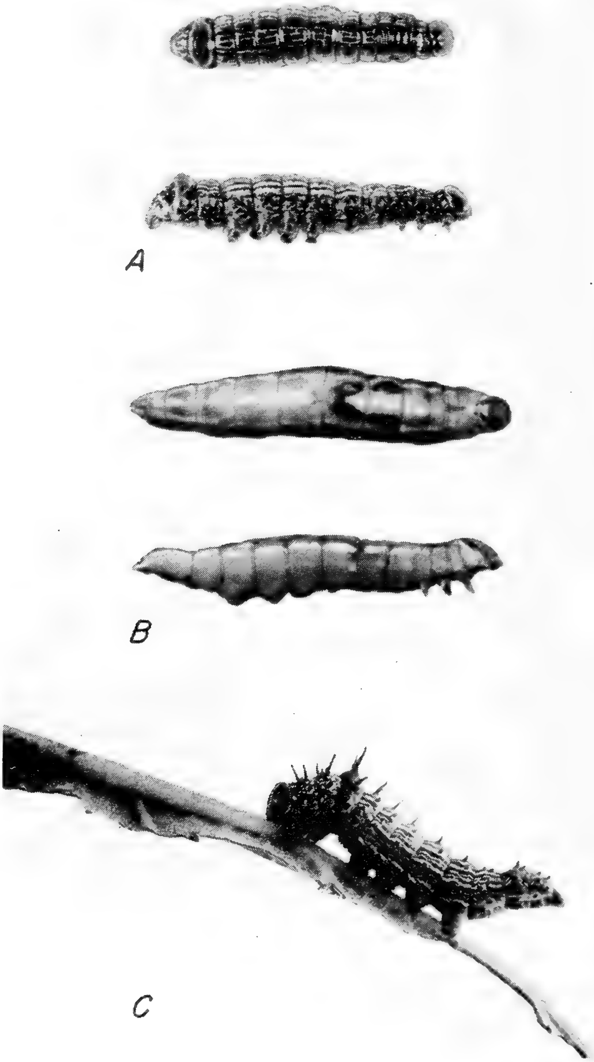

FIGURE 81.—Notodontid larvae: *A*, *Symmerista albicosta*; *B*, larva of the saddled prominent (*Heterocampa guttivitta*); *C*, the red-humped apple tree caterpillar (*Schizura concinna*). (C, Courtesy Conn. Agr. Expt. Sta.)

thoracic segments (fig. 81, *A*). The body is smooth, shining, and naked, and increases in width back to the orange-red enlargement on the eighth abdominal segment. It has a yellow subdorsal and a yellow stigmatal stripe on each side, five median, dorsal, blackish lines on the abdominal segments, three blackish, lateral lines between the yellow stripes on each side, and some black markings below the stigmatal line on a pale lilac ground. The legs are orange to orange red. The larvae have only three median, dorsal, blackish lines during the early instars.

This species ranges from Nova Scotia and southeastern Canada south to Florida and westward to Minnesota and Kansas. The larvae feed on various species of oak, particularly white oak and bur oak, and sometimes on basswood, beech, elm, and maple. They are gregarious during the early instars and often are common to abundant locally in the forests, sometimes causing considerable defoliation. The moths emerge from May to July, the eggs are deposited in small masses on the under sides of the leaves, the larvae may be found from June to October, and transformation to the pupa takes place in a thin, white, tough, oval cocoon spun among the leaves or in the duff on the ground. The winter is passed in the pupal stage. According to some writers there are two generations a year in the South.

Symmerista albifrons (A. & S.).—The larva of this species is similar in appearance to *S. albicosta* and the two go under the same common name, but *S. albifrons* has only three median, dorsal, blackish lines throughout the larval period. Its distribution is similar to that of *S. albicosta*, but apparently it is more abundant in the Midwest and in Florida than in other sections. Records show that the larvae are often abundant in Minnesota, and they feed on paper birch, elm, basswood, and scarlet oak, and sometimes on white oak. The life cycle is similar to that of *S. albicosta*.

The moth of **the saddled prominent** (*Heterocampa guttivitta* (Wlkr.)) is brownish gray with a wing expanse of 1½ to 2 inches. The forewing is crossed with more or less indistinct and variable dark markings. The full-grown larva is about 1½ inches long, and of variable color markings, though most often yellowish green, or light green with a bluish cast. The head is large with a broad reddish lateral band, and the body is smooth, usually with a reddish-brown or purplish saddle-shaped patch on the back and often with other markings similar in color (fig. 81, *B*).

This species ranges from eastern Canada south to Florida and Texas and west to Colorado and Nebraska. Its favored food plant is beech, although sugar maple and apple are sometimes severely attacked. In periods of abundance many other species of trees are fed upon when associated with the favored food species. The moths emerge late in May and early in June. The female is capable of depositing about 500 eggs, and these are laid singly on the leaves. Hatching takes place in about 9 or 10 days. The first instars feed on the epidermis of the leaves, but later instars devour all but the principal veins. They become full grown in 5 weeks or more, depending somewhat on the weather and food supply. Pupation takes place in the leafmold sometime between the middle of July and late August. In the Northeastern States there is only one generation.

Patch (*334*), Collins (*97*), and others have published reports on serious outbreaks in New England and New York. Outbreaks have occurred in this region in 1907–09, 1917–20, 1930–31, and 1940–41. In some areas where heavy defoliation occurred for two consecutive years there was considerable mortality of the trees, and on many of the trees that survived some of the large branches and large portions of the tops were killed. Quite often large numbers of the green-striped maple worm (*Anisota rubicunda*) are associated with outbreaks of *Heterocampa guttivitta.*

The moth of *Heterocampa manteo* (Dbldy.) is ashy gray with a wing expanse of about 1½ to 1¾ inches. The forewing markings are rather indistinct, and the hind wings have a brownish tinge. The full-grown larva is about 1½ inches long with very variable coloration. The head is large with two broad, lateral bands, the inner brown or black and the outer creamy white. The body is smooth, yellowish green with a pale, mid-dorsal longitudinal line, and with more or less reddish-brown coloration on each side bordered laterally by a creamy yellow stripe, below which is a yellowish, stigmatal stripe. This species is known to occur in the eastern part of the United States from Maine to South Carolina and Alabama, and west to the Lake States. Its food plants include oak, beech, basswood, paper birch, elm, and other deciduous trees. In the Northeastern States, the moths emerge, for the most part, during June and July. The larvae may be found from July to October. The winter is passed in the leafmold or topsoil as prepupal larvae. Laboratory records indicate that occasionally some prepupal larvae remain dormant in the soil throughout an entire year. It is a rather common species in the hardwood forests, occasionally causing severe defoliation in sporadic outbreaks, and is often associated with *Symmerista albicosta* and *S. albifrons.*

Heterocampa umbrata (Wlkr.) is found on maple and oak; *H. biundata* (Wlkr.) on beech, birch, wild cherry, maple, and other deciduous growths; and *H. bilineata* (Pack.) on elm and birch. Their life cycles are similar to that of *H. guttivitta.*

The larva of *Dicentria lignicolor* (Wlkr.) closely resembles those of species of *Schizura.* The full-grown larva is about 1½ inches in length. The head is bilobed and pale, with a dark, brownish irregular branched band on each side of the face, meeting on the vertex. These bands outline small, whitish patches on the face. On the first abdominal segment there is a large dorsal tubercle which is slightly cleft and each terminal wart has a dark hair. The eighth abdominal segment has a smaller, brownish tubercle. The sides of the thoracic segments are deep pea green, as are also in part the sides and backs of abdominal segments 4 to 9. The venter and a long, triangular patch on the back of the thorax, the first three and tenth abdominal segments, and the venter and part of the sides of other segments are marked with shades of light brown and reddish brown. There is also a light patch on the back of the sixth abdominal segment.

This species has been recorded from Maine to Georgia and west to Texas and South Dakota. Its food plants include various species of oak and beech. In the Northeastern States the moths emerge in July and August, the larvae are found from August to October, and the winter is passed as prepupal larvae in tough parchmentlike cocoons on the ground.

The moth of **the red-humped caterpillar** (*Schizura concinna* (A. & S.)) is grayish brown with a wing expanse of from 1 to 1⅜ inches. The forewings are obscurely marked, but the hind wings are nearly concolorous. The full-grown larva is about 1 inch long. The head is coral red, the body is marked with black and yellowish lines, and on the back of the first abdominal segment is a conspicuous red hump. The body is armed with short, stout, black spines in a double row on the back and smaller ones along the sides of the body (fig. 81, *C*). This species is distributed from Canada to the Gulf of Mexico and from the Atlantic to the Pacific. The larvae commonly feed on apple, wild black cherry, elm, poplar, rose, and willow, and sometimes on other deciduous growths. They are often locally abundant in unsprayed apple orchards, along roadsides and fence rows, and on ornamentals.

There may be one or two generations, depending on the climatic range, the moths emerging from May to July, and in July and August. The eggs are white and are deposited in masses of 100 or less on the under sides of the leaves. The larvae are gregarious, feeding from the under sides of the leaves, at first skeletonizing and later devouring all but the midrib. They completely defoliate one branch before migrating to another. The full-grown larva constructs a parchmentlike cocoon in the duff on the ground, in which it hibernates, pupating in the spring. In light infestations the most practical control practice is to collect and destroy the colonies as soon as they are discovered. There should be no injury by this insect where spray programs are carried out.

Schizura ipomoeae Dbldy., **the unicorn caterpillar** (*S. unicornis* (A. & S.)), and *S. leptinoides* (Grote) feed on apple, wild cherry, willow, and other deciduous growths, and *S. badia* (Pack.) feeds on viburnum. These species are sometimes common locally, but their natural control factors prevent serious outbreaks.

Four species of *Cerura* are more or less common in the eastern part of the United States. *C. borealis* (Bdv.) feeds on wild cherry, and *C. occidentalis* Lint., *C. cinerea* Wlkr., and *C. multiscripta* Riley feed on poplar and willow. The larvae have rather large broad heads, but the prothoracic segment of each with its pair of lateral tubercles is wider. The body tapers gradually to the end, the anal plate is long, and the anal legs are modified, forming stemapoda, which are filamental and extensile. The color is green and brownish or tinged with red or purplish. Exclusive of caudal appendages the larvae measures 1 to 1½ inches. The caudal appendages measure up to about ⅔ inch.

The full-grown larva of *Fentonia marthesia* (Cram.) is nearly 2 inches long. The head is pale green, rather large, flat in front, subconical, and with the vertex high and conical. It is pinkish on the sides. The prothorax has a small, double, reddish tubercle on the back, and the body is thickest in the middle, pale green, and marked by a dorsal yellowish-white stripe, and occasional pinkish spots. The anal legs are represented by two slender filaments held outstretched, not quite so long as the body is thick. This species ranges from Maine to Florida and Texas. The larvae feed on the foliage of beech, maple, poplar, oak, and sycamore. The moths emerge in June and July, the larvae may be found from July to October, and the winter is passed as pupae in thin, silken cocoons spun between leaves on the ground.

The full-grown larva of *Gluphisia septentrionis* Wlkr. is pale green and about 1¼ inches long. The head is rounded, green, and smooth, with a blackish stripe on each side. The body tapers toward each end, is unarmed, is marked with a yellow subdorsal line on each side, and on the back between the subdorsal lines is a series of pinkish to reddish blotches usually most prominent on the thoracic segments and the abdominal segments 3 to 9. In some of the earlier instars the head is without the lateral stripe, and there are no pink spots on the body. This species favors the cooler regions and ranges from Canada to the Middle States and west to Colorado. The native poplars are the favored food plants, particularly *Populus tremuloides*. There is at least a partial second generation in some localities. The moths emerge late in May and in June, and in July and August; the larvae may be found from June to September, and the winter is passed in the pupal stage on the ground in cocoons composed of silk and leaves.

Family LYMANTRIIDAE (LIPARIDAE)

The Tussock Moths or Liparids

The family Lymantriidae includes some of the most serious defoliators in the United States. The moths are rather plain in appearance and of medium size. The females of some species are wingless, others, though winged, have such a heavy body that they are unable to fly, or for only short distances, but others are rather strong flyers. Both sexes when winged have pectinate antennae, those of the males very prominent, but the wingless females have rather narrowly pectinate or serrate antennae. In a few species the female uses the abdominal hairs for packing and covering her eggs, and others coat them with a viscid secretion which hardens and forms a protective covering. The hairs of some species, in all the stages, are poisonous to man when they come in contact with the skin. This is particularly true of the browntail moth.

The larvae of our native species are hairy and have conspicuous dorsal tufts of hairs on certain segments, hence the common name "tussockmoths." Some of the native species and those introduced species that have become established in this country are marked with brightly colored spots, stripes, or tubercles.

The male moth of **the white-marked tussock moth** (*Hemerocampa leucostigma* (A. & S.)) is ashy gray with feathery antennae and has a wing expanse of about 1¼ inches. The forewings have wavy bands of a darker shade and a conspicuous white spot near the anal angle. The female is wingless and has simple antennae. Its body is stout, hairy, and of a dirty-white color. The eggs are deposited in a mass on the old cocoon, and are covered with a frothlike substance which hardens and forms a protective covering. The egg masses are from ½ to ¾ inch long. The full-grown larva is about 1¼ inches long. It can be identified by its coral-red head, the pair of upright pencils of long black hairs on the prothorax and another black tuft on the eighth abdominal segment, the brushlike tuft of white or yellowish hairs on each of the first four abdominal segments, and the reddish dots on the sixth and seventh abdominal segments. The body is slender, cream yellow, with a broad black longitudinal stripe on the back and a broader, grayish one on each side. The sides of the body are clothed in white and blackish hairs radiating from rows of small yellow tubercles.

This species occurs in the eastern part of the United States and Canada, and west into Colorado and British Columbia. It is a rather general feeder on foliage of deciduous trees and shrubs. The more favored species include apple, basswood, elm, horsechestnut, the poplars, Norway, silver, and sycamore maples, rose, sycamore, willow, and wisteria. The winter is passed in the egg stage, and hatching takes place between April and June, depending on the climatic region. The newly hatched larvae skeletonize the leaves, later eat holes through other leaves, and finally devour all but the main stem. They can spin down on silken threads and when small may be carried long distances by the wind. The larval stage is completed in 30 to 40 days, when grayish cocoons, consisting of silk and hairs from the body, are spun under branches or in crevices. The pupal stage lasts about 2 weeks. In the vicinity of Washington, D. C., there are three generations a year, two in New Jersey and Connecticut, one with a partial second in Massachusetts, and usually only one farther north. This is a serious pest of shade trees, principally in cities and the larger villages. It is commonly found in deciduous forests, but seldom in abundance. In 1897 Howard (*241*, *242*) published on the results of studies of the parasites of this species, and in 1899 (*243*) on its life history and habits.

The adults and larvae of *Hemerocampa definita* (Pack.), **the definite-marked tussock moth,** closely resemble those of *H. leucostigma* in form and size, and in the arrangement of the tufts of hairs on the larvae. The female, clothed in golden-brown hairs, deposits her eggs in a mass on the old cocoon and uses the hairs from her body for packing and covering the eggs. These egg masses are sometimes mistaken by the layman for those of the gypsy moth. The larva is yellow with a pale, almost colorless, dorsal stripe and a black spot behind each of the second and third tufts of hairs on the abdomen. It is seldom of economic importance.

The male of **the rusty tussock moth** (*Notolophus antiqua* (L.)) is of a rusty color, otherwise both sexes are similar in form and coloration to the white-marked tussock moth. The eggs are deposited in a cluster of a single layer on the cocoon and are naked. The full-grown larva is about 1⅛ inches long and can be identified by its black head, dark-gray body, the black hair pencil on each side of the second abdominal segment, and the reddish-orange tubercles bearing the hairs. The tufts on the prothorax and abdomen are similar to those on the larva of the white-marked tussock. It has been recorded from the northern parts of the United States, Canada, and Europe. It is most common in the Northern States and occasionally is abundant locally. The larvae feed on a wide variety of deciduous trees. They are recorded as injuring coniferous seedlings in Europe. There is normally one generation, possibly a second in Massachusetts and south, otherwise its seasonal history is similar to that of the white-marked tussock moth.

The genus *Olene*, **the oak and pine tussocks,** has several species indigenous to the eastern part of the United States. The larvae have the tufts of hairs characteristic of the tussock moth group and have a black head and gray or brown body rather densely clothed with hairs. Some species have a plumose black hair in each of the lateral tufts. The moths are gray or brownish and are quite prominently marked, but it is difficult to determine them specifically. Both sexes are winged, and the female has a rather heavy body. In the Northern States the moths emerge from late in June to August. The eggs hatch late in the summer, the young larvae feed for a few weeks, then seek a place to hibernate under loose bark or in crevices, and complete their growth in the spring.

Olene atomaria (Wlkr.), *O. basiflava* (Pack.), and *O. vagans* B. & McD. are sometimes common locally in the Northeastern States, and in general are oak feeders, although sometimes found on apple and birch. *O. tephra* (Hbn.) is reported from Quebec and Maine on oak. *O. meridianalis* B. & McD., is recorded from the Southeastern States on oak. *O. cinnamomea* G. & R. is found on elm and has been recorded from New Hampshire and Massachusetts west to Wisconsin. *O. plagiata* (Wlkr.) (=*pini* Dyar) is found in the Northeastern States and from Quebec to Wisconsin. Its larvae attack jack pine, pitch pine, red pine, white pine, spruce, and sometimes fir. This species is an important forest pest, outbreaks having occurred in Wisconsin in 1909–10 and 1922, causing considerable mortality over extensive areas.

The Gypsy Moth

The male of **the gypsy moth** (*Porthetria dispar* (L.)) has a slender body and is dark brown with blackish bands across the forewings. It flies well, by day, in a zigzag line of flight. The female is nearly white with wavy blackish bands across the forewings, and the abdomen is clothed in yellowish hairs. The wing expanse is about 2 inches, but because of the large, heavy abdomen she does not fly. The eggs are deposited in masses usually of 400 or more and are packed in yellowish hairs removed by the female from her body. They are deposited on under sides of branches, on tree trunks, under loose bark, in cavities, on fences, in stone walls, in fact, any place near where the larvae pupated. The mature larva is from 1½ to 2½ inches long. The head has yellow markings, the body is dusky or sooty-colored and hairy, and on the dorsum is a double row of 5 pairs of blue spots, followed by a double row of 6 pairs of red spots (fig. 82). The pupa is dark, reddish brown, has a sprinkling of reddish hairs, and is attached to some object by a few silken threads.

Distribution.—The gypsy moth was accidentally introduced into Massachusetts from Europe about 1869. At present most of New England, excepting the northern half of Maine and probably some of the colder areas in New Hampshire and Vermont, is infested to some extent. Several local infestations have been found in the eastern part of New York, also infestations embracing some 700 square miles in the northeastern part of Pennsylvania. In New Jersey a severe infestation was found in a plantation of blue spruce near Somerville in 1920. These trees had been imported from Holland about 1910, prior to the enactment of the Federal Plant Quarantine Act, and there seems to be no doubt that the pest was introduced into New Jersey with the shipment of trees. Eradication work in New Jersey was begun soon after the infestation was discovered, and the insect was found at that time in scattered localities embracing about 400 square miles surrounding Somerville. As far as is known no egg clusters have been found in the State since 1935. A small infestation was found in 1914 at Bratenahl, near Cleveland, Ohio, but this was promptly exterminated.

In 1923 an area known as the "Barrier Zone" was established by the Bureau of Entomology in cooperation with the State of New York. This zone embraced an area of over 8,000 square miles extending from Long Island Sound east of the Hudson River (excluding Westchester County, N. Y.) to the Canadian border, a distance of over 250 miles ranging in width from 25 to 30 miles, where intensive eradication work is centered in an attempt to prevent westward dispersion of the pest. Burgess and Baker (*70*) published a history of the work against the gypsy moth.

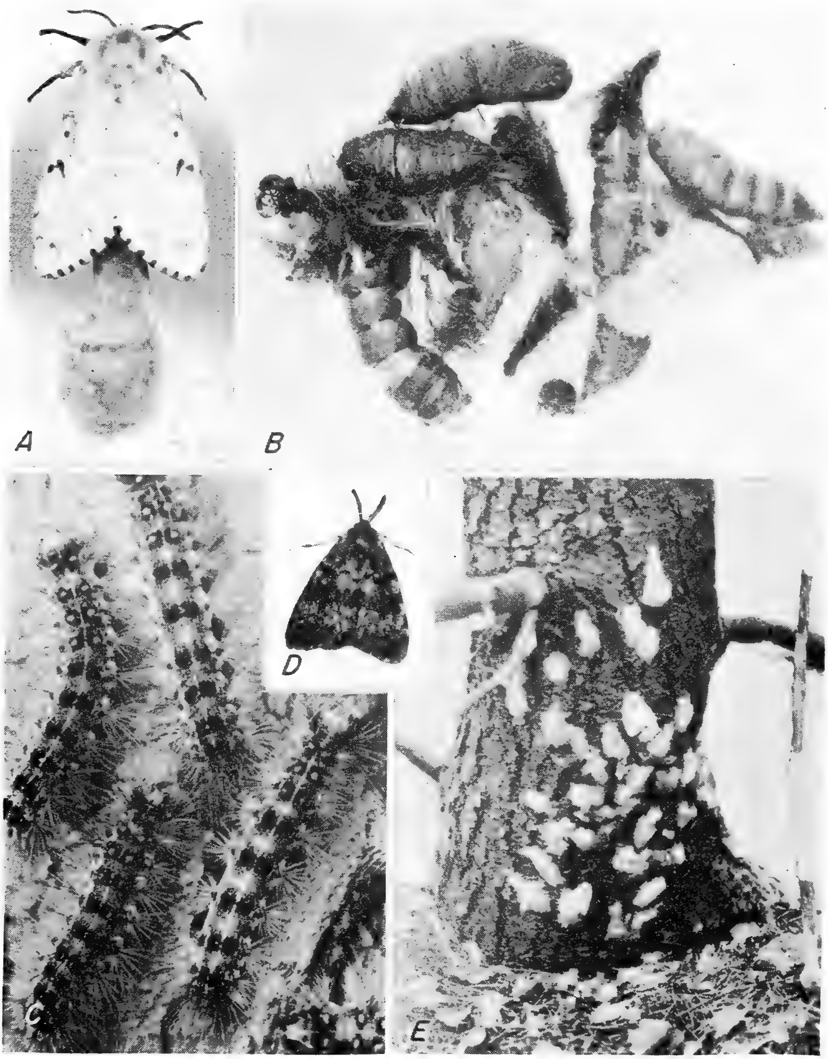

FIGURE 82.—The gypsy moth (*Porthetria dispar*) : *A*, Female moth ; *B*, pupae ; *C*, larvae, or caterpillars ; *D*, male moth ; *E*, egg masses. All about ¾ natural size.

The Federal Plant Quarantine Act of August 20, 1912, with revisions, regulates the shipment of all evergreen products, nursery stock, forest products, and stone and quarry products originating within the infested areas. The inspection required by this act has aided materially in preventing the shipment of the pest to other parts of the United States.

Food Plants of the Gypsy Moth.—Apple, speckled alder, basswood, gray and river birch, hawthorn, oaks, poplars, and willows are most favored by the larvae of the gypsy moth. Species distinctly less favored, though eaten by the larvae in all instars, include black birch, paper birch, and yellow birch, the cherries, chestnut, elm, black gum, hickories, hornbeam, larch, maples, and sassafras. Species not favored by the young larvae but favored by the larger larvae include beech, hemlock, southern white cedar, and the pines and spruces native to the eastern part of the United States. Those species of trees not at all favored as food include ash, balsam, butternut, black walnut, catalpa, red cedar, flowering dogwood, American holly, locust, sycamore, and yellow poplar.

Seasonal History and Character of Work.—The moths emerge and mate, and the females deposit eggs late in July and in August. The winter is passed in the egg stage, and hatching takes place about the first of May. The larvae spin down on silken threads, and the first instars may be borne long distances by the wind. The greatest dispersion by wind occurs on hot days when convection currents from the heated surface of the ground are prevalent. Pure stands or mixtures of the favored species or stands containing mixtures of favored species, and some of the less favored, may be completely defoliated, but the greater the proportion of the latter class, the less danger there is of an infestation building up enough to cause serious defoliation. The larvae pass through five and six instars for the males and females, respectively, becoming full grown late in June or early in July. The period in the pupal stage is about 10 days to 2 weeks.

Economic Features.—Although outbreaks, both regional and local in character, now occur at more irregular intervals in New England since the introduced parasites have become established, this pest still causes more or less defoliation over thousands of acres of forest growth each year. An infestation may exist for several years in a farm woodlot or a large forest without causing sufficient defoliation to attract attention, because of the influence of the various natural control factors, and then may suddenly increase to outbreak proportions. Following severe defoliation over large areas the infestation usually diminishes owing to overpopulation and other natural control factors, and a period of years elapses before it builds up again, thus giving the trees an opportunity to recover. It frequently happens, however, that the amount of foliage present is just sufficient to maintain the population to maturity, in which case the trees may be completely defoliated, or nearly so, for two or more consecutive years. One complete defoliation will not kill thrifty hardwoods, but is fatal to the conifers. Repeated defoliation of hardwoods so reduces their vigor that secondary insects often contribute considerably to the mortality of the trees, especially during periods of deficient rainfall.

The aesthetic value of the trees in parks and woodland recreational areas, along roadsides, and the shade and ornamental trees in residential areas necessitates enormous expense each year for protection against this pest.

Natural Enemies.—Since 1905 many millions of parasites and predators of the gypsy moth have been imported from Europe and Japan. Of the many species imported, 15 are known to be established in New England, and about 10 of these are now of considerable importance in checking the ravages of this pest. Burgess and Crossman (*73*) gave an account of the early introductions.

Two parasites of gypsy moth eggs, *Anastatus disparis* Ruschke and *Ooencyrtus kuvanae* How., are quite well distributed, particularly through the older infested areas, the latter species being more effective in the areas of milder climate. These two parasites take a tremendous toll of eggs each year.

Apanteles melanoscelus Ratz., *Compsilura concinnata* Meig., and *Sturmia scutellata* R. D. are larval parasites and apparently are well distributed through the northeastern part of the United States. When the gypsy moth infestation was discovered at Pittston, Pa., in 1932, all three of these imported parasites were present there in considerable numbers. *A. melanoscelus* passes through two generations during the larval period of the gypsy moth, and then hibernates until the following spring in its cocoon attached to some portion of a tree or other object. Owing to the long exposure of its cocoons to hyperparasites it is seriously handicapped, but in some years it increases so that it is very effective. *C. concinnata* is especially effective in light infestations, where it frequently parasitizes 40 to 50 percent or more of the hosts. It has a wide range of native hosts and has dispersed far beyond the limits of the area known to be infested by the gypsy moth. Because of these propensities this parasite is being colonized in other parts of the United States and Canada to aid in the control of other lepidopterous pests. *Sturmia scutellata* is most efficient where its puparia are protected in the leaf mold by a covering of snow during the winter, and in such localities it often parasitizes over 50 percent of the gypsy moth.

Apanteles lacteicolor Vier., *Hyposoter disparis* Vier., *Monodontomerus aereus* Wlkr., and *Phorocera agilis* R. D. are known to be well established in New England. *Calosoma sycophanta* L. has well demonstrated its efficiency as a predator. In heavy woodland infestations of the gypsy moth this beneficial beetle has been taken in traps at the rate of over 4,000 per acre.

A disease known as "wilt" causes the death of enormous numbers of larvae and pupae each year, epidemics often occurring when conditions are favorable. Severe winter temperatures sometimes kill large numbers of unprotected eggs. Insectivorous birds commonly attack the gypsy moth, particularly in the early larval instars.

In spite of the efficiency of the introduced parasites, and other natural control factors, outbreaks in certain parts of New England occur all too frequently. In Europe, where the gypsy moth has been present for centuries, outbreaks also occur periodically. It is believed that the aggregate effect of the introduced natural enemies of the gypsy moth in the United States is approaching that which exists in central Europe. In many New England localities infested by the gypsy moth, the natural enemies have been important factors in preventing outbreaks, and in the older infested areas they are responsible for a lengthening of the intervals between outbreaks.

Control.—The importance of control by silvicultural practices wherever applicable should be emphasized. This consists of developing stands that will be resistant to gypsy moth attack by reducing the proportion of species favored as food by the larvae. With few exceptions, the elimination or reduction of the more favored food species will conform to desirable silvicultural practices.

Behre, Cline, and Baker (*27*) conclude:

> Information based on averages over a period of many years and secured from a large number of woodland plots shows that in mixtures of hardwoods serious defoliation is not likely to take place where the volume of favored food tree foliage constitutes less than one-half the total, but, where the protection of conifers is involved, a somewhat greater reduction is recommended. Where conditions are particularly favorable for increase of the insect, it may be advisable to reduce still further the volume of favored foliage, perhaps even to the extent of complete elimination.

Egg clusters can be destroyed by saturating them with a creosote mixture commercially prepared for this purpose.

Spraying with lead arsenate (p. 53) was for many years the most effective measure for destroying the larvae. Recently, airplane spraying with DDT has proved to be much more effective and cheaper. In some cases, particularly where a few ornamental and shade trees are concerned, a burlap band may be tied around the tree trunk and folded down at the middle of the band. This affords shelter for the larvae during the daytime. These bands should be examined frequently, and the larvae congregated beneath them destroyed.

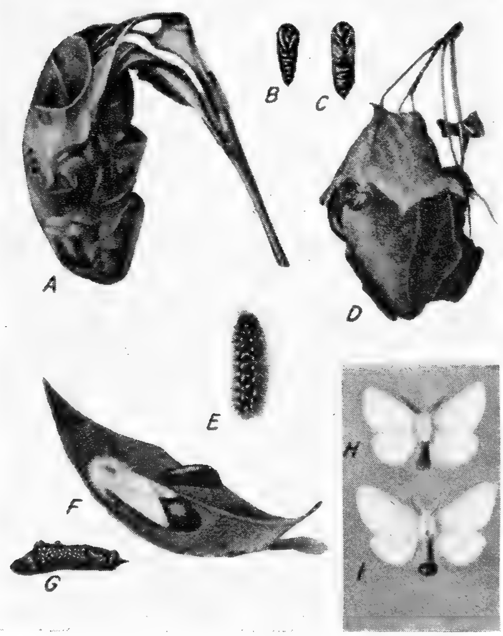

FIGURE 83.—The brown-tail moth (*Nygmia phaeorrhoea*).—*A*, Winter nest; *B*, male pupa; *C*, female pupa; *D*, cocoon in leaves; *E*, full-grown caterpillar; *F*, female depositing eggs on a leaf; *G*, egg mass on leaf; *H*, male moth; *I*, female moth. All about ¾ natural size.

The Brown-Tail Moth

The brown-tail moth (*Nygmia phaeorrhoea* (Donov.)) is pure white except the tip of the abdomen, which is densely clothed with brown hairs. The female (fig. 83, *F*, *I*) has a rather stout abdomen and a wing expanse of about 1½ inches, while the male (fig. 83, *H*) is more slender and slightly smaller. The eggs are usually deposited on the underside of a leaf in elongate oval masses ½ to ¾ inch in length. Each mass contains about 300 eggs, which are closely packed and covered with brown hairs from the abdomen of the female (fig. 83, *F*, *G*).

The full-grown larva (fig. 83, *E*) is about 1½ inches long, the head is light brown, the body dark brown to almost black, with a broken white line on either side and two conspicuous reddish spots on the back near the posterior end. Numerous tubercles with long, barbed hairs and with many short, brown hairs between are situated on the back and sides of the body. These hairs are poisonous and cause a severe rash when they come in contact with the human skin.

Distribution.—The brown-tail moth was first found in the United States at Somerville, Mass., in 1897, having been accidentally introduced from Europe. Later it became established in the eastern part of Connecticut, in Rhode Island, the eastern part of Vermont, and in New Hampshire, Maine, and the Provinces of New Brunswick and Nova Scotia. In recent years the most serious infestations have been confined to the southeastern part of Maine, the southern half of New Hampshire, and the eastern part of Massachusetts.

The Federal Quarantine Act of 1912 regulating the shipments of nursery stock, the introduction and establishment of its parasites, and the eradication programs carried on by the Federal, State, and Municipal Governments have greatly reduced the infestations of the brown-tail moth and thus prevented widespread dispersion. The work against the brown-tail moth was also described by Burgess and Baker (*70*).

Host Plants.—Pear, apple, plum, cherry, and hawthorn are most favored; but oak, rose, and willow are commonly attacked and occasionally other deciduous trees and shrubs are infested. Although all the oaks common to New England were severely attacked by the brown-tail moth for several years after its establishment in the United States, the white oak now seems to be the only oak particularly favored by this insect.

Seasonal History and Character of Feeding.—There is one generation annually in New England. The moths issue during the first half of July. They fly at night, are strong fliers, and are attracted to lights. The eggs hatch early in August, about 3 weeks after they are laid. The young larvae are gregarious and feed on the epidermis, first on the leaf bearing the egg mass and later on other nearby leaves, causing the leaves to turn brown or become scorched in appearance. They soon begin to spin their winter webs by fastening two or more leaves together near the tip of a branch, spinning silk over the outside of the webbed leaves and fastening them securely to the twig, thus making a rather tough grayish web 2 to 6 inches long, in which they hibernate during the winter (fig. 83, *A*). They molt two or three times, and continue their feeding until cold weather stops their activity. The larvae from one or more egg masses may hibernate in one web. As soon as the leaf buds begin to swell in the spring the larvae emerge and begin to feed on bud scales and the unfolding leaves, usually devouring all but the midribs. The larvae become full grown about the middle of June.

Silken cocoons (fig. 83, *D*) are spun usually among the leaves at the tips of the twigs, in which the larvae transform to pupae. The pupa is dark brown, about 5/8 inch long, and has yellowish-brown hairs scattered over the surface (fig. 83, *B*, *C*). When abundant the cocoons may be spun in a mass. About 2 weeks are spent in the pupal stage.

Economic Features.—During August and September the young larvae skeletonize the leaves and spin their webs for hibernation on the terminals; thus when abundant they may cause serious injury because their silk checks the growth of the leaves in the spring and the larvae become serious defoliators. Moreover, the larvae are a serious menace to public health because of the irritation or rash caused by the poisonous barbed hairs when they come in contact with the human skin.

NATURAL ENEMIES.—The introduced parasites *Carcelia laxifrons* Vill., *Compsilura concinnata*, *Sturmia nidicola* Towns., *Apanteles lacteicolor*, and *Meteorus versicolor* Wesm., are effective enemies of this pest, as is also the introduced predator *Calosoma sycophanta*. A fungus disease, *Entomophthora aulicae* Reich, which attacks the larvae is an effective enemy. Low winter temperature often plays an important part in the control of this pest. Burgess and Crossman (*73*) discuss the natural control of this pest.

CONTROL.—Spraying with an arsenical or DDT (p. 53) is the most effective method of artificial control in the forest. See caution on p. 23). Correct orchard practice will control this insect in the orchard. In residential areas, on farms, and along roadsides and fence rows, the method used is to cut off and destroy the winter webs before the larvae begin to emerge in April.

Fence rows, neglected orchards, and waste land are ideal breeding places for this and other insect pests, so it is advisable to eliminate all worthless apple, pear, wild black and choke cherries, and other favored food plants that are of little or no value.

The Satin Moth

The satin moth *Stilpnotia salicis* (L.) (fig. 84) has a wing expanse of from 1½ to 2 inches and is clear white with a satin luster. The head, thorax, and abdomen are black but are so densely clothed with long, satiny, white hairs as to appear white. The eggs are deposited on leaves, branches, and trunks of trees or on other surfaces in masses ranging from 100 to 400 each, although 1 female may deposit as many as 1,000 eggs. The masses, roughly oval in shape and about ⅝ inch long, are covered with a glistening white secretion. On hatching, the larva feeds during two instars, then seeks a crevice or depression on some part of the tree, sometimes making an excavation by chewing the bark, and spins a cocoonlike hibernaculum in which it spends the winter.

Feeding is continued the next spring. The full-grown larva is 1¾ to 2 inches long, the head is black with a bluish tinge and sparsely clothed with short hairs, the body blackish on the dorsum with a broken row of large white blotches down the middle and a narrow broken white subdorsal line on each side. The sides of the body are mottled with black and white, and each segment has a transverse row of reddish-brown tubercles bearing yellowish-brown hairs. The pupa is about 1 inch long, shining black, and is clothed with golden and whitish hairs. The cocoon may be spun in the leaves, on the twigs, or on other objects, and consists of a loosely woven structure of silk (Burgess and Crossman, *72*).

DISTRIBUTION.—The satin moth is widely distributed throughout Europe and Asia, and was first discovered in Massachusetts in June 1920 near the Malden-Medford city line, and in July 1920 at New Westminister, British Columbia. By 1937 it had dispersed into all the New England States and the Maritime Provinces of Canada, and in 1944 it was found in New York, near Albany. From British Columbia it had spread into the States of Washington and Oregon, west of the Cascade Range. Federal and State quarantines have been maintained to prevent shipment of this species into areas not infested.

SEASONAL HISTORY AND CHARACTER OF FEEDING.—There are two generations annually in portions of Japan and Europe. In New England

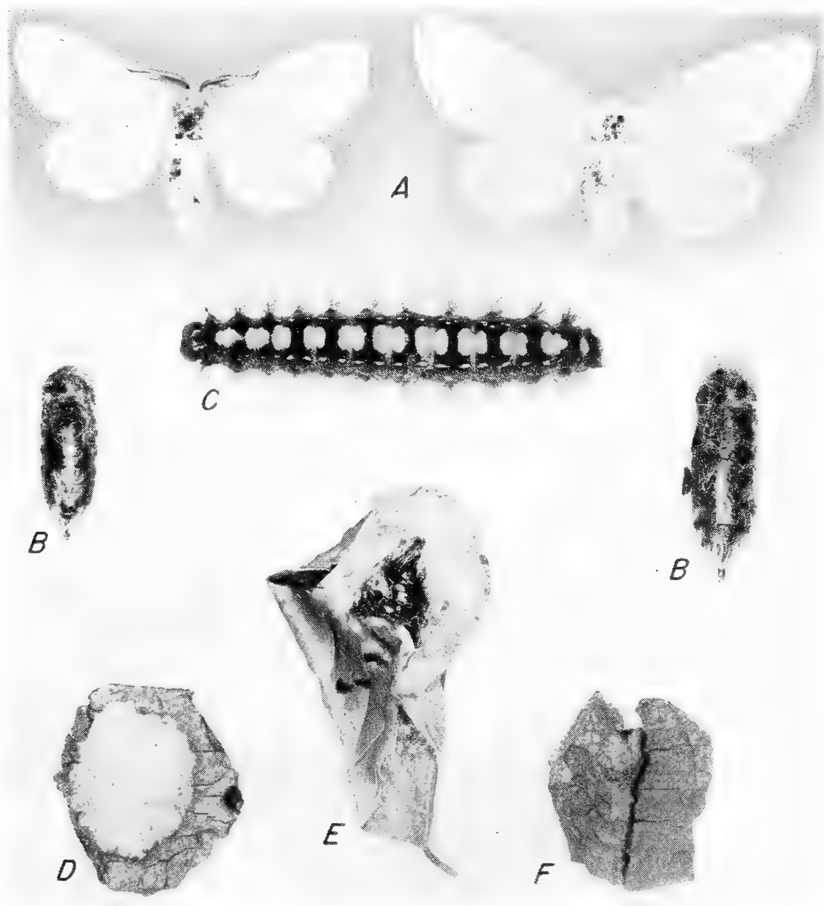

FIGURE 84.—The satin moth (*Stilpnotia salicis*) : *A*, Adults ; *B*, pupae ; *C*, larva ; *D*, egg cluster ; *E*, cocoon ; and *F*, hibernating web on bark.

the moths emerge between the latter part of June and late in July. Both sexes are strong fliers and are attracted to lights. Most of the eggs are deposited during July, oviposition reaching a peak about the middle of the month. Hatching takes place in about 15 days, or early in August. The larvae feed on various species of poplar and willow, the native species of the Northeastern States apparently being least favored. The young larva feeds only upon the epidermis of the leaves. After feeding for 5 or 6 days the first instar encloses itself within a small silken web, where it molts. The second instar feeds for 5 or 6 days, migrates to a branch or trunk of the tree, constructs its hibernaculum and then molts before retiring for the winter. Occasionally a few larvae continue their activity until late fall. The larvae emerge from hibernation during the latter part of April or early in May and usually attain full growth in June. Beginning with the fourth instar the larvae devour the entire leaf substance instead of skeletonizing it. Both sexes pass through seven larval instars before pupation, and about 9 or 10 days are spent in the pupal stage.

ECONOMIC FEATURES.—Since its discovery in Massachusetts in 1920 the satin moth has caused serious defoliation in many parts of New England. The shade and ornamental poplars and willows are most severely attacked, although one serious infestation has been observed in a natural stand of large-tooth aspen. Municipalities and private property owners have spent large sums in spraying to prevent defoliation. In severe infestations larvae often migrate from defoliated trees to fences, walks, and buildings causing serious annoyance to nearby dwellers.

NATURAL ENEMIES.—Four foreign species, *Compsilura concinnata*, *Sturmia scutellata*, *Eupteromalus nidulans* (Thom.), and *Calosoma sycophanta*, introduced as natural enemies of other forest pests, and several native insects attack the satin moth. Of these *C. concinnata* and *E. nidulans* are most important as control agents. Several European parasites of the satin moth have been imported, but thus far in the New England infested area only *Apanteles solitarius* Ratz. has become of importance as a control factor. In the Washington and Oregon infested area, in addition to the important parasites noted above, an introduced parasite, *Meteorus versicolor*, has become established and is now a very effective parasite. A native tachinid, *Tachinomyia similis* (Will.), is also of considerable importance as a parasite of the satin moth in Oregon and Washington. Jones, Webber, and Dowden (*260*) published on the enemies of this insect.

FAMILY LASIOCAMPIDAE

The family Lasiocampidae has less than 30 species in North America, and the tent caterpillars are its best known representatives. The moths are of medium size and have stout hairy bodies. The larvae of all species are very hairy, but vary in form from nearly cylindrical to very much flattened. Two species are important pests in the eastern part of the United States.

The moth of **the eastern tent caterpillar** (*Malacosoma americana* (F.)) has a wing expanse ranging from 1⅕ to 2 inches. It is stout bodied and dull reddish brown, with two whitish stripes extending obliquely across the forewings (fig. 85, *A*, *a*). The eggs are deposited in masses of from 150 to 350, each mass encircling a twig (fig. 85, *A*, *b*). They are cemented together and coated with a dark gluelike substance which hardens and forms an oval-shaped dark-brown mass, with a varnished appearance. The caterpillar (fig. 85, *A*, *d*) when full grown is about 2 to 2½ inches long, and cylindrical. The head and body are deep black with a white stripe along the back, and with many short, irregular, brownish markings along the side of each segment. Also on each side is a row of oval, pale-blue spots nearly surrounded by black. The body is sparsely clothed with long, fine, light-brown hairs.

The cocoon is oval, about 1 inch long, and composed exteriorly of coarse, whitish silk surrounding the tougher parchmentlike lining. A yellow, powdery substance is mixed with the silk.

This moth is generally distributed throughout the United States east of the Rocky Mountains. The foliage of the wild cherries and apple is most favored as food, but other plants such as plum, peach, hawthorn, pear, rose, and some of the deciduous forest and shade trees are often attacked, particularly when the supply of favored food becomes exhausted.

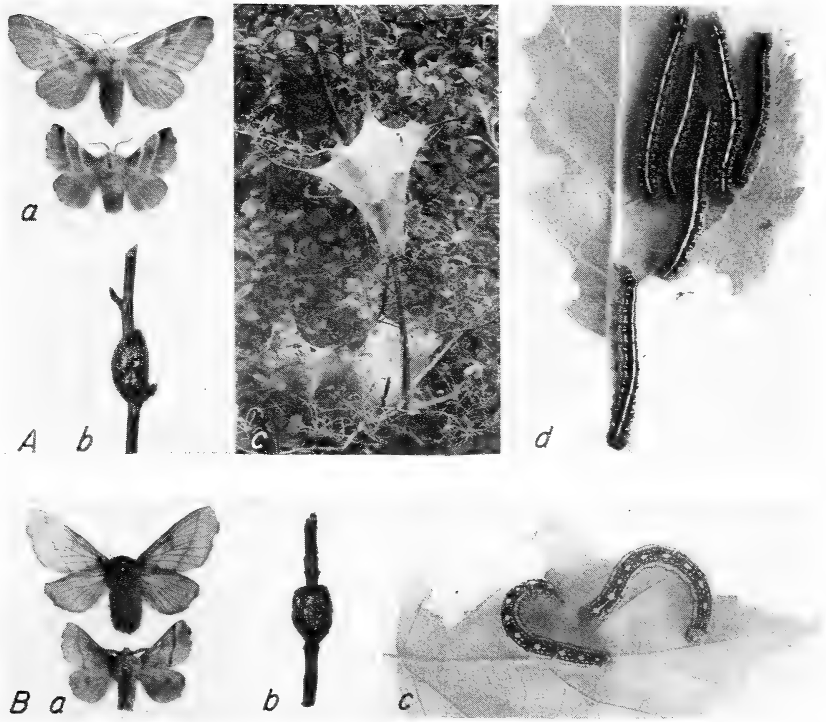

FIGURE 85.—Tent caterpillars. *A, Malacosoma americana*: *a*, Adults; *b*, egg cluster; *c*, tent; *d*, caterpillars; *B. M. disstria*: *a*, adults; *b*, egg cluster; *c*, caterpillars. (Courtesy Conn. Agr. Expt. Sta.)

There is one generation a year. The eggs usually begin to hatch during the first warm spell in spring, as soon as the wild-cherry leaves begin to unfold or a little earlier. The larvae are gregarious and soon begin to construct their tent of silk in a nearby crotch, enlarging it as they grow (fig. 85, *A*, *c*). During cloudy and rainy weather the larvae usually remain within the nest, but when the weather is favorable they go out on the foliage and feed at regular intervals, spinning threads of silk wherever they go. In about 6 weeks after hatching they become full grown and transform to the pupal stage, which lasts from 10 days to 2 weeks. In the Northeastern States hatching usually begins about the second or third week in April, the larvae generally attain full growth by early June, and the moths are active during the latter part of June. The eastern tent caterpillar is usually abundant each year in one or more localities and often over a considerable territory. The tents are more or less common in the forks of branches on wild cherry and apple during May and June. During periods of abundance trees are often completely defoliated and undoubtedly materially weakened, though rarely killed.

Where spraying programs are not feasible, much can be done in the way of protecting shade and roadside trees and in reducing the population of the eastern tent caterpillar by the following methods carried out cooperatively:

1. Cut and burn all wild cherry, and seedling and worthless apple trees along roadsides, fence rows, and on land of scenic and recreational value. This not only aids materially in preventing outbreaks of the eastern tent caterpillar but also reduces the hazard of injury by many other common insect pests.

2. Collect and destroy the egg masses during the winter months when they can be seen easily on the twigs. Small remunerations are sometimes offered to school children, 4–H Club members, and Boy and Girl Scouts for collecting the egg masses.

3. In the spring after the eggs have hatched and as soon as the small caterpillars have formed tents large enough to be seen easily, they can be sprayed with DDT, with effective results.

The moth of **the forest tent caterpillar** (*Malacosoma disstria* Hbn.) is light buff brown with a wing expanse from 1 to 1½ inches, the forewings having two darker oblique lines near the middle (fig. 85, *B*, *a*). The egg mass contains from 100 to 350 eggs cemented together, and entirely encircling a twig (fig. 85, *B*, *b*). The mass is cylindrical or ringlike in shape, ending squarely at each end, and is coated with a dark-colored, gluelike substance. The full-grown larva is about 2 inches long. The head and body generally are pale bluish, and there is a row of keyhole-shaped white spots along the back (fig. 85, *B*, *c*). The cocoon of whitish silk usually is spun between leaves or in any type of a crevice that offers protection.

The insect is distributed throughout the greater part of the United States and Canada. The foliage of ash, birch, black gum, red gum, sugar maple, oak, and poplar is preferred, but other deciduous forest and shade trees are also commonly fed upon.

There is one generation a year. The majority of the moths issue during a period of about 2 weeks, from early May in the South to late June and July in the Northeastern States. Egg laying soon takes place, and hatching occurs the following spring at about the time the leaf buds are bursting. The caterpillars are gregarious until nearly full grown and do not spin a tent, but only a silken mat on the trunk or branch where they congregate when at rest or during their molting periods (fig. 86). About 5 or 6 weeks from the time of hatching each caterpillar surrounds itself with an oval cocoon composed of several layers of silk in which it transforms to the pupal stage. The moth develops and issues 10 days to 2 weeks later.

This species probably is the most widespread defoliator of deciduous forest and shade trees throughout the eastern part of the United States. It has attracted attention since colonial days, though sometimes outbreaks have occurred at rather long and irregular intervals. Serious outbreaks have been known to persist for 3 to 5 years or more before the natural factors were able to bring the pest under control. Recent outbreaks have caused serious injury to maple-sugar orchards in Vermont (fig. 87 *A*, *B*), and to deciduous forests in New England, New York, Minnesota, Michigan, Mississippi, and Louisiana.

In areas where the tree growth is of sufficient value to warrant the expense, particularly in areas of high recreational value, the foliage can be protected from the ravages of this insect by timely spraying with a stomach poison (p. 52).

FIGURE 86.—Mass of forest tent caterpillars (*Malacosoma disstria*) on the trunk of a tree.

The moth of *Tolype velleda* (Stoll.) has a wing expanse of 1½ to 2½ inches. The head and thorax are white, the abdomen is gray, and on the middle of the back is a large blackish spot. The wings are gray, sometimes dusky, and are crossed by white lines. The full-grown larva is gray with many faint longitudinal lines and is about 2½ inches long. The body is flattened and has lateral lappets, each of which has many long hairs thus forming a fringe along each side of the body. The metathorax has a dorsal pair of warts bordered posteriorly by a velvety black band, which may be concealed when the larva is at rest. The species ranges from Quebec south through the Atlantic States and west to Michigan. The larvae feed on apple, ash, aspen, basswood, cherry, elm, maple, oak, and other deciduous trees, but have never been reported in abundance. The moths emerge in September and October, the eggs are deposited in rows and are covered with hairs from the abdomen of the female, the larvae may be found from June to August, and the pupae are in flattened, tough, parchmentlike cocoons on the bark in August and September. There is one generation annually. *Tolype laricis* (Fitch) is a smaller species, and the larvae feed on larch. Its range and life cycle are similar to those of *T. velleda.*

The lappet moth (*Epicnaptera americana* (Harr.)) is reddish brown, with the inner angle of the forewings and the costal margin of the hind wings deeply notched and with a pale band edged with irregular dark-brown lines beyond the middle of each wing. The wing expanse is from 1¼ to nearly 2 inches. The full-grown larva is about 2½ inches long and flattened, with lateral lappets. The body is bluish-gray above and somewhat mottled; with transverse scarlet bands on the back, one on the second and one on the third thoracic segments, and in each of the bands are three black dots. This species is quite generally distributed through the eastern part of the United States and southern Canada. The larvae feed on the foliage of aspen, wild cherry, hickory, oak, and other deciduous trees. There is one generation in the northern part of its range and at least a partial second generation farther south. It is often found by collectors but never reported as very common. The moths emerge in May and June and in July, the larvae may be found from May to August, and the winter is passed in the pupal stage in tough flattened cocoons, usually on the bark.

FIGURE 87.—Injury by *Malacosoma disstria*: *A*, Maple-sugar orchard defoliated in June 1936 (these trees had also suffered heavy defoliation in 1935); *B*, same orchard in July 1937 showing dead tops which resulted from the defoliation.

FAMILY ZANOLIDAE

The family Zanolidae is represented in North America by one genus in which there are only three species. The moths resemble the Notodontidae, but they differ in lacking maxillae. The two species here treated are more or less common in the Eastern States.

The larva of *Apatelodes torrefacta* (A. & S.) is about 2 inches in length when fully grown. The head is rounded and yellowish, the body whitish to yellow but blackish underneath, and the back is marked by a row of black spots more or less connected to form a line. There is also a lateral row of black spots, and the dorsal sutures are black. The body is densely clothed with long, fine, white or yellow hairs, and from the second and third thoracic and the eighth abdominal segments arise long pencils of hairs, pale at the base and black at the tip. This species is distributed throughout the eastern part of the United States. Its food plants include blackberry, wild cherry, speckled alder, maple, and various other trees and shrubs. The moths emerge in June and July, the larvae may be found from June to September, and the winter is passed in the pupal stage on the ground.

The full-grown larva of *Apatelodes angelica* (Grote) is 2 to 2¼ inches in length. The head is rounded and brown, mottled with light and dark shades. The thorax has two broad black transverse bands on the back, otherwise the body is gray and marked with more or less of a network of fine wavy black lines. On the back of abdominal segments 1 to 7 some of these lines assume a V-shape, and on each of these segments are four yellowish-green spots, those on the first segment rather faint. The ventral area of the body is flattened. Long brown and white hairs from the prothorax project over the head, and whitish hairs from the middle of the second and third thoracic segments also project forward. Those on the third segment are shorter and intermixed with short, stiff, red hairs. Below the spiracles are two rows of fascicles of white hairs of unequal length, mingled with a few longer brown ones. Other parts of the body are sparsely clothed with short white and black hairs. This species has been reported from Ontario, Canada, and the New England States to Florida, and west into the Ohio Valley. The larvae feed on ash and lilac. In New England the moths emerge in July, the larvae are found in August and September, and the winter is passed in the pupal stage on the ground.

Family GEOMETRIDAE

The Geometers, Loopers, or Measuring Worms

The larvae of the Geometridae move about by bringing the anal segments up to the thoracic feet, thus forming a loop of the body, and then extending the whole body again in the direction desired. Because of this mode of locomotion they are commonly known as geometers, measuring worms, inchworms, loopers, or spanworms. The moths, in general, are delicate and small to medium in size. They have a small head, slender body, relatively large and broad wings which are thin and clothed with fine scales. In many species the markings on the hind wings are similar to those on the forewings and often the lines are continuous on both. They are not strong fliers. Many species hold their wings in a horizontal position when at rest. In a few species the females are wingless or have only rudimentary wings.

The larvae are elongate and usually quite slender, and the abdominal segments are sometimes ornamented with tubercles. The abdominal legs are more or less rudimentary or obsolete, except those on the sixth and tenth segments which as a rule are well developed. In many species the larvae closely resemble twigs and some have the habit of attaching themselves by the posterior prolegs or claspers to a twig or stem and stretching out at full length so as to appear like a spur or short twig. All species are foliage feeders, and the majority inhabit the forests and areas bordering woodlands.

The pupae are all rather slender, but the mode of pupation varies with the different species. Some pupae are encased in flimsy cocoons among the leaves, some are attached to twigs or other objects, and others are formed in cells in the ground.

A large number of species are represented in the eastern part of the United States. Many of these are more or less common each year, and some are well-known defoliators of forest and shade trees, appearing in outbreaks at irregular intervals. Those species of most importance and those generally most common are discussed in some detail, including a brief description of the adults, but others which sometimes are more or less common, are reported more briefly.

The moth of *Brephos infans* (Moeschler) has a wing expanse of about 1⅛ inches. It is chocolate brown, the forewings marked with white and the hind wings with reddish orange. The full-grown larva is about 1 inch in length. The head, thoracic shield, and body are green or sometimes yellowish brown, and the body has two fine, yellowish, longitudinal lines on the dorsum and two similar subdorsal lines and a broad yellowish subspiracular stripe on each side. The prolegs on the third, fourth, and fifth abdominal segments are rudimentary. This species is distributed from Labrador to New York, and its food plants include gray birch, paper birch, and poplar. The moths emerge in April and May, the larvae are active from May to July, they pupate in July, and hibernate in the pupal stage.

The fall and spring cankerworms are serious pests of deciduous trees and have been known in the northeastern part of the United States for more than two centuries. Both species have much in common. When abundant the larvae of either species, or sometimes both working together, defoliate the trees, leaving only the midribs and larger veins, thus causing enormous damage. They may be controlled by the measures given on pages 52–53.

Porter and Alden (*354*) listed in 1924 the distinguishing characteristics of the fall and spring cankerworms as follows:

Stage	*Fall cankerworm*	*Spring cankerworm*
Egg	Brownish gray, in form of a flowerpot, laid in a compact, single-layered mass in exposed locations, chiefly in the fall.	Dull pearl, oval in shape, laid in loose clusters in protected places, almost exclusively in the spring.
Larva	A pair of rudimentary prolegs on the 5th abdominal segment.	No prolegs on the 5th abdominal segment.
Pupa	Enclosed in a tough cocoon, with particles of earth woven in with the silk.	No cocoon formed.
Adult	Abdomen without spines	Abdominal segments bearing double transverse rows of reddish spines.

The male moth of **the fall cankerworm** (*Alsophila pometaria* Harr.)) (fig. 88, *D*) is brownish gray with a wing expanse of 1 to 1⅜ inches. The forewings are rather glossy with purplish reflections and are crossed by two jagged whitish bands, sometimes both nearly obsolete so that only the outer band is represented near the costa by a pale quadrate spot; the hind wings are grayish brown, each with a faint blackish discal dot. The female moth is wingless and of a shiny, dark, ash-gray color. The abdomen is without spines in both sexes. The full-grown larva is about 1 inch long, and varies in color from a very light green to a very dark, brownish green. On the back there is a median, longitudinal, darker stripe and sometimes suggestions of other faint lines. The head and anal segment also vary from pale green to almost black, and are sometimes mottled. There are three pairs of prolegs—a very small pair on the fifth abdominal segment, and larger ones on the sixth and anal segments.

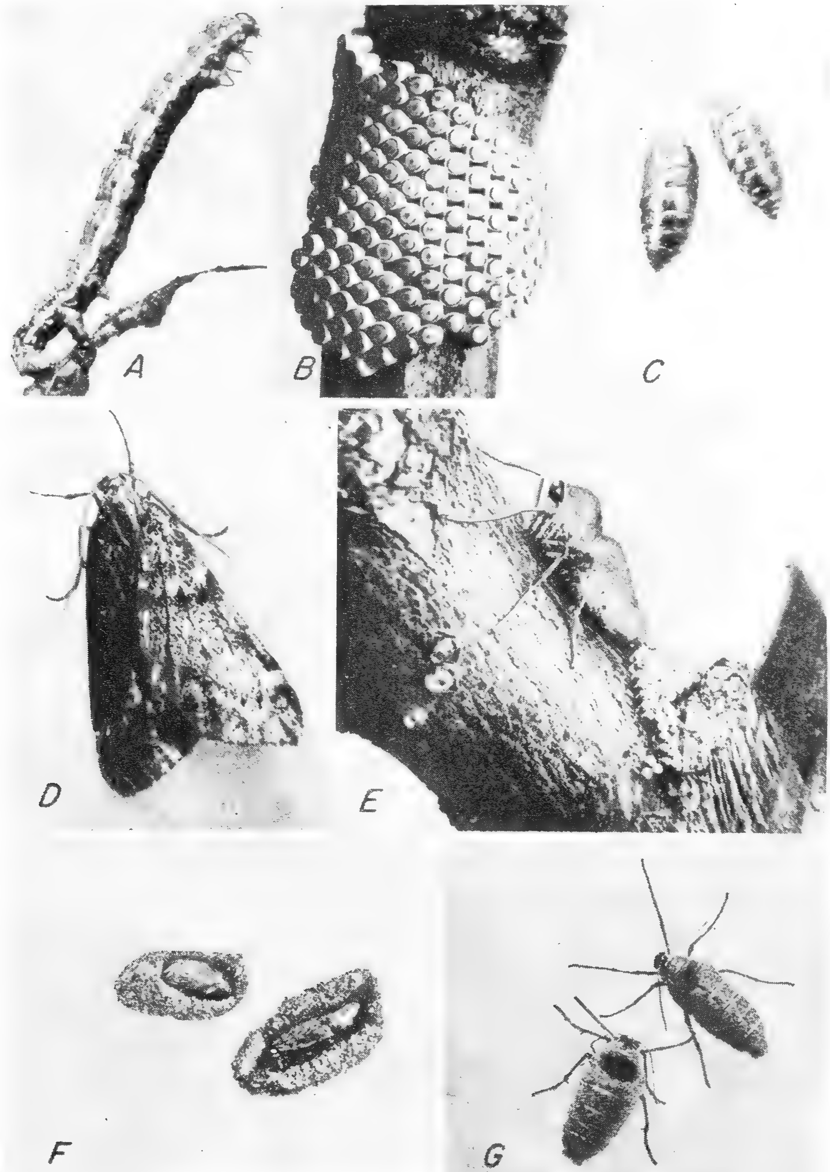

FIGURE 88.—Various stages of the fall cankerworm (*Alsophila pometaria*): *A*, Full-grown larva, × 2½; *B*, cluster of eggs, × 7; *C*, pupae, × 2¼; *D*, male moth, × 3; *E*, female moth laying eggs, × 3; *F*, pupae in cocoons, × 1¾; *G*, female moths.

This species is found from Nova Scotia and southern Canada through the Northeastern States, south to North Carolina, west to Missouri, and northwest to Montana and Manitoba. It has also been reported from Colorado and California. It has a wide range of food plants, but elm and apple seem to be most preferred. The moths emerge in November and December, usually not until there has been some freezing weather. Occasionally the emergence of a few moths is delayed until spring. The eggs are usually deposited on the smaller branches and twigs in clusters averaging about 100 eggs. The winter is passed in the egg stage and hatching takes place early in May. The young larvae seem to prefer the newly formed leaves on the tips of the branches, skeletonizing them, but in later instars they devour all but the midribs and larger veins of the leaves. The larval stage extends over a period of 4 to 5 weeks; the full-grown larvae entering the soil for pupation during the first or second week in June.

The male moth of **the spring cankerworm** (*Paleacrita vernata* (Peck)) (fig. 89) has a wing expanse of 7/8 to 1 1/4 inches. The first seven joints of the abdomen each bear two transverse, dorsal rows of stiff, reddish spines, pointed posteriorly. The forewings are silky with brownish-gray scales loosely attached. They are crossed by three jagged, dark lines, sometimes nearly obsolete except on the median and submedian veins and on the costa, where they are always distinct. A pale subterminal band is somewhat similar to the outermost band in *Alsophila pometaria*. The hind wings are pale, ashy gray, with a dusky discal dot. The female moth is wingless, generally whitish and brown or black, but not uniform in color. The two rows of spines on the back of the first seven joints are more prominent than in the male, and often give the back a reddish aspect.

The full-grown larva is 3/4 to 1 inch in length, and varies from reddish to yellowish brown or yellowish green and sometimes blackish. The head is dirty white, mottled with brown, the body lines are irregular, numerous, considerably broken, distinct in some individuals and to some extent missing in others. There are two pairs of prolegs, which are present on the sixth and anal segments.

This species is found from Nova Scotia south to North Carolina, southwesterly to eastern Texas, westerly to Colorado, and north to Manitoba. It has also been found in California. Apple and elm seem to be the preferred food plants, but several of the oaks, cherries, hickories, maples, and others are included in the list of hosts. The moths issue in the spring soon after the frost is out of the ground. The eggs are deposited in crevices in the bark in masses ranging from a few eggs to 100 or more. The habits of the moths, the date of hatching of the eggs, and the habits of the larvae are very similar to those of the fall cankerworm (*Alsophila pometaria*). The larvae become full grown and enter the ground for pupation at about the same time as do the fall species. No cocoon is formed, but pupation takes place in a cell and the winter is passed there.

The full-grown larva of *Synchlora aerata* (F.) is brownish, about 7/8 inch in length, with curved lateral appendages on the back. Its food plants include apple and willow. There may be two generations in some localities. The larvae may be found from June to September, the winter is passed as pupae in the ground, and the moths emerge late in May and June and in August. The full-grown larva of *S. rubrifrontaria* Pack., is similar in appearance to the preceding species, except that it is green with a reddish tinge, especially on the lateral appendages. Its favored food plant is sweetfern. The larvae are

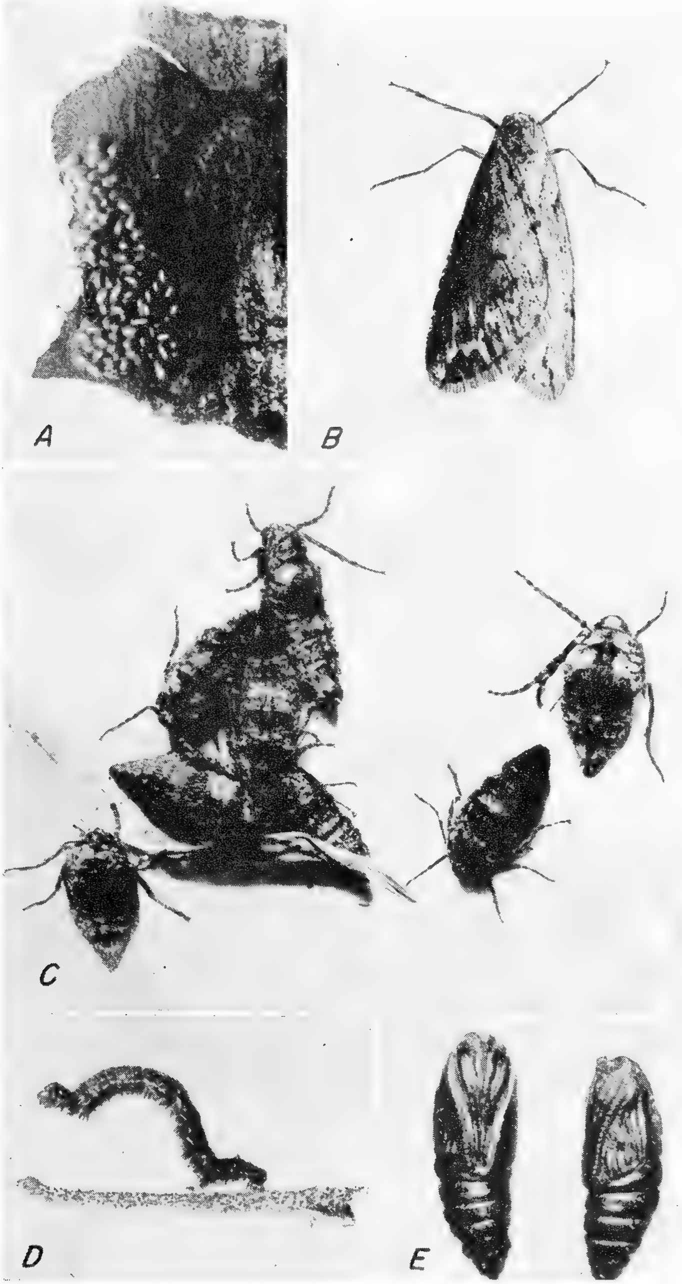

FIGURE 89.—Various stages of the spring cankerworm (*Paleacrita vernata*): *A*, Eggs on inner surface of a piece of bark, × 3½; *B*, male moth, × 2½; *C*, female moths, × 3½; *D*, partly grown larva, × 3; *E*, pupae, × 4.

active from July to September, the winter is passed as pupae in the ground, and the moths emerge in June.

The full-grown larva of *Cosymbia pendulinaria* (Guen.) is about 7/8 inch in length. The head is light brown, the body slender and light green sometimes tinged with brown. Its favored food plant is sweetfern. The moths emerge between May and June, and July to August, the larvae are found during June and July, and September and October. The winter is passed as pupae in the leaves.

The male moth of **Bruce's spanworm,** (*Operophtera bruceata* (Hulst)) is pale grayish with shadings and flecks of brown scales and has a wing expanse of about 1 1/8 inches. The female is wingless and light brownish gray. These moths resemble somewhat the adults of the cankerworms. The full-grown larva is about 3/4 inch in length, bright green, with three narrow yellowish-white stripes on each side of the body. There is only one pair of prolegs in addition to the anal claspers. This species is reported in Canada from Alberta to the Atlantic coast and in the northern part of the United States. Its favored food plants include sugar maple, poplar, and beech. The moths emerge in November and lay their eggs in crevices of the bark on the trunk and larger branches of trees. Hatching takes place early in the spring, the larvae becoming full grown about the first week in June, when they enter the ground to pupate. There is one generation annually. Serious outbreaks have been reported in Alberta, Canada, and in Vermont and Wisconsin.

Calocalpe undulata (L.), **the cherry scallop shell moth,** is pale fawn brown, and has a wing expanse of about 1 1/2 inches. The forewings are marked with about 12 whitish scalloped parallel lines, the submarginal line being more zigzag than the others, and the discal dot is large and black. The hind wings have 6 whitish lines, becoming more pronounced toward the outer margin. The full-grown larvae are about 7/8 inch in length and have a dark-amber head and thoracic shield. The body is blackish above with four broken longitudinal yellow lines, the venter is straw yellow, sometimes with a broken, blackish stripe along the base of the legs. The markings are somewhat variable. This species is common and is widely distributed in the United States and Canada, although not a serious pest. The larvae feed on wild cherry, making a nest by fastening together the leaves toward the end of a branch, living gregariously and feeding on the upper epidermis of the leaves in the nest (fig. 90). When necessary they enlarge their nest or move to another branch. The leaves in the nest turn brown and give the tree an unsightly appearance. In the Northeastern States there is one generation, but the moths emerge from May to September. The eggs are deposited in a cluster on a leaf of the current year's growth, the larvae may be found from June to October, and the winter is passed as pupae in the ground.

The full-grown larva of *Pero honestarius* (Wlkr.), the species also known by some authors as *Azelina ancetaria*, is about 1 1/2 inches in length. The head is quadrate, angular, and dark brown with clypeus and mouth parts somewhat lighter. The body increases in girth toward the anal end. It is brown, with variable lighter and darker markings. This species occurs in the eastern part of the United States. The data available indicate two generations annually and

FIGURE 90.—Characteristic webs of the cherry scallop shell moth (*Calocalpe undulata*) on wild black cherry.

that its food plants are wild cherry, larch, and black locust. The larvae feed during July, early in August, and in September and October, and the moths from these broods emerge in August and in May or June.

The moth of **the grapevine looper** (*Lygris diversilineata* (Hbn.)) is ochreous yellow, with a wing expanse of 1⅓ to 2 inches. The forewings are marked with diverse rust-brown lines, and an area just beyond the middle of each forewing is usually tinged with purplish brown. The hind wings are paler, the outer third marked with diffuse dark-brown lines and more or less tinged with purplish brown, the color being most pronounced toward the anal angle. The full-grown larva is slender, about 1½ inches in length and pale green, with pinkish or reddish markings, sometimes nearly all reddish. The head is flattened in front and bilobed. The thoracic and abdominal segments 7 to 10 are very short, while abdominal segments 1 to 6 are very long.

This species is found in eastern and southern Canada and the northeastern part of the United States west to Wisconsin and Missouri. Its favored food plants are grape and Virginia creeper, and records indicate it sometimes causes considerable damage to these vines. The moths emerge late in July and August, and deposit their eggs, usually in rows of 8 to 12 eggs each, on the older vine growth. The winter is passed in the egg stage, and hatching usually occurs during the latter part of May or early in June. The larvae mature in 6 or 7 weeks. They are inactive during the day and usually hide on the underside of the leaves. Pupation takes place in loose webs generally on the foliage, the duration of the pupal stage lasting about 10 days. Isely (*252*) discussed this looper. Some authors have reported two generations annually, and that the second generation passes the winter in the larval stage.

Eulype hastata (L.) **the spear-marked black moth**, is recorded in the United States from the Atlantic to the Pacific. The larvae feed on birch, sweetfern, sweetgale, and willow. They are gregarious and spin together leaves forming a nest in which they live. The full-grown larva is about 1 inch in length. The head is shiny black and the body dark brown to black, with a series of minute, black dots forming a slender stripe on each side, below which are some spots varying from white to brick red. In New England the moths emerge late in May and June and again in August, the larvae may be found from June to September, and the winter is passed in the pupal stage on the ground. Apparently there is at least a partial second generation.

The larva of *Bapta semiclarata* (Wlkr.) when full-grown is about ¾ inch long, and light green with a brownish head. It feeds on wild cherry and is recorded from the Atlantic States. The moths emerge in May, the larvae are found from June to early in August, and the winter is passed in the pupal stage.

The larva of *Deilinea erythremaria* (Guen.) is about 1⅛ inches long when full grown. It is light green and the head has a red stripe on each side. The body is marked with a red lateral stripe on each side more or less broken, and on the back are diffuse reddish patches. Its food plants are poplar and willow. The larvae feed during July, August, and September. The winter is passed in the pupal stage, and the moths emerge in June and July.

The moth of *Physostegania pustularia* (Guen.) has a wing expanse of about 1 inch and is a delicate, pure-white insect. The forewings are marked with four brownish spots on the costal margin, from the inner three of which arise slender brownish lines. These lines may be faint or entirely absent in some specimens. The full-grown larva is about 5/8 inch in length. The head is pale green, slightly bilobed, and the mandibles are tipped with black. The body is green marked by a double, longitudinal, whitish, dorsal line, bordering which are thickly set yellowish-white lines, and the spaces between the segments are yellowish. The skin on the body is much wrinkled. This species occurs in the northeastern part of the United States and west into the Mississippi Valley. It is sometimes very abundant locally. Red maple is its favored food plant. The larvae feed during May and June, and the moths emerge late in June and July.

The full-grown larva of *Semiothisa granitata* (Guen.) is about 7/8 inch in length, light green, sometimes with a brownish tinge above. The head is brownish on the sides, the face much lighter, and the body has a light, longitudinal stripe on each side of the back between which are two finer lines.

This species is found in the northeastern part of the United States, and its larvae feed on white pine, spruce, fir, and larch. The moths emerge in June, the larvae are present from July to September, and the winter is passed in the pupal stage in the duff on the ground. The full-grown larva of *S. ocellinata* (Guen.) is about 1 inch in length and green with a reddish tinge. The red is composed of many obscure wavy lines. This species is found in the Northeastern States, and the larvae feed on black locust. The larvae are active in June and July, and the moths emerge in July or August.

The full-grown larva of **the currant spanworm** (*Itame ribearia* (Fitch)) is a little over 1 inch in length, light yellow, and dotted with black. It is a common species in the Northeastern States. The larvae feed on currant, and are found from the time the leaves open in May until June or early in July. The moths emerge in July.

The full-grown larva of *Eufidonia notataria* (Wlkr.) is about 1 inch long. The body is deep green with a narrow, subdorsal and stigmatal white stripe and a greenish-white line on the back. The head has a light brownish tinge. According to Dyar's list (*141a*) this species is distributed through the Atlantic States. Its food plant is white pine. The moths emerge late in May and in June, the larvae are found from July to September, and the winter is passed in the pupal stage.

The full-grown larva of *Melanolophia canadaria* (Guen.) is about 1¼ inches in length. The head is rather flat, oblique, and pale greenish, sometimes tinged with light brown. The body is smooth and greenish, and has a broad subdorsal stripe on each side, separated on the back by a broken purplish-brown line. The stigmatal stripe is yellowish suffused with purplish red, and the venter is greenish, tinged with purplish brown. This species is widely distributed in the United States and Canada. Its food plants include wild cherry, basswood, oak, and sweetgale. Some authors list also hemlock, larch, pine, and spruce. The moths emerge in May and June, the eggs hatch in about

10 days, the larvae feed during June, July, and early August, and the winter is passed in the pupal stage in the ground. McDunnough (*286*) recorded adults emerging in confinement late in August and early in September.

Anacamptodes ephyraria (Wlkr.) is found on hemlock in the Northeastern States. The full-grown larva is 7/8 inch in length. The head is broader than the thorax, brown, and bilobed. The body is greenish tinged with reddish-brown, the second abdominal segment usually having a prominent swelling on each side. The larvae feed from May to July and the moths emerge in August. *A. larvaria* (Guen.) is found on poplar in the New England States. The full-grown larva is 1 1/8 inches long. The head is brown and quadrate. The body is yellowish green, with a reddish band on the second abdominal segment, a series of broad irregular reddish blotches on the back, and a pair of blunt tubercles on the back of the eighth abdominal segment. The larvae feed from July to September, the winter is passed as pupae in the ground, and the moths emerge in June.

The full-grown larva of *Ectropis crepuscularia* (Schiff.) is about 1 1/4 inches in length. The head is brownish and somewhat mottled. The body is reddish to chocolate brown, with a pair of blunt tubercles on the top of the eighth abdominal segment. The food plants include the foliage of birch, maple, oak, walnut, and other deciduous trees and shrubs. The larvae are found from May to September, and the adults have been recorded late in April and May, late June and July, and in October. The winter is passed in the pupal stage in the ground.

Epimecis virginaria (Cram.) is the largest moth of the family in the eastern part of the United States. It has a wing expanse of about 2 inches and varies greatly in color. Some color forms are light gray dusted with brown, the forewings with five well-marked lines, and other forms are dusky or almost black with the markings indistinct. The full-grown larva is stout and about 1 1/2 inches long. The head is small and reddish brown, the body yellowish to dark brown, and marked with many fine, irregular, wavy, longitudinal, pale yellowish lines, and the venter and legs are yellowish to light brown (fig. 91, *C*). This species is recorded from the Atlantic States. Some authors have reported it very common in Florida, and state that the larvae feed on yellow poplar. A local outbreak occurred in Connecticut, defoliating a small area of sassafras in 1936. In this infestation the larvae were active in June and July. They fed at night and the nearly full-grown larvae were found in the duff beneath the trees during the daytime. The pupae were formed in the ground. Some moths emerged from late in August to late in October, but the majority hibernated as pupae, and the moths emerged in May and June. This indicates that where conditions are suitable there may be a partial second generation.

The full-grown larva of *Nacophora quernaria* (A. & S.) is 2 inches in length and slate gray. The head is angular and bilobed, and the body is stout, with many brownish wartlike tubercles. The backs of the first two thoracic segments are marked with reddish brown and black. The segments of the body are somewhat swollen, this condition being particularly noticeable on the tops and sides of the second thoracic and second abdominal segments and the venter of the third segment.

This species occurs in the Atlantic States, and its larvae feed on oak. The moths emerge in May and June, the larvae may be found from June to September, and the winter is passed in the pupal stage.

The male moth of *Phigalia titea* (Cram.) is pale ash color with blackish-brown markings and has a wing expanse of about 1½ inches. The head in front is brown, the vertex white, the thorax whitish with a black collar, and the abdomen has two rows of black dots on the back. The forewings are speckled with dark brown and have three blackish lines, the two inner parallel, the outer diverting and parallel to the outer edge, sometimes obsolete, but indicated by black spots.

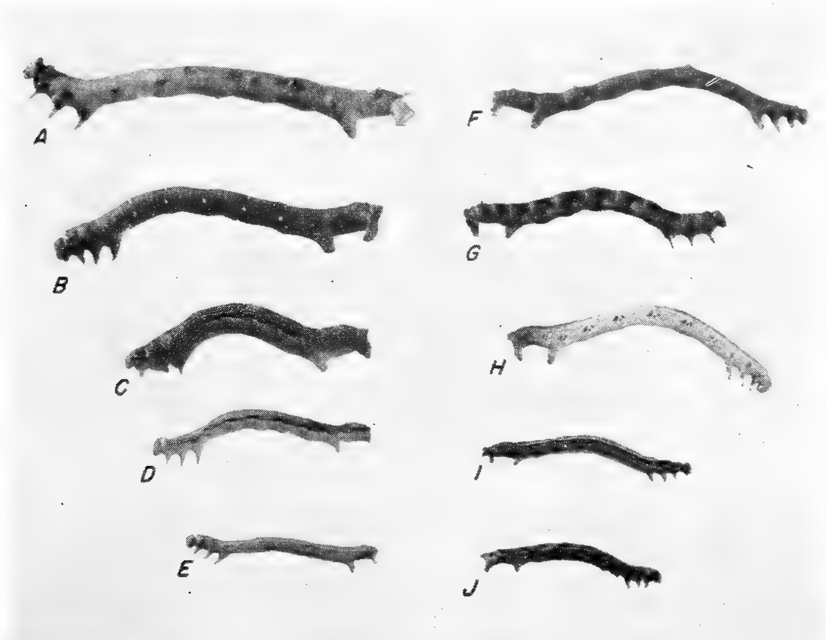

FIGURE 91.—Larvae of some of the more common and destructive species of Geometridae: *A, Amphidasis cognataria; B, Lycia ursaria; C. Epimecis virginaria; D, Erannis tiliaria; E, Lambdina fiscellaria; F, Ennomos subsignarius; G, Phigalia titea; H, Cingilia catenaria; I, Lambdina athasaria pellucidaria; J, Lambdina athasaria.*

The outer margin has a broad diffuse shading edged with whitish and marked with a row of intervenular blackish spots. The hind wings are lighter and marked with three lines, the middle most distinct and the inner and outer usually present only on the inner edge. The female has only partly developed wings, the forewings reaching to the second abdominal segment. The full-grown larva is about 1½ inches in length, is flesh colored with many fine wavy longitudinal blackish lines, which gives it a drab appearance. The head is flat, quadrangular, and heavily mottled with black, the thoracic segments are thick, and all body segments have hairy tubercles, which are most prominent on the first three and the eighth abdominal segments (fig. 91, *G*).

This species is reported from the Atlantic States. It is often common and occasionally locally abundant in oak woodlands in the Northeastern States. The larvae feed on the foliage of oak and various other deciduous growths. The moths emerge in April, the larvae are found from May to July, and pupation takes place in the ground, the pupae remaining in that stage from July until April.

The male moth of **the linden looper** (*Erannis tilaria* (Harr.)), also called **the lime tree winter moth,** is buff with a wing expanse of about 1¾ inches. The forewings are marked with two transverse, wavy, brown bands and sprinkled with brownish dots, the hind wings are somewhat lighter in color, with no prominent markings. The female is wingless, about ½ inch in length, and varies from a light gray to brownish, with two rows of black spots on the back. The antennae and legs are ringed with black and yellow or are of the body ground color. The full-grown larva is about 1½ inches long. The head is rusty brown, the body bright yellow with 10 longitudinal wavy black lines on the back, the outer one on each side usually is heavier than the others, and the legs and prolegs are yellow (fig. 91, *D*).

This species ranges throughout the Eastern States and Canada, and westward to the Rocky Mountains. It is rather common in the forests, and sometimes causes serious defoliation over rather extensive areas in the Northeastern States. The larvae are general feeders on the foliage of deciduous forest and shade trees, particularly the oaks, apple, birch, elm, hickory, basswood, and maple. The moths emerge from October to December, the eggs are deposited singly or in small groups usually in crevices on the bark, and pass the winter in this stage. Hatching takes place in April or early May, and the larvae become full grown in June or early in July. Pupation takes place in cells in the ground.

The moth of *Lycia ursaria* (Wlkr.) has a stout body, is gray, marked with diffuse blackish lines crossing both the fore and hind wings, and has a wing expanse of about 2 inches. The full-grown larva is vinous in color and 2 inches in length. The prothorax has four large whitish spots in front and the body is marked with many irregular wavy longitudinal black lines and creamy-white spots. The spots are usually most prominent on segments 1 to 5, each segment having a pair on top and one just behind each spiracle, also segments 3 to 5 have an additional subventral spot on each side (fig. 91, *B*). This species was recorded by Dyar (*141a*) as present in the Atlantic States. It is sometimes very common in the New England States. Apparently willow is its most favored food plant, but larvae also have been taken on apple, blueberry, wild black cherry, elm, maple, and poplar. The moths emerge in April and May, the larvae are active from May to July, the pupae are formed in the ground, and the winter is passed in the pupal stage.

The pepper and salt moth (*Amphidasis cognataria* Guen.), also known in the larval stage as **the cleft-headed spanworm,** is dull white sprinkled with dark brown or black. It has a stout body, and a wing expanse of about 2¼ inches. The forewings are narrow, with a long outer edge, and crossing them are three diffuse lines and an outer distinct blackish hair line. The hind wings have three dark lines. The full-grown larva is about 2 inches in length. The head is deeply cleft, flat in front and granulated. The prothoracic segment is raised in front with a blunt tubercle on each side, making the front of the cervical shield angular; the fifth abdominal segment has a pair of lateral tubercles, and the eighth a pair of converging pale granulated tubercles. The body is of even width for its entire length, and varies from greenish to reddish brown, resembling twigs of some of its food plants. In addition to the large and broad anal claspers there is one other pair of prolegs situated on the sixth abdominal segment (fig. 91, *A*). This species was recorded by Dyar (*141a*) as occurring in the Atlantic States. It is usually common in the Northeastern States, where the larvae feed on willow, poplar, wild cherry, sweetfern, apple, locust, and various other deciduous growths.

The moths emerge from May to July, depending on the locality and season, and the larvae may be found from July to October. The pupa is formed in the ground and the winter is passed in this stage.

The full-grown larvae of the species of *Euchlaena* common in the Eastern States are in general, about 1½ to 2 inches in length, and gray or brown, somewhat mottled or marked with dark brown or black. Some species and their food plants are as follows: *E. serrata* (Drury), maple, apple; *E. obtusaria* (Hbn.), chestnut; *E, effecta* (Wlkr.), rose, sweetfern, willow, wisteria; *E. johnsonaria* Fitch, oak, cherry; and *E. pectinaria* (Denis and Shiff.), oak, poplar, and wild cherry.

The full-grown larva of *Plagodis serinaria* (H.-S.) is about 1½ inches in length. The head is bilobed and angular, and the body dull brown with blotches of lighter and darker shades. On the back of the sixth abdominal segment is a prominent transverse swollen area. This species is found in the Atlantic States, and the larvae feed on yellow birch and maple. The moths emerge in May or June, larvae may be found from June through August, and the winter is passed in the pupal stage.

The full-grown larva of *Hyperetis amicaria* (H.-S.) is green to brownish, and about 1¼ inches long. The head is rather small and flattened in front, and the body is marked with a pair of whitish spots on the back of all the segments except the first thoracic. The spiracles are black. This species is widely distributed through the eastern part of the United States. Its larvae feed on alder, yellow birch, beech, and other deciduous growths. The moths emerge late in May and June, the larvae are found from July to early in September, and the winter is passed in the pupal stage.

The full-grown larva of **the filament bearer** (*Nematocampa limbata* (Haw.)) is about ¾ inch in length, and greenish-brown. The head is slightly bilobed, and rusty red marbled with a paler hue. The body is cylindrical and has a pair of prominent tubercles on the first abdominal segment, a pair of long slender fleshy brownish filaments on each of the second and third segments, and a pair of small tubercles tipped with rusty red on the eighth segment. There is a broad white stripe on the back extending from the prothorax to the first pair of filaments. This species occurs in the eastern part of the United States and Canada. Its food plants include apple, gray birch, wild black cherry, chestnut, horsechestnut, maple, oak, and other deciduous trees and shrubs. The larvae are active from May to July, and the moths emerge from late in June to August. Presumably the winter is passed in the egg stage.

The moth of the **elm spanworm** (*Ennomos subsignarius* (Hbn.)), also called **the snow-white linden moth,** is frail and pure white, and has a wing expanse of 1¼ to 1½ inches. The forewings are angulated, and the hind wings more or less notched. The full-grown larva is about 1½ inches long, with the large head and the anal segment bright red and the body dark brown to blackish. This larva closely resembles an elm twig (fig. 91, *F*.).

This moth is recorded from Nova Scotia, Canada, the Atlantic and Middle States, and Colorado. The food plants include elm, basswood, red maple, yellow birch, and other deciduous growths found in lowlands. Sometimes it is a serious pest of shade and forest trees, occasionally defoliating large areas in forests, particularly in maple swamps. The moths emerge in July and lay their eggs in clusters on tree trunks and beneath branches. The winter is passed in the egg stage, and hatching takes place in the spring at about the time the foliage opens. The larvae become full grown in June and transform to pupae between leaves spun together, on the undersides of branches or in crevices of the bark.

The full-grown larva of *Nepytia canosaria* (Wlkr.) is about 1 inch long. The head is pale whitish, or sometimes reddish brown, with five or six large and some minute black dots. The body is whitish with a yellowish or reddish tinge marked with black dots and a yellowish lateral stripe, below which are four dark, wavy hair lines. Some specimens have a subdorsal row of white spots edged with brown. This species occurs through eastern and southern Canada and in the northeastern part of the United States. The larvae feed on hemlock, spruce, fir, and larch. The moths emerge in August and September, and the larvae are active from June to August.

The genus *Lambdina* (*Ellopia* auct.) was erected by Capps (*80*), because in the study of this group he found that no species of true *Lambdina* occurs in the New World. This genus includes some of the most serious defoliators of coniferous forest trees in North America. In recent years at least five species are known to have occurred in outbreaks, either locally or over extensive areas, and in different parts of the United States and Canada. The larvae of some of these species are very similar in color and markings. "The larvae of *pellucidaria*, *athasaria* (Wlkr.) and *fiscellaria* Guen. are alike at maturity, within the normal range of variation, so that they cannot be distinguished with certainty" (Dyar, *141*). The three are important in the Eastern States and are discussed in detail below.

The moth of **the hemlock-looper** (*Lambdina fiscellaria fiscellaria* (Guen.)) varies in color from a creamy tan to a grayish brown with a purplish tinge. The wing expanse is about 1¼ inches. The forewing has two transverse irregular purplish-brown lines and a dot of the same color midway between the lines near the costal margin, and sometimes the outer line is bordered externally with ochreous. The hind wing has only one transverse line. The full-grown larva is about 1¼ inches in length and ranges from yellowish green to grayish or darker, and the head and body are flecked with black spots (fig. 91, *E*).

This species is distributed from Georgia to Wisconsin and southwestern Ontario and northeasterly to Newfoundland. The favored food plants are hemlock and balsam fir. Various other plants such as arborvitae, yellow birch, blueberry, wild cherry, maple, oak, and spruce are sometimes attacked.

The moths emerge late in August and September. The females lay an average of about 100 eggs each. These are deposited singly or in groups of 2 to 3 on the twigs or needles, or in crevices of the bark. The winter is passed in the egg stage. Hatching generally takes place early in June, and the larvae become full grown in August or early in September. The larvae in all instars spin, and when disturbed drop and remain suspended for some time on their silken threads. A considerable number of the needles are cut off near the base, or only one side of the needle is eaten, which causes the remaining part to dry up and drop to the ground. Pupation may take place in crevices of the bark on the trees or in the duff on the ground, and the moths emerge about 3 weeks later. This is a serious pest of hemlock and balsam fir, particularly in stands where these trees predominate. One complete defoliation is fatal to hemlock or balsam fir, and there are many records of large tracts being ruined during outbreaks of the pest. Between 1924 and 1928 severe outbreaks occurred in Michigan, Wisconsin, New York, and Maine causing a heavy mortality of hemlock on a great many acres. De Gryse and Schedl (*129*) and Watson (*425*) published accounts of this insect and its habits in Canada.

The moth of *Lambdina athasaria pellucidaria* (G. & R.) is smoky to ash gray in color and has a wing expanse of about 1½ inches. The head and front of the prothorax is ochreous and the body ash colored with an ochreous tinge. The forewings are crossed transversely by two irregular diffuse dusky lines, the discal dot between them, and the outer line slightly sinuate. The hind wings have a line which appears as a continuation of the outer line of the forewings. The full-grown larva is 1 to 1½ inches long and pale straw to greenish yellow with black markings, which vary considerably in intensity. The head is densely marked with dark and light-brown frecklelike spots, and the body markings are as follows: The dorsal area is of the ground color with faint irregular longitudinal stripes composed of blackish dots and short wavy lines; the sides to below the subventral fold have similar stripes but they are blacker and more distinct, especially a lateral one; the subventral fold is pale, sometimes with an orange tinge; the tubercles and spiracles are black; and the venter is pale with faint, dark lines. The cervical shield and legs, except the anal claspers, are the color of light honey. Some specimens are much darker, the dorsum tinged with reddish brown and the sides almost entirely black (fig. 91, *I*).

This species was reported in 1900 and 1902 from the Atlantic States by Dyar (*141a*), who recorded the food plant as yellow pine. Local outbreaks occurred in stands of pitch pine on Cape Cod, Mass., in 1913, 1922, 1932, and 1933, and on Long Island, N. Y., in 1933, and in a plantation of red pine in Connecticut, in 1942–43. The moths emerge in May and June, the eggs are laid on the needles, and the larvae become full grown late in September. Pupation talkes place in the duff beneath the trees in September and the insects pass the winter in the pupal stage.

Lambdina athasaria athasaria (Wlkr.) is also a looper on hemlock. The moth has a wing expanse of about 1¼ inches and is similar in shape, color, and markings to *L. athasaria pellucidaria* but is smaller and more delicate in appearance. The full-grown larva is about 1¼ inches in length, and is yellowish with dark markings. The head is marked with irregular brown to blackish spots. The body, above, is obscurely marked with areas of brown, white, and yellow, the sides much darker, with wavy lines of dark brown or reddish brown interrupted by an occasional dash of yellowish white, and the venter has five broken, wavy, brown lines. The legs and prolegs are dotted with irregular-shaped, dirty-brown spots (fig. 91, *J*).

This species was listed by Dyar (*141a*) as occurring in the Atlantic States. Local outbreaks have occurred in Massachusetts and Connecticut in recent years. Houser (*240*) reported a serious outbreak that occurred in Ohio about 1925. Hemlock is its preferred food plant.

The moths emerge in May and June, hatching occurs in July, and the larvae become full grown the latter half of September. Pupation takes place just beneath the top crust of the leaf mold, and the winter is passed as pupae.

The moth of **the chain-spotted geometer** (*Cingilia catenaria* (Drury)) has a wing expanse of 1¼ to 1¾ inches. The head and thorax at the base of the patagia are orange yellow, the body is white with black markings, the wings are smoky white and thin, the outer margin of both forewings and hind wings is marked by a faint black line, which is interrupted by several black spots, and half way between this line and the discal dot is an irregular line of black dots. The antennae of the males are very plumose. The moths are day fliers. The eggs, when freshly laid, are pale green, later turning a dark violet. They are deposited singly in a promiscuous manner, often dropping to the ground. The full-grown larva is pale straw yellow, slender, cylindrical, and nearly 2 inches in length. The head is dotted with black. The body is marked with lines on the sides just above the spiracles, which are interrupted on each segment by two conspicuous black dots, presenting a chain-dotted effect. Beneath there are three hair lines on each side, and in some specimens a faint fourth line is present (fig. 91, *H*). The pupa is whitish marked with black blotches and is in a cocoon of loose network among the leaves.

The moths emerge from August to October, the eggs are deposited in the fall, hatching takes place late in the spring, the larvae are active from June to August, and 3 to 4 weeks are spent in the pupal stage. This species is distributed through the eastern and northern parts of the United States and west to Minnesota, and in Nova Scotia and southern Canada. It has a long list of food plants, the more important being rather low-growing shrubs, sprouts, and small trees found in pastures and cut-over woodland areas which include bayberry, blueberry (Phipps, *351*), huckleberry, sweetfern, alder, balsam, gray and paper birch, wild cherry, oak, poplar, and willow. Local outbreaks are frequent in the Northeastern States.

The moth of *Deuteronomos magnarius* (Guen.), **the notched-wing geometer,** has a wing expanse of 2 inches. It is yellowish, spotted with brown, with the outer third of the wings somewhat shaded and outer edges unevenly notched. The full-grown larva is about 2¼ inches in length and yellowish green, tinged with red. The head is bilobed, rather small, and the antennae are large. The body is smooth, slightly granular, gradually increasing in thickness from the head to the sixth abdominal segment with the first to sixth abdominal segments longer than the others. There are prominent reddish, swollen areas on the backs of abdominal segments 2 to 5, and another on the venter of the third. The back of the eighth abdominal segment bears two conical tubercles, and the cervical and anal shields are somewhat roughened. This species was recorded by Dyar (*141a*), as occurring in the northern part of the United States. In the Northeastern States the larvae are known to feed on white ash, gray birch, and yellow birch. Chestnut, hickory, basswood, maple, and beech are listed by other authors. The larvae are most noticeable in July and August, when they are approaching full growth. They spin spindle-shaped cocoons in leaves drawn together with silk, and the moths emerge in September and October.

The full-grown larva of *Tetracis lorata* Grote is about 1½ inches in length and resembles a rough twig. The head is grayish, flattened and square in front but not notched. The body is dull reddish brown with white markings, and there is a black median line from the fifth abdominal segment to the end of the supraanal plate. The tubercles are prominent. This species has been recorded in the United States from Maine to Pennsylvania and west to Iowa. The larvae have been collected and reared on wild cherry. Other authors list hemlock and sweetfern as the food plants. The moths emerge in June, the larvae are found from July to September, and the winter is passed in the pupal stage.

The full-grown larva of *Abbottana clemataria* (A. & S.) is about 2½ inches in length and purplish brown, resembling the bark on a twig. The head is rounded and slightly bilobed. The body is cylindrical, with the second thoracic and fourth abdominal segments swollen above, and the tubercles on the back of the fifth and ninth abdominal segments are rather prominent. This species occurs from Nova Scotia south through the Middle Atlantic States and west into the Mississippi Valley. Its food plants include bittersweet, wild cherry, maple, and poplar. The moths emerge in May, larvae are present from June to August, and the winter is passed as pupae spun up in the leaves on the ground.

The full-grown larva of *Prochoerodes transversata* (Drury) is purplish brown to light wood brown and about 2 inches in length. The head is rounded and flattened in front. The second thoracic segment is swollen and streaked with reddish, the hinder part of the fourth abdominal segment is swollen above and marked with white, and the back of the eighth segment bears a pair of prominent tubercles. This species is recorded from the Atlantic States and Canada. Its food plants include apple, blueberry, wild cherry, sweetfern, maple, and willow. There are two generations in the Northeastern States. The first moths emerge in May and June, and the next brood in August. The larvae may be found from June through September, and the winter is passed in the pupal stage.

Family LACOSOMIDAE

The moths of the family Lacosomidae somewhat resemble those of the silkworm. They differ markedly in structure, however, and also the habits of the larvae are very different. The moths are stout with pectinate antennae, and falcate forewings, more or less bent at the middle and with heavy veins. The hind wings have the humeral angle much enlarged, and the frenulum at most rudimentary.

So far as is known only two species are found in the eastern part of the United States, and only one of them is at all common. This one, *Cicinnus melsheimeri* (Harr.), **Melsheimer's sack-bearer,** ranges from southern New Hampshire to Wisconsin and southward, and, although not of economic importance, it often attracts attention. The moth is reddish gray, finely sprinkled with minute black dots. Both wings are crossed by a narrow blackish band, and the forewings have each a black discal spot or bar. The wing expanse is about 1½ to 2 inches. The larva feeds on oak, most commonly on scrub oak. The newly hatched larva draws together two leaves with strands of silk, making a shelter. Later it constructs a neat ellipsoidal portable case of pieces of leaves and silk, leaving a circular opening at each end. It deserts the case at will. When at rest it anchors the case with strands of silk, and its head and anal end stop up the openings. If it desires to move to another twig, it bites off the strands of silk and transports the case to the new location. The moths emerge in May and June, and the larvae are found from July to October. The other species, *Lacosoma chiridota* Grote, is a dark yellowish-brown moth with forewings deeply scalloped and a wing expanse of about 1 to 1¼ inches. The larvae feed on oak, and the habits, seasonal history, and distribution are somewhat similar to those of *Cicinnus melsheimeri.*

Family PSYCHIDAE

The Bagworms

Each member of this family lives within a case or bag made of silk, usually strengthened and more or less camouflaged by an outer layer of bits of leaves or stems. The larva never leaves the case, the excrement is forced out through a small opening in the lower end, and there is a large opening at the top from which the head and several segments of the larva may protrude when feeding, moving about, or enlarging the case.

Only one species, **the bagworm** (*Thyridopteryx ephemeraeformis* (Haw.)) (fig. 92) is commonly seen. The male moth is sooty black with broadly feathered antennae and hairy body and legs, and has a wing expanse of about 1 inch. The wings become almost transparent after a short flight. The female is without functional eyes, legs, or antennae, is maggotlike in appearance, soft, yellowish-white, and almost naked (Howard and Chittenden, *244*). The numerous soft, white eggs are packed in the pupal case. The full-grown larva attains a length of ¾ to 1 inch, and is dark brown, with the head and thoracic plates yellowish with numerous black spots. The cases of the mature larvae may be from ¾ inch to 1½ inches long. This species is found from southern Massachusetts to Kansas and south to Florida and Texas. It is principally a pest of shade trees, shrubs, and hedges, though it favors evergreens of all kinds, especially arborvitae, causing partial or complete defoliation. It has been known to flourish on native cedars, cypress, and willows in Texas.

The moths emerge in September and October. Mating takes place without the female leaving her bag, and then the eggs are deposited in the pupal case. The winter is passed in the egg stage. Hatching takes place in late spring, and the larvae crawl to the nearest foliage and immediately begin to construct their cases. Large quantities of silk are spun and the case or bag is enlarged as the larva grows, so that it may conceal itself within at any time (fig. 92, *D*). The young larva first feeds on the epidermis of the leaf, and later eats all but the larger veins. It becomes full grown, attaches its bag with silk to a twig, and pupates within, in August or September. On deciduous trees the bagworm can be controlled by hand picking the bags in winter, but on evergreens this method is impractical, and spraying the foliage with lead arsenate (p. 53) when the larvae are feeding is the most efficient method of control. **For caution in the use of arsenicals see p. 34.**

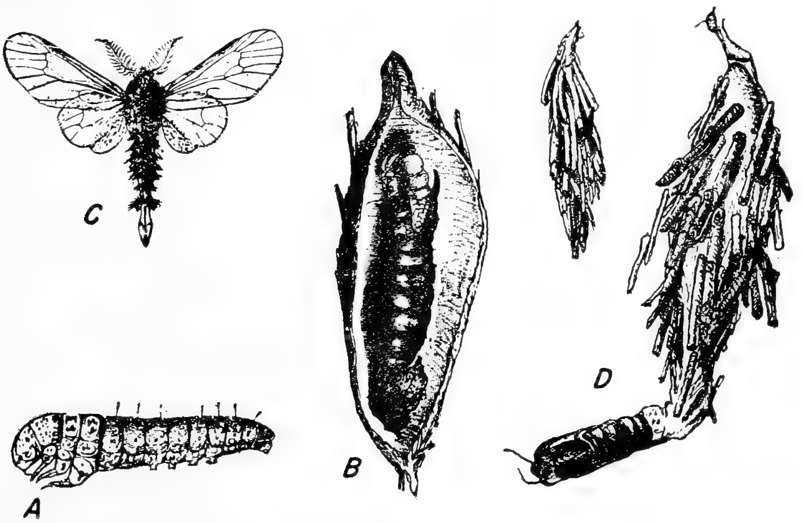

FIGURE 92.—The bagworm (*Thyridopteryx ephemeraeformis*): *A*, Full-grown larva; *B*, female pupa; *C*, adult male; *D*, characteristic cases, or bags.

FAMILY LIMACODIDAE

The Slug Caterpillars

The moths of the Limacodidae are medium to small, vary greatly in appearance, and many are delicately colored. The bodies are stout, and the vestiture often long and woolly. The larvae are sluglike and the large head is concealed in the thorax. The thoracic legs are small and the prolegs replaced by sucking disks. The larvae are of various forms, one group smooth and another with spines. The prepupal larva hibernates in its oval or nearly spherical cocoon, which is of densely woven silk spun between leaves or attached to a twig. The moth pushes off a lid at one end of the cocoon when ready to emerge. Representatives of this family occur throughout the United States. They are rather general feeders on foliage of trees and shrubs. In general the life cycles and work of the various species are similar, so, in the following paragraphs, two of the better-known native species are briefly mentioned, and an introduced species is discussed in some detail.

The full-grown larva of **the hag moth** (*Phobetron pithecium* (A. & S.)) bears nine pairs of lateral brown processes, of which the third, fifth, and seventh are longest and are curved and twisted, sug-

FIGURE 93.—Larvae of the saddleback caterpillar (*Sibine stimulea*). (Courtesy Conn. Agr. Expt. Sta.)

gesting the disheveled locks of a hag. These appendages are clothed with stinging hairs. **The saddleback caterpillar** (*Sibine stimulea* (Clem.)) has a characteristic green patch on the back resembling a saddlecloth, and the saddle is represented by an oval purplish-brown spot. The body of the larva, evenly rounded, is armed along the sides with fascicles of spines, and has two large tubercles at the anterior and posterior ends armed with spines (fig. 93). A nettling effect is caused when the spines come in contact with the human skin. The larvae of these native species are rarely abundant enough to cause serious defoliation, but several species are armed with irritating spines.

The oriental moth (*Cnidocampa flavescens* (Wlkr.)) has a wing expanse of $1\frac{1}{4}$ to $1\frac{1}{2}$ inches (fig. 94, *A*). The thorax and inner portion of the wings are yellow, while other portions of the body and wings are light reddish brown. The eggs are oval (fig. 94, *D*), flattened,

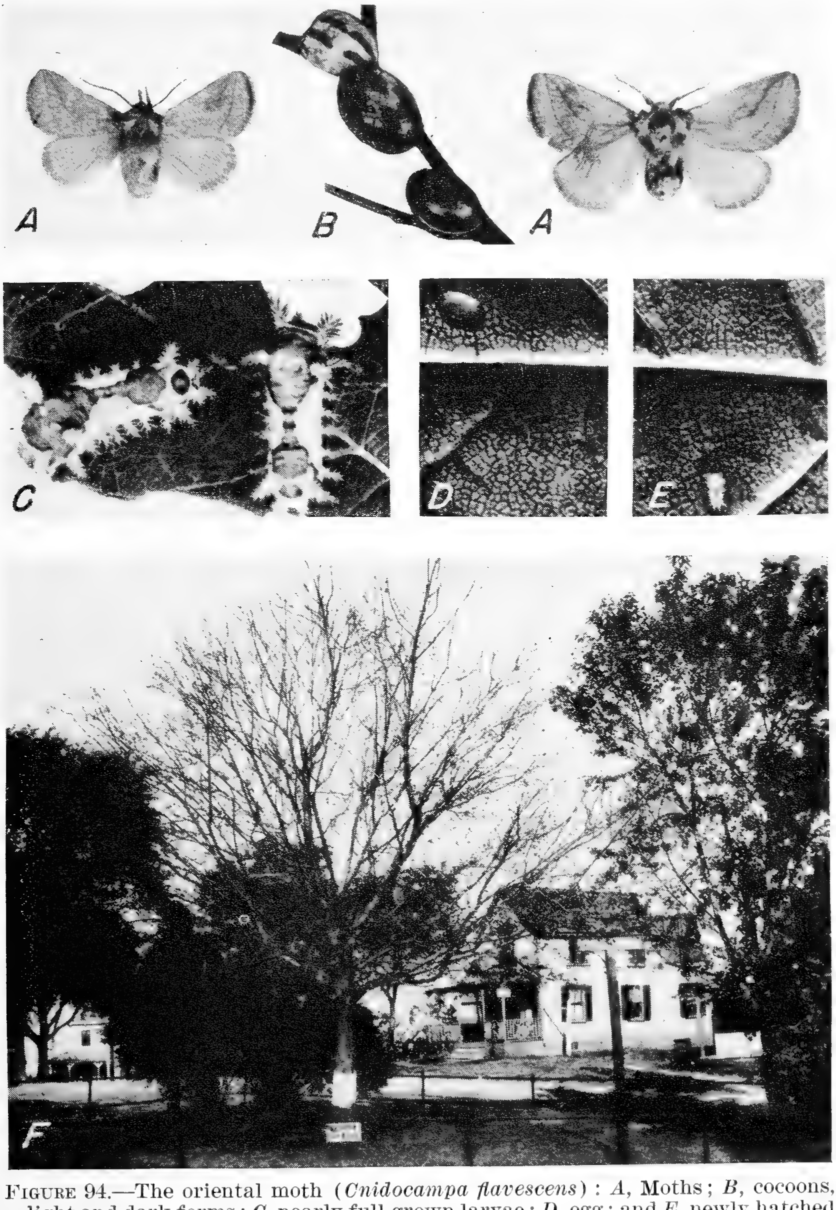

FIGURE 94.—The oriental moth (*Cnidocampa flavescens*): *A*, Moths; *B*, cocoons, light and dark forms; *C*, nearly full-grown larvae; *D*, egg; and *E*, newly hatched larva; *F*, defoliated Norway maple.

about $\frac{1}{16}$ inch in length, and are colorless until the embryos develop. They are deposited on the undersides of the leaves, usually singly or in small groups (Collins, *98*).

The partly grown sluglike larva is shaped somewhat like a dumbbell, the central area being a little constricted, and the ends from which long spiny tubercles arise are enlarged. When full grown it is about $\frac{7}{8}$ inch in length, and has markings of yellow, blue, green, and purple, the upper surface having a dumbbell-shaped purple area which is enlarged over the extremities. The coloring, together with the long spiny tubercles, presents a very striking appearance. The cocoon is gray brown, sometimes marked with white, is about $\frac{1}{2}$ inch in length, elliptical, smooth, and hard, and is firmly attached on one side to the bark of a twig, branch, or crotch. The pupa is light brown.

The oriental moth is a native of Asia and was accidentally introduced into the United States, probably on nursery stock, sometime prior to 1906, when it was found in the Dorchester district of Boston, Mass. It is now firmly established but known to occur only in eastern Massachusetts. It has been intercepted at other points of entry on foreign nursery stock. Norway maple, sycamore maple, buckthorn, black birch, wild and cultivated cherry, apple, pear, and plum are most favored as food plants in its present range. When abundant it is known to feed on other maples, oak, aspen, willow, honeylocust, hickory, and hackberry.

In Massachusetts there is one generation annually. The moth issues by forcing off a circular lid from the upper end of the cocoon late in June or July, and is active at night. The eggs hatch in about a week. The larvae at first feed on the lower epidermis of the leaves, but during later instars they eat all but the large veins. Larvae may become full grown in about 5 weeks, but stragglers are found until the first of October. Each forms its cocoon by spinning a network of threads around itself and attaching them to the bark. It then continues from within to spin more silk and apparently secretes a liquid which fills the spaces between the threads and hardens. The larva passes the winter in its cocoon and transforms to a pupa about the first week of May. In confinement, a moth has laid as many as 551 eggs, and dissections of other females indicate that some may lay nearly 1,000 eggs. In addition to its being a defoliator of shade, ornamental, and fruit trees, it is obnoxious because of the severe irritation people suffer when they come in contact with the larval spines.

Among its natural enemies, *Chaetexorista javana* B. & B., a parasitic fly was introduced from the Orient in 1929 and 1930, and is exerting a considerable influence in the control of this pest. Cocoons are sometimes attacked during the winter by squirrels.

Family MEGALOPYGIDAE

The Flannel Moths, or Puss Caterpillars

The *Megalopygidae* is a small family of stout-bodied moths which have long crinkly hairs on the wings, body, and legs. They have a wing expanse up to $1\frac{1}{2}$ inches, and the males are usually somewhat smaller than the females. The eggs are laid in small batches, usually on leaves, and are packed or covered with hairs from the abdomen of the female. The full-grown larva ranges from $\frac{3}{4}$ inch to $1\frac{1}{4}$

inches in length. The head is light colored, and the body short and flat. It is rather densely clothed with long, soft hairs, so that it appears about one-half as broad as long. Some of the hairs have stinging propensities and may cause much discomfort when in contact with the human skin. The seven pairs of prolegs are borne by abdominal segments 2 to 7 and 10; but those on segments 2 to 7 are without hooks. The cocoons are parchmentlike in texture.

The three species treated here are rather common, and sometimes abundant locally in some areas in the eastern part of the United States.

The puss caterpillar (*Megalopyge opercularis* (A. & S.)) has a rather wide distribution throughout the States south of Virginia. The moth is yellowish-brown, the forewings marked with dark brown, particularly toward the anterior border. There are long, wavy, white hairs on the wings, especially along the veins. The larva is densely clothed in long, yellow and reddish-brown or mouse-gray hairs, those near the posterior end being tufted to form a sort of tail (fig. 95, *A*). Its food plants include the foliage of citrus, hackberry, elm, plum, sycamore, oak, rose, and other deciduous trees, and shrubs. The larvae feed gregariously for a few days, skeletonizing the foliage. In later instars they devour the entire leaf. Sometimes this species becomes numerous enough in the south to cause noticeable defoliation, but it is principally injurious because of its sting. The severity of the sting increases with the growth of the larva. Bishopp (*29*) describes this caterpillar and discusses the effects of its sting.

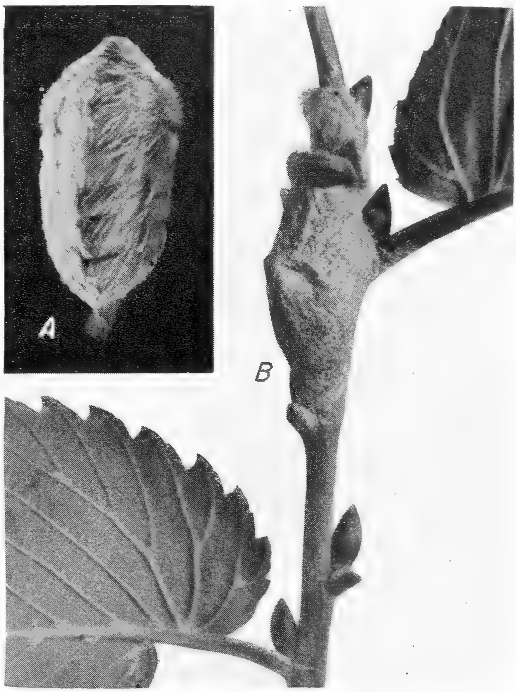

FIGURE 95.—The puss caterpillar (*Megalopyge opercularis*): *A*, Full-grown caterpillar; *B*, cocoon opened to show beveled cap, or operculum.

There may be two generations in the south. The maximum number of grown larvae of the first generation seem to occur in June and July and those of the second generation in September and October. Apparently there is more or less overlapping of the generations, and probably some strains have only one each year. This species passes the winter in the prepupal stage within the cocoon which is usually spun on some part of the host tree (fig. 95, *B*). Pupation takes place in the spring, and the moths emerge from April to June. The number of eggs deposited ranges from 300 to 600. The eggs hatch in 4 to 8 days.

Lagoa crispata Pack., is more commonly found in the Northern States than in the South. The moth is cream-colored and the fore-wings are marked with wavy lines of crinkled black and brownish hairs. The larva is cream white when young, and fawn, shading to mouse gray in front, when full grown. It has a wide variety of food plants including bayberry, sweetfern, locust, apple, and many others. According to Bishopp (*29*), its stinging propensities are not highly developed. Apparently this species has only one generation, and the larvae are found from July to September. It passes the winter as a prepupal larva in a tough cocoon.

The moth of *Norape cretata* (Grote) is pure white with a little crinkly hair. The wing expanse is about 1¼ inches. The larva has a spotted body, sparsely clothed in tufts of hair. During the early instars the larvae are gregarious. Pupation takes place in tough cocoons in the ground. This species feeds on redbud, and ranges from New Jersey and southern Pennsylvania southward, at comparatively low elevations. Sometimes it is rather abundant in the vicinity of Washington, D. C.

Family PYRAUSTIDAE

The Pyraustidae is a large family, which until rather recently has been considered by most students of Lepidoptera as a subfamily of Pyralididae. The moths are small to medium size, rather slender and fragile in structure, and some are striking in appearance. Although there are many species common to the eastern part of the United States, comparatively few of them live on trees and shrubs in the forests. The larvae are generally very active and of varied habits; some live gregariously in webs among the leaves, some are solitary and live in rolled or folded leaves, and others are borers in stems or roots of plants. Occasionally larvae bore into the woodwork of buildings to pupate, and thereby disfigure painted surfaces.

The moth of **the grape leaf folder** (*Desmia funeralis* (Hbn.)) is black with white markings, the forewings in both sexes have two large oval spots, and on the hind wings of the male there is one spot. In the female there may be a divided spot on the hind wing. The fringe of the wings is more or less white. The wing expanse is about ¾ to 1 inch. The full-grown larva is about 1 inch in length, glossy, translucent yellow-green on the sides and somewhat darker above. The head and cervical shield are light brown, and there are darker brown spots on the sides of the first two thoracic segments (Strauss, *398*).

This species is distributed in Canada from Nova Scotia to Ontario, and in the United States east of the Rocky Mountains, and in California. It is a well-known pest of grapevines. The food plants include wild and cultivated grape, Virginia creeper, and redbud. There are two or more generations in the South, but there may be only one in its northern range. The moths emerge in the vicinity of Washington, D. C., from late in April through most of June, and late in July and August, and larvae may be found until October. In Massachusetts, moths emerge in June and the larvae are active in July and August. The winter is passed in the pupal stage on the ground.

The moth of **the basswood leaf roller** (*Pantographa limata* G. & **R.**) is white, shaded with pale yellow and with many elaborate markings of olive or dull brown. The wing expanse is about 1⅜ inches. The full-grown larva is about 1 inch in length, and is bright green, with the head and cervical shield black. It is generally distributed throughout the eastern part of the United States, and is a leaf roller on basswood. The moths emerge in June or July, and the larvae may be found feeding from July to September. Each larva rolls the apical half or more of a leaf in the form of a tube in which it lives (fig. 96). The full-grown larva passes the winter in a cocoon constructed by folding a part of a leaf and lining it with silk, this leaf dropping to the ground in the autumn with other falling leaves. Pupation takes place late in spring. This species is often abundant, though it seldom, if ever, causes complete defoliation.

FIGURE 96.—Characteristic work of the basswood leaf roller (*Pantographa limata*).

The moth of *Phlyctaenia tertialis* (Guen.), **the elder leaf tier,** is brown, marked with creamy white spots and streaks, some specimens being much lighter than others. The wing expanse is about ⅞ inch. The larva is light green, with two broad white stripes on the back, and is sparsely hairy. When full grown, the larva is whitish or pinkish, translucent, and about ¾ inch long. This species is generally distributed through the Northeastern States, south to Virginia and west to Kansas. The larvae feed on the foliage of elder, sometimes causing much defoliation in the Northeast. The winter is passed as prepupal larvae in their hibernacula, which are usually spun in hollow stems or in the pith of elder. The moths emerge in June in the Northern States, and the larvae are found from July to September. In southern New England and farther south there are two generations, or at least a partial second, the moths emerging in May and June, and in August, and the larvae are found from June to September.

FAMILY PYRALIDIDAE

As now constituted, the species recognized under the Pyralididae are of little importance in the forest. Only one of these, *Omphalo-*

cera dentosa Grote, need be discussed. This moth is reddish brown to olive brown, with a wing expanse of about $1\frac{1}{2}$ inches. The forewings are dusted and streaked outwardly with darker shades, and the median space is brownish black: the hind wings are reddish to blackish. The full-grown larva is about $1\frac{1}{2}$ inches in length. The head is blackish, dotted with white, and the body black dorsally and laterally. It is marked by many small white spots arranged in two more or less irregular, transverse rows on each segment. The venter is brown. The head and body are sparsely clothed in light and dark hairs. This species is distributed from southern New England to Iowa and southward into Texas. Britton (*56*) reported it as feeding on barberry and as sometimes abundant locally, particularly on hedges and in nurseries. The moths emerge late in June and July. The larvae may be found during August and September.

Each larva spins together several leaves on a twig and in this web constructs a rather dense silken tube in which it lives. Its excrement adheres to the tube, thus causing an unsightly appearance in addition to the injury by defoliation. The larva pupates in a tough cell composed of silk and particles of soil.

Family EPIPASCHIIDAE

The family Epipaschiidae comprises a large group of species, most of which are tropical insects, and comparatively few species are found in North America. The larvae are normally leaf rollers or web makers.

The pine webworm (*Tetralopha robustella* Zell.) is one of the North American forms. The moth has a wing expanse of from $\frac{7}{8}$ to 1 inch. The forewings, in general, have the basal third purple-black, the center third grayish, and the outer third blackish, fading toward the distal portion. The hind wings and body are smoky-gray (fig. 97, *C*). The full-grown larva is about $\frac{3}{4}$ inch in length. The head and the cervical and anal shields are tan with darker markings, and the body is yellowish brown with two prominent, dark-brown longitudinal stripes on each side (fig. 97, *B*). It is generally distributed from New England to Florida and west to Wisconsin, and has been recorded as attacking pitch, red, and white pines in New England, loblolly pine in Florida and Maryland, and jack pine in Wisconsin.

The moths emerge late in June and in July and August, and the larvae may be found feeding from August to October, occasionally to early November. The larvae live in silken tubes extending through more or less globular masses of excrement held together by strands of silk. These masses are formed on the twigs and enclose the needles upon which the larvae feed. They range in size up to 5 or 6 inches, depending on the number of larvae using them, which may be from 2 or 3 up to 25 or more (fig. 97, *A*). Pupation takes place in an oval-shaped cell in the soil. This species is sometimes very common in New England, particularly in plantations, and may cause some injury to seedlings or small trees. There are no records of it injuring the larger trees. Usually most of the injury has been done when first noticed. In plantations hand picking probably would be the cheapest method of control.

Another North American species is *Tetralopha asperatella* (Clem.). The full-grown larva is about ¾ inch in length. The head is mottled with brown and yellow, and the body is brown, with two dorsal lines and a broad stigmatal stripe of yellowish. The spiracles and legs are blackish. The larvae usually are gregarious and web together two or more leaves, in which they live (fig. 98). This species is generally distributed through the oak regions of the Eastern States and is sometimes locally abundant. The moths emerge in June and July, and the larvae are found from July to October. The winter is passed as prepupal larvae in cocoons spun in the duff on the ground. These change to the pupal stage in the spring.

Some common species very similar to the above are found on maple and poplar. Another, whose adults are determined as *Tetralopha*, near *asperatella*, is sometimes locally abundant on beech in New England. The larva of this species is yellowish green, the head being mottled with light brown. The body usually has two pale-brownish stripes on the back, and the spiracles are black. The life cycle is similar to that of *T. asperatella*. Another species, *T. militella* Zell., apparently is distributed

FIGURE 97.—*Tetralopha robustella: A*, Web nest on red pine; *B*, full-grown larva, × 2, *C*, adult, × 2. (*B* and *C*, Courtesy Conn. Agr. Expt. Sta.)

FIGURE 98.—Characteristic nest of *Tetralopha asperatella*.

through most of the eastern part of the United States, and occasionally attracts attention locally. The larvae feed on sycamore.

FAMILY PHYCITIDAE

The family Phycitidae contains many species of prime economic importance. It is a difficult group to classify because of the instability of many of the characters. In some cases, therefore, it may be necessary to study a large series of specimens and to utilize every available character of structure in addition to data on the biology and host relationships in order to determine the species accurately.

The larvae of the various species differ considerably in habits. Here are found leaf rollers, some living in a tube of silk mixed with frass or in a silken case within a folded leaf or leaves; others are borers in shoots, in the bark of trees, in roots, cones, or fruits, some feed on stored food, and a few are predaceous on coccids.

About 25 species of *Acrobasis* are known to occur in the eastern part of the United States, and their identification is difficult. Most of them are bud or leaf feeders.

The moth of **the pecan leaf casebearer** (*Acrobasis juglandis* (LeB.)) is dark mouse gray, with the head, thorax, and base of wings grayish to white. The wing expanse is about 3/4 inch. The forewings are blackish at the middle of the costa, with an antemedial reddish area toward the inner margin. The hind wings are ashy-gray. The full-grown larva is about 5/8 inch long. The head and legs are black and the body olive green (Gill, *183*). This species is distributed from Ontario to Florida and Texas. The larvae feed on various species of hickory and walnut. The moths emerge from late in May through July. The young larvae feed throughout the summer on the lower epidermis of the leaves, and each hibernates in a small case constructed on a bud or twig. In the spring they eat into the buds, migrate to other buds and construct new cases when necessary, and finally finish their feeding upon the foliage. The case is attached to a stem at one end, the other being open so that the larva can crawl out to feed. Although the amount of foliage consumed is not great, the larvae often eat into the stems of the compound leaves, causing them to break off (fig. 99). This, together with the bud injury, is sometimes very serious (Moznette et al., *309*).

FIGURE 99.—Larvae of the pecan leaf casebearer (*Acrobasis juglandis*) in their cases, and injury done to pecan leaflets.

The moths of **the pecan nut casebearer** (*Acrobasis caryae* (Grote)) are rather dark gray, with a ridge or tuft of long dark scales extending across each forewing near the middle. They have a wing expanse of about ⅝ inch. The full-grown larva is about ½ inch long, and its general color is a dirty olive-green. This species is one of the most important insect pests of the pecan in the Southeastern States and Texas (fig. 100).

There may be three or four generations in the Southern States depending upon the locality and the season. The winter is passed as a partly grown larva in a small case near the base of a bud. Early in spring it feeds on the buds and later bores into the tender shoots, maturing in May. Larvae of the next generation appear in May and

FIGURE 100.—Clusters of nuts infested by the pecan nut casebearer (*Acrobasis caryae*).

June and bore into and destroy from 2 to 5 of the recently set nuts. Larvae of later generations seem to prefer the shucks and usually gnaw only through the surface, causing little damage. Eggs for the last generation are usually laid late in July to early in September, and the larvae construct their hibernating cases in August or September (Moznette et al., *309*).

Acrobasis caryivorella Ragonot is a common species on hickory in the Northeastern States, and is recorded west to Illinois and Missouri and south to Texas. The moths emerge in June and July. The full-grown larva is about ¾ inch long. The head and cervical shield are blackish, and the body is dark grayish-green. In the spring, when it is most noticed, the larva mines the tender shoots and webs together the tips of the new growth. It lives in a frass tube, and transforms in a large oval cocoon.

Acrobasis comptoniella Hulst is often common to abundant on bayberry and sweetfern in the northeastern part of the United States.

The moths are gray, with a wing expanse of about 7/8 inch. The forewings are bluish-gray with the antemedial area shaded with dull red. The hind wings are brownish gray. The full-grown larva is about 3/4 inch long. The head is dark red, the cervical shield pale red, and the body brownish black. The larvae attract attention in June and July. Each lives in a frass tube spun between leaves, enlarging it to form a case when nearly full grown. The moths emerge in July and August.

Acrobasis betulella Hulst is closely related to *A. comptoniella* and is recorded from Maine to New York, and from Colorado and California. The larvae of this species feed on black, gray, and paper birch. *A. rubrifasciella* Pack. is similar to *A. comptoniella* and attacks alder and hazel in the Northeastern States. *A. coryliella* Dyar is found in the New England States on *Corylus* (hazelnut). The larvae are noticed in May and June and the moths emerge in July. *Mineola vaccinii* (Riley) is common in New England, and it has been reported as attacking the fruit of blueberry and huckleberry. Franklin (*166*) stated that it sometimes caused serious injury to wild cranberry fruit. The larvae bore into the fruit late in the summer and the moths emerge the following July.

The moth of **the spruce coneworm** (*Dioryctria reniculella* (Grote)) is silvery gray, sometimes with a brownish tint and has a wing expanse of 3/4 to 1 inch. The forewings are shaded with light and dark gray and ornamented with transverse zigzag white lines and a white discal spot. The full-grown larva is about 5/8 inch long. The head and cervical shield are reddish brown, the body is reddish or amber brown, and each segment is ornamented with piliferous warts.

It has been reported from various localities in the northeastern part of the United States from Maine to Michigan and from Colorado. Its principal food plant is spruce, although some authors have recorded it as attacking pine. The moths emerge late in June or in July. The larvae mine the young cones and the tender terminal growth, surrounding them with a mass of webbed excreta. They are active in the spring, and their feeding causes the new growth to curl and the scales to separate from the axis of the cone. Often, when they are first noticed the injury has already occurred. In ornamental plantings, the destruction of the infested cones prior to June first is advisable.

Dioryctria abietella (D. & S.) is very similar to *D. reniculella* and is probably often confused with it. The full-grown larva is about 3/4 inch long. The head is shiny brown, cervical shield blackish shading to gray in front, body dull with a purplish tinge and ornamented with piliferous warts, and the anal shield is large and dull brown. It is well known in Europe, and although it is present in the United States its distribution is uncertain. Carl Heinrich of the U. S. National Museum furnished the following information:

> The larvae of *D. abietella* have a variety of habits. They are both primary and secondary. They bore into new and otherwise uninfested terminals and into terminals that have been attacked by *Rhyacionia buoliana*. They attack both healthy and diseased cones of pine, spruce, and Douglas-fir. They bore into and feed on the cambium of smooth bark on the trunk and branches of all species of pine and Douglas-fir; and they also feed in galls on any part of the tree. The species seems to be distributed throughout the range of the genus *Pinus*.

The larvae bore into cones and shoots of pine and spruce, feeding on the seeds and basal parts of the scales in the cone during the autumn. The partly grown larvae hibernate during the winter, and complete their growth and pupate late in the spring (Tragardh, *410*). The moths emerge late in July and August in New England from white-pine leaders infested with the white-pine weevil (*Pissodes strobi*) and from the cambium of Douglas-fir.

Dioryctria amatella Hulst is larger than *D. abietella*. T. E. Snyder stated in correspondence that it is distributed generally throughout the Gulf States, being one of the most common injurious species of the pitch moths, damaging both 1- and 2-year-old yellow pine cones and the terminals of yellow pine natural reproduction and nursery stock, and it is also one of the most common pitch moths found in wounds of coniferous trees. This insect has been found emerging from terminals and pine cones in June and July and from September to early in November.

The Zimmerman pine moth (*Dioryctria zimmermani* (Grote)) is gray, with a wing expanse of 1 to 1½ inches. The forewing ground color is gray shaded with reddish and marked transversely with zigzag lighter and darker lines. The hind wings are pale yellowish white, the color deeper toward the terminal fringe. The full-grown larva is about ¾ inch in length. The head is chestnut brown, and the body varies in color from a dirty white, through reddish yellow to green, with a series of black dots, from each of which arises a single bristle.

This species is probably distributed over most of the United States wherever suitable host trees are available. It attacks many species of pine, including Austrian, pitch, red, Scotch, Swiss, white, yellow, and others. According to Brunner (*69*), the moths emerge in Idaho and Montana from early in May to the middle of September, the maximum flight occurring during July. Britton (*58*) found that the moths emerged from late in June to early in August in Connecticut. The eggs are deposited on the bark, often near wounds, and the newly hatched larvae bore into the terminals or into branches, often into those already infested by some other insect, such as the white-pine weevil. Before the larvae are half grown they may move and bore into another section of the tree sometimes several feet away from the first point of attack. The winter may be passed as larvae, in any instar, and also in the egg stage, as the eggs deposited late in the summer do not hatch until spring. Pupation takes place in the larval tunnel close to the surface. The moths emerge approximately 1 year after the eggs are laid.

Trees of all sizes may be attacked. In Massachusetts pitch-pine trees growing in a more or less open situation seemed to be more subject to attack, than those in dense stands. The tunneling of the tips of branches causes them to turn brown and to break off. This injury not only retards the growth but may spoil the shape of the trees. Brunner (*69*) found that sometimes a space a foot or more wide and several feet long on a tree trunk had the cambium literally honey-combed with tunnels, and on one tree he counted 27 nearly mature larvae at work. In plantations, trees up to about 15 or 20 years of age occasionally are so seriously injured that the growth below the point of attack is greatly retarded, and the trees seldom if ever recover (fig. 101).

In nurseries and in plantations where the crowns have not closed, and the infestation is severe enough to warrant the expense, timely pruning and destruction of the infested tips and the removal of brood trees will be found practical.

The moth of *Tacoma nyssaecolella* Dyar is powdery gray with a wing expanse of about ⅝ inch. The forewings have a whitish antemedial line, on each side of which are patches of dark gray. The full-grown larva is black with a yellowish head. This species is sometimes locally abundant in Massachusetts, and has also been recorded from New Jersey to western Pennsylvania. The larvae are leaf folders or rollers on tupelo. Considerable frass becomes lodged in the loose web spun in the folded leaf or nest of each larva. In Massachusetts the larvae are found in July and August, the winter is passed in the pupal stage, and the moths emerge late in June and in July.

FIGURE 101.—Scotch pine tree showing injury by the Zimmerman pine moth (*Dioryctria zimmermani*).

The moth of **the locust leaf roller** (*Salebria subcaesiella* (Clem.)) is gray, with a wing expanse of about 1 inch. The forewings are powdery gray with a shading of reddish near the base and a broken black terminal line. The hind wings are cloudy, shaded toward the outer margin. The full-grown larva is nearly an inch in length. The head and cervical shield are blackish, the body is green, with about five faint yellowish-green lines on each side of the dark-green median line.

This species is distributed from Ontario to Maine, south to West Virginia and west to Colorado. The larva feeds on locust and wisteria. The moths emerge from May to July, and in August and September. Records indicate that in the Northeastern States there is one generation and occasionally a partial second. The larvae can be found from June through September, and are usually between two or three leaves spun together with silk. They are usually quite common and often attract attention, although the records indicate the species is seldom a serious pest. The winter is passed as pupae in silken cocoons among the leaves on the ground. *S. virgatella* (Clem.) is also a leaf roller on locust. The full-grown larva is light green with a light brown head. Its life cycle is similar to that of *S. subcaesiella*.

The moth of *Salebria semiobscurella* (Hulst) is ash gray with a wing expanse of about ⅞ inch. The forewing is pale gray at the base, followed by a blackish shade, and the outer two-thirds is powdery gray with obscure lines. The base of the inner margin is reddish. The full-grown larva is about ⅞ inch in length. The head is yellowish, flecked with brown, the body yellowish green with brick-red lines on the back and sides. The red lines are absent from the sides of some specimens. This species is a leaf roller on sumac, and is sometimes very abundant in the Northeastern States. It ranges from Maine to Texas. The moths emerge in June and July, the larvae are found from July to September, and the winter is passed in the pupal stage.

The lesser cornstalk borer (*Elasmopalpus lignosellus* (Zell.)) girdles the roots of black locust seedlings in forest nurseries in Arkansas, Louisiana, Mississippi, North Carolina, and Tennessee. The moths vary somewhat in color and size, the male being ochre yellow to light brown and the female generally darker. Their forewings are long and narrow and the expanse is from ⅝ to 1 inch. The full-grown larva is about ⅝ inch long. The head is brownish black, the cervical shield dark brown, and the body greenish white with rather conspicuous, somewhat broken, longitudinal stripes of dark brown.

The species is well distributed through the Southern States and has been taken as far north as Massachusetts. It is also found in Mexico, Central America, and South America. A gall-like injury is formed on the lower stem of black locust in the nurseries, and the seedlings are killed or break off at the ground line (fig. 102). Injury is especially common in sandy soil recently in grass or weeds. In the Southern States where this injury occurs there may be from three to four generations a year. For control measures see pp. 33–34.

The moth of *Canarsia ulmiarrosorella* (Clem.) is fuscous gray, with a wing expanse of ¾ inch. The forewing is more or less dusted with white and is crossed by dark gray or blackish wavy lines. The full-grown larva is about ¾ inch long, and bright green, with the margins of the segments faintly tinged with yellow and with pale dorsal and stigmatal lines. The prothoracic and mesothoracic segments each bear a small blackish spot on the subdorsal area. The larva is very sparsely hairy. This species ranges from Canada to Texas, and its larvae feed on elm. The moths emerge in May and June, and in August. The larvae are usually solitary, and conceal themselves in a silken web between the leaves upon which they feed. There are two generations, and the larvae are active from June to October. The winter is passed in the pupal stage in crevices or under loose bark. This is not considered a serious pest, but it is sometimes abundant enough on elm shade trees to attract attention.

Family PTEROPHORIDAE

The Plume Moths

The plume moths are rather small and frail in appearance. They have long, slender legs with long spurs and strong scale tufts. The forewings in most species are deeply cleft at the middle of the outer margin, and the hind wings are divided into three parts resembling feathers; hence the common name "plume moths." The eggs are of

FIGURE 102.—Black locust seedlings showing injury to roots by *Elasmopalpus lignosellus.*

the flat type. The larvae are usually hairy and mostly leaf rollers, but a few are borers. The pupae of most species are suspended by the caudal extremity. Although there are many species represented in North America, the larvae of most of them feed on annual and perennial plants and brambles, and few are of much economic importance.

The grape plume moth (*Pterophorus periscelidactylus* Fitch) is frequently abundant locally in the Northeastern States on wild and cultivated grape. The moth is yellowish brown marked with dull whitish streaks and spots, and has a wing expanse of about ¾ of an inch. The eggs are deposited singly or in groups of 2 to 10 in the small crotches on old canes. There is one generation annually (Whitcomb and Tomlinson, *431*). The larvae are greenish white and hairy, and about ½ inch in length when full grown. They feed on the tender, expanding leaves early in the spring. Each larva webs together one or more terminal leaves and blossom clusters in which it lives. They become fully grown late in May or June and the moths emerge in June and July.

Hand picking and destroying the webbed leaves containing the larvae has been recommended as the simplest method of control for many years. Whitcomb and Tomlinson (*431*) reported that a dormant application of either 1 percent of sodium dinitro cresylate or oil emulsion diluted to contain 3 percent of actual oil gave good control.

Family MOMPHIDAE

One species of Momphidae, *Chrysoclista linneella* Clerck, **the linden bark borer,** has attracted some attention in recent years. This is a small orange and black moth of European origin, first recorded in this country in 1928, when it was found infesting linden trees near New York City. It is now known to occur in the southeastern part of New York, the northeastern part of New Jersey, and in the vicinity of Boston, Mass. So far as is known the insect has been found infesting only European linden in this country. The full-grown larva is about ¼ inch in length. The head is light brown, and the body whitish, with the contents of the alimentary tract visible through the integument.

The moths emerge in the spring, usually between the last week in May and the middle of June. Although the eggs have not been observed, it is probable that they are deposited on the branches of their food plant, and upon hatching the young larvae bore directly into the bark. Their work is confined to tunneling in the corky and green portions of the bark, principally in the trunk and the undersides and basal portions of branches. The young larvae feed for some time during the summer, hibernate in their galleries, and complete their feeding in the spring. Pupation takes place in cells formed in the galleries close to the outer surface of the bark. This insect probably causes little damage, except for furnishing possible modes of entrance for secondary organisms.

Family GELECHIIDAE

The Gelechiidae are a large family of moderately small moths. The forewings are narrow, and the hind wings more or less trapezoidal, usually with the outer margin concave and sometimes quite emarginate with a projecting apex. The larvae vary greatly in habits, and many species are very destructive. Some feed between spun leaves or shoots, some are leaf miners, and others feed in seed heads or roots.

Many are solitary and conceal themselves in a folded or rolled leaf or in one or more leaves webbed together.

The moth of *Recurvaria apicitripunctella* (Clem.) is buff yellow shading into white, with a wing expanse of about $\frac{7}{16}$ inch. The wings have a silky fringe, the forewing marked with blackish spots and dots, and the hind wing very narrow and concolorous with the fringe. The full-grown larva is about ¼ inch long. The head, cervical shield, and true legs are pale brown, and the body is greenish, sometimes with a brownish tinge.

It is found throughout the northeastern part of the United States, south to the District of Columbia and west into the Lake States. Hemlock and bald cypress are its food plants. The moths are active from early June to the middle of July. The life cycle and habits are quite similar to those of *Recurvaria piceaella*. The larva feeds during late summer and fall, mining and webbing together the leaves, forming a broad, flat web of six or eight mined leaves in which it passes the winter. On the arrival of spring it continues its work by mining more leaves, and becomes full grown late in May or early in June. The brown, mined needles in the webs give the tree a very unsightly appearance. Local outbreaks have been recorded in Massachusetts. For control use the same measures as for *Epinotia nanana* (see p. 472).

The moth of *Recurvaria piceaella* (Kearf.) is grayish with head and thorax pale yellow to whitish. The forewings have three diagonal, irregular light bands crossing them, and are marked with a few rather conspicuous blackish spots. The hind wings are rather broad and are pearly, slate gray. The wing expanse is about ⅜ inch. The full-grown larva is about $\frac{5}{16}$ inch in length, reddish to light cinnamon brown, with the head and thoracic shield light brown.

It is distributed in the United States from Maine to Colorado, and attacks Colorado blue spruce, Norway spruce, red spruce, and white spruce. The life cycle and habits are very similar to those of *Epinotia nanana* (p. 472). The moths are active from June to the middle of July, depending somewhat upon the season and locality. The eggs are deposited on the needles, hatching takes place in July, and each young larva mines one or more needles during the summer and fall. The insect passes the winter as a partly grown larva in a mine, resumes feeding as a miner again early in spring, and completes its growth about the last of May. Each larva mines several needles and enough silk is spun to hold the mined needles on the twigs for many weeks. The dried mined needles cause an unsightly appearance on ornamentals. In forests it probably never becomes abundant enough to cause serious injury. The control is the same as for *E. nanana* (p. 472.)

The moth of *Recurvaria thujaella* (Kearf.) is cream white, heavily dusted with black and brown scales and has a wing expanse of about ⅜ inch. The forewing has three oblique, blackish bands, and the apical region is shaded and has strong costal and terminal dots. The hind wing is gray with a brownish tinge. The larva is dull reddish, with head, cervical shield, and anal plate blackish. It is a leaf miner of arborvitae, and is sometimes very abundant, although probably not so important as *Argyresthia thuiella*. It has been recorded from the northeastern part of the United States and southeastern Canada. The eggs are deposited in the small crevices between the scalelike leaves late in June or early in July. The small larva bores into a leaf, hollowing out a considerable portion of a spray without again coming out into the open. It passes the winter in the larval stage, and pupates in May, and the adults issue in June. The control is the same as for *A. thuiella* (p. 487).

Recurvaria juniperella (Kearf.) is a leaf miner of red cedar and common juniper in the Northeastern States. The larva is pale green with a pinkish tinge, and the head, cervical shield, and true legs are light brown. It is seldom of much economic importance. The moths issue in June. The life history is probably very similar to that of *R. thujaella*. The control is the same as for *Argyresthia thuiella* (p. 487).

The moth of **the pine needle miner** (*Exoteleia pinifoliella* (Chamb.)) is yellow brown marked with white or gray. The tip of the forewing and three bands dividing the wing into equal parts are white or grayish. The hind wing is fuscous. The wing expanse is about $\frac{3}{8}$ inch. The mature larva is about $\frac{3}{16}$ inch in length, and yellowish brown, with the head, thoracic shield, and anal plate dark brown. It is distributed through the eastern part of the United States. The food plants are pitch pine, Virginia pine, shortleaf pine, and loblolly pine and jack pine.

In the Northeastern States the moths are active during June and the first half of July. The eggs are deposited on the pine needles. On hatching, the larva bores into a needle, burrowing toward the tip, but later reversing and mining toward the base. Winter is passed as a partly grown larva within its mine. Early in spring the larva resumes its feeding, entering fresh needles if necessary. The pupa is formed in the larval burrow in late May or early June. There is probably only one generation a year in the Northeastern States. Some authors indicate two or more generations annually. When infestations are severe, the mining of the foliage undoubtedly affects the annual increment. In addition it gives the trees a sickly and unsightly appearance. It is believed a lead arsenate-fish oil spray, such as is recommended for *Epinotia nanana* (p. 472), applied the first warm days late in March or early in April would be effective. Also the combined lead arsenate-nicotine spray recommended for *Argyresthia thuiella* applied when the moths are flying should give good results. **For caution in the use of arsenicals, see p. 34.**

The moth of *Battaristis vittella* (Busck) is very similar in color and pattern to the preceding species, but according to Busck (*78*), it is larger and without scale tufts and at once recognized by the black tornal dash. The full-grown larva is about $\frac{1}{4}$ inch in length. The head, cervical shield, and anal plate are brown to dark brown, and the body is yellowish.

This species is widely distributed through the eastern part of the United States. It has been reared from the buds of red pine and mugho pine in Connecticut and Massachusetts, cones of Scotch pine and Austrian pine in New York, cones of longleaf pine in Florida, cones of Virginia pine and from a cecid gall on loblolly pine in Maryland. The moths emerge in New England from the middle of June until early in July and probably somewhat earlier in the Southern States. The insect passes the winter as a partly grown larva in a bud or cone of its host plants. The larvae resume feeding early in the spring and pupate in May or early in June. This species sometimes causes some damage in plantations in southern New England. It was particularly abundant in 1941 through southern Connecticut, although not so injurious as *Rhyacionia buoliana.* Often the larvae are heavily parasitized by Hymenoptera.

The moth of *Anacampsis innocuella* (Zell.) is ash gray or slightly darker, with a wing expanse of 3/4 to 7/8 inch. The forewings have a pale, wavy, transverse line well beyond the middle followed by a blackish shade, three blackish dots in the cells, and two in the fold. The hind wings have a brownish tinge. The larva is a leaf roller on poplar, and is translucent, the green food showing through the body wall. The head is dark brown, the cervical shield brown, and the true legs and tubercles are black. It is solitary and feeds on various

FIGURE 103.—Characteristic work of *Anacampsis innocuella.*

species of poplars. Usually, during the day it is found in a leaf rolled cylindrically (fig. 103), and when nearly full grown, it severs the petiole and finishes its feeding in the rolled leaf on the ground. Sometimes this species is very common in the Eastern States. It has been recorded from Massachusetts to Colorado and Texas. The larvae feed during May and June, and the moths issue in June and July.

The moth of *Anacampsis rhoifructella* (Clem.) is grayish brown with a wing expanse of about 5/8 inch. The forewings have markings quite similar to those of *A. innocuella.* The larva varies from pale brown to dark brownish red. It is quite possible that two species are confused under this name, as one is recorded as feeding in the fruit spikes of sumac in the spring, living in a silken gallery within the fruit cluster, and leaving strings of frass outside. Other records indicate the larva is a leaf folder or roller on *Viburnum* (most commonly on *V. dentatum*). In Massachusetts these larvae feed during the latter part of May and June, pupating early in July, and the moths emerge in July. The species is found in the northeastern part of the United States, often locally abundant and causing the host plant to have an unsightly appearance.

The moth of *Fascista cercerisella* (Chamb.) is velvety black, with the head and collar white. The forewings are slightly bronzed and marked with three costal spots and a few white terminal points. The hind wings are pale. The wing expanse is about 3/5 inch. The larva is white with black markings and webs together the leaves of redbud. This species occurs from Maryland to Illinois and through the Southern States. There are at least two generations, the moths emerging from May to September. In Texas the larvae were found feeding as late as October.

The palmerworm (*Dichomeris ligulella* (Hbn.)) is about 1/2 to 5/8 inch in length. The head and cervical shield are yellow-brown and the body is greenish, translucent, with two narrow dorsal lines and two wider lateral lines whitish. This species is distributed through the northern part of the United States from New England west through Minnesota and in Canada. Its food plants include apple, cherry, hazel, oak, pear, and plum.

As far as is known, the insect passes the winter in the adult stage, and there is one generation annually. Soon after the foliage appears in the spring eggs are laid on the undersides of the leaves. Hatching usually occurs late in May, and the larvae become full grown in 25 to 30 days. The larvae are leaf rollers and skeletonizers and may feed in the open or beneath the protection of folded or rolled leaves. In orchards they sometimes eat holes in the young fruit. Pupation takes place in the rolled leaves or in the litter on the ground, and the moths emerge in July or early in August. The records available indicate that this insect is generally quite common, often injurious in apple orchards, and that in the past long periods of years elapsed between serious outbreaks. Defoliation of oak and hazel by this species was widespread in 1941 over northern Minnesota. For control see page 367.

The adult of **the juniper webworm** (*Dichomeris marginella* (F.)) is a brownish moth having a wing expanse of about 5/8 inch. The forewing is brown with white front and rear margins, and the hind wing fringed and of a uniform gray color. The fully grown larva is about 1/2 inch in length. The head, the cervical shield, and the legs are dark brown or black, and the body is light brown with a median longitudinal line and two broader dorso-lateral lines of darker brown.

This species is an introduction from Europe and known to occur in the United States from Maine to North Carolina and west to Michigan and Missouri. Its food plants include Irish juniper, common juniper, and red cedar. The moths issue in June and early in July. The larvae are gregarious and web up the foliage of several twigs on which they feed. Apparently the life history has not been completely worked out, but records indicate there may be two generations a year. Larvae feed from April to early June, and in September. The pupae are formed in the web. It is an important pest in nurseries and on ornamental plantings, sometimes causing serious losses from defoliation.

Family OECOPHORIDAE

This family includes about 100 species of moderately small moths, few of which are ever of much importance as pests of trees in the eastern part of the United States. The larvae of most species are more or less concealed feeders, either rolling, tying, or webbing the leaves of the host plant.

Machimia tentoriferella Clem. is a light-ochreous moth with a wing expanse of ¾ to ⅞ inch. The forewings are dusted with black and each has two black discal dots, a spot of black in the fold, a broken postmedial line parallel to the outer margin, and a series of black terminal dots. The hind wings are smoky brown. The larva is a green leaf tier, with a large head, and tapering body. It constructs a web on the underside of a leaf along the midrib, causing the leaf to fold. It is solitary in habit and feeds in the open. Although common in the Northeastern States and a rather general feeder on wild cherry, mountain-ash, maple, oak, etc., it has never been of much economic importance. The larvae feed in July and August, and the moths issue late in August and September.

The species of *Psilocorsis* are also leaf tiers. The moths are light brown and have a wing expanse of about ¾ inch. The forewings are marked with transverse streaks of a darker shade, a blackish discal dot, and at least a trace of a blackish terminal line. Knowledge of the larvae and food plants are necessary for determination, as all species are quite similar. The larva ties two leaves together and between them feeds on the epidermis or skeletonizes them, causing the leaves to turn brown.

Psilocorsis faginella (Chamb.) is common in the Northeastern States. The larva feeds on beech. It is whitish, tinted with pink, and the head and sides of the prothorax are brown. The larvae feed during August and September, pass the winter in the pupal stage, and the moths issue late in May and June. *P. reflexella* Clem. and *P. quercicella* Clem. are found on oaks in the Eastern States. These leaf tiers of the family Oecophoridae are seldom, if ever, abundant enough to warrant control measures in the forest. A protective arsenical spray (p. 367) applied to the foliage of shade and ornamental trees should prevent injury.

Family BLASTOBASIDAE

The moths of the family Blastobasidae are rather small, with long antennae; the scales on the head are long, often covering the face and the base of the antennae. The scape of the antenna is broad and is armed with a fringe of strong bristles, and the hind wings are lanceolate and narrower than the forewings. Little is known about the habits of many of the species. Of those whose habits are known, the larvae, in general, are borers in cones, nuts, and seeds; some, however, are scavengers in nuts, following borer infestation, and in insect galls. Others are predaceous on scale insects.

Valentinia glandulella (Riley), **the acorn moth,** is generally distributed through the oak regions of the Atlantic States westerly into the Central States, and in California and Oregon, and occasionally is abundant enough to do considerable damage. The larvae are grayish white or yellowish, with blackish dorsal marks, and the cervical and anal shields are brownish. Acorns are the preferred food, but the larvae have also been found in chestnuts and hickory nuts. Although it was long supposed that this species attacked only fallen acorns that had been infested by the acorn weevil, Carl Heinrich found it in 1915 attacking perfectly healthy acorns. He reared moths from larvae taken from acorns on trees at Falls Church, Va. Apparently there is one generation a year; the moths emerge in June, and the larvae feed during late summer, maturing in September and October. The larvae often enter the ground to pupate but sometimes pupate in the fallen acorns.

Family AEGERIIDAE

The Clearwing Moths

The adults of many species of the family Aegeriidae resemble bees and wasps in appearance more than they do ordinary moths. They are moderate in size. The antennae are usually spindle-shaped, tapering to both base and apex and terminated by a small silky tuft; sometimes the antennae are pectinate. The body is often stout and in some species brightly colored, and the wings generally have the greater part of one or both pairs free of scales. The forewings are very narrow, often transparent, with short outer margins and well-marked anal angles. The hind wings are narrow but somewhat broader than the forewings, more or less transparent, and often with only the margins and veins scaled. The adults are diurnal; they frequent flowers, and fly swiftly. The larvae are white, without markings, and are borers, generally living within the main stem or solid part of the plant. Some species important as pests of forest or shade trees and ornamental shrubs are discussed.

The hornet moth (*Aegeria apiformis* (Clerck)) is brownish black, with yellow markings on the head, sides of thorax, and bands on the abdomen. The tibiae and tarsi are orange, and the wings are transparent, with brown margins. Wing expanse is 1¼ to 1¾ inches. The full-grown larva is about 1½ inches long, the head reddish, and the body white.

This species is an introduction from Europe, but is now widely distributed through the northern part of the United States. The larva is a borer in the roots and base of trunks of poplar and willow. The burrows permit the entrance of decay organisms. Two years are required to complete its life cycle. The moth emerges in June, and the larva completes the growth late in the following summer. It spins a stout cocoon in the wood borings in or close to the injured base and roots of the tree, passes the winter as a larva in its cocoon and pupates in the spring. Between 1930 and 1932, it seriously injured the larger roots of some Carolina poplar trees in Revere, Mass. For control measures, see page 24.

Aegeria tibialis (Harr.), a native species, is similar to *A. apiformis*, and is sometimes mistaken for it, as it also attacks poplar and willow.

The moth of **the maple callus borer** (*Conopia acerni* (Clem.)) is more or less tawny, the wings largely hyaline tinged with yellow, and the interspaces near the apex of the forewing are light yellow. The anal tuft is light red (fig. 104, *C*). The wing expanse is ¾ to 1 inch. The full-grown larva is about ½ inch long, the head is brownish, and the body is white (fig. 104, *A*).

This species is distributed from Canada, through the eastern part of the United States, and west to Nebraska. It attacks both the hard and soft maples. The moths emerge in May and June and deposit the eggs in roughened places on the tree trunk, preferably on or near wounds. The eggs hatch in a short time, and the young larvae bore into the bark and sapwood. Some of the frass from the larva is forced out of the burrow and can usually be found around the wound. The larva pupates in its burrow in the spring and just prior to the emergence of the moth the pupa forces itself part way into the open, and after the moth emerges the pupal shell is left exposed (fig. 104, *B*, *b*, and *D*). Trees slightly wounded from any cause and then attacked by this insect may suffer severe injury. The borer reduces the vitality of the tree, frequently prevents healing of wounds and is responsible for ugly scars.

Adults of *Conopia corni* (Hy. Edw.) are blackish with the margins of the forewing wholly black, otherwise they are similar to *C. acerni.* The larvae bore in small branches of silver and red maple causing gall-like swellings.

The adults of **the rhododendron borer** (*Conopia rhododendri* (Beut.)) are the smallest of the clearwing moths. They are blackish with three yellow transverse stripes on the abdomen and have a wing expanse of only 3/8 to 1/2 inch. The larvae bore in the stems and branches of rhododendron, working just under the bark, causing them to wilt, and sometimes to break off. The moths emerge in May and June and deposit their eggs on the twigs. The larvae become full grown before arrival of cold weather in the fall, hibernate in their burrows, and transform to pupae in the spring.

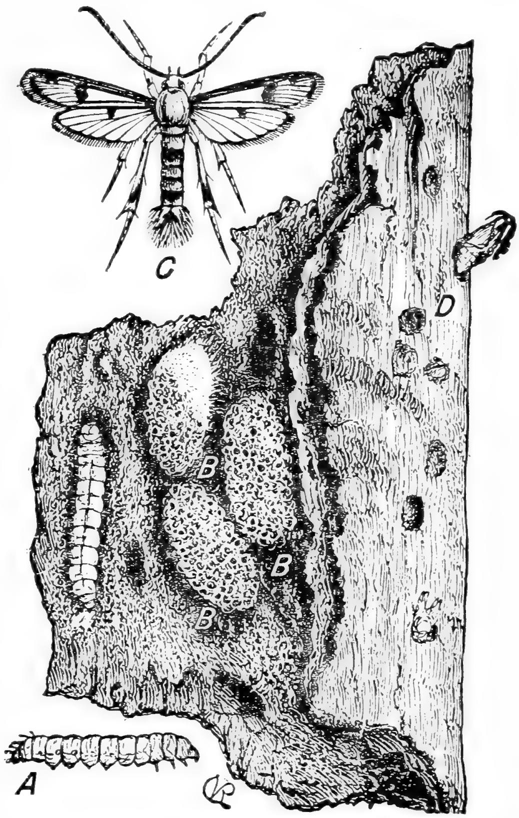

FIGURE 104.—The maple callus borer (*Conopia acerni*): *A*, Larvae; *B*, cocoons; *C*, adult; *D*, pupa.

The adults of **the dogwood borer** (*Conopia scitula* (Harr.)) are blue-black with a yellow stripe on the second and fourth segments of the abdomen, and have yellow-banded legs. The wing expanse is from 5/8 to 7/8 inch. The larvae are white, with pale brown heads, and they bore in the cambium of flowering dogwood, gaining entrance under rough bark or around wounds. The life cycle is similar to that of *C. rhododendri.* Artificial control is not practical in the forest. Shade trees and ornamentals should be kept in a thrifty condition and protected from mechanical injuries. In some cases the borers can be dug out and the wounds then properly dressed, or the infested parts removed and burned, preferably delaying this until after the

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leaves have opened, because some species of trees bleed if cut early in the spring. (Also see page 24.)

The moth of **the pitch-mass borer** (*Parharmonia pini* (Kellicott)) is blue-black with the collar, a band on the fourth abdominal segment, the under side of the abdomen, and the anal tuft orange. The forewing is opaque and blackish, with a metallic blue or green reflection. The hind wing is thinly covered with black scales, and is transparent along the inner margin. The wing expanse is from 1 to 1¼ inches. This species is found in Georgia and Tennessee, and north to Canada. The food plants include white pine, pitch pine, and spruce.

The eggs are deposited on the bark of the tree trunk in midsummer, usually near a wound or just below a branch. After hatching the larvae spend 2 or 3 years boring in the inner bark and sapwood causing a considerable exudation of pitch which accumulates at the entrance to the gallery. The galleries are more or less transverse and winding. Pupation takes place in the mass of pitch at the entrance to the gallery, and just prior to the emergence of the moth the pupa works itself partly out of the pitch mass so that the moth may emerge without becoming entangled in the pitch. The moths issue in June or July. Although this insect does not kill the tree, its galleries cause defects which lower the value of the trees for lumber. Artificial control is not practical in the forest. Mechanical means may be used in ornamental or shade trees, but are recommended only when severe infestations occur (p. 27).

The moth of **the persimmon borer** (*Sannina uroceriformis* Wlkr.) is bluish-black, the palpi and base of the tegulae are sometimes orange, and the fourth segment of the abdomen is reddish on top, with a narrow blackish center line. The wings are opaque except for a small transparent area near the base of the hind wing. The wing expanse is about 1 to 1¼ inches.

This species ranges from the District of Columbia to Kansas and through the Southern States. The larvae bore into the solid wood of the tap root and stem of persimmon, sometimes extending their burrows in the roots from 16 to 18 inches below the ground. They become fully grown late in April or May. Pupation takes place in cocoons composed of silk and frass in the burrows. The moths emerge from May to July depending on the climatic range. H. R. Johnston, of the Division of Forest Insect Investigations, reported in May 1938 that damage in a nursery in Tennessee appeared to be more severe in grafted plants. The nurseryman reported a loss of about 50 percent of his persimmon plants in 1937 as a result of injury by this insect. For control see page 28.

The moth of **the ash borer** (*Podosesia fraxini* (Lugger)) is black with a wing expanse of ⅞ to 1¼ inches. The antennae are yellowish at the tip, the forewings are opaque, blackish brown, with a violet reflection and a red cross bar at the end of the discal cell, and the hind wings are transparent with a narrow black border. It is generally distributed, and has been recorded as attacking white, red, green, and European ash and sometimes the mountain-ash. The larvae bore into the trunk and branches, but more commonly into the trunk just below the surface of the soil. They are serious pests of shade trees and windbreaks, particularly in some of the prairie regions. Young trees are more seriously injured than large trees. Cutting and burning the infested parts is the only remedy.

The lilac borer (*Podosesia syringae* (Harr.)) attacks lilac, privet, and ash. The moth is somewhat similar to *P. fraxini*. The body has a brownish tinge and sometimes the abdomen is marked with yellow. It is generally distributed through the Eastern States and from Texas and Colorado to Canada. The white or yellowish larvae bore into the main stems, causing them to wilt or become unhealthy in appearance, and sometimes to break off (fig. 105). There is one generation a year. The moths emerge late in April and May in New England. Grayson (*198*) reported that in Virginia the moths emerge in August and September, and the winter is passed as partly grown larvae in the cambium. For control cut and burn the infested parts.

FIGURE 105.—Section of ash tree showing injury by the lilac borer (*Podosesia syringae*).

FAMILY OLETHREUTIDAE

The Olethreutidae form a large family having a great number of species, many of which are of prime economic importance. Four species, at least, are common introduced pests. Nearly every type of larval activity is represented. A great many of the species are borers in the roots, stems, bark, seeds, or fruit of trees, shrubs, or low-growing plants, several are leaf tiers, some are exposed feeders on the leaves or flowers, and a few are leaf miners.

The following discussion of species of this family which are forest pests of more or less importance, illustrates the wide differences in habits of the different species.

The European pine shoot moth (*Rhyacionia buoliana* (Schiff.)) is rusty orange red, with whitish legs, and has a wing expanse of about ¾ inch. The forewings are marked with several irregular forked silvery cross lines, and the hind wings are a plain dark brown. The egg is small, flat, and yellowish when first laid, but later it turns a reddish brown. The larva is brownish, with the head and thoracic shield black, and when fully grown it is about ⅝ inch in length. The pupa is about ⅜ inch in length and chestnut brown.

This insect is an introduction from Europe, first recorded in the United States in 1914, when it was reported as having caused serious injury to Scotch pine on Long Island, New York. Busck (*77*) reported that it had been discovered in nine States, principally in nurseries. It is now known to occur from Massachusetts south to Virginia and west to Illinois and Michigan, and Nova Scotia, southern Ontario, and British Columbia. Red, mugho, Scotch, and Austrian pines seem to be the most favored host plants in the Northeastern States. Many other species of pines are also attacked, and some of these too may prove to be favorable hosts if the insect becomes more widely distributed in the natural ranges of these trees (Busck, *77*, and Friend and West, *171*).

There is one generation a year. The moths issue during June and early in July. The eggs are deposited near the tips of the twigs, either on a needle sheath or the twig itself. They hatch in about 10 days, and the young larvae bore into the bases of the needles. During the latter part of the summer the larvae leave the needles and bore into buds. The injury to the buds causes a flow of pitch which hardens over the larval burrows. Hibernation takes place either in the bud or under a mass of pitch on the bud. At this time the larvae are about $^3/_{16}$ inch long. In the spring the larvae bore into other buds or the developing shoots, usually killing them. They attain full growth in May. Pupation takes place in the burrow, the pupal stage lasting about 18 days.

In the United States the European pine shoot moth is a serious pest in nurseries, on ornamentals, and in plantations. In plantations it ceases to be a real menace after the crowns close. The destruction of the terminal and lateral buds and new shoots causes a malformation of young trees and a retardation of growth. In severe infestations the wholesale destruction of buds and shoots causes the development of adventitious buds, and as a result bushy tips are formed in place of normal growth. Often the injured shoot survives but bends or curls at the point of attack, thus causing a permanent crook or "post horn" in the leader or lateral, as the case may be (fig. 106).

The larvae are susceptible to subzero (Fahrenheit) temperatures, and north of the annual minimum isotherm of $-10°$ F. the frequent occurrence of low winter temperatures should keep the population of the insect down to a harmless level. In the northern range in young plantations or where *Pinus mughus* is used in ornamental plantings the infestation is often perpetuated because of snow protection during periods of severe cold. Parasites from its native habitat in

Europe have been introduced into this country by the Federal Bureau of Entomology and Plant Quarantine, and three of these have become established.

After the canopy closes in a stand of pine, usually little damage results from this pest. Prior to this, however, in regions favorable for this insect it is advisable to make an annual inspection of the plantations and to cut off and destroy all infested tips. The month of May is the best time of year to do this work, as many larvae die from natural causes during the winter, and the tips containing living larvae are most conspicuous after growth starts in the spring. Friend (*171*) stated that one should not wait until the infestation becomes heavy before starting control measures. In stands of sufficient value

FIGURE 106.—Red pines, about 12 years old, showing bushy and distorted growth and loss in height increment because of continued infestation of buds by the European pine shoot moth (*Rhyacionia buoliana*).

to warrant the expense an application of powdered lead arsenate at the rate of 8 pounds, with 2 pints of fish oil, to 100 gallons of water, or derris, 8 pounds, with 2 quarts of fish oil, to 100 gallons of water may be used. This should be applied as a mist spray at the time the new needles of red pine are about one-half the length of the old needles, which in Connecticut is usually between June 23 and July 7. It is essential that the buds and new needle sheaths be covered with the insecticide to be effective. (See also p. 34.)

The Nantucket pine tip moth (*Rhyacionia frustrana* (Comst.)) is reddish brown with silver-gray markings and has a wing expanse of about 7/16 inch. The larva is yellowish to pale brown, with the head and thoracic shield dark brown. Fully grown larvae are about 3/8 inch in length.

Its distribution is from Massachusetts south to Florida and west through the Central States to Texas. A variety, *Rhyacionia frustrana bushnelli* (Busk), occurs in Minnesota,, the Dakotas, and Nebraska, and at Fort Bayard, N. Mex., where it was probably introduced on nursery stock from Nebraska. The food plants include all species of the two- and three-needle pines, or hard pines, with the exception of slash pine and possibly longleaf pines. Records indicate there may be one generation a year in Massachusetts, two in Pennsylvania, northern Virginia, and Nebraska, and four or more in Louisiana and Texas. In the North the moths are active during May and early June; in the region having two generations the moths are active from about the middle of April to the middle of May, and again in late June and early July; and in the South they are active during February to March, May, July, and August to September.

The eggs are circular, flattened, and light yellow, and are usually laid singly on either the needles, buds, or shoots. On hatching, the larva begins to feed on a new shoot near the base of the needles or the base of a bud, sometimes penetrating the needle fascicles. A protective web is spun over the place where the larva is feeding, and this in turn soon becomes covered with pitch. Later the larva bores either into a bud or the succulent growth near the tip of the shoot, and continues to mine until it has completed its development. A light silken cocoon is spun in the burrow in which the larva pupates. The length of the larval stage varies according to the geographical range and the climate, but records indicate it is never less than 3 weeks, and may be 5 weeks in the North. Winter is passed in the pupal stage. In the Eastern and Southern States *Rhyacionia frustrana* pupates within the injured twig tip, but the form *bushnelli* in the Midwestern States drops to the ground at the end of the last generation and transforms in the litter or soil. This is a serious pest of seedling and sapling pines, in nurseries, plantations, or natural stands, but after the trees reach a height of about 25 feet they are not seriously injured. It mines the tips of the twigs, which causes deformity in growth and loss in height increment, and where heavy infestations persist over a period of years some of the less vigorous trees succumb. For further information on this pine tip moth, see Packard (*323*).

It has been observed in the Central States that hard-pine plantations in the proximity of native yellow pine stands usually suffer relatively little damage from the tip moths, owing to control by native parasites. A few years ago *Campoplex frustranae* Cush., a hymenopterous parasite of *Rhyacionia frustrana* in the Eastern States, was introduced into plantations in Nebraska which were heavily infested with *R. frustrana bushnelli.* It became established readily and has aided materially in bringing about the control of this pest. As a general measure of control, avoid planting infested stock, particularly in areas where the tip moth is not already present. The utilization of fast-growing stock and restriction of planting to better sites will assist the trees in outgrowing the tip moth injury. After the tip moth has become established in a stand of hard pine, it is practically impossible to eradicate it. The removal of infested tips in young stands will aid in reducing the infestation, but this is expensive, particularly in regions where there are two or more generations a year.

Rhyacionia rigidana (Fern.) has a wing expanse of about ¾ inch, and the forewings are similar to those of *R. frustrana*, except that the gray bands are more extensive. The larva and its habits are also similar to those of *R. frustrana.* Its distribution is from New York to West Virginia and North Carolina. The food plants are red, pitch, Jersey, Corsican, Scotch, and loblolly pines. In New York there is one generation a year, and the moths emerge late in April and early in May. The larvae bore into the tips of the current year's growth, transform to pupae in July, and hibernate as pupae in the burrows in the buds. Other authors have recorded two generations a year. Although little is mentioned in economic literature about this insect, it is possible it may have been confused at times with *R. frustrana.* It caused considerable injury in a plantation of red pine in 1932–33 at Croton Falls, N. Y.

The pitch twig moth (*Petrova comstockiana* (Fern.)) is reddish brown mottled with gray, and with hind wings very pale. The wing expanse is about 5/8 inch. The fully grown larva is about 1/2 inch long; pale brown to brownish white, with the head and thoracic shield dark brown. The pupa is dark brown. It is recorded from Massachusetts to Virginia, and west into Minnesota. The hard pines are its food plants. The moths issue late in May and June. Eggs are laid on the twigs, probably singly. On hatching the larva bores into a twig or small branch just below the tip and a pitch mass forms over the entrance hole. It tunnels downward in the twig for 3 or 4 inches and hibernates as a partly grown larva under the pitch mass (fig. 107). Feeding is resumed in the spring, and the larva matures and transforms to the pupal stage in the burrow in May. The pupa is capable of moving, so that a part of it protrudes through the pitch mass when the moth is to emerge. There is one generation a year. Occasionally it is somewhat destructive, as the injured twigs and small branches break off, thus deforming the tree. In ornamental plantings it is advisable to remove the larvae from their burrows in the twigs, but this operation is not practical in the forest.

FIGURE 107.—Twig of red pine opened to show larva of the pitch twig moth (*Petrova comstockiana*). Note pitch mass over the opening of the gallery.

Petrova albicapitana (Busck), like *P. comstockiana,* is a pitch twig borer. The full-grown larva is about 1/2 inch long. The head and thoracic shield are light brown, the body is reddish, and tubercles are small and shiny. It is distributed from Quebec to Saskatchewan, in Canada and through the northern part of the United States from

New England to Montana and Idaho. Its food plants include jack, lodgepole, and ponderosa pines. The larvae are solitary in habit, and each bores into a young branch, particularly at the juncture of smaller branches, where a mass of pitch forms over the entrance hole. It has a 2-year life cycle. Branches that have been infested break off or cause deformities, the injury being more noticeable in open stands. For control see *P. comstockiana.*

The larvae of *Petrova virginiana* (Busck) bore into the small branches of Virginia pine (*Pinus virginiana*), and their work is somewhat similar to that of *P. comstockiana.* Heinrich (*217*) stated:

"They differ in habit chiefly in that *comstockiana* bores only in stems of the same year's growth, while *virginiana* normally attacks the bark of older twigs and branches. The work can be easily recognized by the large hard nodules of frass-stained pitch found at the exit holes of the galleries."

The species ranges from southern New Jersey south through Virginia, and is often very common in the vicinity of Washington, D. C. The larvae pass the winter in the galleries, pupating early in spring, and the moths emerge in May. For control see *Petrova comstockiana.*

Eucosma gloriola Heinrich (*219*) is a coppery-red moth with two shining gray transverse bands on the forewings. The hind wings are dark grayish brown. It has a wing expanse of about ⅝ inch. The larva is a dirty white, with a yellowish-brown head and a round blackish spot on the side of the hind margin; the thoracic and anal shields are yellowish. It was first recorded in 1930 in southwestern Connecticut, and now is known to occur in other sections of Connecticut, in New York, and in Maine. The moths issue in May. The larvae feed during June and July by boring in the center of the shoots of white pine, causing 6 or 8 inches of the twigs to die. Pupation takes place in the soil. There is one generation a year. This insect attacks the side shoots so the principal damage occurs on ornamentals or in plantings before the crowns close. The dying twigs cause an unsightly appearance. No practical control measures are known.

Proteoteras aesculana Riley is an olive-green moth, more or less mottled with yellow and gray, and with some small black markings, the wing expanse is from ½ to ¾ inch. The larva bores in seeds, stems, and terminal twigs of horsechestnut and maple, sometimes causing considerable injury during May and June. The moths emerge in July and August. This species is common and apparently is generally distributed through the northern half of the United States and southern Canada. **The boxelder twig borer** (*Proteoteras willingana* Kearf.) and *P. crescentana* Kearf. are borers in stems and twigs of boxelder and maple. For control measures for these three species collect and burn the infested twigs the latter part of June.

Evora hemidesma (Zell.) is a reddish-brown moth, with a darker median band on the forewing. It has a wing expanse of about ½ to ⅔ inch. The full-grown larva is dark green, almost black, sparsely hairy, with light-colored tubercles and a light-brown head. It is about ¾ inch long. This species is distributed from Maine westerly to Manitoba and southerly to Virginia and Kentucky. The larva is found as a common leaf roller on spiraea from May to July. The moths emerge in July and August.

The moth of *Episimus argutanus* (Clem.) is dull reddish or grayish brown, mottled with darker colors. Fresh specimens are tinged with purple. The wing expanse is about 1/2 inch. The full-grown larva is about 1/2 inch long. The head is light brown, and the body light green, more or less tinged with red. This species, usually common, is distributed throughout most of North America, Central America, and the West Indies. Its food plants include sumac, poison ivy, witch-hazel, and various shrubs. Each larva lives in a rolled leaf or between two leaves fastened together with silk. There are two or more generations a year. In the New England States the moths emerge in May and June, and from July to September. The larvae are found from June to late in September, and the winter is passed in the pupal stage.

The adult of *Zeiraphera ratzeburgiana* (Ratz.) is a light brown moth, with a wing expanse of about 1/2 inch. The forewings have darker diagonal markings, somewhat variable, and the outer margins are straight. The full-grown larva is about 3/8 inch in length. The head is brownish yellow, the cervical shield paler, and the body yellowish or grayish green. Heinrich (*217*) stated: "The species is an introduced one in this country, but is apparently well distributed through the spruce regions of the Northern States and Canada." The small larvae feed in the opening buds on the tender needles in the spring, webbing terminal needles together. The pupae are formed on the terminal twigs, and the moths emerge during July and August. This species was abundant on spruce along the coast of Maine about 1882–84 and 1934–36.

The eye-spotted bud moth (*Spilonota ocellana* (D. & S.)) is dark, ashy gray, with a large, irregular, whitish median band on the forewing. The wing expanse is about 3/5 inch. The full-grown larva is about 3/4 inch long, dark brown, with a black head. This species is an importation from Europe, and is recorded as occurring in North America from coast to coast, chiefly in the Northern States and in southern Canada.

Its food plants include apple, blackberry, hawthorn, larch, laurel, oak, pear, and plum. Although some forest trees are attacked, it is chiefly a pest of apple. The moths emerge in June and early in July. The eggs are laid on the under side of the leaves, and hatching takes place later in the summer. The small larva feeds a short time, then migrates to a twig and spins a tiny silken case in which it hibernates. In the spring it resumes feeding, attacking the opening buds and unfolding leaves. As the leaves expand the larva binds them together with silk, feeding inside. It becomes full grown in June and constructs a silk-lined cocoon in the leaves in which it pupates.

Epinotia nanana (Treit.), a dark smoky-brown moth, has a wing expanse of about 7/16 inch. The forewing has a rather blunt apex, which is black and defined below by a white dash. A blackish band crosses from the middle of the costa to before the anal angle. Fresh specimens have five distinct white spots on the costa, and the wing is also flecked with whitish scales. There is a continuous black line in the fringe. The hind wing is nearly concolorous. The full-grown larva is about 5/16 inch in length. The head, cervical shield, thoracic legs, and anal plate are blackish. The body is dirty white to reddish. The pupa is brownish, darkening with age.

This moth is an introduction from Europe, now known to occur in the United States from Maine to Ohio and Michigan. The food plants include red spruce, white spruce, Norway spruce, and Colorado blue spruce. The moths are active in June. Eggs are deposited on the needles, usually one per needle, and hatch in July. The young larva avoids the needles of the current season's growth and usually begins its mine near the base of one of the older needles. The late A. B. Proper [31] found that 10 or more needles are mined by one larva before cold weather stops its activity. The winter is passed as a partly grown larva within the last needle it has mined. On the first warm days in April feeding is resumed, the larva mining more rapidly and spinning more silk around the bases of the needles. When the larva is nearly full grown it may move about on the twigs leaving evidence of its activity in one or more spots, often mining needles of the previous year's growth. Proper also determined that about 15 needles are mined in the spring before full growth is attained in May. As considerable silk has been spun, the mined needles are webbed together and often lie more or less in bunches appressed to the twig (fig. 108). Pupation takes place in a whitish cocoon usually spun between the mined needles and the twig.

FIGURE 108.—Terminal of a red spruce heavily infested by *Epinotia nanana*.

Sometimes this insect causes serious defoliation, particularly in the spruce forests along the coast of Maine. The dried, mined needles webbed together on the twigs of ornamentals, even in a light infestation, give the trees an unhealthy and unsightly appearance.

For control of this insect, spray as soon as possible after the eggs have hatched, or early in the spring when the larvae are becoming active after their hibernation through the winter, using powdered lead arsenate at the rate of 5 pounds to 100 gallons of water plus 4 ounces of fish oil or linseed oil to each pound of the lead arsenate, as an adhesive. The poison must be retained on the foliage for a rather long period in order to be effective, as a larva can obtain a toxic dose

[31] Unpublished notes.

only when it vacates one mined needle and is boring into another. Therefore an adhesive is essential. The spray should be applied as a mist. If it seems desirable to combine a contact insecticide with this spray, one pint of 40-percent nicotine sulphate can be added to the above formula.

The moth of **the maple trumpet skeletonizer** (*Epinotia aceriella* (Clem.)) is white, dusted with gray or brown, and has a wing expanse of about 5/8 inch. The full-grown larva is about 1/2 inch long and is light green with a yellowish head. The foliage of red maple and occasionally sugar maple is attacked. The larva eats only the parenchyma between the larger veins on the under side of the leaves. It usually attacks one of the larger leaves spinning a silken web on the under side, causing the leaf to fold, and in this fold it forms a long blackish trumpetlike frass tube. This tube increases in size with the development of the larva and may reach a length of 2 inches before the larva is fully grown. The larvae feeds from this tube skeletonizing the area covered by the web, and this causes the leaf to crumple. This species is distributed from North Carolina to Ontario and Quebec. The moths emerge in June, and the larvae may be found from late in July to September. The characteristic work of the larva sometimes attracts attention, but the injury caused is not considered serious, even when the insect is abundant. For control apply an arsenical spray (p. 53, formula 1) to the under side of the foliage.

Laspeyresia youngana (Kearf.) is a dark brown moth, with a wing expanse of about 3/8 inch. The forewing is bronze brown, broadly banded with lead color except toward the base. The hind wing is smoky brown. The larvae bore into cones of spruce, feeding upon the seeds. It is rather widely distributed throughout the Northern States and Canada. Heinrich (*218*) reported two generations annually, adults appearing in April and May and in August and September. The winter is passed in the larval stage, the larvae hibernating in the center of the cones. Control measures are not recommended for the forest.

The moth of **the hickory shuckworm** (*Laspeyresia caryana* (Fitch)) is smoky black with lead-colored stripes. The wing expanse is about 1/2 inch. The forewing has short, whitish streaks along the costal margin. The full-grown larva is about 3/8 inch long and has a light-brown head and creamy-white body. This species is recorded from Canada, the eastern part of the United States, and west to Missouri and Texas. It feeds on the nuts of the various species of hickory and pecan (fig. 109, *A*) (Gill, *183* and Moznette et al., *309*).

There may be from one to four generations a year depending on the climatic range. The winter is passed in the larval stage in the fallen pecan or hickory shucks. In Florida, the moths of the first generation emerge between the middle of February and the latter part of April, while farther north the emergence is somewhat later, the emergence, in general, occurring when the foliage and nuts of the pignut are developing. Just before emergence time the pupal skin is extended a short distance through the circular cut (fig. 109, *B*). The eggs are deposited on the nuts or foliage, and the young larvae bore into the nuts. Small green or nearly mature nuts may be attacked.

To control the insect, gather and destroy all infested nuts in the winter. The removal of hickory trees growing in the immediate

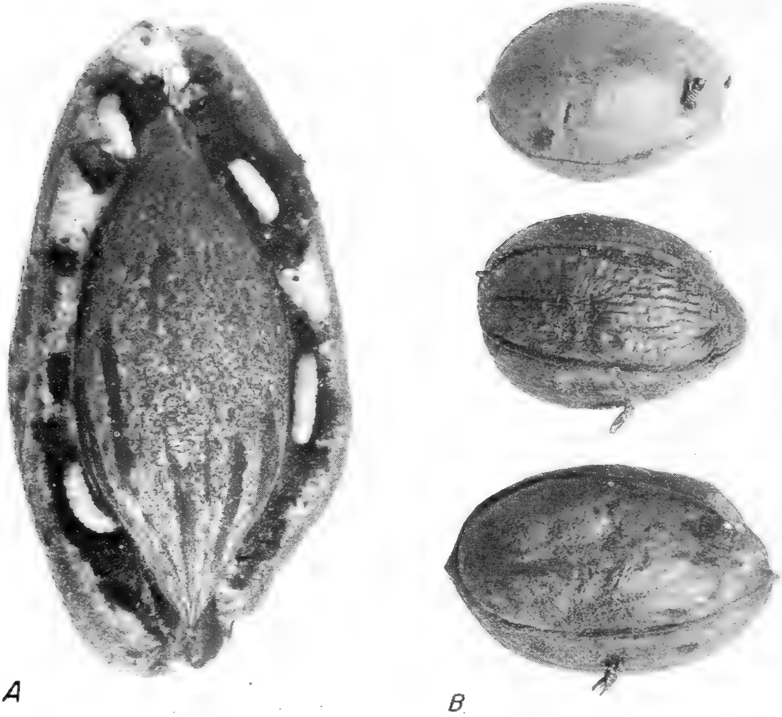

FIGURE 109.—The hickory shuckworm (*Laspeyresia caryana*): *A*, Larva in the shuck of a nearly mature nut, × 2; *B*, pupal skins protruding from shucks of pecan nuts.

vicinity of pecan orchards will aid materially in reducing the infestations in the orchards.

The moths of **the filbert worm** (*Melissopus latiferreanus* (Wlsm.)) are extremely variable in color, size, and structure (Henrich, *218*). The full-grown larva is white or pinkish and about ¾ inch in length. This species is apparently well distributed from Montreal southward, and through most of the United States. The larvae are borers in oak acorns, beechnuts, hazelnuts or filberts, and chestnut burs. According to Forbes (*165*) there may be two generations, or at least a partial second generation in Missouri. Keen (*262*) stated that there is only one brood a year, and that the larvae hibernate in cocoons within the ground.

The moth of **the locust twig borer** (*Ecdytolopha insiticiana* (Zell.)) has a wing expanse of ¾ to 1 inch. The forewings are dark, ashy brown with a large, dull, pinkish-white patch on the outer part and several small blackish spots near the middle of this patch. The hind wings are mouse gray. The fully grown larva is about ½ to ¾ inch in length, reddish to straw yellow, and darker along the dorsal line. The head is dark brown, and the thoracic shield honey yellow.

This borer occurs throughout the eastern part of the United States, and is also recorded from Arizona, California, and Colorado, and from

Manitoba and Ontario, Canada. Black locust is its food plant. In Ohio, Indiana, Illinois, Kentucky, Tennessee, and in the vicinity of Washington, D. C., there are two generations a year, possibly more farther south, while in the North there may be only one generation. Moths of the first generation may be found from early in May until the end of June, and those of the second generation from early in July to October. The eggs hatch within 5 to 6 days. The larva is a twig borer, attacking only new growth and forming an elongate gall from 1 to 3 inches in length. During the summer the life cycle may be completed in from 35 to 40 days. In the vicinity of Washington, D. C., larvae may be found in nearly all instars from late in May to early in November. The full-grown larva emerges from the gall, spins a flat bean-shaped cocoon in the leaves on the ground, passes the winter in this stage, and pupates in April. It is of considerable economic importance. In addition to the injury caused to the small branches, the elongate galls crack open with age and disfigure the tree. Cut and destroy the infested twigs before the larvae escape. This will be of some value but practicable only on a very limited scale. (See also Control of Borers on p. 32.)

Taniva albolineana (Kearf.) is a dark brown moth with a wing expanse of about ½ inch. The forewings have three irregular, transverse, grayish-white fasciae, more or less broken, particularly the outer one. The hind wings are brown with a much lighter fringe. The full-grown larva is cylindrical and about ⅜ inch in length. The head is yellowish brown, the thoracic and anal shields are of pale greenish color, and the body is a light, greenish brown, semitransparent, and sparsely clothed with fine hairs. It is distributed from Maine to North Carolina and west to Colorado and Idaho, also in Canada in Ontario, Manitoba, Alberta, and British Columbia. Its host plants are blue spruce, Norway spruce, and Engelmann spruce.

The moths emerge from the middle of May to the middle of June depending on the locality and the season. The eggs are deposited on the needles, usually in groups of 6 or 7 eggs each. Hatching takes place in 10 or 12 days, depending on the prevailing temperatures. Soon after hatching the larvae bore into a green needle near the base, and feed gregariously during their early instars. As they increase in size the tendency to separate becomes apparent. Shortly after the feeding is begun they construct a web reaching from the entrance hole in each needle to the twig and this affords them protection when the mined needles are severed from the stem. All frass is forced out of the entrance holes in the needles, much of which adheres to the webbing. Feeding continues until heavy frosts appear. Each larva then enters a hollowed-out needle, and with the head near the entrance hole it spins a web over the hole for protection and hibernates until spring. Feeding is resumed late in March or early in April. Some external feeding is done just prior to entering the prepupal stage. It has been found that each larva will destroy an average of 10 needles on blue spruce. Pupation takes place from the middle of April to early in May in silken cocoons constructed in the old webbing along the main stems of the branches.

It is particularly a pest of ornamental spruce trees, infesting the entire crown of small trees, but on large trees the heaviest infestation is usually on the lower branches, decreasing gradually toward the top of the crown. A simple and efficient method of control consists in forcing a strong stream of water through a small-aperture nozzle attached to a garden hose and washing the webs loose. The operation should start as high as the infestation is found on the trees, and care should be taken to wash all webs down as the work progresses. After all the webs have been washed to the ground, all loose needles and webs around the base and beyond the edge of the crown should be immediately removed and burned. The most opportune time for this treatment is in March before the leaf buds begin to swell, or in the fall just before the cold weather sets in.

Family TORTRICIDAE

The tortricids, or bell moths, as they are sometimes called because of their shape when the wings are folded, constitute a large and widespread family. Many species are represented in the eastern part of the United States, and with few exceptions they are small with a wing expanse of less than 1 inch. They are of variegated color but usually of dull shades, with stout body, and wide, oblong, fringed wings. The costa of the forewings is often sinuate and the antennae threadlike. They are active at night. The eggs are flattened and oval. The larvae, in general, are called leaf rollers or leaf tiers because of their habits of rolling a leaf or spinning several leaves or shoots together in which they live in concealment. They are elongate, never conspicuously marked except for the shields and tubercles, and are sparsely clothed with hairs, although many may appear as naked to the casual observer. Pupation usually takes place on or close to the food plant, and the pupae are enclosed in flimsy cocoons of silk. The pupae have two transverse rows of short stout spines on most of the abdominal segments. Just prior to the emergence of the adults the pupae move so as to protrude from the cocoons.

Many species of this family are common in the forest and on shade trees, and some of them are pests of considerable importance. Some species are restricted as to food preference and others are general feeders. The species most common as pests in the eastern part of the United States are discussed in the following pages.

Amorbia humerosana (Clem.) is a light gray moth, slightly mottled and dotted with minute black scales. The forewings have darker gray bordering the costa and brownish on the inner margin, and the hind wings are brownish gray. The wing expanse is about ⅞ to 1 inch. The larva is light green and has a light-brown head. This species ranges from Nova Scotia and Ontario south through Pennsylvania, and is usually common in the New England States. The larva is a leaf roller and has a long list of food plants, including willow, apple, and poplar. The moths emerge in May and June, the larvae are active from July to September, and the insect passes the winter in the pupal stage.

Adoxophyes furcatana (Wlkr.) is a pale, straw-yellow moth. The forewings are marked with fine golden brown lines, an irregular oblique light-brown band reaches from before the middle of the costa to before the anal angle, and a second one from three-fourths the way out on the costa to the anal angle. The hind wings are white. The wing expanse is about ¾ to ⅞ inch. The full-grown larva is about ¾ inch long and light green. The body tapers toward the ends. This species ranges from Maine to Pennsylvania and west into the Mississippi Valley, and is a leaf roller on sycamore. In Massachusetts, the larvae are found in May and June, and the moths emerge in July.

Sparganothis pettitana (Robinson) is a pale lemon-yellow moth with a wing expanse of about ⅞ inch. The forewings are sometimes marked with light-brown scales on the costa or arranged more or less in two oblique lines; the hind wings are white. The full-grown larva is about ¾ inch long, with the head reddish brown, the cervical shield brown shading to blackish posteriorly and on the sides, and the body dull yellowish green. This species ranges from Canada through the Atlantic States to Florida and west to the Mississippi Valley. The larvae are leaf rollers, commonly found on maple and occasionally on various other food plants. The moths emerge late in June or July, and the larvae are active during May and the early part of June. *S. reticulatana* (Clem.) and *S. sulfureana* (Clem.) are common general feeders and probably have about the same range as *S. pettitana.*

The moth of *Archips rosana* (L.) varies in color from a dull light brown to olive brown, and the wing expanse ranges from ¾ to ⅞ inch. The forewings have dark but somewhat variable markings, and the hind wings are mouse gray, often with the outer third yellowish brown. The full-grown larva is about ¾ inch long. The head and cervical shield vary from light to dark brown, and the body is dull green. It is a European species recorded in the United States from New England to Minnesota and Missouri, and in Canada in the Provinces of Nova Scotia and British Columbia. The larva is a rather general feeder and sometimes is a serious pest of privet and bush fruits. Hatching takes place in May. Each larva spins two or more leaves together on the tips of the growth and feeds on the leaves within the web during May and early June. The moths emerge from the middle of June to the middle of July. The winter is passed in the egg stage on the twigs. The trimming of hedges, or hand picking, and destroying the webs often gives satisfactory control.

Archips infumatana (Zell.) is light brown and has a wing expanse of ¾ to 1 inch. The forewing has a purplish tinge, and the base a broad fascia and a subterminal streak of dark, chocolate brown. The full-grown larva is about ¾ inch long, the head and cervical shield are black, and the body is dull green with black and prominent tubercles. The food plant is hickory, and the life cycle and habits are very similar to those of the preceding species.

The moth of **the ugly-nest caterpillar** (*Archips cerasivorana* (Fitch)) is dull orange and has a wing expanse of ¾ to 1 inch. The forewing is irregularly speckled with dark reddish brown and has three patches of the same color, one below the end of the cell and two on the costa at and just beyond the middle. The hind wing is orange. The full-grown larva is about ¾ inch long, yellow, with the head and cervical shield black. It is generally distributed through the Northern States and Canada. The feeding is usually confined to the wild black cherry and chokecherry. The larvae are gregarious, and form a dense web by spinning several leaves together, enlarging it when necessary, in which they stay while feeding (fig. 110). Pupation takes place in the web, the pupae moving to the outer wall just before the moths emerge. The winter is passed in the egg stage, the larvae may be found from May to July, and the moths emerge from early in July to early in September, depending on the climatic region. They are usually common, but are of little economic importance, except that the nests often disfigure roadside shrubs. To control this insect cut and destroy the webs containing the larvae or spray with an arsenical (p. 53, formula 1).

Archips fervidana (Clem.) is brownish with a wing expanse of ¾ to ⅞ inch. The forewing is yellowish brown with dark patches, as

FIGURE 110.—Nest of the ugly-nest caterpillar (*Archips cerasivorana*) on wild cherry.

in *A. cerasivorana*, and the hind wing is gray. The full-grown larva is about ¾ inch long. The head and cervical shield are black, and the body is a gray green. It is generally distributed through the oak regions of the Northeastern States, and west to Wisconsin, and is usually common on scrub oak, also on seedling and sprout growth of red oak, black oak, and scarlet oak. The larvae live gregariously in a web (fig. 111). Their life cycle and habits are very similar to those of *A. cerasivorana*, and the control is the same as for that species.

The adult of **the fruit tree leaf roller** (*Archips argyrospila* (Wlkr.)) is a brownish moth with a wing expanse of ⅝ to ⅞ inch. The forewings are mottled with cream, straw color, and brown scales, and have three more or less prominent cream-colored areas along the costa. The tips of the wings are rectangular. The hind wings are mouse gray. Fifty to 100 eggs cemented together in small round or oval convex masses are usually deposited on the smaller branches or twigs. The fully grown larva is about 3/4 inch in length, and is light green with the head and thoracic shield either dark brown or black. The pupa is about 1/2 inch in length, is light brown, and is formed within a rolled leaf.

This insect is distributed throughout the United States, and is a general feeder. In addition to a variety of fruit trees it also attacks many deciduous forest and shade trees, including ash, boxelder, horse-chestnut, hickory, locust, elm, oak, Osage-orange, poplar, sassafras, soft maple, walnut, and willow. The moths are active during June and July. There is one generation a year, and the winter is passed in the egg stage. Hatching takes place late in April or May at about the time the buds of its food plant begin to open. The length of the larval period is about 1 month. The larvae feed on the opening buds and unfolding leaves which they web together with silk. Later the larvae roll up a single leaf or several leaves, webbing them with silk, and if disturbed when out feeding they either retreat very rapidly to the nest or drop down on silken threads. Pupation takes place in flimsy cocoons spun in the rolled leaves. The young larvae injure the terminal growth by feeding on the unfolding leaves. Later they may attack the blossoms and young fruit as well as the foliage, sometimes causing complete defoliation of their food plant.

FIGURE 111.—Oak leaves webbed together by *Archips fervidana* to form a nest. A few pupae are shown protruding from the lower part of the nest.

The moth of **the oblique-banded leaf roller** (*Archips rosaceana* (Harr.) has a wing expanse of 3/4 to 1 1/4 inches, and is light brown, with three more or less distinct dark-brown, oblique bands across the forewings. The hind wings are cream to brownish yellow and shaded toward the inner margin with gray. The fully grown larva is about 3/4 inch in length, pale green to yellowish green, with a brownish head, and the thoracic shield somewhat paler.

It is distributed through much of Canada from Nova Scotia to British Columbia and throughout most of the United States. The larva is a leaf-tier, solitary in habits, and is a general feeder on the foliage of deciduous trees and shrubs, particularly those of the family Rosaceae. Usually in most of the Northern States there are two generations annually, although in the colder portions there may be only one each year. Winter is passed as small larvae, each in a tightly woven case spun under bud scales, beneath loose bark or between leaves. The larvae become active in spring, when the new leaves are unfolding. After 4 or 5 days of surface feeding each larva rolls a leaf or ties two or more together with silk and conceals itself within this shelter. It continues to feed on the foliage or flower buds of its food plant, and matures in June. The larva is very active and if disturbed will spin down on a silken thread. Moths from the overwintering generation emerge in June and in July. Larvae of the summer generation may be found from late in June to August and their moths emerge in July and August. The small larvae that overwinter hatch from the eggs in August or September. Larvae of the summer generation sometimes cause considerable injury by gouging in the green fruit of their food plant. Greenwood (*203*) reported on the life history of this insect.

The large aspen tortrix (*Archips conflictana* (Wlkr.)) is a dull, light-gray moth, with a wing expanse of ¾ to 1¼ inches. The forewing is of a darker shade at the base, and an oblique patch extends from just before the middle of the costa to the inner margin two-thirds of the way out. There is also a subterminal patch. The hind wing is concolorous.

The full-grown larva is about 1 inch long. The head is black or brownish, and the cervical shield black with the exception of the front margin and a narrow dorsal line of dull white. The body is dull olive green, although some specimens are darker, and the anal shield is black.

It has been recorded from New York and Utah north to Alaska and Labrador. The food plants are the large-toothed and small-toothed poplars. The moths emerge in June, and the flat, green eggs are deposited in flat masses on the upper surface of the leaves. Hatching takes place in July, and the young larvae crawl to the under surfaces of the leaves and feed on the tissues. They are very active, spin much silk, and are leaf rollers. Late in July or August they enter hibernation, remaining until the new growth starts in the spring. Each larva rolls a leaf more or less funnel-shaped, in which it lives and eats, and when necessary, it migrates and repeats the performance. Pupation takes place in the rolled leaf, usually early in June, but the exact time depends on the climate. This insect is sometimes a serious defoliator in the poplar forests of northern Maine and New Hampshire, and in some of the Canadian Provinces.

The adult of **the spruce budworm** (*Archips fumiferana* (Clem.)) (fig. 112) has a wing expanse of about ⅞ inch and is very variable in general color and markings, depending on the host species on which the larva has fed. The form occurring on spruce and balsam fir is a dull gray, with the forewings overlaid with bands, streaks, and spots of brown. In the middle of the upper margin of the forewings there is a whitish spot. The eggs are pale green and oval, and are laid on the foliage overlapping one another like the scales of a fish. The mature larva is about 1 inch in length, tapering slightly from the middle to the end. It is dark brown or dark reddish brown with conspicuous, whitish-yellow, piliferous tubercles. The head is shining black and the thoracic shield brownish. The pupa is about 5/8 inch in length and is of a pale brownish yellow, later changing to dark reddish brown (Swaine, Craighead, and Bailey, *403*).

This species is distributed throughout practically the entire range of its food plants and is one of the most destructive forest insects in North America. There are apparently a number of biological vari-

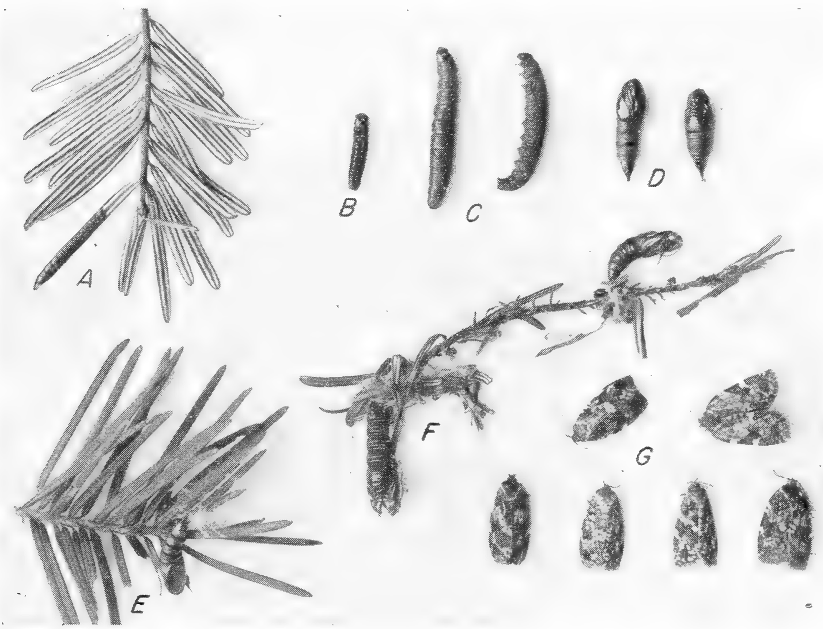

FIGURE 112.—The spruce budworm (*Archips fumiferana*): *A*, Eggs on under side of fir needle; *B*, half-grown larva; *C*, full-grown larvae; *D*, pupae; *E*, fir twig with pupa attached; *F*, defoliated fir twig with empty pupal cases; *G*, adults.

eties, or races, that are distinct in their food habits, the food plants including alpine, balsam, and lowland firs, Douglas-fir, black, red, and white spruces, Scotch, jack, red, ponderosa, and lodgepole pines, hemlock, larch, and probably other conifers. The greatest economic damage has been caused to spruce and balsam fir in southeastern Canada, Maine, and northern Minnesota. In the Lake States a biological race that prefers Scotch pine and jack pine was studied by Graham (*192*). In the West, Douglas-fir and true firs are the preferred hosts in some localities and lodgepole pine in others. Recently serious defoliation of ponderosa pine has occurred in Colorado.

In the Northeast, the moths are active late in June and in July, and in the Lake States during July and early August. The eggs hatch within 8 to 12 days, and the young larvae crawl about until they find suitable places, often under bark scales, to spin their small hibernacula. The overwintering larvae become active almost coincidentally with the bursting of the buds of their food plants. In the Northeast this may take place in April or early May and in the Lake States from May to early June. They first tunnel in the old needles and then bore into the center of the opening buds, remaining concealed as long as the developing foliage permits, and they feed on the pollen in the staminate flowers if these are present. As soon as the new growth becomes from 1 to 1½ inches long, the larvae, then in the fourth and fifth instars, begin tying the tips of several twigs together, and later this nest becomes quite pronounced. The feeding now is chiefly along the side of the lengthening tip, the needles being chewed off from the stem, and sometimes the soft bark is gnawed. Because of its habit of feeding on the leaf bases, the amount of foliage destroyed exceeds by far the actual food requirements. The mature larva spins a loose silken web either in the nest or attached to a twig, and within this web it transforms to a pupa.

Adverse weather conditions, diseases, predators, and many species of insect parasites normally play an important part in the control of this pest. However, when conditions are favorable for its increase the combined effects of all the natural enemies do not prevent outbreaks. Extensive outbreaks are often brought to an abrupt end by the effects of partial or complete starvation of the larvae. In the case of the form that feeds on jack pine, the normal fluctuations in abundance of staminate flowers from year to year have an important influence on the survival of young larvae that have overwintered on the trees.

Suggestions for preventing serious injury by the spruce budworm in spruce-balsam fir forests subject to attack, have been made by several investigators. Swaine, Craighead, and Bailey (*403*) advocated the utilization of fir on a short-term rotation. Others included such practices as removal of overmature, slow-growing stands of fir; encouragement of mixed hardwood-softwood stands; favoring of spruce seed trees in logging, particularly white spruce; avoidance of fir on thin soils subject to excessive drying and on poorer sites. Graham and Orr (*197*) recommended that logging operations should be distributed so as to result in the breaking up of future balsam fir-spruce types into comparatively small blocks of uneven age. This will reduce the acreage of such types as will be in a susceptible stage of development at any one time. For preventing budworm injury in Scotch pine and jack-pine stands in the Lake States, Graham (*192*) recommended the following practices: Maintain fully stocked and even-aged stands to prevent development of trees with excessively large crowns; fill in openings and do not space seedlings more than 6 by 6 feet apart, so that the crowns will close at the age of 10 to 15 years; remove susceptible trees in liberation cuttings; reduce staminate flower production by the removal of old trees with large crowns; log jack pine as soon as it is mature.

Trees in ornamental plantings can be protected by spraying with lead arsenate or DDT (p. 51) just as the shoots are opening in the spring. Fair results have been obtained in Canada and New York in recent tests with DDT spray applied from airplanes.

For cautions on the use of arsenicals and DDT, see pages 25 and 34.

Argyrotaenia quercifoliana (Fitch) is a cream-yellow moth, dotted with brown, and has a wing expanse of about ¾ inch. The forewings have two oblique brown bands, also a curved subterminal streak usually connected by a line in the discal fold to the outer oblique band, and finer lines to outer margin. The hind wings are white. The full-grown larva is about ¾ inch long, light green with amber-yellow head, and pale legs. It is distributed from Quebec to Texas, and the food plants are black, red, white, and pin oaks. The larvae are leaf rollers and feed during May and early June, and the moths issue in the latter part of June. Occasionally the insect causes serious defoliation, though usually the damage is rather local (Frost *173*).

The moth of **the red-banded leaf roller** (*Argyrotaenia velutinana* (Wlkr.)) has a wing expanse of about ½ to ¾ inch and is mottled with brown, but the markings are somewhat variable. The forewings have an oblique band from the middle of the costa widening to cover the outer third of the inner margin, with a blackish triangular patch beyond it on the costa, also a more or less oval, grayish patch in the apical area, and the inner margin of the basal half often is shaded with gray. The hind wings are grayish brown. The full-grown larva is about ¾ inch long; the body is pale grass green and the head is pale green, tinged with brown (Frost *173*). It is a general feeder and often causes considerable injury, perhaps more often in the orchard and garden than in the forest. It ranges from Canada south to North Carolina and Tennessee, and west to Iowa and Texas. There are two or three generations each year. It hibernates in the pupal stage beneath bark or in duff on the ground, and the moths of the first generation emerge between March and May, depending on the climatic location.

The moth of *Argyrotaenia quadrifasciana* (Fern.), **the four-lined leaf roller,** is lemon yellow heavily dotted with orange, is marked with two oblique reddish lines, and often the outer margin is shaded with brownish red. The hind wings are grayish. The wing expanse is about ¾ inch. The fully grown larva is ½ to ¾ inch in length, the head apple green, often tinged with reddish brown, and the thoracic shield and body apple green. There is one generation a year, and winter is passed as partly grown larvae in silken hibernacula on the twigs or trunk of the host tree. The larvae may be found from late in June to late in May of the following year. The moths emerge about the middle of June (Greenwood *203*). The four-lined leaf roller is distributed from Canada south to Maryland and west to Illinois and Arkansas. It is common in the Northeastern States and apparently apple is its favored food plant.

The moth of **the hickory leaf roller** (*Argyrotaenia juglandana* (Fern.)) is brownish, with a wing expanse about ⅔ to 1 inch. The forewings are dark brown crossed by two parallel oblique blackish lines, the second usually extending to the anal angle, and the hind wings are mouse gray. The full-grown larva is nearly ¾ inch in length. The head is pale green tinged with brown, the body pale and semitranslucent. This species is distributed through the Northeastern States and Canada west to Wisconsin. The larvae feed on hickory, each rolling a leaf in a conspicuous manner. The moths emerge in June and July in New England, and the larvae are found in May and June.

The pine tube moth (*Argyrotaenia pinatubana* (Kearf.)) is rust red, and has a wing expanse of about $^{9}/_{16}$ inch. The forewings have two whitish oblique bands crossing them, and the hind wings are pearl gray. The fully grown larva is about ½ inch in length; its body is greenish yellow, and the head greenish brown with a dark brown or black patch on each side. It feeds on white pine. The pupa is greenish yellow. There are two generations a year. The moths issue late in April, early in May, and in July. The larvae mature early in July and from October to early in November. Each larva draws together from 5 to 20 needles and fastens them with silk (fig. 113), making a tube. The larva feeds on the tips of the needles, and when not feeding conceals itself within the tube. It also pupates in the tube and passes the winter there in the pupal stage. Its distribution is from Canada south to Florida and west to Missouri, and probably throughout the range of white pine in the eastern part of the United States. Though often very common it is not considered a pest of economic importance. When abundant the numerous tubes made by the larvae give the white pine trees an unsightly appearance.

FIGURE 113.—Work of the pine tube moth (*Argyrotaenia pinatubana*) on white pine.

The moth of **the black-headed budworm** (*Peronea variana* (Fern.)) is grayish, with greatly variable markings of brown, orange, white, and black. The wing expanse is about ⅝ inch. The full-grown larva is about ½ inch in length, with a brownish head and bright-green body. In the earlier instars the head is black (Balch, *15*).

The moths emerge in July and August and lay their small, flattened, oval eggs on the under side of the needles. Hatching takes place in the spring at the time the buds of its food plants are opening. The larvae spin a web and feed on the new growth, becoming full grown in July. Pupation takes place in a web on the twigs.

This species is distributed through the northeastern part of the United States and from the Gaspé Peninsula in Canada to Alaska. Its food plants include fir, hemlock, and spruce, the balsam fir apparently being most favored. The feeding is confined largely to the new growth, and an infestation can be recognized by the brownish appearance of the trees in July and August, caused by the webbing together of the half-eaten needles. The injury caused is somewhat like that caused by the spruce budworm. There is less danger of outbreaks in mixed stands. Pure stands of mature balsam fir that become infested should be cut.

FAMILY PHALONIIDAE

The Phaloniidae are closely related to the Tortricidae. In North America more than 100 species are known to occur, but comparatively little is known about their habits.

One European species, *Phalonia rutilana* (Hbn.), is important enough to be discussed here. The moth has a wing expanse of about 3/8 inch. The head, thorax, and forewings are yellow with deep-red markings, the red on the forewings consisting of four broad bands, often the outer one connected with the third. The hind wings and abdomen are gray. The full-grown larva is brownish yellow, with the head and cervical shield somewhat darker. This species was introduced from Europe about 1878, and is now known to occur in the United States from Maine to New Jersey and Indiana. The larvae feed on juniper, particularly the common juniper (*Juniperus communis*), on which this species is sometimes abundant. The moths emerge in June. The larvae spin webs on the foliage, and their feeding causes a browning of the host plant. The larvae become full-grown late in May or early in June and pupate in the webbing.

Junipers of sufficient value to warrant the expense can be protected by an arsenical spray (p. 53) applied early in the spring.

Family **HELIOZELIDAE**

This is a small family, and its strongly flattened larvae are tissue feeders forming small blotch mines. They do not leave the mines until they are full grown. By that time a considerable part of each mine is filled with frass.

There are three genera represented in North America, but only one species, **the tupelo leaf miner** (*Antispila nyssaefoliella* Clem.), is recorded as being very destructive. The moth is dark brown and has a wing expanse of about 5/16 inch. The larva has a dark-brown head and cervical shield, and the body is pale green. The cocoon is spun within the mine; the outer wall, composed of the upper and lower epidermis of the leaf, is then cut away so that the case with its occupant drops to the ground (fig. 114). The moths emerge in May. It is widely distributed through the eastern half of the United States and is a blotch miner of tupelo, sometimes causing a complete browning of the leaves late in summer. A combined lead arsenate-nicotine spray (p. 53) applied when the moths are flying should aid in the control of this insect.

Family **GLYPHIPTERYGIDAE**

The family Glyphipterygidae, closely related to the Tortricidae, is represented by about 40 species in North America, but most of these are relatively unimportant as pests.

The one important species is **the apple and thorn skeletonizer** (*Anthophila pariana* (Clerck)). The moth is dark gray to dark reddish brown, often with a purplish tinge. The wing expanse is about 1/2 inch, and the markings on the forewings are variable. The full-grown larva has a pale-brown head, a yellowish-green body with prominent black tubercles, and is about 1/2 inch in length. This species is of European origin. It was first found in the United States in August 1917 in Westchester County, N. Y., by E. P. Felt, and is now known to occur in the Northeastern States from New Jersey to Maine. Its food plants in the United States are chiefly apple and to a lesser degree thorn and pear, whereas in Europe it is recorded as feeding on mountain-ash, birch, and plum.

FIGURE 114.—Tupelo leaf mined by *Antispila nyssaefoliella*.

Porter and Garman (*355*) recorded at least three generations and a partial fourth in Connecticut. The moths are active from early in June to September. The minute, green eggs are deposited singly on the under side of the leaves, usually next to the midrib. The larvae feed at first on the lower surface of the leaf beneath loosely spun layers of silk. When about one-third grown, the larvae migrate to the upper side of the leaf and spin a light web across from the opposite edges, drawing the two edges of the leaf partly together. Here the larvae consume all except the lower epidermis and the veins. Pupation takes place in a white cocoon, pointed at both ends, which is usually spun in a fold or curl of a leaf. It has not been definitely established in which stage this insect passes the winter. In many localities the foliage has been completely skeletonized by late August, and the leaves have turned brown and dropped to the ground early in September. This is particularly so on apple trees where a complete spray program has not been carried out. Although recorded as attacking some forest trees in Europe, thus far it has not been of importance as a forest pest in the United States.

FAMILY YPONOMEUTIDAE

In the more typical forms of Yponomeutidae the wings are comparatively broad with the venation only a little reduced. The larvae vary considerably, and few species are important as pests of tree growth.

The moth of **the arborvitae leaf miner** (*Argyresthia thuiella* (Pack.)) varies from white to light gray and has a wing expanse of 3/8 inch. The forewings are marked with brown including a median band broken below the costa; the hind wings are light fuscous. The larva is about 1/8 inch in length. The head and cervical shield are shiny black, the body is green with a reddish tinge, and the legs and anal plate are black. It is recorded from Canada south to the Middle Atlantic States and west to Missouri. Its food plant is arborvitae. The moths issue from late in May to early in July, depending somewhat on the season and the locality. The eggs are deposited on the inner edges of the leaves. The young larvae enter the leaves and excavate small areas between the upper and lower leaf surfaces (fig. 115). They hibernate as partly grown larvae in their mines and continue their mining again in the spring, maturing in May or June. Pupation takes place in the mines.

The mined leaves turn brown, giving the trees a sickly and unsightly appearance. Probably its greatest injury is on hedges and specimen trees in ornamental plantings. Although severe infestations sometimes occur in the forests it is doubtful that serious permanent injury results. *Recurvaria thujaella* Kearf. and *Argyresthia freyella* Wlsm. are often associated with this insect and their work may be confused. The latter species also attacks red cedar. The most efficient control measure now known is a combined spray of lead arsenate and 40-percent nicotine sulfate (p. 53) applied at the time the moths are flying. The nicotine is applied as an ovicide and the lead arsenate to poison the young larvae which hatch from eggs missed by the contact spray.

The moth of *Atteva aurea* (Fitch) is orange to brownish, with a wing expanse of about 1 to 1¼ inches. The forewings have alternate bands, four of orange and four of pale yellow, the yellow being cut into rounded spots by a fine black network. The hind wings are translucent and smoky. The larva is dark olive brown with white lines. Ailanthus is the preferred food plant, and the larvae live gregariously in a web. This species ranges from New York to Illinois and southward, and is sometimes very common in the Southern States. It is believed by some authors that this insect was introduced from South America.

The moth of **the European honeysuckle leaf roller** (*Harpipteryx xylostella* (L.)) is brown with the head and top of thorax white. It has a wing expanse of about ¾ inch. The forewings are strongly falcate, dark reddish brown, with the inner margin broadly marked with whitish or lemon yellow, including a fine spur extending upward beyond the end of the cell. The hind wings are grayish brown. The full-grown larva is about ¾ inch long. The head is mottled with yellow and brown, and the body is yellowish green with a broad, longitudinal, dorsal, reddish band. This is an introduction from Europe, first reported in this country near Boston, Mass., but now known to occur from Maine to New York. It is a leaf roller on bush honeysuckle (*Lonicera* sp.). The moths emerge late in June and July. Apparently the winter is passed in the egg stage, as the larvae feed in May and June. It is sometimes abundant, causing considerable concern to owners of ornamental shrubs.

FIGURE 115.—Tips of arborvitae leaves eaten out by the arborvitae leaf miner (*Argyresthia thuiella*).

FAMILY COLEOPHORIDAE

Nearly one hundred species of Coleophoridae are known in North America. The adults are plain little moths with markings limited to dustings of scales of lighter or darker shades. The wings are narrow with an expanse of less than 1/2 inch. Many of the species are so similar that to make accurate determinations it is often necessary to have the larval cases and food-plant records as well as specimens of the adults. The larvae are leaf miners, at least during the first instar, but after this they construct portable cases that they carry around on the hinder part of the body wherever they go. In subsequent instars some species are external feeders, but others continue as miners, as a rule, never leaving the case but feeding by mining in a circle or from each side of the point of entrance as far as they can reach without becoming detached from their cases.

In walking about the larva protrudes the head and most of the thorax from the case, and these exposed parts are strongly chitinized. The anal segment is also protected with a large chitinized plate, as this segment is pushed out through a small opening in the posterior end of the case when excrement is being extruded. The case is made from a part of the mined leaf lined with fine silk. It is enlarged when necessary or a new one is made so that the larva is sheltered at all times. The pupa is dark colored and is formed within the larval case.

These insects are widely distributed throughout the United States and Canada. The foliage, flowers, fruit, and seeds of various plants serve as food for one or more species. Many have one generation annually and their life cycles are similar. Some species are known to have two generations a year, and at least one in the West requires 2 years to complete its life cycle. The adults of the single-brooded species issue in the summer and deposit their eggs, as a rule, on the leaf surface of the food plant. Hibernation takes place as a partly grown larva within the case, which has been fastened securely to a twig or branch. As the foliage begins to develop in the spring the larva resumes feeding, consuming much more food than in the earlier instars. It attains full growth and changes to a pupa late in spring or early in the summer. Of the species having two generations a year, one brood of the larvae hibernate in the cases.

A few species are of considerable importance as defoliators, some cause injury to the opening buds, and others injure young fruit. Some of the more important species are briefly mentioned here.

The moth of **the pecan cigar casebearer** (*Coleophora caryaefoliella* Clem.) is brownish and has a wing expanse of about 3/8 inch. The larva is similar to other larvae of this group. The cigar-shaped case is brown and about 1/4 inch in length. The distribution ranges from New Hampshire to Florida and to the western border of Texas. The pecan, the various species of hickory, and black walnut are the favored food plants. There is one generation a year, the moths, issuing during June. The larvae feed first as miners, then construct small cases. Hibernation takes place in these cases as partly grown larvae. New cigar-shaped cases are constructed in the spring, and the feeding is resumed upon opening buds and young foliage, sometimes causing serious damage (Gill, *183* and Leiby, *272*).

The adult of **the cigar casebearer** (*Coleophora fletcherella* Fern.) has a wing expanse of about 7/16 inch. The wings are dark gray to grayish brown with the apex tinged with grayish ochre. The larva is golden brown with a black head. The case is brown, cylindrical, shaped like a cigar, and about 5/16 inch in length. This insect is distributed throughout the Northern States, probably being found in most sections where apples are grown. It is also reported from New Mexico. This is probably a native species that fed originally on wild haws. Although principally a pest of apple, it also attacks pear, cherry, hawthorn, plum, and quince. It has a life cycle and habits similar to those of *C. caryaefoliella.* The larvae inflict the most injury in the spring when they feed on the expanding foliage and later eat the flower and fruit stems, as well as making small holes in the young fruits.

The moth of **the larch casebearer** (*Coleophora laricella* (Hbn.)) is silvery to grayish brown. It has narrow wings fringed with long hairs, with a wing expanse of about 3/8 inch. The eggs are reddish brown, and upon magnification resemble inverted jelly molds having 12 to 14 ridges extending from the apex down the sides. The full-grown larva is about 3/16 inch long, with the head, thoracic shield, and anal plate black. The case is a part of the mined leaf lined with silk. It is light grayish and shaped somewhat like a cigar. The pupa is brown and is formed within the larval case.

Coleophora laricella is of European origin, and was first recorded in the United States in 1886 at Northampton, Mass. It has now spread throughout most of the range of larch in the eastern half of the United States and Canada. The host plants are American larch (often called tamarack or hackmatack) and European larch.

The adults emerge from the last of May to the first of July, depending somewhat on the locality and the season. The eggs are deposited promiscuously on the foliage, one or more to a leaf. On hatching, the larva bores directly into the leaf, feeds as a miner until September, and then constructs its case. As cold weather approaches, it prepares for hibernation by migrating to a twig or branch where it fastens the case securely from within. It resumes feeding in April, as soon as the foliage begins to develop, and eats the inner portion of the leaves, causing them to appear bleached. The larvae attain full growth during the latter half of May. The injury is seldom conspicuous in the fall. The greatest devastation is in the spring, when the injured foliage shrivels and dries. Serious defoliation retards the growth of trees and when it is continued for two or more years it causes considerable mortality.

Some 18 or 20 species of native parasitic Hymenoptera attack the larch casebearer in the Northeastern States, but none have ever been recorded as abundant enough to bring about appreciable control. In some localities birds play an important part in the control of this insect. Between 1932 and 1936 the Bureau of Entomology and Plant Quarantine imported parasites of this pest from its native habitat in Europe, and these were liberated in infested larch stands in the Northeast. Two of the introduced species, *Chrysocharis laricinellae* Ratz. and *Bassus pumilis* Ratz., have been recovered in the vicinity of some of the colonization points in northern New England and New York, thus proving their establishment.

For artificial control apply a dormant spray of lime-sulfur (p. 54) early in April before the buds open. (See caution, p. 37.)

The moth of **the elm casebearer** (*Coleophora limosipennella* (Dup.)) is buff colored, with gray markings, and has a wing expanse of nearly 1/2 inch. The larva is dark brown, with the head somewhat lighter. The larval case is dark brown, about 3/8 inch in length, with a crook at the anterior end and with the posterior part somewhat flattened and lighter in color. The moths issue in July, and in general the life cycle is similar to that of other single-brooded casebearers. The mines are confined to areas between the principal veins of the leaf. *C. limosipennella* is an introduced species, first attracting attention in this country near New York City in 1901. It has now been recorded from most of the Northeastern States. The favored food plants include English, Scotch, and American elms. This insect is primarily a pest of shade and ornamental trees, and outbreaks are usually extremely local. The mined parts of the leaves quickly turn brown and, if numerous, give the tree an unsightly appearance. Control is the same as for *C. laricella.*

The moth of **the birch casebearer** (*Coleophora salmani* Heinr.) is grayish brown, with a wing expanse of about 7/16 inch. The larva is dark brown, about 3/16 inch long when full grown, and the last four of its five instars are spent as a casebearer (Gillespie, *184*). The moth was first reported in 1927 near Bar Harbor, Maine, and is now known to occur in several towns in the eastern part of that State. The most favored food plants are paper birch, gray birch, European white birch, and speckled alder. Foliage of severely infested trees turns brown, presenting a scorched appearance. The moths are present in the field from the the middle of June to early in August. The young larva spends from 16 to 21 days in a mine before constructing its case. It hibernates as a partly grown larva in its case, which is attached to some part of the tree. In May the larva resumes feeding, attacking buds and tender leaves, and mining as far as it can reach without becoming detached from the case. A new case is constructed when the old one is outgrown. There is one generation annually. Control measures are the same as for *C. laricella.*

Family **GRACILARIIDAE**

The Gracilariidae are the largest of the leaf-miner families and includes about half of the lepidopterous species having leaf-mining habits. There seems to be a difference of opinion among authors in the groupings of some of the species in this family, a few having arranged them in 9 genera and others into as many as 17. However, by far the greater number of species of Gracilariidae fall within 2 groups, both of which are placed by some authors under the genus *Lithocolletis* Hbn., while other authorities list them under two genera, *Cameraria* Chapman and *Phyllonorycter* Hbn. Some 200 North American species fall within these two groups. *Gracilaria* also is a large genus, which has some common and widely distributed species (Ely, *144*, and Needham, Frost, and Tothill, *318*).

The adults are tiny moths often beautifully arrayed in shining scales and plumes, and with their more or less lanceolate wings overlaid with glistening shades of silver or burnished gold. The larvae are miners, at least during the early instars when they are highly specialized sap feeders, with the body, head, and mouth parts very flat. Some change their form and habits when partly grown, and after the sap-feeding period, they feed more upon the tissues or parenchyma of the leaf and spin silken threads across the loosened epidermis, forming tentiform mines, or skeletonize the leaf from a shelter made by folding over a part of the leaf. The larvae of one group continue to be depressed and flattened in form until just before pupation, whereas those of the other group become cylindrical with the head similar to the free-living caterpillars. The change from one type of larva to the other may take place in different instars in different genera and even in members of the same genus, and a marked change in form is always associated with changes in habits. In the early instars the legs and prolegs are sometimes absent and at most only rudimentary, whereas in later instars there is a considerable variation in the development of the legs.

The full-grown larva of most species spins a silken cocoon, usually within the feeding mine or shelter in which it pupates. The pupae of all the Gracilariidae have considerable power of movement. Some species pass the winter as larvae, some as pupae, and others in the adult stage. Although most highly specialized and most numerous, these leaf miners seldom become pests of real economic importance. Their effect on the plant varies with the character of the leaf attacked, as well as with the extent and nature of the injury to the tissues. In severe infestations the mining of the foliage undoubtedly reduces the vitality of the host plant to a considerable extent, and the disfigurement caused by the mined, shrivelled, and tattered foliage renders the trees or shrubs unsightly. Many species are represented in all parts of the United States and Canada. Their host plants include a wide variety of trees, shrubs, and plants.

Some species have a single generation and others may have several in one year. Moths of this family may be found from early spring to fall. The eggs are deposited on the foliage of the food plant. In some species the larvae are gregarious, one mine often containing several larvae. Some species in the genus *Marmara* are miners in the bast of twigs of apple, balsam-fir, chestnut, oak, pine, willow, and other trees (Forbes, *165*).

The solitary oak leaf miner (*Cameraria hamadryadella* (Clem.)) is one of the more common species of the Gracilariidae. It infests many species of oak, and the disfigured foliage caused by it often attracts attention. There may be several mines on a leaf, and each of the whitish blotch mines, made on the upper side of the leaf, contains only one larva (fig. 116). The winter is passed as a larva in the mine of the dried leaf. It has been reported that there may be as many as 5 or 6 generations a year in the vicinity of Washington, D. C.

The gregarious oak leaf miner (*Cameraria cincinnatiella* (Chamb.)) is another common blotch miner on oaks, principally white oak. The larvae are gregarious, sometimes 10 or more larvae being in a single mine, and in severe infestations there may be several mines to a leaf (fig. 117). There are two or more generations a year, and the winter is passed in the pupal stage. The best control measure is to rake up and burn the infested leaves in the winter.

The moth of **the lilac leaf miner** (*Gracilaria syringella* (F.)) has a dark-brown body, with a wing expanse of about ⅖ inch. The forewings are brownish, marked with six irregular transverse patches of yellow, and the hind wings are grayish brown. The full-grown larva has a brownish yellow head, the body is pale yellowish and translucent, and about ⅓ inch long. The partly grown larva in the mine is glossy, greenish, and sparsely clothed with long, fine hairs. This is an introduced species which is now widely distributed through many of the Northeastern States and parts of Canada. Its food plants on this continent are lilac and privet. The larvae feed gregariously between

FIGURE 116.—Oak leaves with the blotch mines of *Cameraria hamadryadella.*

the upper and lower epidermis for about 3 weeks after hatching, then vacate the mines and curl the leaves by spinning several strands of silk. They continue their feeding by skeletonizing from the upper surface in the curled leaves. The injured parts of the leaves dry up and give the bush a very unsightly appearance. Pupation takes place in the duff on the ground. There are two complete generations, the moths emerging in May and July. Larvae are active in June and July, and August and September. The winter is passed in the pupal stage. For control, spray with a combined lead arsenate-nicotine sulfate solution (p. 53) before the larvae curl the leaves.

FIGURE 117.—Blotch mines of *Cameraria cincinnatiella* on white oak leaves.

FAMILY LYONETIIDAE

The Lyonetiidae, as usually defined, include a number of species of tiny moths having a number of structural characters in common, but having larvae whose form and habits differ considerably. As presently constituted this family is a heterogeneous assemblage of genera. The majority of the species, however, fall within one genus, *Bucculatrix*, the ribbed-cocoon makers. The adults of this genus have the vertex of the head rough or tufted, the face smooth, and the basal segment of the antennae extended to form an eye cap fringed with stiff hairs. The wings are lanceolate, the hind pair with broad fringe, and usually brown, black, or silvery white markings.

The larvae are usually rather stout and greenish. The body is cylindrical. The head has the front extending about two-thirds of the way to the vertex, and the thoracic legs and prolegs are well developed. The newly hatched larvae at first form serpentine mines in the foliage of their food plant but later emerge and feed externally, skeletonizing the leaves. Pupation takes place within elongate silken cocoons which are sometimes spun on the foliage, though more often on twigs or small branches. In most species the cocoons are spun in a characteristic manner with longitudinal ridges or ribs, but they may vary in size, color, and the number of ribs. The pupae are rather short and spindle shaped, and the appendages are loosely attached, not being cemented to the body wall. The dorsal surface of the abdomen is provided with minute spines, segments 3 to 7 in the male and 3 to 6 in the female are movable, and the tenth abdominal segment has prominent lateral projections ending in stout laterally directed spines. Just prior to emergence of the moths the pupae are protruded from the cocoons.

The moth of **the birch skeletonizer** (*Bucculatrix canadensisella* Chamb.) has a wing expanse of about $\frac{5}{16}$ inch. The forewings are brown, marked transversely with diagonal white bars, and the hind wings are gray. The body is brown and white. The eggs are white, disk-shaped, and are deposited singly and scattered over the leaf. The full-grown larva is about 1/4 inch in length and yellowish green. Small, flat, white, molting webs are very noticeable on the leaves where larvae are present (fig. 118). The small brown spindle-shaped pupa is enclosed in a brownish-white cocoon. This cocoon is ribbed longitudinally and is fastened to the under side of a leaf or to debris on the ground. The insect is generally distributed in Canada and the northeastern part of the United States, west to Minnesota and southward in the higher altitudes to North Carolina. The larvae show a preference for gray, paper, yellow, and European white birches. Black birch is also sometimes infested. The pest has not been recorded as feeding on red birch.

FIGURE 118.—Full-grown larva and molting web of the birch skeletonizer (*Bucculatrix canadensisella*), × 4. (Courtesy Conn. Agr. Expt. Sta.)

The adults are active from the last of June to the last of July. The larvae hatch from the eggs in about 2 weeks, each boring through the bottom of the egg directly into the leaf, where it makes a serpentine mine. It feeds as a miner for 3 or 4 weeks and then comes out and spins a small, flat, white web within which it molts. After molting, the larva emerges from the web and feeds externally on the soft parenchyma of the leaf, skeletonizing it. In about 4 days it molts again in the same manner and completes its feeding in another week, when it drops to the ground and spins its cocoon. Thus the total larval period requires from 6 to 7 weeks. Freshly spun cocoons may be found from the last of August to late in September. The species hibernates as pupae in the cocoons. There is one generation each year. When this insect is abundant, the mining of the leaves by the young larvae and the skeletonizing by the older larvae may cause complete defoliation. Outbreaks occur at frequent intervals, and the birches over wide areas are severely attacked. This defoliation occurs toward the end of the growing season, and undoubtedly affects the growth the following year. For control, spray with a stomach poison (p. 53).

The full-grown larva of *Bucculatrix pomifoliella* Clem., **the apple bucculatrix,** or **ribbed cocoon maker of apple,** is about 1/4 inch long, with a brown head and a dark yellowish-green body. The larvae feed on apple and hawthorn and are sometimes abundant on unsprayed trees, causing the foliage to become brown and shriveled. This species is distributed quite generally in eastern Canada and through the United States from the Atlantic coast to Texas and the Rocky Mountains. The moths emerge in the spring at about the time the foliage is expanding. The pale, greenish eggs are deposited on the lower sides of the leaves. The habits of the larvae are somewhat similar to those of *B. canadensisella.*

The full-grown larvae usually construct their cocoons on the lower surfaces of twigs, although occasionally some are spun on the fruit and foliage. There is one generation in the Northern States, but farther south there are two generations annually, the moths of the second generation emerging about the first of August. The winter is passed in the pupal stage in the small, whitish, ribbed cocoons. When abundant, many cocoons may be constructed side by side on a twig, and these are particularly noticeable after the foliage drops in the fall. The control measures would be the same as for *B. canadensisella.*

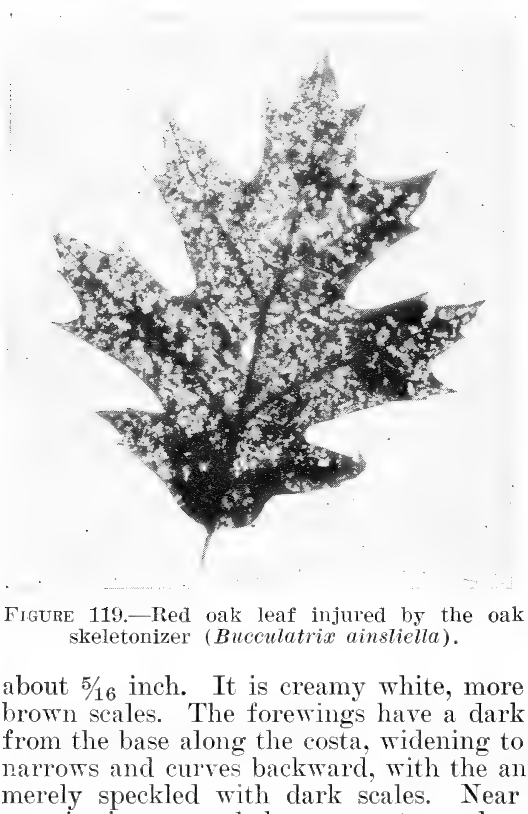

FIGURE 119.—Red oak leaf injured by the oak skeletonizer (*Bucculatrix ainsliella*).

The moth of **the oak skeletonizer** (*Bucculatrix ainsliella* Murt.) has a wing expanse of about $\frac{5}{16}$ inch. It is creamy white, more or less obscured by dark brown scales. The forewings have a dark brown longitudinal band from the base along the costa, widening to the apical third, where it narrows and curves backward, with the anterior margin to the apex merely speckled with dark scales. Near the middle of the inner margin is a purple-brown spot so shaped that when the wings are closed it presents the appearance of a broad oval patch one-half of which is on each forewing. The hind wings are pale, silvery gray. The full-grown larva is about $\frac{1}{4}$ inch in length and is yellowish green. The molting webs, cocoons, and pupae are similar to those of *B. canadensisella.*

It is found in the Northeastern States, but the exact range is not known. The food plants include red, black, and white oaks. In eastern Massachusetts there are two generations a year. Moths are active during the latter half of May and late in July and early in August. Larvae feed during June and early July and from late August to the middle of October or until cold weather stops their activities. The larvae feed just as do those of *Bucculatrix canaden-*

sisella (fig. 119). When the larvae are disturbed they spin down on silken threads. The cocoons in which the pupae pass the winter are spun on fallen leaves or debris on the ground and sometimes on the trunks of trees (fig. 120). Occasional outbreaks cause considerable concern, particularly to owners of large country estates. It sometimes becomes necessary to practice artificial control to prevent severe skeletonizing of the oak foliage. Outbreaks were recorded in Essex County, Mass., in 1929 and again in 1934. This insect can be controlled by the same measures as recommended for *B. canadensisella.*

Family COSSIDAE

The moths of the Cossidae have rather heavy spindle-shaped bodies, and narrow, strong wings. They are nocturnal fliers and deposit their eggs on the bark of trees or within the tunnels from which they have emerged. The larvae are borers in forest, shade, and fruit trees, making large galleries in the wood and causing serious injury.

The adult of **the carpenter worm** (*Prionoxystus robiniae* (Peck)) is a grayish, stout-bodied moth. The female has a wing expanse of 3 inches, while the male is somewhat smaller. The forewings are mottled and slightly translucent. The hind wings of the female are smoky, and those of the male are yellowish to orange with base and margins blackish. The eggs, numbering from 300 to 400 per female, are dark brown and oval. The larvae are 2 to 3 inches long when full grown and are reddish white with a brown head. The brownish pupa is formed in a cell in the wood, but it wriggles to the surface so that a part of it is projecting when the moth emerges.

FIGURE 120.—Cocoons of the oak skeletonizer formed beneath loose bark.

This species is widely distributed throughout the United States and southeastern Canada. It attacks green ash, elm, locust, maple, poplar, oak, and other hardwoods. The moths emerge in June and July, and the females deposit their eggs in crevices of bark or near wounds. The young larvae bore through the bark and into the sapwood and heartwood of the trunk and branches of the tree, and then tunnel more or less vertically (fig. 121). It is believed 3 to 4 years are required to complete the life cycle. The large burrows, up to ½ inch in diameter, cause serious deformities and also permit the entrance to the heartwood of moisture and destructive fungi (fig. 122). Use the control measures recommended on page 498 for *P. macmurtrei.*

The little carpenter worm (*Prionoxystus macmurtrei* (Guer.)) is very similar to *P. robiniae* and is often confused with it, especially in the larval stage. Though the infestations are usually very local, it is widely distributed, being recorded from eastern Canada and the Atlantic States south to Texas and west to Minnesota. The larva is a borer in oaks, and its habits are similar to those of *P. robiniae*. According to Hutchings (*250*), in Canada the larva spends the first season in the outer layers of bark, the second year in the sapwood, and the third summer it continues boring into the woody part of the tree until September. It usually passes the third winter as a pupa in the tunnel, although occasionally pupation is delayed until spring. Some trees are "brood trees," being continuously infested and becoming badly honeycombed. All parts of the tree over 1 inch in diameter may be attacked. For control, tree sanitation should be practiced. Infested branches may be cut off during the winter and burned. All wounds should be painted. In valuable trees, some of the caterpillars may be killed by inserting a pointed barbed wire into the burrow wherever sawdust is noticed, or carbon disulfide may be injected into the burrows which should then be stopped up with putty, grafting

FIGURE 121.—Larvae and work of the carpenter worm (*Prionoxystus robiniae*).

wax, or some other plastic material. (See also measures on pages 24–27, under Borers in Living Trees.)

The female of **the leopard moth** (*Zeuzera pyrina* (L.)) is heavy-bodied, with a wing expanse of about 2½ inches and is a feeble flier. The male has a more slender body and is somewhat smaller. The white thorax has seven black spots, and the black abdomen is cross-banded with white hairs (fig. 123). The wings are thickly dotted with blackish spots. (Howard and Chittenden, *246*).

The eggs are oval and salmon colored. The full-grown larva is about 2 inches long, and pale yellow, frequently with a pinkish tinge. The head and thoracic and anal plates above are brownish black, and the body is sparsely hairy and spotted with brown or black tubercles. The pupa is brown with a sharp protuberance on its head, which it

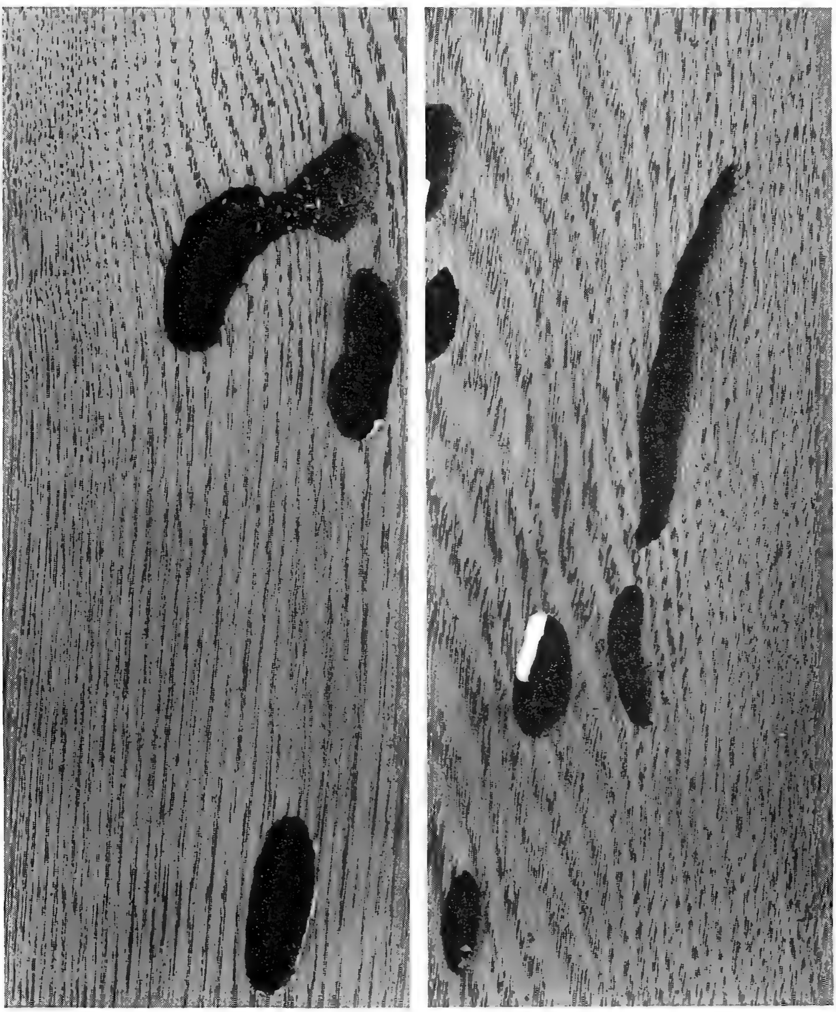

FIGURE 122.—Defects in oak lumber caused by larvae of the carpenter worm.

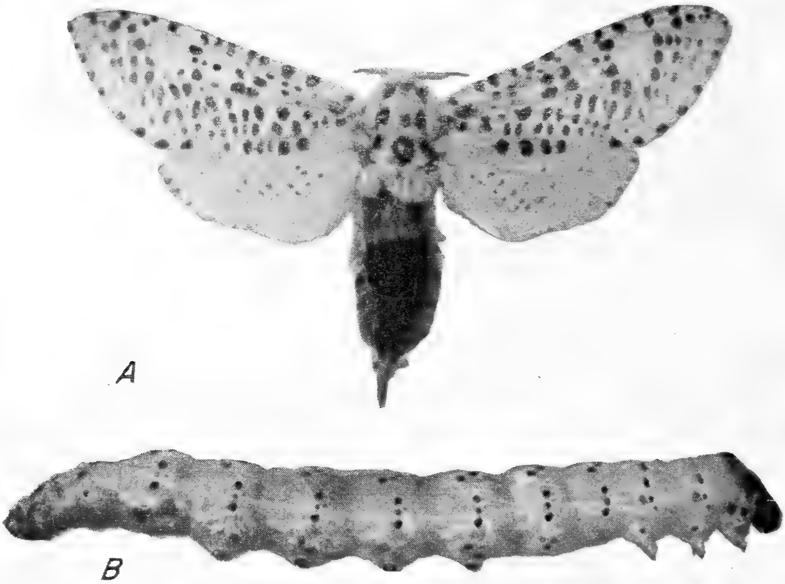

FIGURE 123.—The leopard moth (*Zeuzera pyrina*): *A*, Adult female; *B*, larva.

uses in pushing its way partly out of the burrow just prior to the emergence of the moth.

This European species was accidentally introduced into the United States sometime prior to 1879. It is well established, and is known to occur in the Northeastern States from Philadelphia, Pa., to the northern border of Massachusetts. The elms and maples are the favored host plants, but many other deciduous trees are also attacked.

The moths issue from May until late in September. The female deposits her eggs singly or in groups of usually 3 or 4 in crevices on the trees. As many as 800 eggs may be laid by a single moth. The larva hatches in about 10 days and bores directly into a twig, branch, or trunk of a deciduous tree, feeding on the living wood. If a larva becomes too large for a branch in which it is feeding it crawls out and bores into a larger one. Nearly 2 years are required for the larva to complete its growth, when it transforms to the pupa within its burrow. This usually takes place the second May or June after the larva has hatched from the egg. The presence of the borer in a tree is revealed by an accumulation of chips, matted excrement, and frass near the entrance to the burrow. The leopard moth larva is very injurious. The small infested twigs wilt and break off, and often larger, nearly severed branches are brought down by high winds, as in many cases the full-grown larva girdles the branch (fig. 124). Where a large larva has worked just under the bark, this splits open the next season leaving an ugly scar.

It is advisable to cut down and immediately burn all heavily infested trees. When only one or two branches are infested they should be cut off well below the parts attacked. In trees of considerable value many of the larvae can be killed by inserting a pointed barbed

FIGURE 124.—Branch nearly girdled by the leopard moth (*Zeuzera pyrina*). (Courtesy Conn. Agr. Expt. Sta.)

flexible wire into the burrows. Carbon disulfide may be injected and the burrows then stopped up with putty, grafting wax, or some other plastic material. Because of its habits, the control of this insect is difficult and expensive. (See control measures on pages 24–27.)

The moth of **the pecan carpenter worm** (*Cossula magnifica* (Stkr.)) is grayish with brown markings. The head is brown, the thorax has faint dark spots, and the abdomen is brownish gray. The forewings are mottled with small brown patches and have each a large brownish area at the distal end, and the hind wings are uniformly darker without markings. The wing expanse is about 1½ inches. The full-grown larva is about 1½ inches in length. The head, cervical shield, and anal plate are shiny dark brown, and the body is pinkish and sparsely clothed in short, fine hairs. This species is distributed through the Southern States and Mexico, and attacks hickory, oak, and pecan. The newly hatched larvae first attack the small twigs, boring into the pith. Later they crawl to larger branches and the trunk and bore into the hardwood, making galleries several inches in length. Usually small heaps of pellets extruded by the larvae can be found at the base of an infested tree, and upon close examination of the tree trunk there will be found one or more holes about the size of a lead pencil from which the pellets are being forced out by the insect. Although the complete life cycle is not known, it is believed there is one complete generation each year in the Southern States. The moths emerge in May and June. The larvae inhabit their tunnels during the fall, winter, and spring, and pupate within the larval gallery in April or May. Measures to control this insect are the same as for *Zeuzera pyrina.*

Family NEPTICULIDAE

The Nepticulidae are a family of minute moths, some having a wing expanse of less than 1/6 inch, and include many species whose larvae are leaf miners on many of our common deciduous forest and shade trees. A few are miners in the bark, and in one genus, *Ectoedemia*, there are several gall-making species. Annette F. Braun, in 1923, discussed this family, the genera, and many species that occur in the Eastern States (see Forbes *165*). The moths are not frequently seen because of their minute size, retiring habits, and very rapid, irregular flight. The larva is slightly flattened, and the head is rather deeply retracted into the prothorax. When full grown, most larvae leave the mines, drop to the ground, and spin dense flattened cocoons in the duff.

The larvae of species in the genus *Nepticula* begin their feeding by making linear mines, and may continue by gradually broadening the mines throughout their course, or some may enlarge them into a blotch mine. The mining of any one species, however, is constant and characteristic in appearance, and in most instances the mine may be used for the identification of the species. The number of generations vary, a few species have only one in a year, and others may have as many as four. The larvae in the genus *Ectoedemia* form galls on twigs or petioles, or are miners in the bark of twigs. So far as is known, the species in this genus have one generation a year. The larvae of *Ectoedemia populella* (Busck) form almost globular galls, about the size of a pea, on the petioles of poplar leaves (fig. 125). Those of *E. castaneae* Busck form cylindrical galls encircling young twigs of chestnut (fig. 126), and those of *E. heinrichi* Busck make flattened-oval, spiral mines in the bark of young branches of pin oak. The larvae of *E. phleophaga* Busck make serpentine mines in the bark of chestnut, and the wounds in the bark resulting from these mines offer favorable places for blight infection.

Family INCURVARIIDAE

The Incurvariidae are a small family, and so far as is known, the females are furnished with piercing ovipositors, the eggs being deposited in the tissues of the food plants. Many of the larvae are miners in early life, later becoming casebearers. There is one well-known species of economic importance in North America, **the maple leaf cutter** (*Paraclemensia acerifoliella* (Fitch)). The moth of this species has a wing expanse of from 1/3 to 1/2 inch. The forewings are of an iridescent steel blue with a purplish reflection. The hindwings are pale smoky brown, translucent, and bordered with a fringe of long hairs. The head is orange, the antennae are black, the legs whitish, and the abdomen is dark brown. The eggs are soft, white, and elliptical, and are deposited in pear-shaped pockets made by the female in the tissues of the leaves. The larva when full-grown is about 1/5 to 1/4 inch long, slender, and somewhat flattened. In general it is a dull white with a broad longitudinal dorsal stripe, and the head and thoracic segments are a pale rusty brown. The pupa is light yellowish brown, about 5/32 inch long, with a transverse row of short, stiff, brown,

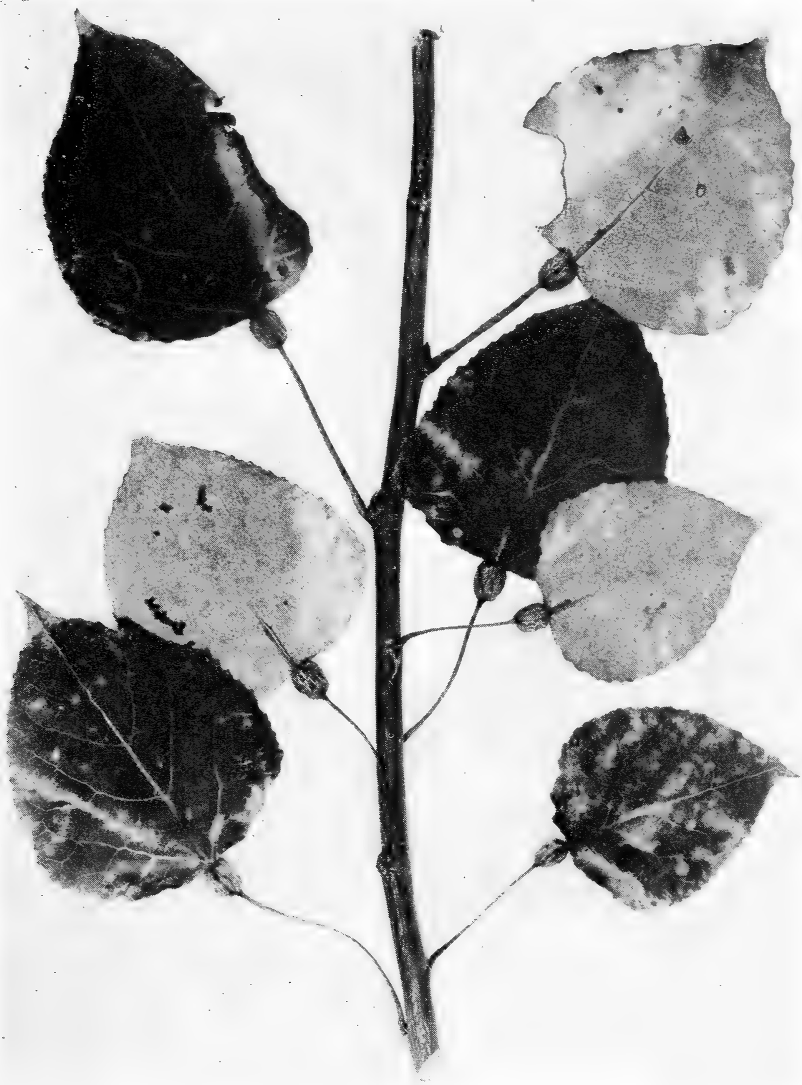

FIGURE 125.—*Galls of Ectoedemia populella* on petioles of quaking aspen.

backward-pointed spines on the backs of abdominal segments 2 to 8, inclusive.

This moth is found in the northeastern part of the United States from New Jersey to Illinois and northward, and in Canada in Provinces of Quebec, Ontario, and British Columbia. The favored food plant is sugar maple, and rarely red maple, birch, and beech, when the more favored food has become exhausted. The moths emerge during May and deposit their eggs in the leaves. Hatching takes place in a few days, and the young larva feeds on the tissues between the upper and lower epidermis of a leaf as a miner for 10 days or 2

FIGURE 126.—Galls on chestnut twigs caused by *Ectoedemia castaneae*.

weeks. It then cuts its oval case out of the mines and lives as a case-bearer. Whenever it is necessary to enlarge its case, the larva cuts out larger oval pieces of the leaf and adds them to its case (fig. 127). The larva becomes full grown late in August or in September and falls with the leaf to the ground, where it changes to a pupa within its case, thus completing one generation annually.

In severe infestations, the leaves begin to lighten in color during the first part of June, when the young larvae have eaten out the green tissues, causing thousands of small blotch mines, which undoubtedly seriously affect the vigor of the trees. As the larvae increase in size the trees are defoliated to a considerable extent, and this may occur several years in succession. For shade trees, and in maple stands of sufficient value to warrant the expense of spraying, an application of lead arsenate and fish oil (p. 53) early in June should control this insect. Some authors suggest the careful burning of the fallen leaves as a control measure.

FAMILY HEPIALIDAE

The Swifts, or Ghost Moths

The swifts, or ghost moths, have rather long and stout abdomens, and the forewings and hind wings are similar in form and venation. The forewing has a separate lobe, or jugum, at the base of the inner margin, which extends under the coastal margin of the hind wing. They are medium to large, having a wing expanse of 1 to 4 inches. The best-known species are yellowish to brown or ashy gray, and the wings are marked with silvery-white spots. The antennae are somewhat moniliform and about as long as the thorax is wide.

The moths are most active in the evening and have a swift zigzag flight close to the ground. The larvae are borers, normally in roots. They are cylindrical, nearly naked, the head is long, and the abdomen is furnished with five pairs of prolegs. So far as is known the larvae

FIGURE 127.—Work of the maple leaf cutter (*Paraclemensia acerifoliella*) on sugar maple.

feed at least two seasons. Pupation takes place in the burrow, but the pupa moves to the entrance hole prior to the emergence of the adult.

In the genus *Sthenopis*, the larvae, so far as known, bore in the roots of trees and shrubs growing in wet ground, and they are able to work below the water level. *Sthenopis argenteomaculatus* (Harr.) works in the base of the trunk and roots of alder, and *S. thule* (Stkr.) in the roots of willow. Both species range through most of the Northeastern States. Their work seldom attracts attention.

THE FLIES

ORDER DIPTERA

By R. T. WEBBER

The Diptera, commonly referred to as flies, are readily recognized by a single pair of functional wings, the hind wings being reduced to mere knobs called halteres. A few species, however, are wingless.

The mouth parts of the adult are either suctorial or vestigial, in some species formed for piercing, in others for scraping. The larvae, usually referred to as maggots, are footless and vary greatly in form, some being slender and elongate, whereas others are stout and cylindrical (fig. 128). The pupa may be free, loosely enclosed, or held immobile within the last larval skin, in which case it is called the puparium. A few species enclose their pupae in cocoons.

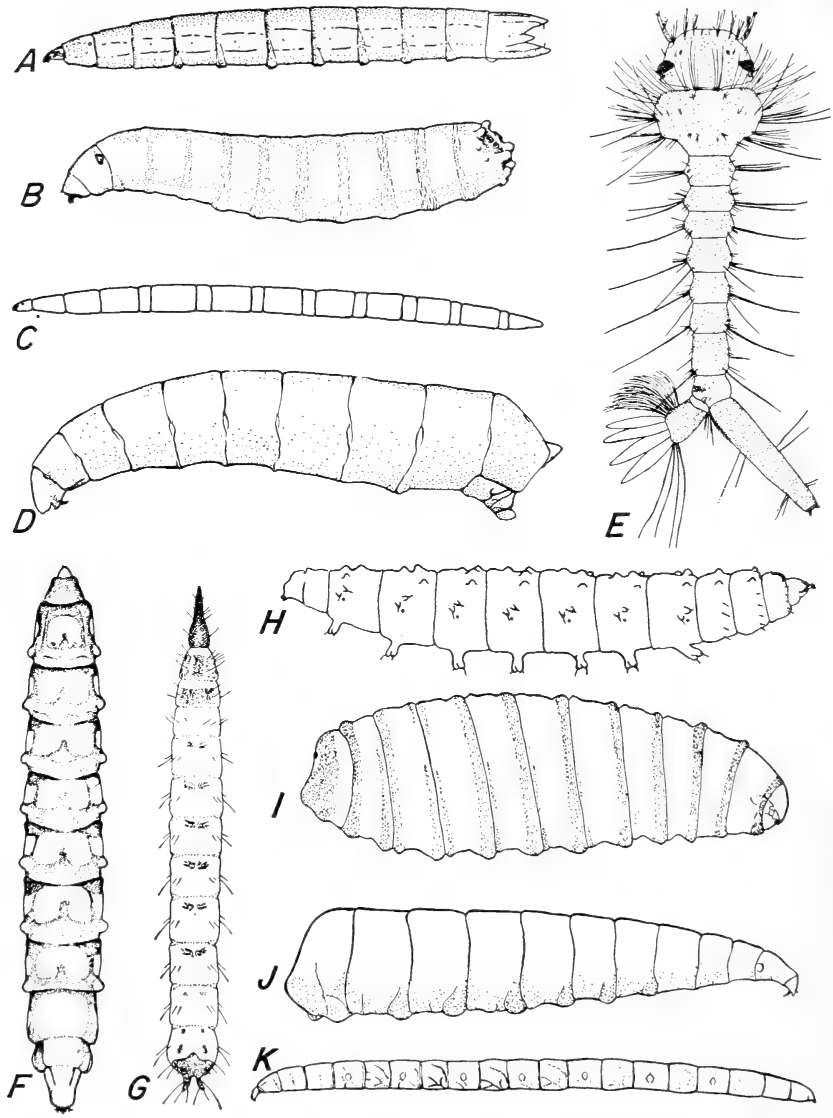

FIGURE 128.—Various shapes of dipterous larvae (after different artists): **A**, *Chrysopilus ornata*; **B**, *Rhagoletis pomonella*; **C**, *Mycetobia divergens*; **D**, *Hylemya cilicrura*; **E**, *Culex restuans*; **F**, *Tabanus atratus*; **G**, *Erinna lugen*; **H**, *Retinodisplosis inopis* O. S.; **I**, *Leschenaultia exul*; **J**, *Musca domestica*; **K**, *Psilocephala frontalis*.

There is a great diversity of habit in the larval and adult stages. Some species are extremely obnoxious to man and animals, some are destructive to crops, and others are beneficial. Practically every dipterous family has representatives in the forests, but from a forester's standpoint only a few species are destructive. With some exceptions, these species belong to families that are for the most part phytophagous—the Itonididae, Tephritidae, Agromyzidae, Chloropidae, and in part, the Tipulidae. The two last-named families include some species that are injurious to field crops, and in the Western States at least two species of Chloropidae and one species of Tipulidae are injurious to forest trees. Exclusive of certain aquatic Diptera (such as mosquitoes and blackflies) and other species that affect man or animals (Oestridae, Hippoboscidae, Muscidae, and Metopiidae in part), most of the other species are either noninjurious or beneficial.

Although some of the species of the aquatic Diptera may be a nuisance, they and others are of much economic importance as fish food. It is principally the small fish that live on insects, but it must be remembered that most fish pass through a carnivorous stage, even though they change their food habits later. Experienced fishermen are well aware of the attractiveness of certain dipterous larvae as fish bait. The larvae of species of tipulids and tabanids are exceptionally favored for this purpose. They may be frequently found in abundance beneath the stones in river beds or under tussocks of grass along the edge of a stream, and also in the leaves and debris that collect on small dams.

Scavenging is the most common habit in Diptera. In the family Muscidae (used in the widest sense) most of the species are scavengers. The predaceous species (such as Tabanidae, Asilidae, and Rhagionidae) and the true parasites (as Tachinidae, Dorilaidae (Pipunculidae)) are common. Several families—Sciaridae, Mycetophilidae, and Drosophilidae, the species of which are mostly fungivorous—may also be included with the beneficial Diptera.

MEANS OF IDENTIFICATION

Most authorities agree on the classification of the Diptera, although it is admitted that some families are weakly characterized and scarcely warrant the standing of families. Until a thorough study has been made of the immature stages, however, some doubt as to the true status of these groups will always remain.

Currans' 1934 revision of Williston's (*434*) Manual of North American Diptera (*124*) will be found most useful in classification of adults. The key to families and genera are simple, and the book is well illustrated.

Comparatively little is known of the immature stages of the Diptera, as may be seen from Hayes (*212*) bibliography of the keys for identification. Malloch (*287*) studied the Orthorrhapha and has given a comprehensive key for family separation. Our knowledge of the Cyclorrhapha, the species of which often present a marked similarity, is fragmentary, and the literature concerning it is widely scattered and often difficult to obtain. At present the key by Brues and Melander (*68*), based largely on food habits, is most helpful. Other important contributions dealing with the immature stages of the

Cyclorrhapha include a paper by Banks (*19*) and the papers by Greene (*201*, *202*) on the puparia and larvae of muscoid flies. The aquatic Diptera have been studied by Johannsen (*255*, *255a*), and his papers are of great value.

Obviously, any key for the identification of dipterous larvae, even as to family, must necessarily be highly technical and of little practical use for those other than the specialist. Since the present work is for the use of those less expert, it is believed that some of the more common species may be sufficiently identified by the character of their injury or by their habits. With this in mind the Diptera herein may be conveniently grouped as follows:

PHYTOPHAGOUS SPECIES

Character of injury and the families commonly concerned:

Gall makers
- Itonididae
- Argomyzidae
- Tephritidae

Leaf miners
- Itonididae
- Agromyzidae

Cambium miners
- Agromyzidae

Fruit- and seed-infesting species
- Itonididae
- Trypeditae
- Chloropidae

Root feeders
- Tripulidae
- Anthomyiidae

KEY TO FAMILIES OF PHYTOPHAGOUS SPECIES

Larvae

1. Larva with a sclerotized structure called "breastbone" near the anterior end ---- Itonididae p. 509.
   Larva not characterized as above ---- 2
2. Head complete, or the posterior portion with deep longitudinal incision; mandibles moving horizontally ---- Tipulidae p. 524.
   Head incomplete, without a strongly developed upper arcuate plate, mandibles moving vertically ---- 3
3. Large larva (9–12 mm.); body tapering or broadly rounded posteriorly; posterior spiracular plate with 3 slits ---- 4
   Small larva (3–4 mm.); posterior segment rarely truncate or with tubercles; posterior spiracular plate usually with more than 3 spiracular openings (if otherwise characterized see Chloropidae, p. 525) ---- Argomyzidae p. 521.
   Slender larva, ranging from 11 to 30 mm. in length with an average diameter of 1 mm. or less (cambium miners) - Agromyzidae, p. 522.
4. Posterior segment with 4 distinct tubercles in a transverse row below the spiracular plates; anterior spiracles with about 6 lobes (*Hylemya*) ---- Anthomyiidae, p. 537.
   Posterior segment with or without tubercles, if present, not arranged as above; anterior spiracles usually with 10 or more lobes in an irregular row ---- Tephritidae p. 524.

Family ITONIDIDAE

The Gall Midges

According to Felt (*148*, *150*, *151*, *153*), whose extensive papers on American galls have furnished the data for this compilation, there are about 900 native species of Itonididae, 700 of them having been reared.

The habits of the species vary greatly. Practically any part of the tree may be affected. There may be a gall, a pronounced swelling, or a mere shrivelling of the living tissue. Some species are found only in the seeds or cones, whereas others live in exposed positions on the leaves or in small pitch patches that exude from injured limbs. A few species live in dead wood.

The adults of this family are small, slender flies, resembling mosquitoes in many respects. They usually have long antennae and broad wings, the latter usually with few longitudinal veins and with or without a cross vein. The tibiae are without terminal spurs.

The larvae range in color from white to orange. The body is slender and somewhat flattened, tapering at both ends. The mouth parts are vestigial or suctorial. The principal character of the mature larva is the presence of a chitinized structure on the ventral side of the anterior end, called the "breastbone." This organ is believed to function as a boring tool, but it is also often used to lacerate or scrape plant tissue, thus causing a flow of sap on which the larva feeds. The larvae of some species are further characterized by their ability to spring into the air for a short distance.

There have been many rearings of Itonididae from recently cut logs or from decayed wood of various kinds. The closely packed larvae of an undetermined species have been observed beneath elm bark in numerous old tunnels of *Hylurgopinus rufipes*. This species appears to be predaceous and is not to be confused with the paedogenetic species of *Miastor*, which lives in colonies beneath the bark of decadent trees or stumps and can be readily recognized by the general absence of a "breastbone," which is present in a few individuals only.

Relatively few of the gall midges are injurious. Control measures are seldom necessary, since the infestation usually disappears after a few years. However, when abundant, the galls may frequently mar the appearance of the tree and cause considerable apprehension.

Individuals other than the specialist may best identify the species by means of the host plant and type of gall. This is a more or less reliable guide, since most species are restricted to a single host or its near relatives. A few species reported as injurious, and a few others mentioned because of their occasional abundance, are described here, and are grouped under the host plant instead of by genera, as is done in the remainder of this publication.

ABIES (Fir)

The larva of *Itonida balsamicola* (Lint.), **the balsam gall midge** is inactive and produces subglobular, basal swellings of about 3 mm. diameter at the bases of the leaves (fig. 129). The species is not believed to be particularly injurious, although it has been reported as abundant on balsam fir in the Adirondack Mountains in New York.

FIGURE 129.—Balsam leaf gall caused by *Itonida balsamicola.*

In this instance the heavily infested trees had lost a considerable portion of their foliage by December, the galls all dropping to the ground. The species is widespread and also infests Frazer fir. The adult is not known.

ACER RUBRUM (RED MAPLE)

The ocellate maple leaf gall (fig. 130) is believed to be caused by *Itonida ocellaris* (O. S.), although there is no positive record of its rearing. The gall or spot, which measures about 3 to 4 mm. in diameter, is yellow and has a red center and margin. The larva of *I. ocellaris* is nearly transparent and lives in an exposed position on the leaf. When full grown, about the latter part of September, the larva drops to the ground, where it spins a crude cocoon in which it pupates. The species is widely distributed but rarely, if ever, injurious. *Dasyneura communis* Felt, **the gouty vein midge,** produces greenish or reddish pouch vein galls about 6 mm. long.

ACER NEGUNDO (BOXELDER)

Itonida negundinis (Felt), **the boxelder gall midge,** produces terminal bud galls with a diameter of 1 to 2 cm. or long fleshy galls along the midrib of the leaf. The species is reported to have caused serious injury at Ames, Iowa.

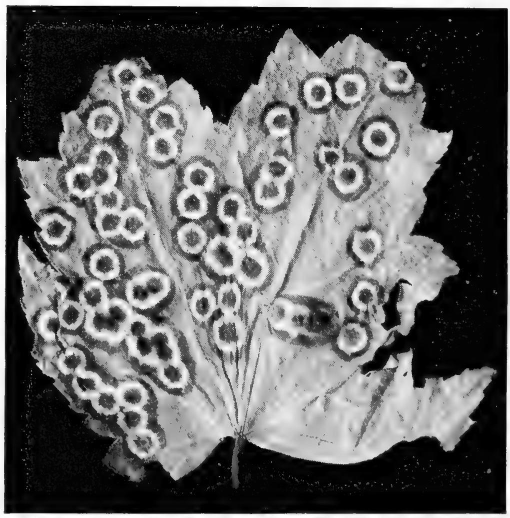

FIGURE 130.—Galls on a maple leaf caused by *Itonida ocellaris.*

BETULA (BIRCH)

Oligotrophus betulae (Winn.), **the birch seed midge,** lives in the seed of birch, and while it does not cause any conspicuous deformity, it renders the seed infertile. The larva is reddish and becomes full grown in October, when a windowlike spot can be seen on the surface of the seed. Transformation occurs within the gall, the larva being inclosed within a fine, white cocoon. The species is of European origin.

BUXUS (Box)

The boxwood leaf miner (*Monarthropalpus buxi* Lab.) is another introduced insect. The adult is orange-colored, about 1/10 inch in length, and appears during the first 2 weeks of May. The larvae mine the leaves, causing oval, yellowish or brownish blisters (fig. 131), which may cover the entire leaf in a heavy infestation.

Middleton and Smith (*302*) obtained satisfactory control by sodium cyanide fumigation, immersion in hot water, or by a nicotine sulfate spray. The spraying method appears to be the most practical, and one application is sufficient for the season. Use 2 pounds of a 50-percent wettable powder or about 2 quarts of a 25-precent emulsion concentrate per 100 gallons of water. For smaller quantities stir 1½ level tablespoonfuls of the 50-percent powder or 4 teaspoonfuls of the 25-percent rate into 1 gallon of water. (See caution on p. 36.)

HICORIA (Hickory)

Caryomyia holotricha (O. S.) is the cause of the **hickory onion gall,** a thin-walled, rust-red hairy, globose leaf gall with a diameter of 2 to 4 mm., found on the leaves of hickory in midsummer. *C. sanguinolenta* (O. S.) makes the **conical hickory gall,** which somewhat resembles the hickory onion gall, but lacks the brown pubescence of the gall of *C. holotricha* and is green or red tinted, becoming brown late in the summer. It is 2 mm. long. *C. tubicola* O. S. makes the **hickory tube gall** (fig. 132), a cylindrical, greenish, oblique leaf gall about 4 or 5 mm. long, with a diameter of 1 mm.

CATALPA (Catalpa)

The catalpa midge (*Itonida catalpae* (Comst.)) is a delicate yellowish fly about 1/16 inch in length, appearing late in May or in June. The young larvae attack the foliage of catalpa, destroying a part of the leaf and causing the injured leaves to wilt and drop off. They also attack the pods and destroy the seed. In a serious attack the trees are stunted and take on a bushy form, which renders them valueless commercially. No satisfactory control methods are known, although a great number of larvae would probably be destroyed by spraying late in May with nicotine sulfate solution. (See caution on p. 36.)

CORNACEAE (Dogwood)

The dogwood club gall, made by *Mycodiplosis alternata* Felt, is usually characterized by a distinct swelling on the smaller twigs. This is a common deformity of the flowering dogwood caused by a small, reddish-brown midge with mottled wings. The full-grown larva is orange-colored and about ⅛ inch long. Larval development is usually completed in the latter part of September, and the larvae drop to the ground and pass the winter in that stage. The adults emerge the latter part of May and attack the young shoots, which will show evidence of infestation about a month later. Cutting off and destroying the galls

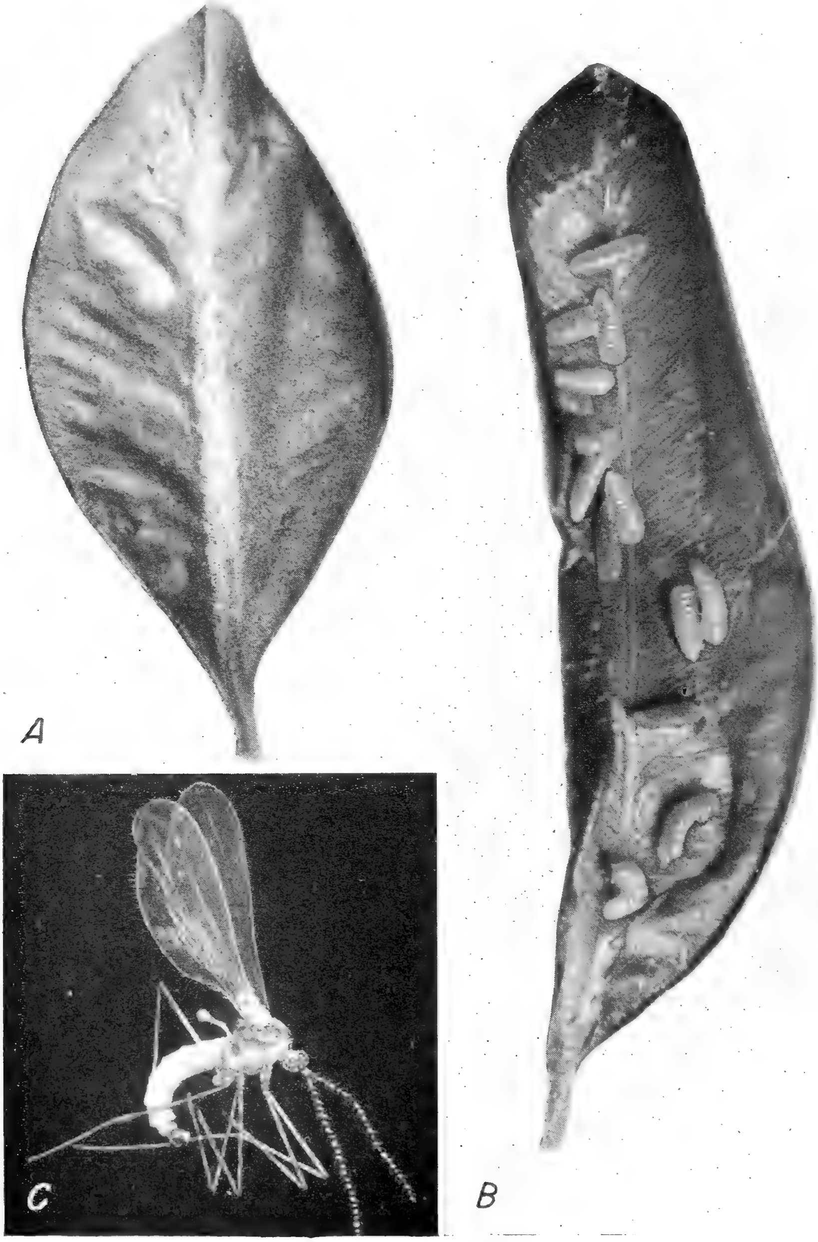

FIGURE 131.—The boxwood leaf miner: *A*, Blisters on leaf, × 4; *B*, maggots exposed by the removal of the leaf tissue, × 7; *C*, adult, or fly, × 12.

before the larvae emerge should prove an effective control in small ornamentals. Felt and Bromley (*154*) obtained a material reduction in a heavily infested tree by using a spray composed of 4 pounds of rosin-residue emulsion and 4 pounds of cube powder to 100 gallons of

FIGURE 132.—Hickory tube gall made by *Caryomyia tubicola.*

water. For applications were made during the period May 14 to June 14.

FRAXINUS (ASH)

The ash bullet gall made by *Itonida pellox* (O. S.) is a fleshy midrib gall. It is subglobular, with a diameter of about 5 mm. The galls are pale green when first formed, changing to a reddish brown later. The species has not been reared. **The ash midrib gall** of *Contarinia canadensis* Felt is a large, tumid, midrib gall found on white ash. It is from 5 to 15 mm. long.

JUNIPERUS (JUNIPER)

The larva of *Contarinia juniperina* Felt, **the juniper midge,** is a small yellowish maggot that produces a blister at the base of the needles, often causing them to drop to the ground. Numerous dead tips are the result of an infestation of this species. The adults emerge in April and lay their eggs beneath the needles. When fully developed the larvae drop to the ground, where they pass the winter in the soil. There is only one generation (Felt, *152*). Pruning and soil treatment are recommended as control measures.

LIRIODENDRON (TULIP)

Thecodiplosis liriodendri (O. S.), **the tulip gall fly,** is yellowish and about ⅛ inch long, and it produces a purplish blister gall with a diameter of about 3 mm. on the leaf. The species also attacks poplar, and was once reported as so abundant that the foliage was seriously disfigured.

PINUS (PINE)

The larva of *Retinodiplosis inopis* O. S., **the gouty pitch pine midge,** is yellowish orange. It is the cause of the subcortical twig swellings with pitch exudations on pitch pine. When full grown it forms its whitish oval cocoon on the needles or tip of the twig. *Contarinia coloradensis* Felt, **the pine bud gall** (fig. 133), produces swollen needles or needle bundles on piñon and stone pine. *Janetiella coloradensis*

FIGURE 133.—Galls on piñion caused by *Contarinia coloradensis.*

Felt makes a globose swelling at the base of needles on scrub pine (fig. 134). *Itonida pinirigidae* (Pack.), **the pine needle gall fly,** is rather common on pitch pine, and is believed to be the species that produces the conspicuous subglobular swelling at the base of the needles, causing their abortion. The larva of *Retinodiplosis resinicola* (O. S.), **the pitch pine midge,** is yellowish orange. It has been reared from extruded resin masses on pitch pine. It lives in the small patches of semifluid resin exuding from wounds in the branches.

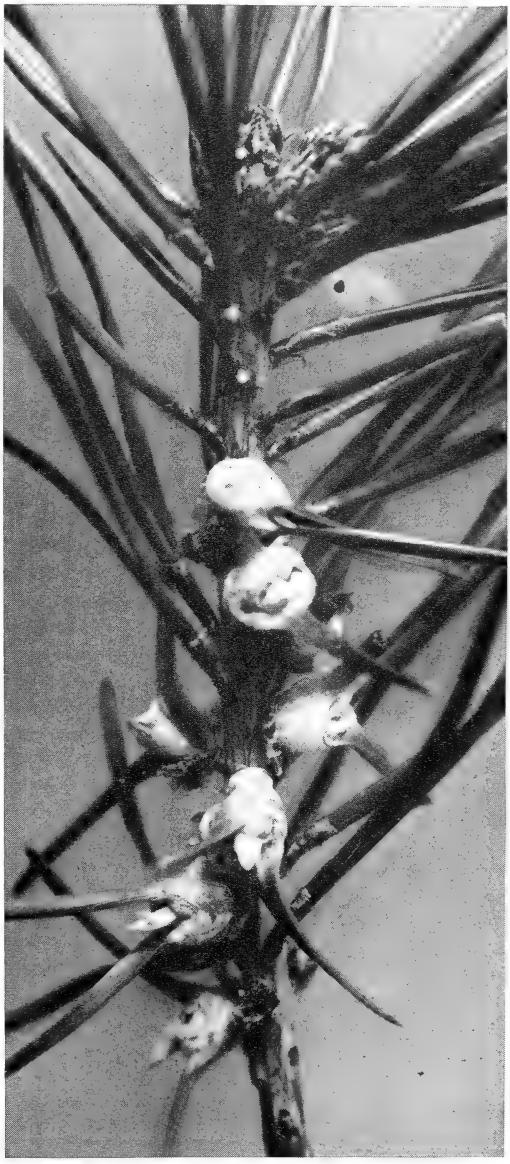

FIGURE 134.—Galls on pine caused by *Janetiella coloradensis.*

PRUNUS SEROTINA (WILD BLACK CHERRY)

The larva of *Itonida serotinae* (O. S.), **the wild cherry bud gall,** is bright yellow or red, and is believed to be the cause of the irregular terminal shoot and bud gall. The gall measures about 1.5 cm. in diameter.

PRUNUS VIRGINIANA (CHOKECHERRY)

Contarinia virginianiea (Felt), **the chokecherry midge,** is one of the causes of swollen and deformed fruit of the chokecherry.

PYRUS (PEAR)

The pear midge (*Contarinia pyrivora* (Riley) emerges late in April and in May and deposits its eggs in the blossom buds. When full grown, the maggots drop to the ground or remain in the infested fruit until they are shed from the tree. There is only one generation, the species passing the winter as a puparium.

Mundinger and Hartzell (*312*) reported satisfactory control with from ¾ to 1 pint of nicotine sulfate in 100 gallons of spray mixture, used with 1 or 2 gallons of summer-oil emulsion.

The spray should be applied when the blossom buds show a trace of pink between the separating sepals. (See caution on p. 36.)

QUERCUS (OAK)

The oak spangles are small saucerlike galls attached by slender stalks to the underside of the leaves. They are usually in clusters and range in color from a pale to a vivid red. They are from 3 to 5 mm. in diameter and are made by *Itonida poculum* (O. S.). **The vein pocket galls** (fig. 135), are elongate pocketlike swellings along the midrib and sec-

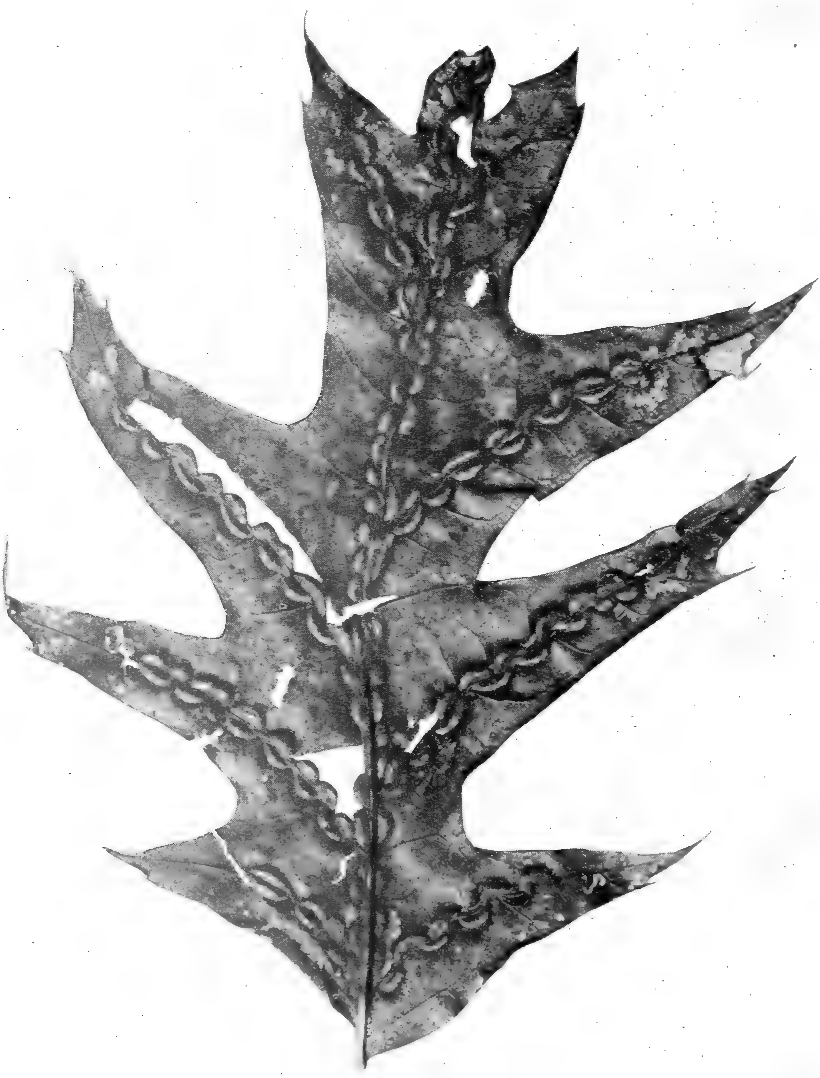

FIGURE 135.—Leaf galls on pin oak caused by *Parallelodiplosis florida*.

ondary ribs of the leaves of pin oak and round-leaved scrub oak. They are about 5 mm. long and are caused by *Parallelodiplosis florida* Felt. **The oak pill gall** is a globose or subglobose, irregular, reddish, wrinkled leaf gall with a diameter of 3 or 4 mm. made on red oak by *Cincticornia pilulae* (Walsh). Undetermined specifically is a leaf gall (fig. 136) caused by *Itonida* sp. on chestnut oak.

RHODODENDRON (RHODODENDRON)

The presence of *Giardomyia rhododendri* Felt may be detected by the swollen, pale-yellowish, inrolled leaf margins which fold over the midrib of the smaller leaves of rhododendron. The affected leaves, when expanded, bear indistinct greenish bulges or, in a heavy

FIGURE 136.—Gall on leaf of chestnut oak caused by *Itonida* sp.

FIGURE 137.—Gall on rhododendron caused by *Asphondylia azaleae.*

infestation, brownish spots, suggestive of a fungus disease. The injury is confined to the new growth, and a certain measure of control seems assured if the leaf tips of the new growth are sprayed with a nicotine-soap solution.

Asphondylia azaleae Felt, **the pinkster bud gall** (fig. 137), produces a brownish fusiform gall about ¼ inch long.

ROBINIA (LOCUST)

Dasyneura pseudacaciae (Fitch), **the locust midge,** is responsible for the folded young leaflets, and *Obolodiplosis robiniae* (Hald.) makes the rolled leaf margins on black locust.

SALIX (WILLOW)

Rhabdophaga salicis (Schr.), **the European willow gall midge,** is an introduced species and probably the most injurious of the many species that infest willow. The twigs are attacked by the young larvae, which form irregularly enlarged galls 1 to 3 cm. long. These galls cause brittleness in the willow canes and make them unfit for binding or basket making. The most satisfactory control means are cutting and burning the infested shoots. *R. triticolides* (Walsh) makes **the wheat ear gall,** which is in reality a bud gall, although not usually recognized as such. It is easily detected by the grouped mass of abnormal leaves. The twigs are irregularly enlarged, the gall being from 1 to 3 cm. long, and the stems between the buds are dwarfed, giving a "wheat ear" appearance. This injury stunts the development of the twig. *R. strobiloides* (Walsh), **the willow cone gall midge,** is widespread, and produces a pine conelike gall about 2 to 2.5 cm. long on the terminal branches, thus preventing the twigs from making a normal upright growth. The species passes the winter as a cocooned larva within the gall, the adult issuing in April or May. *R. rhodoides* (Walsh) makes a large, loose rosette gall (fig. 138) about 1 to 2 cm. long. *Phytophaga rigidae* (O. S.), **the beaked willow gall fly,** produces an apical, fusiform, beaked gall (fig. 139) about 2 cm. in length, usually on the lower shoots. The larva of this species is pale orange, and overwinters in a channel within the gall, the adult issuing in May.

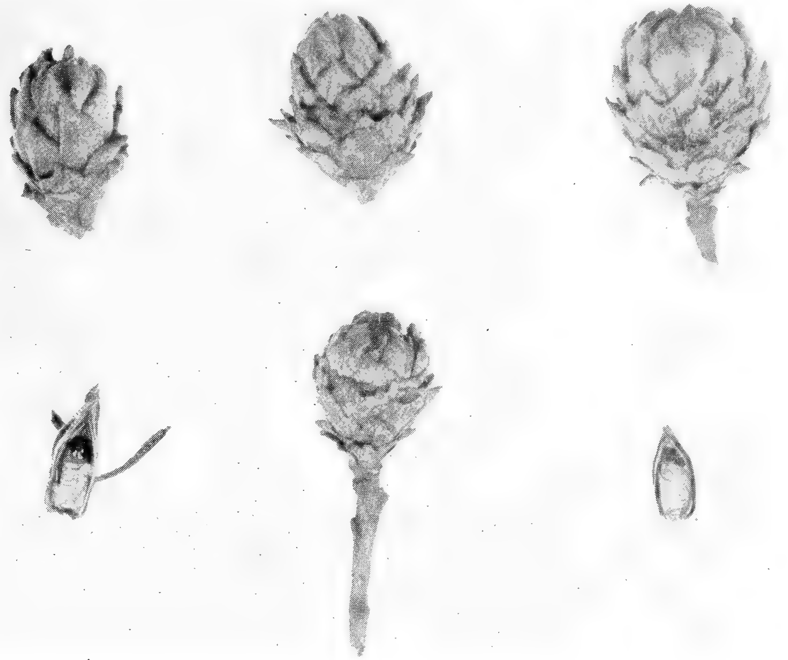

FIGURE 138.—Galls on willow caused by *Rhabdophaga rhodoides.*

FIGURE 139.—Beaked willow galls caused by *Phytophaga rigidae.*

TAXODIUM DISTICHUM (Bald Cypress)

Retinodiplosis taxodii Felt, **the cypress seed midge,** has been reared from the cones of bald cypress. The larvae deform the seed, producing irregularly globose, thick-walled, somewhat spongy, modified seeds in cones about 5 to 7 mm. in diameter. *Itonida anthici* Felt produces **the cypress flowering gall,** a whitish flower - shaped fungoid gall. It is occasionally abundant and readily recognized. The species is interesting, since it simulates a fungus so closely that at one time it was believed to be one. *Thecodiplosis ananassi* (Riley) makes **the cypress twig gall,** a fusiform gall 1 to 25 cm. long (fig. 140). *Itonida taxodii* (Felt) makes **the cypress leaf gall,** a conical, globular or elongate deformation of the leaf.

Figure 140.—Gall on bald cypress caused by *Thecodiplosis* sp.

TILIA (Linden)

Itonida citrina (O. S.), **the linden twig gall midge,** causes irregular swellings 4 to 8 mm. in diameter on the terminal bud of linden. The species has sometimes been abundant enough to seriously stunt the growth of the trees. The species, which is unknown in the adult stage, may prove to be the same as the European species *Contarinia tiliarum* Kieff. *Itonida verrucicola* O. S., **the linden wart gall** (fig. 141),

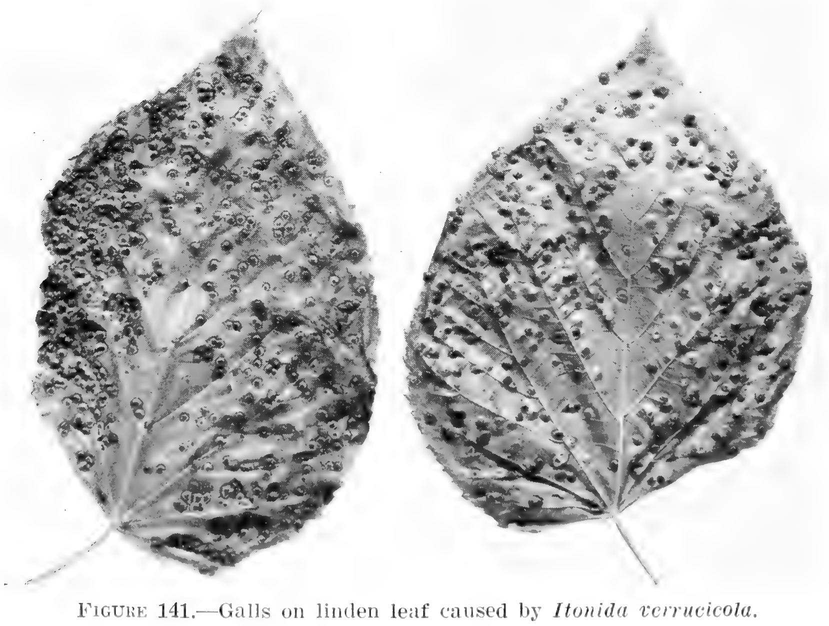

Figure 141.—Galls on linden leaf caused by *Itonida verrucicola*.

makes a subglobular, brownish leaf gall that shows equally well on both sides of the foliage.

ULMUS (ELM)

Oligarces ulmi Felt was described from material reared from the decaying bark of an elm in New York. It has also been reported as severely damaging the twigs of cedar elm in several counties in Texas.

FAMILY AGROMYZIDAE

The agromyzids are small insects, usually blackish or yellowish, with short antennae and a bare or pubescent arista. Oral vibrissae and mesopleural bristles are present.

The larvae of this family differ from other leaf-mining Diptera mainly as follows: The head is incomplete and not differentiated from the thorax; a buccopharyngeal armature is present, the mouth hooks are usually quadrangular or triangular with two to four teeth; the posterior segment is not produced into a prominent tubercle. The maggots are small, 3 to 4 mm. in length, or slender forms of 1 mm. or less in diameter.

These flies are essentially phytophagous and have a wide range of hosts. Most of the species belonging to the genus *Agromyza* are usually stem and root miners, although a few species mine beneath the bark, and a few are gall makers. The species of the genus *Phytomyza* are leaf miners. Dipterous leaf miners of woody plants are few in number, and, with the exception of the **holly leaf miner** (*Phytomyza ilicis* (Curt.), none have caused injury serious enough to warrant control measures.

Leaf Miners

Agromyza clara Mel., **the catalpa leaf miner,** makes a serpentine mine which later becomes a blotch mine often involving the entire leaf. The host plant is *Catalpa bungei.*

Agromyza ulmi Frost., **the two-winged elm leaf miner,** mines the leaves of American elm. The species has a single generation, overwintering in the puparium and emerging as adult early in the spring. *A. viridula* Coq. makes a blotch mine in the leaves of red oak. The larva of *A. melampyga* Loew makes a curved linear mine in the leaf of mock orange that later expands at its distal end, forming a blotch mine an inch or so long and half as wide.

The holly leaf miner (*Phytomyza ilicis* (Curt.)) makes a tortuous yellow-brown mine in the new foliage (fig. 142). Several kinds of holly are attacked. The adults appear early in the spring and have an extended emergence period. There is only one generation, the species passing the winter in the puparium within the mine. Satisfactory control has been obtained by Felt and Bromley (*154*) by using a spray of 2 gallons of volck, 1 pint of nicotine, and 1 pound of lead arsenate to 100 gallons of water. The spray was applied when the adults were about to emerge. On small plants an infestation can be greatly reduced by picking off the infested leaves and destroying them.

An introduced European species, *Phytomyza obscurella* var. *nigritella* (Zett.) Mel., mines the leaves of wild black cherry, peach, and bush honeysuckle. The mine is linear in form, the frass being arranged in conspicuous rows of spots along the center. There are two generations a year, the species overwintering in the puparium.

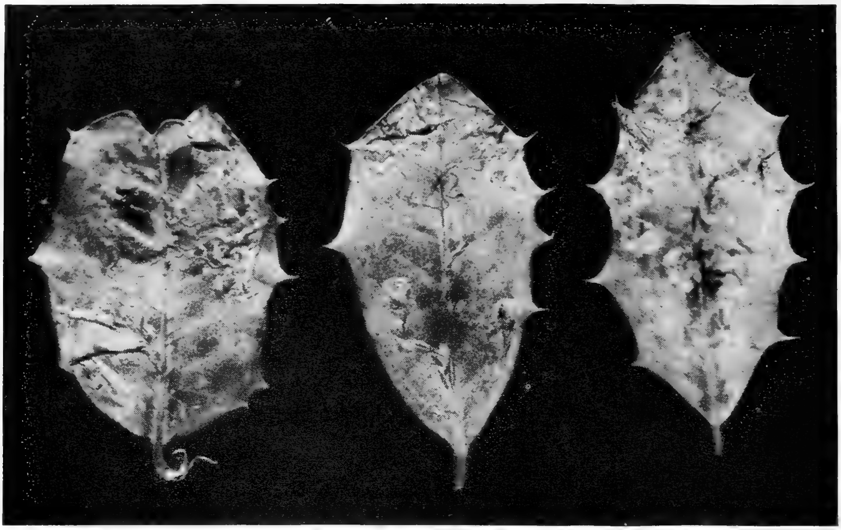

FIGURE 142.—Mines of the holly leaf miner (*Phytomyza ilicis*).

Gall Makers

Agromyza schineri Gir., **the poplar twig gall fly,** causes irregular, oval swellings about 3 mm. in length on the smaller twigs of *Populus* spp. The larva is greenish yellow and furnished with strong tridentate, jet-black mandibles. The species passes the winter as larvae within the galls, the adults emerging early in the spring. The adults are black and about ⅛ inch in length.

Agromyza tiliae Coud., **the linden bark gall fly,** causes irregular, oval, subcortical twig swellings about 1 cm. long in linden. The species overwinters in the puparium, the adults issuing in the spring.

Cambium Miners

At least four dipterous species mine the cambium of living trees, causing the defect in lumber known as "pith-ray flecks" (fig. 143). This injury is sometimes serious enough to make the wood unsuitable for fine-grade cabinet work or veneers. In cherry a disintegration of woody tissue, due to pith flecks, has been observed. The infested trees are difficult to detect unless the bark is removed and the cambium exposed.

Brown (*66*) has given a good account of the origin of pith flecks and the injury attributable to them. He stated that specimens of river birch examined in the latter part of April were infested with larvae of *Agromyza pruinosa* Coq. that were boring downward in the cambium, having already reached a point about 6 feet from the ground. A number of mines were traced back to their sources, which were suppressed lateral twigs on branches of about 5 years' growth in the crown of the tree.

Some mines could be traced for about 40 feet down the stem to the base of the tree; others extended some distance into the roots. The greatest number occurred in the basal portion of the trunk, owing to the frequent turnings of the immature larva.

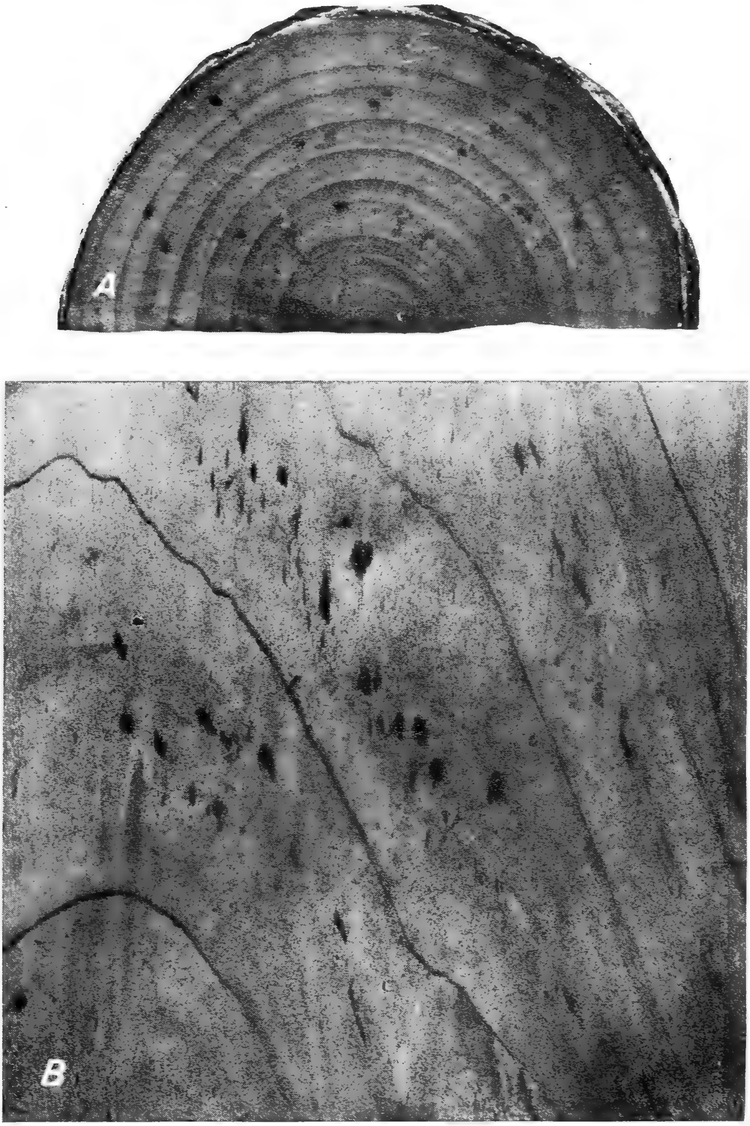

FIGURE 143.—Pith flecks: *A*, in river birch, transverse section, caused by *Agromyza pruinosa*; *B*, in silver maple, tangential section, caused by *A. aceris*. Natural size.

Pupation takes place about the last of June, the larvae boring small holes through the bark at ground level, where they make their exit. If they reach ground level before they are ready to pupate, they reverse their mines and go upward a short distance, and then again turn downward. Pupation takes place in the soil about ½ to 2 inches from the point of exit. The species passes the winter in the puparium.

Greene (*199*) briefly described the larva, pupa, and adult of *Agromyza pruinosa*. His data, relative to the seasonal history of the species is corroborative of the earlier work of Brown. In 1915 Malloch (*287*) described the adult and immature stages of *A. pruni* Gross., and Greene (*200*) described in detail two more species of cambium miners, namely, *A. aceris* and *A. amelanchieris*.

Although it is not at all certain that the species are monophagous, they are separated by the writer on that basis, *Agromyza aceris* Greene working in red maple, *A. amelanchieris* Greene in serviceberry, *A. pruinosa* Coq. in river birch, and *A. pruni* Gross. in *Prunus* sp.

Family TEPHRITIDAE

The Fruitflies

The fruitflies are small flies, usually with pictured wings, indistinct vibrissae, and prominent ovipositors. The larvae are usually pale yellowish, cylindrical, and tapered slightly toward the cephalic end.

The family is essentially a phytophagous one. Most of the native species of economic importance belong to the genus *Rhagoletis*, the larvae of which live within the pulp of fruits. Other species are gall makers, or they live in the flower heads, buds, or stems of various small plants.

Among the more common species that attack the fruit of woody plants are **the apple maggot,** or **blueberry maggot** (*Rhagoletis pomonella* (Walsh)), which has been bred from the fruit of apple, hawthorn, dogwood, wild plum, and chokecherry; and **the cherry fruitfly**, or **cherry maggot** (*R. cingulata* (Loew)), which attacks cherry, fringetree (*Chionanthus virginica*), and wild tea olive (*Osmanthus americana*). The last-named species is the well-known cherry fruitfly, distinguished by the white crossbands on the abdomen from the **black cherry fruitfly** (*R. fausta* (O. S.)), another species that attacks cherry. In *R. fausta*, the abdomen is wholly black.

The larvae of **the walnut husk fly** (*Rhagoletis suavis* (O. S.)) live in the husks of black walnut. Characteristic of their injury are the blackened hulls, which become slimy within, causing the husks to stick to the shell. *Euleia limata* (Coq.) lives in the fruit of holly, and *Toxotrypana curvicauda* Gerst. in the fruit of papaya.

Superfamily *TIPULOIDEA*

Crane Flies

The crane flies derive their name from their long slender legs. The abdomen is elongate and the mesonotum has a distinct V-shaped suture. A number of species are common in the forest, particularly along the edge near fields or meadowland. The larvae are cylindrical and wormlike and have an extremely tough skin. Some species attain an enormous size, the extended larva measuring nearly 60 mm. in length and about 11 mm. in width.

The species may be aquatic, semiaquatic, or terrestrial, the latter habit predominating. Most of the species are phytophagous, although many are decidedly carnivorous. Several species have been reported as injurious to crops, but only a few attack woody plants. In this country *Phoroctenia angustipennis* (Loew) is recorded as damaging prune trees in Oregon. In Europe several species are reported as injurious to deciduous and coniferous plants.

The larvae of *Tipula abdominalis* Say live under stones in brook beds and beneath saturated decaying leaves or clumps of grass adjacent to water. This is one of the large species of *Tipula*, and because of its abundance and value as fish bait is much sought after by fishermen. Alexander (*1*) listed species of the genera *Limonia* (*Dicranomyia* and *Rhipidia*), *Tipula*, and others as occurring in decaying wood just beneath the bark, and *Tanyptera* species in nearly solid wood. Johannsen (*254*) in 1909 bred *Phoroctenia apicata* (O. S.) from decayed elm.

Of peculiar interest is *Chionea valga* Harr., **the wingless snow-midge,** whose midwinter appearance is frequently the cause of inquiry. These spiderlike creatures may be often observed walking awkwardly over the snow, even when the temperature is below freezing. They are of no economic importance.

The family Sylvicolidae (Rhyphidae, Anisopodidae, Phryneidae), sometimes called the **"false crane flies,"** consists of only three genera, the adults of which are of a more or less diverse structure. The larvae have the abdominal segments divided transversely, as in the Therevidae. *Mycetobia divergens* Wlkr. (fig. 128, *C*) has been bred from rotting wood and has also been found in the flowing sap of an elm tree. *M. persicae* (Riley) has been bred from gum and frass taken from the base of peach trees infested by borers.

Family CHLOROPIDAE

Frit Flies

The frit flies are small, bare flies with hemispherical heads characterized by a large frontal triangle and usually short antennae. The auxiliary vein is vestigial, and the second basal cell is confluent with the discal cell.

Parker (*328*) described the larva of *Chloropisca glabra* Meig. as elongate, about 6.5 mm. in length. From its greatest width of 0.7 mm. the body tapers to 0.5 mm. at the posterior end and to 0.2 mm. at the anterior end; it is sharply truncated posteriorly, and the segmentation is indistinct. The posterior spiracles of the third instar are prominent, each with three spiracular openings, and the anterior spiracles slightly raised and seven-branched. The tracheal trunks are readily seen through the body wall. Most of the species are phytophagous, the larvae feeding on grasses, cereal crops, and other plants.

Siphonella inquilina Coq. has been bred from buttonbush twigs. In the West, Essig (*145*) reported *Oscinis sulphurhalterata* End. and *Oscinella conicola* (Greene) as having been bred from the cones of lowland fir, *Abies grandis*. *Chlorops* spp. and *Oscinella* spp. have been bred from dead hickory.

Chloropisca glabra is predaceous on the sugar-beet louse. *Gaurax anchora* Loew. *Pseudogaurax signatus* (Loew), and *Madiza oscinina* Fall. are probably scavengers. The last two species have, however, been bred from spider egg sacs and may be predaceous at times *G. apicalis* Mall., *Oscinella coxendix* (Fitch), *M. glabra* Fall., and *Hip-*

pelates sp. have been bred from weeviled white-pine leaders by MacAloney (*278*). These species are likewise believed to be scavengers, although *G. apicalis* is apparently sometimes parasitic.

NONPHYTOPHAGOUS SPECIES

BLOOD-SUCKING DIPTERA

Hosts and families commonly concerned:

- On mammals
  - Culicidae
  - Ceratopogonidae
  - Simuliidae
  - Tabanidae
  - Rhagionidae
  - Muscidae
  - Hippoboscidae
  - Calliphoridae
- On poultry
  - Muscidae
- On song birds
  - Calliphoridae
  - Metopiidae
  - Hippoboscidae
- On game birds
  - Culicidae
  - Calliphoridae
  - Simuliidae

KEY TO ALL FAMILIES

LARVAE

1.	Larvae aquatic or semiaquatic	2
	Larvae terrestrial	5
2.	Head incomplete; retractile; mandibles moving vertically — Tabanidae, p. 529.	
	Head complete; mandibles opposed	3
3.	Thoracic segments not fused	4
	Thoracic segments fused and dilated — Culicidae, p. 526.	
4.	Larvae metapneustic with anal retractile gills; last 3 or 4 segments greatly swollen, giving the larva a club-shaped appearance — Simuliidae, p. 528.	
	Larva metapneustic with or without retractile anal or caudal gills — Ceratopogonidae, p. 527.	
5.	Larvae viviparous; ectoparasites of various warm-blooded vertebrates — Hippoboscidae, p. 529.	
	Larvae not viviparous	6
6.	Mandibles or mouth-hooks normally sickle-shaped — Rhagionidae, p. 536.	
	Mandibles or mouth-hooks short and hooklike — Muscidae, p. 537. Calliphoridae, p. 538.	

FAMILY CULICIDAE

Mosquitoes

The Culicidae, or mosquitoes, are slender flies with no ocelli, generally with a piercing proboscis, and, in the males, thickly plumose antennae. The wings are long and narrow, with six fully developed longitudinal veins that reach the wing margin. All the species, so far as is known, are aquatic in their early stages, feeding on algae and other organisms in the water.

The malaria mosquitoes, *Anopheles* spp., and **the yellow-fever mosquito** (*Aedes aegypti* (L.)) are well-known representatives of this family. In some locations the mosquitoes constitute one of the greatest annoyances to man and animals, and occasionally their abundance is such that field work must be abandoned for a time. This is also true in recreational areas where mosquitoes are frequently so troublesome that the place becomes uninhabitable.

Control measures vary according to the species concerned. According to Bishopp (*33*), the **northern house mosquito** (*Culex pipiens* L.)

C. quinquefasciatus Say, and *Aedes aegypti* (L.) breed in many places—rain pools, ornamental pools, cisterns, cesspools—in fact, in any place where there is standing water. These are generally called domestic mosquitoes. The most important control measure is the elimination of such breeding places. Where elimination is impractical the water should be treated (King, *263*). Kerosene is the most commonly used oil, although in extensive breeding areas a weekly spraying with No. 2 fuel oil is recommended. The oil should be used in sufficient quantity to form a slight film over the surface. Where oil is objectionable, gasoline or powdered borax may be substituted. Ginsburg (*187*) reported good results from the use of a pyrethrum larvicide.

The control of forest-inhabiting mosquitoes that breed in marshes and swamps is principally a matter of drainage or the use of biological control measures, and the chief requisite is community action. Where drainage is impractical or would be detrimental to wild life, as in certain coastal or inland areas, ditching is usually resorted to. Deep pools are dug in the lower sections and stocked with fish that will eat the wrigglers. Open ditches radiate from these pools to the higher levels. When the water is high, the fish work out; when low, they return to the pools. Some areas may be treated with an application of the oil or with a pyrethrum larvicide.

There is no known repellent that will give relief from mosquito attack for more than a few hours. The following available repellents are effective and safe when used individually or in combination: Dimethyl phthalate, dimethyl carbate (cis-bicyclo [2,2,1]-5-heptene-2,3-dicarboxylic acid, dimethyl ester), Indalone (*n*-butyl mesityl oxide oxalate), and R–612 (2-ethyl-1,3-hexanediol). These are described by Travis and Morton.[32]

These chemicals vary greatly in their effectiveness against different species and on different individuals. Laboratory and field tests have shown that a mixture of Dimethyl phthalate 3 parts, Indalone 1 part, and R–612 1 part, is more effective against a wider range of insect species and on more individuals than any one of the repellents when used alone. Dimethyl carbate may be substituted for R–612 if the latter is not available.

Some of the repellents, alone and in combination, are now available in many drug stores under proprietary or trade names.

Family **CERATOPOGONIDAE**

Punkies, "No-see-ums," Sand Flies

The family Ceratopogonidae is allied with the family Chironomidae, but was separated from it by Malloch (*288*). The chitinized mouth parts and short metanotum without longitudinal groove are characteristic of the family. Both aquatic and terrestrial species occur.

Adults of the aquatic genus *Culicoides* **(punkies)** are blood suckers, as are also those of the genus *Leptoconops*. They attack both man and animals. Other genera attack insects. Because of their minute size, the bite of these flies is often felt before its cause is apparent.

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[32] Travis, B. V., and Morton, F. A. use of repellents and miticides. Bur. Ent. and Plant Quar. E–698, 6 pp. 1946. [Processed.]

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Some of the species feed during all hours of the day, but a greater number appear most active at dusk.

The most important species breed in fresh-water inlets along the seacoast, others in rot holes in trees, and still others in debris along the borders of fresh-water streams or ponds. The larvae of *Forcipomyia* are terrestrial. *F. specularis* (Coq.) has been taken from under the bark of trees, in cow dung, and in decaying vegetable matter, and has also been bred from weeviled leaders of white pine. *Dasyhelea* spp. have been bred from exuding sap on elm trees. *Culicoides* spp. have been taken from tree pockets and *Ceratopogon brumalis* Long from rotten elmwood and from ant nests.

The control measures [33] vary according to the species. Those that breed in salt marshes and in the dead leaves and silt along their edges may be best controlled by diking and automatic tide gates. The control of species breeding in inland areas along streams has not been thoroughly worked out, but it is believed that the removal of vegetation and the straightening of the banks will reduce breeding. For temporary relief either of the following spray mixtures will be found satisfactory if applied to the breeding places.

(1)	Pyrethrum extract concentrate (20 to 1)	1 part.
	Lubricating oil (S. A. E. 5)	20 parts.
	or	
(2)	Pyrethrum extract concentrate (20 to 1)	1 part.
	Kerosene	6 parts.
	Lubricating oil (S. A. E. 10)	12 parts.

These mixtures when brushed over window screens will exclude sand flies from the house for 24 to 48 hours. The mixtures may also be used on the skin to prevent being bitten. DDT is now replacing many of the older sprays used in mosquito control.

Family SIMULIIDAE

Blackflies, Buffalo Gnats

The Simuliidae are small, thick-set flies with no ocelli and 10- or 11-jointed antennae. The abdomen has 7 or 8 segments, the first segment bearing a conspicuous flaplike scale fringed with long hairs.

The larvae of this aquatic family live in well-aerated water, such as swiftly flowing streams or brooks, and are never found in still or stagnant water.

Blackflies rank on a par with the mosquitoes as a common nuisance. They attack all warm-blooded animals. Some species are vicious biters and their persistence in getting in the eyes, nose, and ears is most aggravating.

The control of blackflies is difficult, being essentially a community problem. One of the most satisfactory measures (O'Kane, *321*) consists of treating their breeding places with a miscible oil. In small areas enough oil is used to give the water a milky appearance. This concentration must be maintained for 3 to 5 minutes, which may be accomplished by frequent additions of a small amount of oil at the starting point. The fact that fish are easily affected by the oil would

[33] "Sand flies" and "punkies." U. S. Bur. Ent. and Plant Quar. E-441, 3 pp., illus. 1948. [Processed.]

necessarily limit its use as a control measure. Experiments by Glasgow (*188*) indicate that the pyrethrum mosquito larvicide used in New Jersey is highly effective for ridding a stream of blackfly larvae, and does little, if any, harm to fish. DDT can be used as a larvicide and as a protective spray on livestock. Temporary relief may be obtained by the use of the repellents described under mosquitoes.

Family TABANIDAE

Horseflies, Deer Flies

The horseflies are stout, bristleless flies with large eyes, and with the third antennal segment annulated and devoid of a style. Five posterior cells are always present, and the empodia are developed pulvilliform.

The typical larva is elongate (fig. 128, *F*), tapering at both ends. The head is small, with strong, downward-pointed mandibles. Usually the abdominal segments are longitudinally striated and encircled with fleshy protuberances, as in *Tabanus atratus.*

So far as known, all the larvae of the Tabanidae are predaceous, except perhaps those of the genus *Goniops.* Most species are aquatic or semiaquatic, living in the mud beneath streams or in the sand along their borders. Other species live in the soil beneath the leafmold. *Leucotabanus annulatus* (Say), **the black horsefly** (*Tabanus atratus* F.), *T. fulvulus* Weid., and an unknown tabanid species have been recovered from wet, rotten logs and stumps.

Because of the blood-sucking habits of the females, the adults of the genera *Tabanus* and *Chrysops* are serious pests of livestock and other animals. Species of *Chrysops*, **the banded-winged horseflies** and **deer flies,** are among the most annoying of forest Diptera. They are active during the hottest weather, and will attack man furiously. The flies are particularly abundant following a rainy season, and control measures are ineffective. Animals may be best protected by darkened shelters, or the heads and bodies of work animals covered with nets. There is no satisfactory repellent.

Family HIPPOBOSCIDAE

In the adult stage the Hippoboscidae are parasites on birds and mammals. They are flattened, louselike insects with apparently single-jointed antennae inserted in a depression. The legs are stout and broadly separated by the sternum. The claws are strong and often denticulated. A wingless species is found on sheep. The larvae develop to maturity within the parent and are deposited when they are about ready to pupate.

The species are seldom seen except on their hosts. **The sheep tick** (*Melophagus ovinus* (L.)) is perhaps the best known representative of this family. Johnson (*256*) reported in 1925 that *Lipoptena cervi* (L.) has been taken from elk and deer; species of the genera *Ornithoica* and *Ornithomyia* from small birds; *Olfersia americana* (Leach) from owls, the red-shouldered hawk, and the ruffed grouse; and *O. fumipennis* (Sahl.) from the bald eagle.

ENDOPARASITIC SPECIES

KEY TO FAMILIES

Larvae

1. Endoparasites of mammals (injurious species) Oestridae *s. lat.* p.530
   Endoparasites of invertebrates (largely beneficial species) 2
2. Host species, Orthoptera:
   Posterior spiracles in pit Sarcophagidae, p.537.
   Posterior spiracles not in pit Conopidae, p.531.
   Host species other than Orthoptera 3
3. Host species, Hemiptera:
   Posterior spiracles with 3 spiracular openings on a common chitin plate at the tip of body (Pipunculidae)-Dorilaidae, p.531.
   Posterior spiracular plates are approximated, located on the tips of the posterior end; sometimes on a distinct tubercle Tachinidae, p.531.
   Host species, Lepidoptera, Hymenoptera, or Coleoptera 4
4. Maxillae and antennae poorly developed; mandibles short, hooklike; posterior spiracles situated upon last segment 5
   Maxillae and antennae well developed; mandibles sickle-shaped; posterior spiracles situated on the penultimate segment Bombyliidae, p.533.
5. Body more or less elongate, segmentation indistinct; posterior end of body rather truncate or broadly rounded, without long processes 6
   Body oval or pyriform, segmentation distinct; antennae wartlike, tipped with a chitinous ocelluslike ring; posterior spiracular plates large round. Living within the abdomen of bees or wasps. (*Conops*) Conopidae, p. 531.
6. Posterior spiracles flush or raised from adjacent area Tachinidae, p, 531.
   Posterior spiracles in deep anal depression Sarcophagidae, p. 537.

Family OESTRIDAE

Warble or Botflies

Most of the oestrids are medium- to large-sized flies resembling small bumblebees. The mouth parts are usually vestigial. The adults are occasionally collected in the field, but it is usually the larvae, or bots, that are seen. The larvae are broadly cylindrical and taper only slightly at each end. The body is either with or without strong spines.

All the species are parasitic on mammals. The best known representatives of this family are probably **the northern cattle grub** (*Hypoderma bovis* (Deg.)) and **the common cattle grub** (*H. lineatum* (De Vill.)). Cattle are the host species, others being accidental. Scarcely less known is **the horse botfly** (*Gastrophilus intestinalis* (Deg.)), which has also been bred from deer and dog. During the last few years the nose and throat maggots of deer and large game animals have been given considerable attention. There are several species of these concerned, the most common probably being *Cephenomyia pratti* Hunt. and *C. phobifer* Clark. The death of a large number of deer is laid to these flies.

Botflies attacking smaller game animals are: *Pseudobogeria* sp. and *P. emasculator* (Fitch) (squirrel parasites), and *P. buccata* (F.) and *Cuterebra cuniculi* Clark (rabbit parasites). *C. cuniculi* is the largest muscoid known, the adult measuring about 26 or 27 mm. in length. Undetermined species of *Pseudobogeria* have also been taken from tame rabbits, meadow mice, and cats.

Family DORILAIDAE (PIPUNCULIDAE)

The Big-Eyed Flies

The big-eyed flies are small dark flies with large heads, mostly composed of large approximated eyes. The body is thinly clothed with fine hairs. The larvae are elliptical, narrowed anteriorly with obscure segmentation. Anterior spiracles are present, and the posterior spiracles are subdorsal from the anal end. The puparia are oval, rounded at both ends, and very deep reddish brown.

The adults frequent flowers and low herbage, and are sometimes fairly common. So far as known, all the species are parasitic on Homoptera and Heteroptera. Several species have been bred from cicadellids and mirids.

Family CONOPIDAE

The Conopidae are thinly pilose flies with the head broader than the thorax and usually with a constricted abdomen with conspicuous genitalia. The first basal wing cell is long and the apical cell is always narrowed or closed.

Adults of this family are slow in flight and are easily captured on flowers. Most of the species are parasitic on bees and wasps, and one species has been recorded as a parasite of Orthoptera (grasshoppers and crickets).

Family TACHINIDAE

Most of the tachinids are stout, bristly flies characterized by a well-developed postscutellum and hypopleural bristles.

The larvae (fig. 128, *I*) are usually cylindrical or elongate-oval with 11 segments, exclusive of the head, and are clothed with more or less interrupted bands of minute spinules. The posterior spiracular plates of the puparium are flush or raised, rarely without a button or situated in a depression.

With the exception of a few species (*Eubiomyia* spp., *Erycia* spp., and others), which are parasitic on predaceous Coleoptera, most of the family are beneficial and of considerable economic importance. It would appear that few, if any, leaf-feeding lepidopterous species are immune from tachinid attack. By no means are the hosts restricted to the Lepidoptera, for species of at least five other orders are likewise found attractive. A few tachinids are known to be parasitic on sowbugs and snails.

Outstanding among the more common native tachinids, both with respect to field-collected and bred specimens, are *Achaetoneura frenchii* (Will.), *Exorista mella* (Wlkr.), and *Neophorocera claripennis* (Macq.). Each of these species has over a score of lepidopterous hosts, many of which are injurious. Particularly favorable hosts are the tussock moths (*Hemerocampa* spp.), tent caterpillars (*Malacosoma* spp.), fall webworms (*Hyphantria* spp.), and the *Datanas*. The species of *Winthemia* are probably as common and as well known as any of the tachinids. The species are superficially similar, and one or another of them are present throughout the season. All deposit similar macrotype eggs on the host larva. Because of these facts, there is much difficulty in identifying these parasites by their host insects. *Winthemia datanae* Town. and its variety are perhaps the most abundant.

Although the species mentioned above are polyphagous, there are a considerable number of tachinids that appear to be restricted to a single host species or to closely allied ones. For instance, *Achaetoneura euchaetiae* Wr. has been reared only from *Euchaetias egle* Dru., *A. melalophae* Allen from *Ichthyura inclusa* Hbn., and *Sturmia nidicola* Town. from *Nygmia phaeorrhoea* Don.

Some species are seldom collected in the field, even in areas where their hosts are plentiful. On the other hand, they may be obtained in abundance by rearing the host species, for example, *Pelatachina pellucida* (Coq.) from *Nymphalis antiopa* L., *Cartocometes io* Ald. from *Malacosoma americana* F. or *M. disstria* Hbn., *Dichaetoneura*

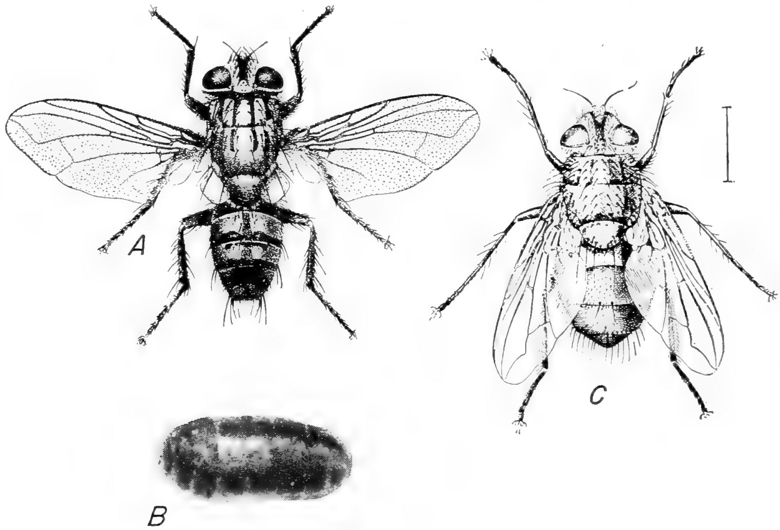

FIGURE 144.—Two beneficial flies, parasites of the gypsy moth and other defoliators: *A*, *Compsilura concinnata*, adult; *B*, puparia of *C. concinnata*; *C*, *Sturmia scutellata*, adult.

leucoptera John. from *Archips cerasivorana* Fitch or *A. fervidana* Clem.

The Tachinidae have played an important role in biological control and there have been many introductions of species into the United States and other countries. Perhaps the most spectacular instance of successful parasite introduction is that of *Bessa remota* Ald. for control of the Leuvana moth in Fiji. In this case, the copra industry, threatened with extinction, was saved by the introduction of a comparatively few flies from the Malay Peninsula.

In this country the introduction of *Compsilura concinnata* (Meig.) (fig. 144), a parasite of the gypsy, brown-tail, and satin moths, has proved highly successful. In the few years of its existence in America this tachinid has made one of the most amazing records as a polyphagous species, having dispersed over a wide area and being credited with over 140 host species.

Other successful introductions include *Chaetexorista javana* D. & B., parasite of the oriental moth (*Cnidocampa flavescens* Wlkr.); *Sturmia nidicola* Town., parasite of the brown-tail moth (*Nygmia* *phaeorrhoea* Don.); and *Sturmia scutellata* (R. D.), parasite of the gypsy moth (*Porthetria dispar* L.). *Chaetexorista* was liberated in Massachusetts in 1929–30 and during the years that followed up to 1936 it showed ever-increasing effectiveness. In 1936 many of the parasites were winter killed and parasitization dropped considerably. Recent observations, however, indicate that it is again on an upward trend. Both species of *Sturmia* are well established in New England and are effective enemies of their host species.

Family BOMBYLIIDAE

Bee Flies

The Bombyliidae, or bee flies, are delicately haired flies, rarely with conspicuous bristles, and often with pictured wings. The bombyliids are among the first flies to appear in the spring. Their flight is swift but broken by abrupt pauses. The habits of the larvae, which resemble the asilids, are diverse. Some of the species live in the nests of various Hymenoptera, others are parasites of Lepidoptera and of white grubs or hyperparasites in Hymenoptera and certain tachinids, and others are predatory on locust eggs.

PREDACEOUS DIPTERA

A considerable number of species of Diptera have been reported as predaceous on forest insects. The larvae of such species may be found under the bark in the burrows of wood-boring insects, in tree pockets, or in dying or decayed wood. Many others are soil inhabiting. Since some scavenging or fungivorous Diptera occupy the same habitat as the predaceous species, confusion of identity will result unless the observer is assured of the habits of the species under study.

KEY TO FAMILIES

Larvae

1. Mandibles sickle-shaped ---------- 2
   Mandibles short and hooklike ---------- Syrphidae, p. 539, Lonchaeidae, p. 536
2. Posterior spiracles approximated; body wholly or in a part longitudinally striated ---------- 3
   Posterior spiracles separated; body not shagreened, reticulated, or striated ---------- 4
3. Head retractile; body usually longitudinally striated; posterior spiracles in a vertical depression; pupa free Tabanidae, p. 529.
   Head not retractile; body finely reticulated; pupa enclosed in larval skin ---------- Stratiomyiidae, p. 539.
4. Head more or less retractile, not cone-shaped ---------- 5
   Head heavily chitinized, cone-shaped, not retractile -- Xylophaginae, p. 536.
5. Posterior spiracles situated upon the apical segment ---------- 6
   Posterior spiracles situated upon the penultimate or antepenultimate segment ---------- 8
6. Apical segment ending in 2 long processes which are fringed with hairs ---------- Rhagionidae, p. 536.
   Apical segment not as above ---------- 7
7. Apical abdominal segment ending in 4 short pointed processes or lips; internal portion of head with a large arched chitinized plate ---------- Rhagionidae, p. 536
   Apical abdominal segment not as above or the internal portion of head is without arched upper plate; apical abdominal segment frequently with projecting processes; spiracles large Dolichopodidae, p. 535, Empididae, p. 535.

KEY TO FAMILIES—Continued

LARVAE—Continued

8. Abdominal segments 1 to 6 subdivided; posterior spiracles situated upon antepenultimate segment
Omphrolidae (Scenopinidae.) p. 535, Therevidae, p. 535.
Abdominal segments usually simple; posterior spiracles situated upon the penultimate segment; thoracic segments each with 2 long hairs, one on each side; apical segment with 6 or 8 long hairs, body straight in life__________________ Asilidae, p. 534.

FAMILY ASILIDAE

Robber Flies

The Asilidae (fig. 145) are moderate- to large-sized, thickly haired flies with tapering abdomen, depressed vertex, and piercing proboscis. The eyes are always separated, and the legs are strong, with stout

FIGURE 145.—Robber fly, *Asilus sericeus* Say; *A*, Adult fly; *B*, puparia; *C*, larva. About ×2.

claws. The larvae are cylindrical and have a thick skin often girdled with protuberances or abdominal processes for locomotion. As a rule the sharply differentiated posterior spiracular segment is characteristic for most species of the family. The larva of *Laphria* have the first six abdominal segments subdivided, the anterior portion of each being furnished with six wartlike retractile protuberances.

Most of the larvae are predaceous. *Asilus notatus* (Wied.) and *Leptogaster flavipes* Loew have been taken from decaying wood in association with tenebrionid and cerambycid larvae; *Diogmites* and *Laphria* spp. from decaying wood infested with coleopterous larvae; and *L. index* McAtee, *L. flavicollis* (Say), and *L. thoracia* (F.) from beetle-infested hickory wood. Other species belonging to several genera live in the soil and are predaceous on white grubs.

Family EMPIDIDAE

Dance Flies

The family Empididae is a large family, most of the species of which have spherical heads, large eyes, piercing mouth parts, and the mystax weak or absent. The abdomen and legs are slender, and the cubital cell is short. The larvae of the empids are cylindrical; they taper anteriorly and have small, retractile heads.

Very little is known regarding the early stages, but a good many of them are believed to be predatory. A few species are aquatic. *Tachydromia* sp. has been bred from weeviled white pine leaders, *Rhamphomyia dimidiata* Loew and *Drapetis nigra* Meig. from rotten tree stumps, and *Platypalpus aequalis* (Loew) from decayed hickory.

As in the chironomids (p. 540) the species of several genera are frequently observed in swarms, dancing up and down under the trees and shrubs near brooks or standing water.

Family DOLICHOPODIDAE

The Long-Legged Flies

The dolichopods are small, bristly flies, usually of a metallic greenish color. The absence of a cross vein between the discal and second basal cells of the wing serves to distinguish the members of this family from their nearest allies. The larvae are cylindrical and resemble the empids, from which they are difficult to separate. They are terrestrial or aquatic and not much is known about any of the immature stages. Species of the genus *Thrypticus* are found in the stems of plants, and *Medetera* sp. was reported by Blackman and Stage (*45*) as bred from larch wood infested with *Polygraphus rufipennis* Kby. and *Eccoptogaster piceae* Swain. It is believed that *M. nigripes* Loew is a primary parasite of *P. rufipennis*. *Dolichopus vittatus* Loew and several undetermined species were reported (Blackman and Stage, *46*) as bred from dead, beetle-infested hickory.

Family THEREVIDAE

Stiletto Flies

The Therevidae, or stiletto flies, resemble the asilids, being differentiated by their plane or convex front, nonprotuberant eyes, and usually fleshy labellae. The posterior branch of the third vein ends beyond the tip of the wing.

The larvae (fig. 128, *K*) are long and slender, tapering at both ends, and move about in a snakelike manner, not drawing their bodies together as do most Diptera. Late-instar larvae have been found in the soil, in decaying wood, and in various other environments. On one occasion seven therevid larvae were collected beneath the bark of a practically dead elm. In the West several species have been reported as predaceous on elaterid larvae.

Family OMPHRALIDAE (SCENOPINIDAE)

Window Flies

The Omphralidae, or window flies, are small to moderate-sized bare flies, usually blackish in color, with the antennae destitute of style or arista. The larvae resemble the Therevidae, from which they may be separated by their smaller size. Larvae of *Omphrale fenestralis* (L.) have been taken from rotten wood, bird nests, fungi, and from the roots of plants. The species is said to be predaceous on larvae of other insects.

Family RHAGIONIDAE (LEPTIDAE)

Snipe Flies

The Rhagionidae, or snipe flies, are moderate-sized, bristleless flies with vestigial squamae. The antennae consist of three joints, the third not annulated. The marginal vein encircles the wing. The species may be either scavengers or predators. Species of *Rhagio* and *Chrysopilus* (fig. 128, A) have been found under dead leaves and in tree pockets, where they probably live as scavengers. *Rhachicerus nitidus* John. is recorded from the decayed trunk of a sycamore. Larvae of *Symphoromyia* spp., on the other hand, live in the soil. The latter are annoying flies, persistently flying about one's head and occasionally attacking one.

A subfamily, the Xylophaginae, is composed of slender species closely allied with the Rhagionidae, but differing in that the third antennal segment is annulated and the marginal vein does not reach beyond the anal angle of the wing. The eyes of the male are separated, and the scutellum is unspined. The larvae, which live under the bark or in the soil, are said to be predaceous on other insect larvae. Larvae of *Erinna lugen* Loew (fig. 128, *G*) have been found in large numbers associated with *Saperda tridentata* under elm bark. Larvae of *Merchantha contracta* Beauv. have been taken from under bark of chestnut, pine, hickory, and oak that were infested with cerambycids. *E. abdominalis* Loew has been taken from under the bark of pine, where it was feeding on beetle larvae.

Family LONCHAEIDAE

The Lonchaeidae are small shining black flies about 5 or 6 mm. in length. The oral vibrissae are absent, the cross veins are never approximated, the auxiliary vein and basal cells are complete, the tibiae have preapical bristles, the ovipositor is elongate and sword-shaped, and the propleura is bare above the bristle. The larvae are slender, and except for the anterior segments, clothed with minute spines. The penultimate segment is free of conical processes, and the stigmatic tubes are small and wartlike.

The species of this family may be either scavengers or predators. *Lonchaea polita* (Say) has been bred a number of times from beetle-infested elm wood, and the species is believed to be predaceous on bark beetle larvae. It has also been bred from beetle-infested hickory wood, from old pumpkin vines, cabbage stalks, and butternut hulls. According to MacAloney (*278*), *L. corticis* Taylor was one of the most important enemies of the white-pine weevil. *L. marylandica* Mall. has been bred from a larva taken under bark.

SPECIES CHIEFLY SCAVENGERS OR FUNGIVOROUS

Under this heading may be included a vast number of the Diptera, the habits and immature stages of which are but little known. Certain species are of economic importance. Others are occasionally of more than casual interest because of their association with injurious species or because of inquiry regarding them. The identification of such species is difficult and should usually be left to the specialist. A few families that include species of such habits are described on the following pages.

Family MUSCIDAE

The Muscidae are medium-sized flies with well-developed squamae, and either hypopleural or pteropleural bristles are present. The antennal arista is plumose to tip. The abdominal bristles are reduced except at the posterior end. The larvae (fig. 128, *J*) of most species taper anteriorly from a usually truncated or broadly rounded posterior end. The body is with or without lateral or dorsal processes, it is amphipneustic, and the mouth hooks usually are paired (in the Muscinae there is only one).

The habits of the family are varied, but it is believed that most of the species are scavengers. **The housefly** (*Musca domestica* L.) is perhaps the best-known member of this large family. This species breeds in manure and decaying vegetable matter, and is believed to be the carrier of many disease organisms. A few species, such as the **stablefly** (*Stomoxys calcitrans* (L.)) and **the horn fly** (*Siphona irritans* (L.), are blood suckers, and they are also suspected of disease transmission.

Family ANTHOMYIIDAE

The Anthomyiidae differ from the Muscidae and allied families in that both hypopleural and pteropleural bristles are absent. The first posterior cell is slightly, if at all, narrowed in the margin.

A number of the species are plant feeders causing serious injury to several crops of economic importance. **The seed-corn maggot** (*Hylemya cilicrura* (Rond.)) was reported by Wilford (*433*) as attacking cedar seedlings and causing considerable damage to nursery stock at Lebanon, Tenn. This species has also been bred from the exposed roots of living larch, in which case the larvae were believed to be feeding on the fungi growing on the decaying bark. The larva of *H. cilicrura* (fig. 128, *D*) is yellowish white and about 1/4 of an inch long. The anal segment has four simple tubercles in a transverse row below the spiracular plates. The posterior spiracles have three spiracular openings, and the anterior spiracles have about six lobes. The basal pieces of the mouth hooks are longitudinally striated on the ventral surfaces.

Control measures, based on preliminary tests, indicate that a 50-percent miscible carbon disulfide solution diluted with water (1 quart of stock chemical to 50 gallons) and sprinkled evenly on the soil at the rate of 1 pint per square foot of surface would give satisfactory results.

Family SARCOPHAGIDAE

The Sarcophagidae differ from the Muscidae in that both hypopleural and pteropleural bristles are present. They are usually grayish or silvery in color, and have a tessellated abdomen. The aristae are plumose for about half their length. The larvae are of the usual muscid-form type with the posterior spiracles located in a pit. The majority of the species are scavengers, others are parasitic. One species, *Wohlfahrtia vigil* (Wlkr.), is said to be the frequent cause of cutaneous myiasis in man and mammals.

Species of the genus *Sarcophaga* are both saprophytic and parasitic. A large number of them breed in mammal excrement, others in dead fish. Dead and dying caterpillars or pupae are also attractive breeding material. There are many records of parasitism, some of which appear doubtful. Several species, the most common of which is **the grasshopper maggot** (*S. kellyi* Ald.), are parasitic on grasshoppers in the Western States. The same species is also said to have been bred from the cerambycid borer *Plectrodera scalator*. In the South, *S. polistensis* Hall has been reared from *Polistes texanus* Cress.

One of the most interesting recent observations concerning sarcophagid parasitism is that of *Sarcophaga aldrichi* Park. Hodson (*226*) reports that the species will not only attack normal larvae and cocooned pupae of the forest tent caterpillar (*Malacosoma disstria*), but it will also breed in carrion. Moreover, when the species develops parasitically there is only one generation a year, whereas two generations develop when it breeds in carrion. Unpublished observations by H. J. MacAloney are to the effect that *S. aldrichi* was the most important insect-control factor in an outbreak of the forest tent caterpillar in northern Minnesota in 1938.

Family CALLIPHORIDAE

The Calliphoridae differ from the Sarcophagidae in that the hindmost posthumeral bristle is almost always lower (more ventrad) than the presutural bristle. The body color is frequently metallic green, blue, or yellow. The aristae are plumose.

The larvae are of the usual muscid form readily differentiated from the sarcophagids in that the posterior spiracles are flush.

The habits of the species are variable. One of the best-known species is **the screwworm fly** (*Cochliomyia americana* C. and P.) which is a major pest of cattle and other animals in the Southeast and West. This species deposits its eggs in wounds, the larva invading the tissues and eventually causing death if the animal is not found and treated.

The greenbottle fly (*Lucilia sericata* Meig.) and **the black blowfly** (*Phormia regina* Meig.) are common scavengers and will attack sheep, cattle, and other animals if these have sores or wounds in which the flies can deposit their eggs. One of the most important control measures in connection with these species is the prompt destruction of carcasses in which the flies breed prolifically.

Species of the genus *Protocalliphora* are parasitic on nestling birds. Johnson (*257*) reported that in a Massachusetts locality in 1929 probably 80 percent of the first brood of bluebirds died from the effect of the blood-sucking larvae of *Protocalliphora* spp. Other host species are the mourning dove, tree swallow, warblers, and crested flycatcher.

Family DROSOPHILIDAE

Pomace Flies

The Drosophilidae are small, plump-appearing flies with conspicuous frontal bristles.

The larva of *Scaptomyza adusta* (Loew) is 11-segmented, uniformly clothed with short spines, and with the posterior segment produced into a large tubercle bearing the spiracles.

Drosophila melanogaster Meig., **the pomace fly,** is typical of the family. This and allied species are frequently seen in large numbers about decayed fruit or vegetables. The flies are attracted by fermenting matter, and they often enter houses and cause considerable annoyance at preserving time. The species breeds prolifically in confinement and has been the subject of many experiments by geneticists.

Other species are fungivorous and a few are strictly phytophagous, mining the leaves of small plants. Malloch (*287*) found *Scaptomyza adusta* in flowing sap, and the same species was recorded as a leaf miner by Chittenden (*85*) and by Frost (*172*). *Drosophila dimidiata* Loew has been bred from fungus in a decayed tree. *Scaptomyza graminum* (Fall.) and *Chymomyza amoena* Loew were reported by MacAloney (*278*) to have been reared from weeviled white pine leaders.

Family STRATIOMYIIDAE

Soldier Flies

The Stratiomyiidae are characterized by a peculiar wing venation, the veins being crowded forward toward the costal margin. The empodium is pulvilliform, the third antennal segment annulated, giving the appearance of more than three segments, and the costal vein ends at or close to the wing tip. The larvae of this family have a nonretractile head with well-developed maxillae and antennae. The body is flattened, its surface finely reticulate.

The family contains both aquatic and terrestrial species. The terrestrial species are mostly scavengers, although a few of them are believed to be predators. The larval habits are variable. Some species live in carrion and manure, whereas others are found in the nests of Hymenoptera or rodents. *Geosargus* spp. have been found in the flowing sap of elm trees, *Zabrachia polita* Say has been bred from beetle-infested elm logs and from decaying pine logs, *Pachygaster* spp. has been taken from decayed wood, and numerous specimens of an undetermined stratiomyiid have been found under elm bark.

Family SYRPHIDAE

Hover or Flower Flies

The spurious vein between the third and fourth longitudinal veins in the Syrphidae is unique and serves to distinguish this family from all others. The adults, known as hover flies, love flowers and are often taken as they hover over them.

The larvae, while differing from one another in many respects, are represented in this family by at least seven forms, each having a reduced head furnished with one pair of short sensory organs. The body segmentation is obscure, usually amphipneustic, with the posterior spiracles situated on two tubes of variable length, which are apparently fused except at the extreme tip.

The species of this large family, which are either terrestrial or aquatic, are primarily beneficial. Many species are scavengers living in decaying vegetable matter, filthy water, or in the nests of various

Hymenoptera. A few are phytophagous, but those species are rarely if ever injurious to woody plants. Other species are predators living in or among colonies of aphids or plant lice. Metcalf (*295*) listed the following genera having species that live in decaying wood of trees: *Mallota*, *Xylota*, *Brachypalpus*, *Pocata*, and *Myiolepta;* and those living in sap flowing from injured or diseased trees: *Brachyopa*, *Chrysochlamys*, *Xylota*, *Ceria*, and *Myiolepta*. Metcalf also listed species of the genus *Xanthogramma* that were bred from larvae found under the bark of oak and cottonwood trees.

Additional rearing records in 1916 of species that have been found under bark, in tree pockets, etc., by Banks, et al. (*20*) are as follows: *Brachyopa vacua* O. S., *Tubifera transversus* Wied., *Blera umbratilis* (Will.), *Mallota cimbiciformis* Fall., *M. posticata* F., *Xylota pigra* F., *Brachypalpus frontosus* Loew, *B. rileyi* Will., *Somula decora* (Macq.), and *Ceria abbreviata* Loew. A species belonging to the Xylotinae has been recovered by Snyder from a prionid burrow in a chestnut pole. *Temnostoma bombylans* F. has been bred from hickory and willow logs and *T. excentricum* (Harr.) from elm logs. According to Metcalf (*297*), the mature larva of *Temnostoma balyras* (Wlkr.) is about ½ inch long and white, except for the prothoracic rakes, which are composed of three rows of prominent teeth and black posterior spiracles. The mouth parts are inconspicuous, and the anterior and posterior segments truncate, with slightly raised spiracles. The larva of *T. obscura* Loew is very similar to that of *T. balyras*.

Family **MYCETOPHILIDAE**

Fungus Gnats

The Mycetophilidae comprise a large number of terrestrial and semiaquatic species resembling mosquitoes, but differing in that the antennae are not verticillate. Ocelli usually are present and all the tibiae are spurred. The larvae have a complete head with opposed mandibles and abdominal spiracles. Three subfamilies are noted. Species of the Sciarinae are frequently found in the galleries of wood-boring beetles or under bark. *Leia bivittata* Say has been reared from elm logs. The larvae of the Bolitophilinae feed on fungi growing on trees and logs; those of the Platyurinae live in slimy webs on fungi found on decaying timber.

Family **CHIRONOMIDAE**

The adults of the family Chironomidae resemble mosquitoes, being distinguished from the latter by the absence of scalelike hairs on the wing and by the discontinuation of the costal vein at the termination of the third vein. The larvae have a complete head and opposed mandibles. They are usually cylindrical in form, with one pair of pseudopods present on the prothorax and one pair on the anal segment. Certain species are soft-skinned, wormlike, and frequently blood red in color, which causes them to be called "blood worms."

Most of the species are aquatic and the adults often appear in great numbers in areas adjacent to or occasionally a considerable distance away from their breeding place. Although these great swarms of midges are the frequent cause of inquiry, they are for the most part inoffensive. The few terrestrial species are scavengers living in decaying vegetable matter and manure. Blackman and Stage (*46*) reported several specimens of an undetermined species bred from well-decayed hickory.

Family BIBIONIDAE

The March Flies

The Bibionidae, or March flies, are awkward appearing, usually with a somewhat flattened head, stout legs, and many-jointed antennae. Malloch (*288*) stated that the larvae differ from all other species in having the false segment behind the head fully developed and armed with spinose processes. The prothoracic spiracles are apparently on the second segment, and metathoracic spiracles are also present. Most of the species are scavengers and feed on decaying vegetable matter, whereas others attack the roots of grass and plants. *Plecia americana* Hardy was bred by Hardy (*209*) from larvae living in rotting wood, and an undetermined species was bred from decayed hickory by Blackman and Stage (*46*).

Family CLUSIIDAE (HETERONEURIDAE)

The flies of the family Clusiidae are small, with large heads and broad wings, the latter usually marked with black or brown. The larvae are slender, cylindrical, and somewhat thickened posteriorly, and the body segmentation is indistinct. Some of the species are able to spring a short distance into the air, as do certain cecidomyids and sepsids. The species are scavengers living in rotten wood and beneath the bark of trees. *Sobarcephala* (*Clusinodes*) *flaviseta* John. has been recovered in large numbers from a rotten tree stump, and a species of clusiid has been reported as often present under the bark of dead trees and in decaying wood.

SAWFLIES, ANTS, WASPS, AND BEES

Order HYMENOPTERA

The order Hymenoptera (meaning membrane-winged) is one of the largest and most important orders of the insects. It includes a vast number of species, many of which have extraordinary instinctive faculties and social habits. The bees, wasps, and ants are among the better-known types. A great many are parasitic in habit, some cause the growth of galls on plants, and many others, in the larval stage, feed on the foliage of plants or bore into the stems of herbaceous plants or into branches or trunks of trees. They undergo a complete metamorphosis.

A few species are wingless, but the order is characterized by its winged members, having four membranous wings. The fore pair are large and more completely veined than the hind pair, although in some species the venation is greatly reduced. The mouth parts are formed for biting, but some are also adapted for lapping or sucking liquid food. The first segment of the abdomen is fused with the metathorax. Each female is equipped with an ovipositor, which may be modified for sawing, piercing, or stinging.

The larval forms of this order show considerable variation. Those of the sawflies, with the exception of the leaf-mining and wood-boring species, resemble caterpillars, having a distinct head with a pair of ocelli, well-developed thoracic legs, and usually abdominal pro-legs. They are generally independent in habits, being mostly free-living and phytophagus, whereas those of the other groups (bees, wasps, and ants) are more like maggots, being legless and somewhat helpless, and are dependent on being fed or being placed in or on their host insects.

This order has been divided systematically into two suborders, as follows: The Chalastogastra, comprising the sawflies and horntails; and the Clistogastra, which includes the ants, bees, wasps, and other forms. Viereck (*422*) in his Hymenoptera of Connecticut gives a good treatment of the order.

Suborder CHALASTOGASTRA or SYMPHYTA

THE SAWFLIES AND HORNTAILS

By J. V. Schaffner, Jr., and William Middleton

The suborder Chalastogastra includes the more generalized forms and the adult is characterized by having the abdomen joined to the thorax in a broad union, in contrast with the constricted waist or slender basal segment of the abdomen in the Clistogastra. The venation of the wings, although displaying a great many differences, is less reduced than in the other suborders. There are no wingless forms. The antennae, which differ greatly in shape and number of segments, are always inserted between the eyes above the base of the clypeus and have their bases exposed. Each female has a complicated ovipositor. In some species it is adapted for boring holes in trees; in other species it consists of two pairs of sawlike plates protected by a sheath.

The larvae of this suborder are all plant feeders, but unlike the larvae of the Lepidoptera each possesses a single pair of ocelli, one on each side of the head. They frequently have six or more pairs of fleshy leglike structures on the abdomen, called prolegs, none of which is provided with hooks or "crochets," whereas in the Lepidoptera there are never more than five pairs of prolegs and all are provided with crochets, except that in the Family Megalopygidae there are seven pairs of prolegs, those on the second and seventh abdominal segments without crochets.

This group of insects is very difficult to classify and needs much further study. The separation of the adults into species is rather difficult, because there is frequently considerable difference between the two sexes. There are many species in the 11 families of this suborder represented in the Eastern States, but comparatively few of them are serious pests of the forest and shade trees in this region. Some of the more important species are of foreign origin.

In the following discussion only species known to be of importance are treated in detail. As the injury is caused by the larvae, and this is the stage most commonly encountered by those persons responsible for the care of trees, the greatest emphasis is placed on the characters of the larvae, their food plants, and their habits.

Superfamily *TENTHREDINOIDEA*

The Sawflies

Sawflies are so-called because the female is equipped with an egg-laying apparatus, which is a saw in appearance and use. The device is composed of three main pieces held within protecting sheaths. The upper piece of the saw is a rigid lance with grooves along which the other two pieces slide. The last two pieces are the saw blades, or lancets, and consist of thin plates with their flat inner surfaces together. Each lancet is usually shaped somewhat like a long acute triangle, and one long side edge slides along a groove of the lance; the other, or lower, long edge is saw-toothed. The exposed outer surface of each blade has several transverse rows of fine teeth. The narrow base of the triangular lance is the point from which springs the rod that attaches the blade to the abdomen and controls its movements.

In general, the egg-laying operation consists of forcing or catching the lance point in the plant tissue and then pushing one saw lance while pulling the other. By this movement the saw is carried through the plant tissue and cuts a pocket or slit, in which the egg is laid. Sometimes the eggs are deposited in definite rows, either with the pockets touching at the ends or separated by regular or variable intervals. At other times they are scattered about in no apparent order. Frequently a definite location, such as the leaf edge or the midrib, is sought for oviposition.

The caterpillarlike larvae are usually naked, although, in a few species they are spined, sparsely hairy, or covered with a gummy or waxy secretion. Each normally has a single pair of eyes, one on each side of the head; three pairs of thoracic legs, usually distinctly segmented; and various numbers of prolegs. When disturbed, the larvae of some species curl themselves up and lie on their sides, whereas others hold their abdomens aloft over their heads.

As a group the sawflies are injurious in the larval stage only, and they may be gregarious or solitary in habit. Most species live exposed and feed on plant foliage, eating the entire leaves or skeletonizing them. Some build webbed nests; a few species mine leaves, leaf petioles, and twigs; others produce galls on the leaves or shoots of willow or poplar; and a few live in catkins, buds, or fruits.

During the feeding period the larvae grow rapidly and shed their skins a number of times. The full-grown larvae either spin cocoons or construct cells in which they transform to pupae and then to adults. The cocoons, either single- or double-walled, may be spun on the leaves, twigs, and other parts of the host plants, or in the litter or earth beneath. Some species make cells in pith, bark, and brashy wood, or in the ground. The larvae that live protected within plant tissue, sometimes form their cocoons and complete their transformation within the mines or cavities made by them.

The adults frequently resemble small wasps or bees. Many of them are slow and not very vigorous fliers. The antennae of sawflies differ considerably in the number of joints and may be feathered, clubbed, threadlike, forked, or with spurs on some of the joints.

The life cycle of these insects seldom requires more than a year. Certain species may have as many as six generations a year with such an overlap of activity after the season is well advanced that all stages

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of development will be present in the field at almost any time. In some species, however, not all of the adults issue from the cocoons in the same season, but some emergence may be delayed until later in the year, or there may be a diapause of one or more years. This division of the period of adult emergence must occasionally make possible the continuance of an infestation which would otherwise cease on account of temporary adversities.

Although reproduction is largely bisexual, studies in recent years have shown that there are some exceptions. Some examples may be cited, such as *Diprion hercyniae* (Htg.), in which the males are extremely rare; *Phyllotoma nemorata* Fall., of which no males are known to exist; and *D. simile* (Htg.), in which parthenogenetic reproduction has been obtained experimentally, but the progeny on reaching the adult stage were all males.

The relationship between sawflies and their host plants seems to be a somewhat limiting one, and apparently few species are able to subsist on a wide range of plants. As in many other species of insects, local outbreaks may occur at irregular intervals, although few species of sawflies have been reported as exceptionally important pests. In recent years, however, more species have been attracting attention as pests in our forests and plantations. Some of these are of foreign origin and of comparatively recent establishment in the United States. The large-scale planting of pure stands of forest trees, particularly conifers, undoubtedly has also favored the increase of some native species of sawflies.

The fluctuation of sawfly populations is influenced by many factors, such as climate, disease, natural insect enemies, and rodents and other predators. These factors have not been extensively studied and are therefore not too well understood. Control by direct measures is difficult and in many cases impractical under forest conditions. Where the growth is of sufficient value to warrant the expense, effective control of sawflies can usually be obtained by a timely spraying of their food plants with a stomach poison for the external feeders, or an ovicide, such as nicotine sulfate, for the leaf miners (p. 53).

Some of the more important families and species are discussed in the following pages. Keys, which are not intended to be broadly inclusive, are given to the larvae of species most frequently encountered in the woodlands or in forest plantations. Although it may be found that some insect descriptions and insect injuries will not fit the requirements of these keys and that some will run to a place in the keys where they do not belong, this situation cannot very well be remedied in those keys which do not include all the species of any group and in which many technical characters are avoided for the sake of simplicity and usefulness.

The keys, unless otherwise stated, apply only to larvae in their last feeding instar.

KEY TO THE LARVAE OF SOME OF THE MORE IMPORTANT SPECIES OF SAWFLIES AND HORNTAILS THAT ATTACK TREES AND SHRUBS

1.	Sawfly larvae feeding on coniferous trees, or the Pinaceae	2
	Sawfly larvae feeding on broad-leaved trees or shrubs	9
2.	Larvae solitary or gregarious, but not in nests of webbing and frass	3
	Larvae in nests of webbing and frass	8
3.	Food plants, species of the Pinaceae other than pine	4
	Food plants, pines	5

KEY TO THE LARVAE OF SOME OF THE MORE IMPORTANT SPECIES OF SAWFLIES AND HORNTAILS THAT ATTACK TREES AND SHRUBS—Continued

4. Arborvitae or juniper—Head light brown; eyes and legs black; body dull green with 3 dark stripes. June–July --------- *Monoctenus melliceps* (Cress.), p. 550.

Balsam fir—Head and outer sides of legs black; body dull green above, lighter beneath, and marked with 6 dark stripes. Gregarious. June–August ------- *Neodiprion abietis* (Harr.), p. 551.

Larch—Head and legs black; body dull grayish green on dorsum, paler beneath. Gregarious. June–September ---------- *Pristiphora erichsonii* (Htg.), p. 573.

Spruce—Dark green with 5 white lines when nearly full-grown; last instar and newly hatched larvae without white lines. Solitary. Late May–July and late July–fall ------------------ *Diprion hercyniae* (Htg.), p. 559.

Spruce—Head brown; body dark yellowish green above, lighter beneath, and marked with gray-green stripes. Gregarious. June and July ------------- *Pikonema alaskensis* (Roh.), p. 575.

Spruce—Green-headed spruce sawfly; head and body green *Pikonema dimmockii* (Cress.), p. 575.

Spruce—Similar to *N. abietis* on balsam fir ------------ *Neodiprion* sp. near *abietis* (Harr.), p. 551.

5. Head black -- 6

Head red or reddish brown ---------------------------------- 7

6. Body yellowish green with double black stripe on dorsum, and the sides mottled with yellow and black. White pine and softer 2-needled pines. May–October --- *Diprion simile* (Htg.), p. 557.

Body yellowish white with 4 rows of black spots. White pine preferred. May–October --- *Neodiprion pinetum* (Nort.), p. 553.

Body grayish green with light dorsal line and 2 lateral whitish lines bordering a dark-green or blackish stripe, which has a tendency to break up into spots; anal segment black above. Red, Scotch, Japanese red, jack, Swiss mountain, and mugho pines. May–June ----------------------- *Neodiprion sertifer* (Geoff.), p. 554.

Body yellowish green with a dull blackish stripe on each side of the dorsum, below which is a broken line of more or less distinct black spots, often those on middle segments obsolete; 2 large blackish spots on anal segment. Jack, pitch, and other hard pines May–June ------------------- *Neodiprion dyari* (Roh.), p. 555.

Similar to and possibly the same as *N. dyari*. Jack pine. May–June ------------------- *Neodiprion banksianae* (Roh.), p. 556.

Body dull grayish green to blackish above, greenish white beneath; light-green dorsal stripe and fainter one on each side, also a dull-blackish stripe at base of legs. Red pine preferred; also on jack, Japanese red, and mugho pines. May–June -------- *Neodiprion nanulus* Schedl, p. 553.

7. Body pale green with 2 longitudinal dark grayish-green stripes on dorsum and a row of black spots above the spiracles on each side. Loblolly and shortleaf pines. May–June ----------- *Neodiprion americanum* (Leach), p. 551.

Body yellowish with 6 rows of irregular black spots. Red, pitch, jack, and other hard pines. May–October ---------- *Neodiprion lecontei* (Fitch), p. 552.

Body dull green; a double longitudinal black line on dorsum, and a broken stripe of black on each side, beneath which is a double row of black spots, the latter sometimes obsolete. Pitch and shortleaf pines, May–October -------------------- *Neodiprion pini-rigidae* (Nort.), p. 556.

Body light green with 2 narrow dorsal stripes, a broad lateral and a narrower one at base of legs dark green; a large blotch on face is black. Solitary. Red and Scotch pine. June and July, and August to late in fall -------- *Diprion frutetorum* (F.), p. 557.

Body greenish and heavily striped. Jack pine -------- *Neodiprion dubiosus Schedl*, p. 557.

Body greenish and lightly striped. Jack pine -------- *Neodiprion swainei* Midd., p. 557.

KEY TO THE LARVAE OF SOME OF THE MORE IMPORTANT SPECIES OF SAWFLIES AND HORNTAILS THAT ATTACK TREES AND SHRUBS—Continued

8\. Head brown; body green with a dorsal stripe of a darker shade. Austrian pine and other hard pines. Solitary. July and August *Acantholyda zappei* (Roh.), p. 584.

Head yellow, dotted with brown above; eyes black; body grayish-green, with dorsal, lateral and ventral stripes of purplish-red. Red and white pine preferred, but other pines acceptable. May and June ... *Acantholyda erythrocephala* (L.), p. 583.

9\. Larvae free feeders: not borers, leaf miners, or inhabitants of buds, galls, aments of willow, or webbed nests ... 10

Larvae borers, leaf miners or inhabitants of buds, galls, aments of willow, or webbed nests ... 21

10\. Larvae coated with a slimy substance, a white powdery secretion, or with white flocculent tufts ... 11

Not coated as above ... 12

11\. Larvae slimy, sluglike, olive green; on upper surface of leaves of cherry, pear, hawthorn, plum, quince, and shadbush. June–September ... *Caliroa cerasi* (L.), p. 565.

Body densely covered with a white powdery secretion; *Cornus* spp. July–October ... *Macremphytus* spp., p. 581.

Body covered with flocculent white tufts. Butternut, black walnut, and hickory. July and August *Blennocampa caryae* (Nort.), p. 582.

12\. Larvae sparsely hairy, bristly, or bearing rows of short spines ... 13

Body naked or bearing minute setae scarcely visible to the naked eye ... 16

13\. Length ½ inch or less ... 14

Length ½ to ¾ inch ... 15

14\. Greenish, with transverse rows of slight tubercles bearing stiff setae; lateral lobes distinct. Gregarious. On butternut, hickory, or oaks. June–August ... Species of Acorduleceridae, p. 550.

Greenish white; clothed with long rather stout bristles. On rose; throughout the summer ... *Cladius isomerus* Nort., p. 571.

15\. Body armed with rows of spines, some being V- or Y-shaped. Head pale or blackish; body leafgreen or with dorsum grayish. On hickory and oak. May and June ... *Periclista* spp., p. 582.

Body sparsely clothed with short, white hairs; head black with yellow markings; body orange yellow, with 2 rows of black spots on each side, the upper row large and more or less rounded. Poplar, with Carolina and Lombardy preferred. May–July and August–October ... *Trichiocampus viminalis* (Fall.), p. 570.

Body sparsely hairy; head mostly black; body yellow, with a row of large black spots on each side beneath which is a row of smaller spots, the latter partially coloring the area containing the spiracles. Willow. May–July and August–October *Trichiocampus irregularis* (Dyar), p. 571.

16\. Body without prominent stripes and the dorsum not heavily spotted ... 17

Body marked with one or more stripes or numerous small spots ... 18

17\. Food plant, ash—Head brownish; body yellowish white or greenish white. Length about ¾ inch. May and June ... *Tomostethus multicinctus* Roh., p. 581.

Ash—Head shiny black; body whitish with a yellowish tinge. May and June ... *Tethida cordigera* (Beauv.), p. 581.

Birch—Head shiny black; body yellowish green shaded with black; more or less distinct black blotches on sides, and a series of spots below spiracles. No distinct dark markings in early instars. Gregarious ... *Croesus latitarsus* Nort., p. 580.

Birch, wild cherry, poplar, and willow—Solitary. Length 1½ inches; head creamy white; body greenish white; eyes and spiracles blackish. June–October ... *Trichiosoma* spp., p. 564.

Rose—on upper surface of leaves. Length about ⅓ inch. Head yellowish; eye spots black; the food in alimentary tract causes the body to appear dark olive green *Caliroa aethiops* (F.), p. 565.

KEY TO THE LARVAE OF SOME OF THE MORE IMPORTANT SPECIES OF SAWFLIES AND HORNTAILS THAT ATTACK TREES AND SHRUBS—Continued

Rose—length about ¾ inch. Head yellowish brown with black markings; body metallic green and dotted with white above, grayish white on venter----------- *Allantus cinctus* (L.), p. 580.

Willow, occasionally poplar—Black or greenish black with a row of large yellow spots on each side of body. Length about ¾ inch. Summer-------------------- *Pteronidea ventralis* (Say), p. 575.

18. Body marked with one or more prominent blackish longitudinal stripes-- 19

Body without longitudinal stripes, but marked with numerous small black, yellowish, or brownish spots-------------------- 20

19. Alder and birch—Head shiny black; body yellowish and marked on each side with a subdorsal and 2 broken subspiracular stripes of black. Length about ⅘ inch. June–September---- *Hemichroa crocea* (Fourcroy), p. 572.

Willow, elm, alder, basswood, birch, maple, and poplar—Head and body yellowish or greenish white, with a black dorsal stripe. Length up to 1¾ inches. Usually coiled when at rest. June–October-------------------- *Cimbex americana* Leach, p. 562.

20. Head light or dark colored; body rather thickset, subcylindrical, with venter flattened; widest on abdominal segments 1 to 3 and tapering toward anal end; yellowish green or red; with many small spots, some bearing minute setae. Length about ¾ inch. July–September---------------------------- *Arge* spp., p. 549.

Birch (gray and paper)------ *Arge pectoralis* (Leach), p. 549.
Cherry (wild)-------------- *Arge macleayi* (Leach), p. 550.
Elm---------------------------------- *Arge* sp., p. 549.
Oak---------------------------------- *Arge* sp., p. 549.
Poison ivy and poison sumac
Arge humeralis (Beauv.), p. 549.
Sumac------------------------ *Arge coccinea* (F.), p. 549.
Willow------------------------------- *Arge* sp., p. 549.

Head brownish or black; body not thick-set; usually green marked with rows of small blackish spots or more or less broken transverse stripes on the dorsum; sides speckled, usually the spots below the spiracles most conspicuous. Length ⅝ to ¾ inch. Spring and summer------------------ *Pteronidea* spp., p. 576.

Alder------------------- *Pteronidea alnivora* Roh., p. 576.
Currant or gooseberry---- *Pteronidea ribesii* (Scop.), p. 577.
Hazelnut---------------- *Pteronidea corylus* (Cress.), p. 576.
Locust--------------- *Pteronidea trilineata* (Nort.), p. 576.
Poplar-- *Pteronidea populi* (Marl.) and *P. plesia* Roh., p. 577.
Willow-------------- *Pteronidea harringtoni* (Marl.), p. 577. and *P. odorata* (Dyar), p. 576.

Head brown, face lighter; body rather plump, grayish green and marked with yellowish spots and rows of black dots. Length about 1 inch. June and July. Honeysuckle-- (*Lonicera*) *Zaraea inflata* Nort., p. 564.

Head yellow orange, eyes black; body yellowish with all segments except the last marked with black spots, which are uneven in size and shape. Length ⅝ to ¾ inch. June and August. Mountain-ash------------- *Pristiphora geniculata* (Htg.), p. 572.

21. Larvae inhabiting nests of web, frass, and leaves---------------- 22
Leaf folders on poplar-- 23
Leaf miners--- 24
Larvae inhabiting galls on leaves, leaf stems, and shoots--------- 25
Larvae inhabiting buds, or aments of willow-------------------- 26
Borers in shoots, twigs, or leaf stems-------------------------- 27
Borers in wood of dead or seriously weakened trees or in dead parts of living trees-- 28

22. Wild cherry—Larvae, prior to last instar, brown with pinkish dorsal line, head dark brown or blackish. Gregarious. June–September---------------- *Neurotoma fasciata* (Nort.), p. 585.

Sand cherry and plum—Gregarious. Webs somewhat similar to those of the fall webworm. June–September-------- *Neurotoma inconspicua* (Nort.), p. 585.

KEY TO THE LARVAE OF SOME OF THE MORE IMPORTANT SPECIES OF SAWFLIES AND HORNTAILS THAT ATTACK TREES AND SHRUBS—Continued

23. Larvae in leaf folds. Usually solitary. May–July
Poplar .... *Pontania bozemani* Cooley, p. 578.
Largetooth aspen .... *Pontania populi* Marl., p. 578.
Smalltooth aspen .... *Pontania robusta* Marl., p. 578.

24. Birch; gray, paper and European white most favored—Larvae whitish, somewhat flattened; underside of first 4 segments with distinct black marks. Late in May–September .... *Fenusa pusilla* (Lep.), p. 567.
Birch; gray, paper and European white most favored—Larvae whitish, somewhat flattened; head brownish; without black spots. Blotch mines remain quite free of excrement. July–October .... *Phyllotoma nemorata* (Fall.), p. 566.
Elm; English, Scotch, and Camperdown most favored—Larvae flattened, whitish, with a greenish cast; head brownish. May and June .... *Fenusa ulmi* (Sund.), p. 568.
Poplar; Lombardy, and varieties—Larvae in blotch mines. May and June .... *Scolioneura* sp., p. 570.

25. Willow or poplar—Larvae usually white or greenish white in galls on leaves .... *Pontania* spp., p. 577.
Willow—Larvae usually yellowish or greenish white in galls or woody swellings on leaf stems, twigs or shoots
Euura spp., p. 578.

26. Larvae in enlarged buds of willow .... *Euura* spp., p. 578.
Larvae infesting aments of willow causing a premature showing of "cotton"; head dark brown; eye spots black, body white with faint grayish spots at bases of hairs. Length about ½ inch
Pontania amentivora Roh., p. 578.

27. Borers in petioles or leaf stems of maple. Larvae about ⅓ inch in length; head brownish, body straw yellow. May and June
Caulocampus acericaulis (MacG.), p. 571.
Borers in shoots of willow and poplar. Larvae white, cylindrical, with fleshy thoracic legs; prolegs on anal segment only, and tip of abdomen is furnished with a short tubular prong. Length about ½ inch. Summer months .. *Janus abbreviatus* (Say), p. 590.
Borers in twigs of currant. Larvae similar to the above species
Janus integer (Nort.), p. 591.
Borers in the stems or stalks of blackberry and rose .... *Hartigia trimaculatus* (Say), p. 591.

28. Borers in dead or weakened trees. Larvae whitish, cylindrical; the thoracic legs fleshy and not jointed; no abdominal legs; abdomens terminate in prominent short processes or prongs ornamented with small but distinct teeth.
Deciduous trees .... *Xiphydria* spp., p. 586.
Tremex columba (L.), p. 588.
Coniferous trees .... *Sirex* spp., p. 589.
Urocerus spp., p. 589.

Family ARGIDAE

Although the family Argidae is comprised largely of tropical insects, a considerable number of representatives are found in the eastern part of the United States, and a few of them are usually common. Since there has been much misidentification of species in this family, many of the published records may be inaccurate. Little has been published about these species, however, and there are few records to show that the larvae ever become abundant enough to defoliate trees over extensive areas.

The adults can be recognized by their three-segmented antennae, which are inserted on the front part of the head. The posterior margin of the mesoscutellum is without a post-tergite, and the anterior margin is V-shaped or slightly sinuate. Ross (*361*) published a monograph on the classification of sawflies and gave the diagnostic characters of this family and a key to the genera.

Those of our common species, in general, are rather stout-bodied, either reddish brown or bluish black, and with the wings more or less fuscous.

The larvae have the body rather thick set and semicylindrical, with venter flattened, widest on abdominal segments 1 to 3, and tapering toward the anal end. They are yellowish green or red and usually spotted.

The full-grown larva of *Arge pectoralis* (Leach) is about 3/4 inch in length; the head is reddish yellow with a black eye spot on each side; the abdomen stout, yellowish, with six longitudinal rows of black, nearly confluent, spots on the upper portion, a subspiracular row of elongated ones on the fleshy projections, and two rows on the underside at the bases of the legs; the spiracles are black and the thoracic legs, except the bases, concolorous with the body. This sawfly is widely distributed through the northeastern part of the United States and the eastern part of Canada. The larvae feed on various species of birch, but more commonly on the gray and paper birches. This is probably the most common species of the Argidae in the Northeastern States and occasionally becomes abundant enough to cause defoliation over limited areas.

The adults emerge during June and July, and the eggs are deposited in slits cut into the margin of the leaf by the female. The larvae normally complete their growth in 5 or 6 weeks, and may be found from July until late in September, depending on the climatic range. The cocoons are spun in the litter on the ground, and the winter is passed as prepupal larvae within the cocoons.

A few other species that occasionally attract attention locally in the Northeastern States are briefly mentioned below. The life history of each is very similar to that of *Arge pectoralis*. In *Arge* sp. on elm the larvae closely resemble those of *A. pectoralis*, but can be distinguished by the black blotch on the anal segment of the body and by their thoracic legs being black on the outer side. In *Arge* sp. on oak the full-grown larva is from 3/4 to 1 inch in length; the head and base of the thoracic legs are blackish; and the body is yellowish green with tuberculate spots and blotch on the anal segment yellowish. In *Arge* sp. on willow, the full-grown larva has a dark brown or blackish head, the outer sides of the thoracic legs are blackish, and the venter is speckled with black dots; otherwise the markings are similar to those of *A. pectoralis*.

Arge coccinea (F.) feeds on sumac. The full-grown larva is about 3/4 inch in length. It has a black head, the outer side of the thoracic legs is black, the body is brick red, and each segment except the last has a transverse row of blackish tuberculate spots. There is a black spot on the back between the prothorax and the mesothorax and another between the mesothorax and the metathorax, and the anal plate is blackish.

Arge humeralis (Beauv.) feeds on poison ivy and poison sumac. The full-grown larva is about 3/4 inch in length. The head is yellowish red, the body brick red and marked with a double longitudinal row of black tuberculate, nearly confluent spots on the back, and a single row on each side. There are also a reddish spiracular and a subspiracular row on each side, but the latter usually are black-tipped on the abdominal segment. A double row on the venter envelops the larvapods.

Arge macleayi (Leach) feeds on wild cherry. The larva resembles that of the species that feeds on willow.

Family ACORDULECERIDAE

The Acorduleceridae is a small family and, as now constituted, contains only one genus, *Acordulecera*. This group needs further study and must be revised before it will be possible to definitely indentify many of its species.

These insects are small, the full-grown larva being less than ½ inch long, with blackish or light head, greenish body, distinct lateral lobes, and each segment with transverse rows of slight tubercles bearing short stiff setae. These larvae feed gregariously, and occasionally some species become so abundant locally in the Northeastern States that their feeding on groups of such trees as butternut, hickory, and the oaks attracts attention. The available records indicate that in the Northeast there is usually one generation, but some species occasionally have at least a partial second. These insects hibernate in the cocoon stage in the ground, the adults emerge in May and June, and larvae are found from June to August.

Family DIPRIONIDAE

The family Diprionidae includes many of the most serious defoliators of conifers. Several species are of foreign origin and are now well established in this country. Ross (*361*) gave the diagnostic characters of the adults as follows: Antennae composed of 13 or more segments, serrate in the female, and pectinate or bipectinate in the male. Mesosterno-pleural sutures atrophied, mesoscutellum with anterior margin V-shaped, posterior margin with an extremely narrow and cordlike postergite. Tibiae without preapical spurs; apical spurs of front tibiae simple.

The full-grown larvae usually range from about ¾ to 1 inch in length. The body is cylindrical, usually yellowish or greenish with grayish, brownish, or blackish stripes or rows of black spots, and with the segmentation distinct. A number of species are similar in appearance and habits and it is not possible to positively identify some of them in the larval stage (Yuasa, *439*).

Until recent years comparatively few species have attracted attention as serious defoliators. Since about 1900, however, the large-scale plantings of conifers in solid blocks of a single species undoubtedly has materially favored the increase of certain sawflies, which now are causing considerable concern to plantation owners and foresters in the Eastern and Northern States. Although many nearctic species have been described, little has been published on the life history and habits of some of them, and undoubtedly further study will prove that a few, at least, are identical. The more important species are discussed in the following pages.

The full-grown larva of *Monoctenus melliceps* (Cress.) is about ⅝ to ¾ inch in length, the head light brown with black eye spots, the body is dull green with three dark longitudinal stripes, and the legs are black. This species occurs through the Northeastern States and Canada, and the larvae feed on eastern arborvitae and juniper. The adults emerge in May, and the larvae are active during June and July, spinning their cocoons in the duff during the latter part of July.

The balsam-fir sawfly (*Neodiprion abietis* (Harr.)), is about 3/4 inch in length as a full-grown larva. The head and the outer sides of the thoracic legs are black. The body is dull green above, lighter beneath, and marked with longitudinal stripes which are wider than the distance between them. The stripe on each side of the dorsal line is usually of a darker shade of green, the lateral stripe and another at the base of the legs are brownish or blackish, this last one sometimes divided.

This species is widely distributed from Quebec to Manitoba in Canada, and in the United States from New England westward to Minnesota and Missouri. The larvae feed on balsam fir and occasionally on spruce. Harris (*210*) recorded the defoliation of ornamental trees for some years prior to 1852, and Brown [34] reported destructive infestations on balsam in Ontario and Quebec as recently as 1938. There are also various reports of this species attacking spruce and pine but, because of their similarity to some closely related species, the individuals are often confused. There is one generation annually. The adults emerge over a period from late in July to early in September. The eggs are deposited singly in slits cut in the needles, and the insects overwinter in the egg stage. Hatching takes place late in May or June, depending on the climatic range. The larvae are gregarious and become full grown in July or August. After the last molt their color fades considerably and they spin reddish-brown cocoons among the foliage on the twigs and in the litter on the ground. Some closely related species also feed on spruce and hard pines, and their larvae are often mistaken for those of *Neodiprion abietis*. Their life histories also are very similar.

The full-grown larva of *Neodiprion americanum* (Leach) is about 7/8 inch in length. The head is reddish brown, the eye spots black, and the mouth parts dark brown or blackish. The body is greenish white with a dull grayish-green longitudinal stripe on each side of the dorsum and a row of black angular spots just above the spiracular line extending from the second thoracic to the ninth abdominal segments, inclusive, and two nearly confluent black blotches on top of the tenth segment. The thoracic legs are black on the outer side, but the prolegs are concolorous with the body (fig. 146, *A*).

This species occurs in the Atlantic States. From about 1935 to 1939 it seriously defoliated loblolly pine in Virginia. A few shortleaf pine intermingled with the loblolly pine were also attacked. There is one generation a year. The winter is passed in the egg stage in the pine needles, although in Virginia a few prepupal larvae have remained in a diapause until the following year. The eggs hatch late in April and early in May. The larvae feed on the old needles, becoming full grown early in June, when they enter the soil to spin their cocoons. The adults emerge early in the fall to deposit their eggs in slits in the needles (Heterick, *224*).

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[34] Brown, A. W. A. SUMMARY REPORT OF THE OTTAWA SECTION Canad. Dept. Agr. Forest Insect Survey 1938, 7 pp., illus. 1938. [Processed.]

When young, the larva of **the red-headed pine sawfly** (*Neodiprion lecontei* (Fitch)) is whitish and unspotted, with the head brownish. Later, after undergoing a series of molts, it becomes yellowish and has six rows of conspicuous irregular black spots on the body, and the head is reddish. It is ⅞ to 1 inch long when full grown (fig. 146, *B*). This species is distributed throughout the pine-growing regions of the eastern part of the United States and Canada, having been recorded from practically every State from Maine to Florida and from Minnesota to Louisiana. It feeds on a wide variety of pines, showing a preference for the hard pines, and is occasionally found on some other conifers. Present records show that its hosts include Virginia, jack, red, eastern white, western white, Scotch, loblolly, lodgepole, mugho, longleaf, pitch, ponderosa, and Austrian pines, and tamarack and deodar. The larvae are vigorous defoliators of small pines. They prefer the old needles as food, but late in the summer they also eat the new foliage, and they frequently feed to some extent on the tender bark of young twigs.

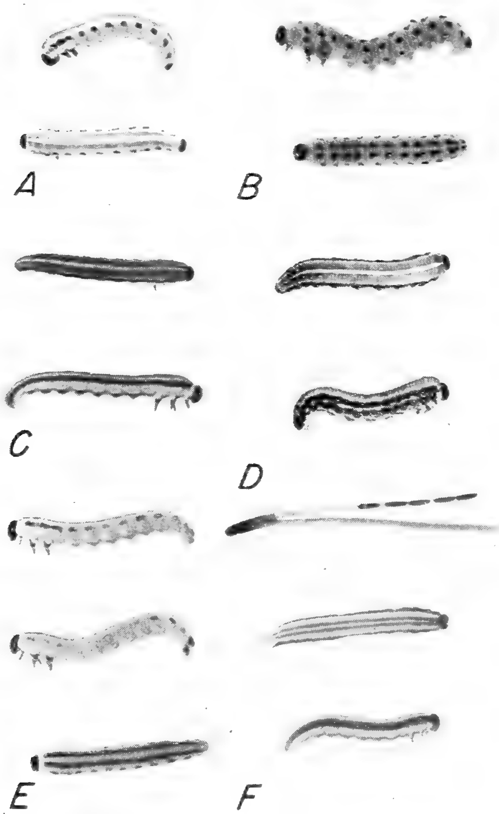

FIGURE 146.—Larvae of pine sawflies (dorsal and lateral views): *A*, *Neodiprion americanum*; *B*, *N. lecontei*; *C*, *N. nanulus*; *D*, *N. sertifier*; *E*, *N. dyari*; *F*, *Diprion frutetorum*.

This sawfly is undoubtedly the most widespread and destructive of our native sawflies that attack pine, being abundant over large areas at irregular intervals. The larvae are practically always found feeding gregariously on the needles of young pine trees or those in open-growth stands. The species is thus most important in young plantations and nurseries and to reproduction and ornamentals. Severe outbreaks have occurred in forest plantations in recent years in New York, the Lake States, and Alabama. In some infestations only small parts of the stands were damaged; in others the defoliation was so extensive that the stands on large acreages were completely ruined.

The life history of *Neodiprion lecontei* (Middleton, *299*) is rather complicated, as there may be one and a partial second generation, or two complete generations annually. Larvae maturing by the second or third week in July may transform to adults in August or September, or some may remain dormant in the prepupal stage in the cocoons and not develop to adults until late in April to July of the next year. Larvae maturing from late in July to October do not transform to adults until the following spring or early part of the summer, and sometimes a few prepupal larvae may remain dormant and not transform to adults until the second year. Broods of larvae may therefore be found feeding from May until late in the fall, the exact periods depending somewhat on the climatic range. The eggs are deposited singly in slits cut in the needles, but usually several eggs are laid in each needle. The larvae become full grown in from 25 to 31 days, and the winter is passed as prepupal larvae in capsule-shaped cocoons in the duff or topsoil beneath trees.

The larva of **the white pine sawfly** (*Neodiprion pinetum* (Nort.)), also called **Abbott's pine sawfly** by some authors, is yellowish white with four longitudinal rows of black spots on the body. The head is black. The larva is nearly 1 inch long when full grown. White pine is the preferred food plant, but published records show that this sawfly is occasionally found on pitch, short-leaf, red, and mugho pines. This species is distributed throughout the eastern part of the United States, westward into Minnesota and Iowa, and northward into the Provinces of Ontario, New Brunswick, and Quebec, Canada. The life cycle and habits are very similar to those of the red-headed pine sawfly.

Neodiprion nanulus Schedl is known locally as **the red pine sawfly.** The larva, when nearly full grown, is about ¾ inch in length and ranges in color from dull grayish green to blackish on top and greenish white beneath. It has a middorsal stripe of light green and a fainter one on each side, also a dull blackish stripe at the bases of the legs. The head is black, and the thoracic legs are black with whitish annulations (fig. 146, *C*). After the full-grown larva has ceased feeding, and before it spins the cocoon, it becomes dull green with four more or less distinct longitudinal blackish stripes on the body, and the head is yellowish brown. This species, unknown prior to 1932, has now been reported from New Jersey and New York, north into Quebec and west into southeastern Manitoba. Its favored food plant is red pine, although it has been found feeding on jack, Japanese red, and mugho pines. White pine trees growing as understories in stands of red pine are sometimes defoliated by the larger larvae. Brown [35] stated that this species had become extremely abundant on red pine in parts of Quebec, Ontario, and southeastern Manitoba. Since 1934 it has been defoliating red pine in the New England States, particularly in plantations. It seems, therefore, that the wholesale planting of red pine in pure stands has been favorable for the increase of this insect. This sawfly has one generation annually, although sometimes a small percentage of the prepupal larvae remain in a diapause in their cocoons for one or more years. The adults emerge in September and October, and the females deposit their eggs in slits cut in the needles of the current year's growth. The winter is passed in the egg stage, and hatching takes place early in May. The larvae are gregarious and usually devour all the mature foliage on one branch before migrating to another. They become full grown in June, before the cur-

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[35] Brown, A. W. A. Annual report of the forest insect survey 1939. Canad. Dept. Agr. Ann. Rpt. Forest Ins. Survey 1939, 37 pp. 1939. [Processed.]

rent year's growth is fully developed, and spin their cocoons in the duff near the base of their host tree.

The full-grown larva of *Neodiprion sertifer* (Geoff.) is about ⅞ inch in length. The head is black and the body is dirty grayish green with a longitudinal dorsal of lighter shade. Laterally there are two whitish lines bordering a stripe of very intense green or sometimes blackish, which has a tendency to break up into spots. The thoracic legs and back of the anal segment are black (fig. 146, *D*). Arising from the dorsal and pleural areas of the body are many short black setae, those on the dorsum being arranged in transverse rows. This species is of European origin and was first discovered in the United States in 1925 near Somerville, N. J. It is now known to occur in at least six counties in New Jersey and in some localities in Michigan and Ohio. Also it was found for the first time in Canada at Windsor, Ontario, in 1939. Reports from Europe indicate that it is a serious defoliator of pine and outbreaks occur at irregular intervals in many countries on that continent. The discovery of this insect in the United States, its life history, and habits are discussed by Schaffner (*374*).

FIGURE 147.—Larvae of *Neodiprion sertifier* showing gregarious feeding habits.

The favored food plants in the United States include red, Scotch, Japanese red, jack, Swiss mountain, and mugho pines. Trees in New Jersey have been severely defoliated during the last few years. There is one generation annually and the life history is very similar to that of *Neodiprion americanum*. The larvae are gregarious and feed on the mature foliage, at first eating along the edges of the individual needles and later devouring all the needles on one branch before migrating to another (fig. 47). Occasionally some of the cocoons are spun on the twigs of the food plant, but generally they are spun in the duff under the trees. The fact that the larvae mature before the current season's growth has fully developed, and that a decided preference is shown for the mature foliage, favors the chances for recovery of severely defoliated trees (figs. 148 and 149).

Neodiprion dyari Roh. is a common species and sometimes is confused with *N. abietis* and *N. banksianae* Roh. The full-grown larva is about ¾ inch long. The head and legs are black, the body is dull

FIGURE 148.—Red pine defoliated by larvae of *Neodiprion sertifer*.

yellowish green with a dull blackish longitudinal stripe on each side of the back and a broken stripe consisting of more or less distinct black spots along the supraspiracular line; often those on middle segments are obsolete. The tenth abdominal tergum has a pair of large blackish spots (fig. 146, *E*). This species feeds on jack, Japanese red, pitch, red, and shortleaf pines in North Carolina, northward through New England, and westward into Minnesota. Occasionally local outbreaks occur in New England, particularly in stands of pitch pine. The life cycle and habits of *N. dyari* are very similar to those of the red pine sawfly (*N. nanulus*). The larvae of *N. banksianae* are very similar in

FIGURE 149.—Edge of large plantation of red pine defoliated by *Neodiprion sertifer* in spring of 1940. Photograph taken after the current year's growth had developed.

appearance to those of *N. dyari*, and the life cycle and food plants of these two species are similar. It is a serious defoliator of jack pine, particularly in the Lake States.

A number of other species, of varying importance in certain sections of the eastern part of the United States and Canada, belong to the genus *Neodiprion*. *N. excitans* Roh. in the southeastern part of the United States, from the Carolinas to Texas, feeds on loblolly and shortleaf pines. *N. eximina* Roh. is found in the eastern part of the United States and feeds on pitch pine and red pine. In the southern part of Connecticut it has one generation and at least a partial second, and it winters in the cocoon stage. *N. fabricii* (Leach) is found in the Southeastern States and feeds on longleaf pine. The full-grown larva of *N. pini-rigidae* (Nort.) is about ¾ inch long. The head is reddish brown. The body is dull green, with a double longitudinal black line on the dorsum and a broken stripe of black on each side, beneath which is a double row of black spots, the latter sometimes obsolete. It occurs in the northeastern part of the United States and feeds on pitch pine. Its life cycle is similar to that of the red-headed pine sawfly.

Data on two additional species of *Neodiprion* found in Canada have been supplied by A. W. A. Brown, of the Canadian Department of Agriculture. It seems probable that these may also occur in the States bordering Canada. The larva of *N. dubiosus* Schedl has a brown head, and the body is heavily striped. It overwinters in the cocoon. It feeds on jack pine from Saskatchewan to New Brunswick. The larva of *N. swainei* Midd. has a brown head and the body is lightly striped. It feeds on jack pine in Ontario and Quebec.

The larva of **the introduced pine sawfly** (*Diprion simile* (Htg.)) (fig. 150) is about 1 inch in length, the head is black, the body yellowish green with a double stripe of black down the back, and the sides of the body are mottled with yellow and black.

This European insect was first discovered in this country in Connecticut in 1914. It is now rather well distributed through the Northeastern States and apparently is most common on ornamental pines. Specific records of occurrence include Maine, Massachusetts, Connecticut, New York, New Jersey, Pennsylvania, Virginia, District of Columbia, and Indiana. It has been reported also from the vicinity of Montreal and Toronto, Canada. White pine (*Pinus strobus*) and other five-needled pines are preferred as food, but records show that the softer two-needled pines are also suitable food plants. It is a vigorous defoliator, and apparently the most serious infestations have been in ornamental plantings of pine and in nurseries.

The seasonal history of this insect is rather complicated, as there may be one or two generations, or one and a partial second generation, annually. The cycle from adult to adult may be about 2 months or as long as 12 months. Adults may emerge from cocoons from April to September. Records show that this species may reproduce parthenogenetically, but when it does the progeny are always males. The eggs are laid in slits cut in the needles of the previous season's growth, and they hatch in 8 to 14 days. The young larvae feed only along the edges of the needles, but after they are 9 to 10 days old they begin to consume the entire needle. The old foliage is preferred, but as the season progresses and the new growth matures it also is eaten by the larvae.

Although larvae may be found from May through September, the periods of greatest abundance are in May and June and in August and September. The larval stage may be completed in 16 to 32 days, depending on the weather. The larvae spin tough white silken cocoons, about $\frac{5}{16}$ to $\frac{7}{16}$ inch in length, among the needles on the twigs or on other parts of the trees or in the litter on the ground. The cocoons soon turn brown and blend rather well with their surroundings. The period spent in the cocoon may range from about 10 days to almost a year. The winter is passed in the prepupal stage in the cocoon (Middleton, *301*). In the United States insect parasites, particularly species of Hymenoptera that attack the hibernating cocoons, play an important part in the control of this pest.

The full-grown larva of *Diprion frutetorum* (F.), prior to the last molt, is about $\frac{4}{5}$ inch in length. The head is reddish brown,

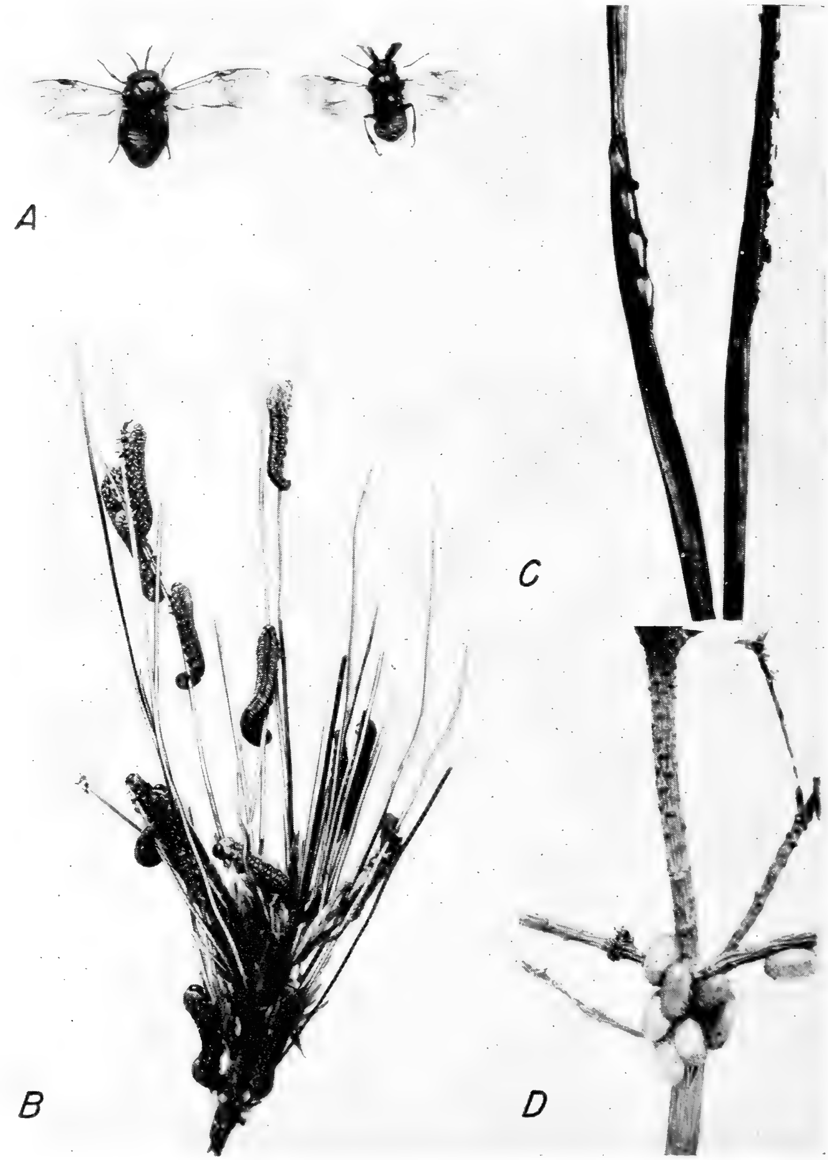

FIGURE 150.—*Diprion simile*: *A*, Adults, twice natural size; *B*, larvae feeding on pine, natural size; *C*, eggs in pine needle, four times natural size; *D*, cocoons, natural size. (Courtesy Conn. Agr. Expt. Sta.)

the eyespots and a large blotch on the face are black, and usually near the middle of the blotch is a light-colored inverted V-shaped mark. The body is light green with longitudinal dark green markings as follows: Two narrow stripes on dorsum, a broad lateral or supraspiracular stripe and a narrower one at bases of the legs on each side. The legs have black markings on the outer side (fig. 146, *F*). After the larva molts into the last instar it loses the darker markings, except for the eye spots. The larvae prefer red pine and Scotch pine. There is one and at least a partial second generation each year in New England. The winter is passed in the cocoon stage, and the adults from this generation may emerge from the latter half of May to the last of July. Those of the next generation may emerge from the latter part of July to the first part of September, or may remain as prepupae in the cocoons until the next spring or later.

Eggs are deposited singly in slits in the foliage. The larvae of the first generation may be found from about June 1 to early in August, and those of the second generation from late in July until late in the fall. They are solitary in habits and their color blends with that of the pine foliage. Some of the cocoons are spun on the

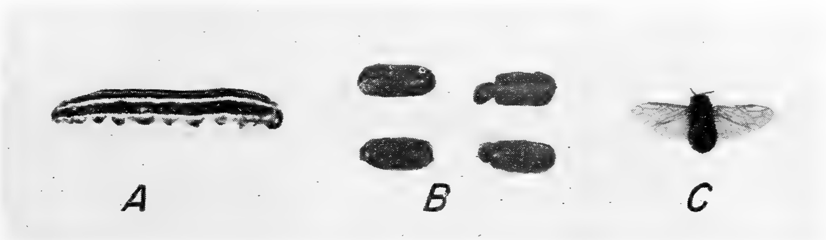

FIGURE 151.—*Diprion hercyniae:* Fifth-instar larva, cocoons, and adult female.

pine twigs, but by far the larger number are formed in the duff near the base of the host tree.

This species is an introduction from Europe and, although not abundant enough to attract much attention, it apparently has been established in North America for many years, because it is now known to occur in Connecticut, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, and in a few localities in Ontario, Canada. The population, however, has been increasing in a number of forest plantations in some of the Northeastern States during the last few years, and in some localities in Connecticut the feeding has been heavy. The presence of excrement and green-needle fragments in the litter on the ground may be the first evidence of a heavy infestation.

The young larva of **the European spruce sawfly** (*Diprion hercyniae* (Htg.)) is yellowish green, but when nearly full grown (about ⅘ inch in length) it is darker green, with five narrow longitudinal white lines. When the larva becomes full-fed and molts into the last instar the white lines disappear and the body shortens somewhat. The larvae drop to the ground to spin their cocoons (fig. 152).

Diprion hercyniae is a native of Europe and was first found in Canada in 1922 near Ottawa, and in the United States in 1929 on Mount Washington, N. H. It did not attract attention, however, until 1930, when it caused serious defoliation of spruce on the Gaspe Peninsula, Canada. It is now apparently well distributed through the Provinces of Quebec, New Brunswick, and Ontario, Canada, and in the United States throughout New England, New York, and New Jersey. This wide range indicates that it had been on this continent some years prior to its discovery. Balch (*17*) published an article on the outbreak of the European spruce sawfly in Canada and on its bionomics, and Dowden (*138*) published an account of its status in the United States (fig. 153).

Its food plants include white, red, black, and Norway spruces, and laboratory experiments indicate that other species of spruce may be attacked. Since the discovery of the outbreak in 1930, thousands of square miles of spruce forests on the Gaspe Peninsula have been

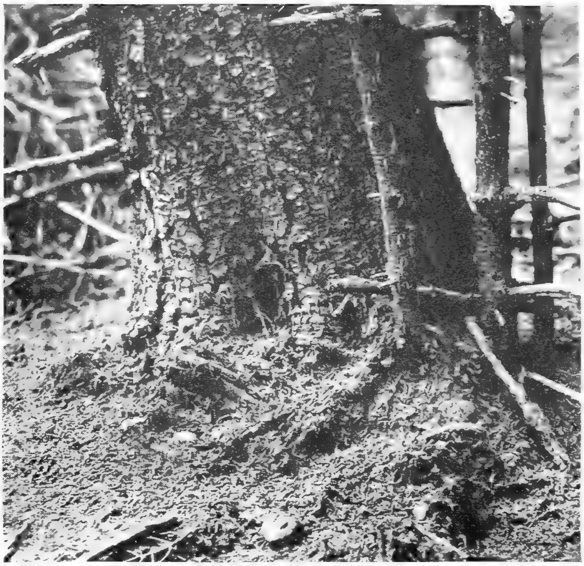

FIGURE 152.—Larvae of *Diprion hercyniae* massed at base of a heavily defoliated spruce tree.

seriously defoliated and as high as 40 to 50 percent of the spruce in some localities has been killed. Heavy infestations began to attract attention in the United States in 1937, particularly in Maine, New Hampshire, and Vermont. Although only a small percentage of affected trees have been killed thus far in the United States, there are large areas where the trees have been very severely defoliated. *Diprion hercyniae* has one generation in the Gaspe region, although often a high percentage of the prepupal larvae in cocoons remain in diapause for 2 or more years.

In most of New England and New York there are two generations annually, and a partial third in some years in the southern extension of its range when weather conditions are favorable. The adults of the first generation emerge from early in May to early in June, depending on the climatic range, and those of the second generation emerge about the first week in July or later. Males are very rare, and reproduction takes place without fertilization. The eggs are laid singly in slits cut in the old needles, and they hatch in a few days. The young larvae begin feeding at the tips of the old needles. The foliage of the older growth is preferred, but that of the current year is sometimes eaten when it is full grown. The larvae mature in about 3 or 4 weeks, when they drop to the ground and spin their cocoons in the litter. Usually some larvae can be found until late in the fall, when cold weather stops their activity. The cocoons range in color from golden to dark brown and are about ⅖ inch in length. The winter is passed as prepupal larvae in the cocoons, and transformations to pupae and adults take place in the spring.

In studying the natural enemies of this species, it was found that shrews, ground-feeding rodents, and predaceous beetles sometimes

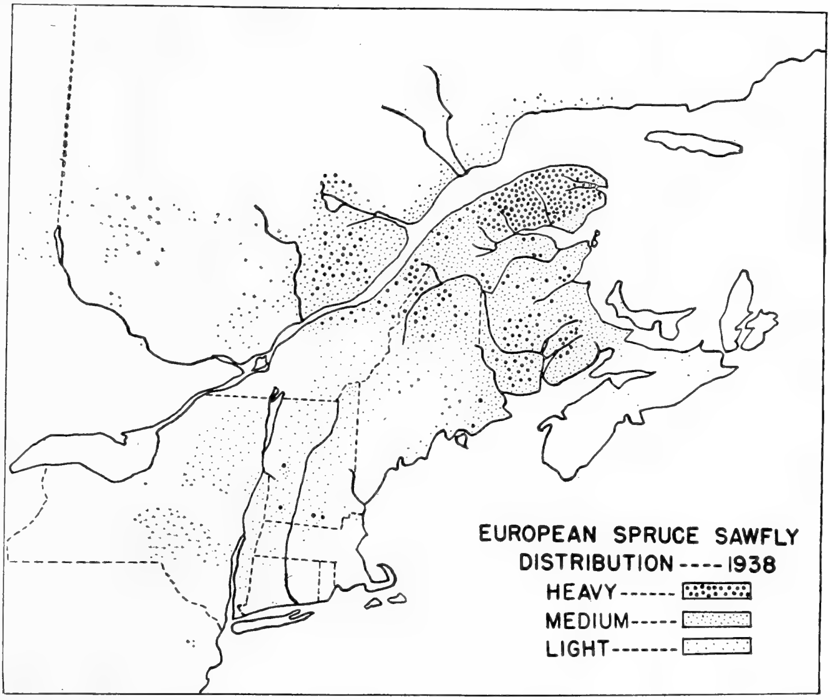

FIGURE 153.—Distribution in America of the European spruce sawfly in 1938. "Heavy" indicates severe defoliation, with most of the old and some of the new foliage eaten; "medium," noticeable feeding on old foliage; "light," larvae present, but no noticeable defoliation.

destroyed as high as 50 percent of the cocoons. Tremendous numbers of larvae may be killed by disease during the summer, particularly in the heavy infestations. In 1940 a larval disease was widespread and was responsible for reducing to a very low point the heavy infestations of southern New Hampshire and southern Vermont. The presence of the disease was noted in a number of localities in Maine in September 1940, and very few living larvae were found at those points. On the other hand, a considerable number of the insects were in diapause in those areas, and whether the disease would carry over to larvae of subsequent generations was problematical. The exact nature of this sawfly disease is not known, nor has it yet been named. It has about the same effect as wilt diseases of other insect larvae. An infected larva rapidly loses its normal green color, changing first to yellowish green and then to black, and soon disintegrates. As the body content dries out the remains often adhere to the needle on which the larva was feeding when stricken.

Thus far, native insect parasites have been unimportant as control factors in the United States and Canada, but in Europe a number of parasites are known to attack this species. Extensive programs have been carried on by the Canadian and the United States Governments in studying this insect and in importing, rearing, and colonizing its natural insect enemies. *Microplectron fuscipennis* (Zett.), a tiny wasplike insect which parasitizes this sawfly in the cocoon, was first introduced onto this continent by the Canadian Government. It is readily bred in the laboratory, and an average of about 25 individuals will develop in a single sawfly cocoon. Many hundred millions of this species have been propagated by the Canadian Entomological Branch, the Bureau of Entomology and Plant Quarantine of the United States Department of Agriculture, and the States of Maine, New Hampshire, Vermont, and New York, and have been colonized throughout the infested areas. The parasite has already become established in many localities, and appreciable percentages of parasitization have been found in some of the infested areas.

One other species, *Exenterus marginatorius* (F.), a larval parasite, was also definitely established in Canada in 1939 and shows considerable promise in some localities.

For control of *Diprion hercyniae* by spraying see pages 53 and 544.

Family CIMBICIDAE

This small family, comprising three genera, includes only a few species. The adults of most species are large, the antennae are clavate or capitate, the abdomen is stout with the lateral margins sharply angulate, the mesosterno-pleural sutures are barely indicated by a slight ridge, the mesoscutellum is without a post-tergite but has the anterior margin **V**-shaped, the tibiae are without preapical spurs, and the apical spurs of the front tibiae are simple (Ross, *361*). In the larva the head is large. The body is cylindrical, tapering toward the anal end, and in life it is covered with a waxy bloom. The larva is capable of ejecting a fluid from spiracular glands when disturbed. Three species often attract attention in the Eastern States.

The elm sawfly (*Cimbex americana* Leach), also called **the giant American sawfly** (fig. 154), is the largest of our American sawflies, the adults being robust and about 3/4 to 1 inch in length. The knobbed antennae and the tarsi are tinged with orange, and the wings are smoky brown. The head and thorax are black. The abdomen of the female is oval, usually steel-blue, and is marked with three or four yellowish spots on each side, but the abdomen of the male is longer, without spots on the sides (some specimens shaded to brown), and there is an oval whitish spot behind the thorax, which is hardly perceptible in the female. The larvae are yellowish white or greenish white, the spiracles are black, and each larva has a black stripe down the middle of the back. The skin is pebbled in texture, and each segment has many transverse wrinkles. When at rest the larvae are usually coiled, with one side of the body adhering to the underside of a leaf. Full-grown larvae are about 1 3/4 inches long.

Cimbex americana is distributed throughout the northern part of the United States, westward into Colorado, and from southern Canada

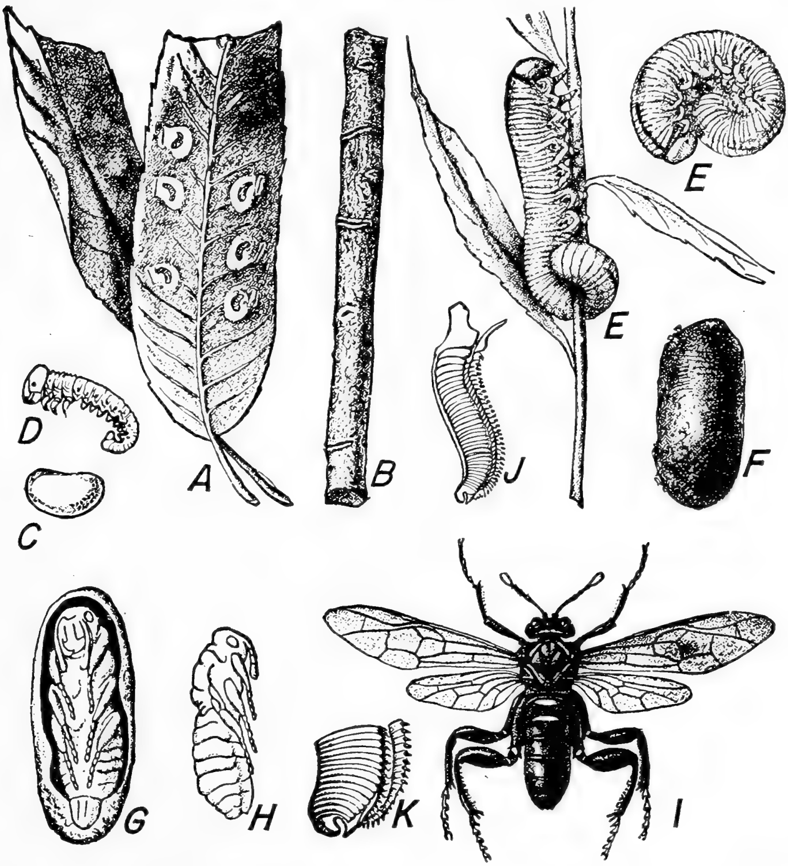

FIGURE 154.—*Cimbex americana*, the elm sawfly: *A*, Willow leaves showing location of eggs; *B*, twig showing incisions made by adult; *C*, egg; *D*, newly hatched larva; *E*, mature larvae; *F*, cocoon; *G*, open cocoon showing pupa; *H*, pupa, side view; *I*, mature sawfly; *J* and *K*, saw of female. *C*, *D*, *J*, *K*, much enlarged, the others less enlarged.

westward into British Columbia. Its principal food plants are elm and willow, but occasionally larvae are found feeding on alder, basswood, birch, maple, and poplar. The larvae are vigorous defoliators, and the adults sometimes cause injury by gnawing into the bark of twigs. This species is generally rather common in New England, and local outbreaks have been observed on the bush and tree willows.

One year is necessary to complete a generation, and laboratory records show that sometimes a considerable number of prepupal larvae in cocoons may hold over in a diapause for at least 21 or 22 months. In New England the period for emergence of adults extends from about the middle of May to the middle of August. The eggs are deposited in pockets cut into the leaf tissue by the female. Larvae may be found from June until October, although probably each completes its growth within 6 to 8 weeks. The full-grown larvae crawl to the ground and spin tough, brown papery cocoons in the litter or among the roots of grass and weeds in the topsoil. The winter is passed as prepupal larvae within their cocoons, and transformation to the pupal and adult stages takes place in the spring or early in the summer. For control see pages 53 and 54.

There are only a few species in the genus *Trichiosoma*, and *T. triangulum* Kby. is probably the most common one found in the Eastern States. The full-grown larva is about 1½ inches in length, the head is creamy white, and the body is greenish white with the eye spots and spiracles blackish. It is solitary and feeds on birch, wild cherry, poplar, and willow. The life cycle is very similar to that of *Cimbex americana*.

The honeysuckle sawfly (*Zaraea inflata* Nort.) is probably the most common species of its genus in the Northeastern States. The larvae feed on honeysuckle and occasionally become locally abundant, causing complete defoliation of groups of bushes. The full-grown larva is rather plump and about 1 inch in length, the head is brown with the face and mouth parts lighter, the body is grayish green and marked with yellowish spots and irregular rows of black dots (fig. 155). This species has one generation annually. The winter is passed as prepupal larvae in cocoons in the ground, the adults emerge in May or early in June, and the larvae usually attain full growth late in June or early in July, although in its northern range the larvae may not become full grown until August.

FIGURE 155.—Larvae of *Zaraea inflata*, dorsal and lateral views.

FAMILY TENTHREDINIDAE

In the adults of the Tenthredinidae the antennae have 7 to 10 segments, ranging in shape from setaceous and filiform to clavate. The mesothorax is without sterno-pleural sutures, the anterior margin of the scutellum is V-shaped, and the posterior margin usually has a distinct post-tergite. The tibiae are without preapical spurs, and the apical spurs of the front tibiae (except in some Nematinae) have the longer spur cleft at the apex (Ross, *361*).

The larvae are leaf feeders, leaf miners, or fruit borers. They range from ⅖ inch to about 1½ inches in length, and are usually largest in diameter at the thorax. The body is greenish or variously colored, with or without distinct markings, and is smooth, glabrous, setiferous, tuberculate, or spinous. Yuasa (*439*) published a monograph on the larval characters of this family, with a key to the subfamilies.

SUBFAMILY PHYLLOTOMINAE

The pear slug (*Caliroa cerasi* (L.)) is nearly ½ inch in length when full grown and has a clean yellow skin (fig. 156). Prior to the last molt the body is so enlarged in front that the head is concealed, and the body tapers toward the anal end. The larva secretes a slimy matter which covers the body, giving it an olive-green color and causing it to resemble a slug. This species is an introduction from Europe and is distributed in North America from Ontario to British Columbia in Canada and from the North Atlantic States to California in the United States. It has been well known as a pest of cherry and pear in the United States since late in the eighteenth century, and occasionally it is found feeding on hawthorn, plum, quince, and shadbush. Often 20 or more larvae are found on a single leaf. Most of the feeding is done from the upper surface of the leaf and only the parenchyma is eaten. This gives the foliage a scorched appearance and causes it to drop prematurely.

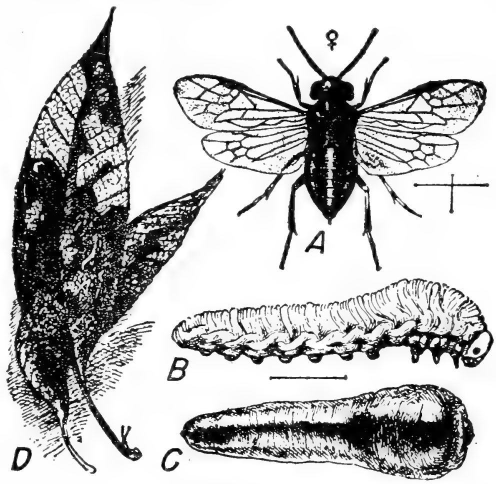

FIGURE 156.—The pear slug (*Caliroa cerasi*): *A*, adult; *B*, *C*, larvae from side and above; all enlarged; *D*, leaf eaten by larva, natural size.

Throughout most of its range in the United States, the pear slug probably has two generations annually. Rearing records in New England, however, show that occasionally there is only a partial second generation, and Harris (*210*) found that some individulas remained unchanged in the ground, in a dormant condition, through two winters.

The winter is passed as prepupal larvae in earthen cells or cocoons, composed of grains of earth and a substance secreted by the larvae. The adults of the first generation emerge late in May or in June, and those of the second generation late in July or in August. The eggs are deposited singly in small semicircular incisions cut in the leaf tissue. Hatching takes place in about 2 weeks, and the larvae complete their growth in about 4 weeks. The full-grown larvae drop to the ground and form their cells in the soil, those of the first generation transforming to adults in 2 or 3 weeks. Thus larvae of the first generation may be found in the field from June to early in August and those of the second in August and September.

In recent years, *Caliroa lineata* McG., a species closely related to the pear slug, has been causing serious damage to pin oak in New Jersey.

The larva of **the rose sawfly** (*Caliroa aethiops* (F.)), also called **the European rose slug**, is yellowish green, but the food in the alimentary tract causes it to appear dark olive green. The head is yellowish and has a black spot on each side, enclosing the eye. The length of full-grown larva is about ⅓ inch.

As the common names of this species imply, it feeds on the foliage of the rose, and is an introduction from Europe. It is now known to occur in the United States and in Canada east of the Rocky Mountains. The larvae feed on the upper surface of the leaflets by a characteristic chafing method, eating only the soft tissue and leaving the veins and undertissues. There is one generation a year (Middleton, *300*).

The larva of *Phyllotoma nemorata* (Fall.), **the birch leaf-mining sawfly,** is somewhat flattened and whitish, with the head and joints of the thoracic legs brownish, and is about two-fifths of an inch in length when full grown. There are no black spots in the middle of the underside of the thoracic and the first abdominal segments, as in *Fenusa pusilla* (p. 567). This sawfly, of European origin, was found in Nova Scotia in 1905 and is now known to occur in the Canadian Provinces of Nova Scotia, New Brunswick, and Ontario, and in Maine, New Hampshire, Vermont, Massachusetts, and New York. It severely attacks gray, paper, and European white birches, and to a lesser degree, red, yellow, blue-leaf, and Alpine birches, and occasionally alder and hazelnut. The larvae feed between the upper and lower surfaces of the birch leaves, producing large blisterlike or blotch mines which remain free of excrement.

Severely infested trees show a marked reduction in the amount of annual growth, and the operators of birch mills have noted that wood from severely injured trees does not turn or work up so well as wood from uninjured trees. In heavy infestations an increase in the number of dead branches and dead tops of trees has been observed, although the death of entire trees cannot be attributed directly to this insect.

Phyllotoma nemorata has one generation annually, and no males have ever been found or reared from field-collected larvae and pupae, a fact which indicates that the species reproduces parthenogenetically. The adults emerge during June and the early part of July, the period of maximum emergence varying somewhat with the changes in climate. The eggs are deposited singly in slits cut in the tissue of the leaf serrations, and seldom are more than two or three eggs laid in a leaf. Usually there is a characteristic browning of the leaf area immediately surrounding the point where the egg was inserted. Hatching takes place in 12 to 26 days. The feeding season extends from July to October, but the larvae usually become full grown in 47 to 57 days after hatching. Usually a larva consumes about 35 to 40 percent of the parenchyma in a leaf before completing its growth. Each full-grown larva constructs a lens-shaped cocoon or hibernaculum of silk within its mine in the leaf (fig. 157). It falls to the ground in its hibernaculum and passes the winter there as a prepupal larva. Transformation to pupal and adult stages takes place in the spring.

In the United States, birds are the most important predators on this insect, and many species have been observed attacking the larvae and prepupae, particularly the latter stage after they have dropped to the ground in their hibernacula. Several native insect parasites attack the eggs, larvae, and prepupae. During the years when the birch skeletonizer (*Bucculatrix canadensisella*) is abundant, *P. nemorata* suffers severely from competition.

Although this sawfly has been recorded in many parts of Europe, apparently no outbreaks have ever been reported. Dowden (*139*) published on the results of studies conducted in Europe in 1929–34 by the Bureau of Entomology and Plant Quarantine, and showed the importance of many natural control factors. It was found that insect parasites killed large numbers of early-instar larvae, before they had mined much of the leaf. Five species have been imported into the United States, and two of them, *Chrysocharis laricinellae* Ratz. and *Phanomeris phyllotomae* Mues., have become established. Spraying with a mixture of nicotine sulfate, soap, and water (p. 53) after the eggs have been deposited and before the mines exceed 1/4 inch in diameter will give satisfactory control on trees of sufficient value to warrant the expense, particularly on ornamentals. (See caution, p. 36.) Picking the infested leaves could be resorted to where practicable, and especially the gathering and destroying of such leaves after they fall to the ground.

FIGURE 157.—Mines and hibernacula of *Phyllotoma nemorata* in leaf of paper birch.

The birch leaf miner (*Fenusa pusilla* (Lep.) (=pumila Klug)), also called **the black-marked birch leaf miner,** is whitish, somewhat flattened, and slightly over 1/4 inch long when full grown. It has distinct black spots in the middle of the under side of the thoracic and first abdominal segments. This is a European species which has become established in North America. It has been reported from Quebec, Ontario, and the Maritime Provinces, Canada, the New England States, and New York, New Jersey, and Pennsylvania. Gray, paper, and European white birches are its most-favored food plants. The young seedling and sprout growth of the gray birch is particularly favored. The larvae are leaf miners and feed between the upper and lower surfaces of the birch leaves, producing blotches or blisters (fig. 158). The females prefer to lay their eggs in newly developing leaves; therefore the tops of trees are most seriously affected.

Fenusa pusilla has three generations and sometimes a partial fourth generation during a year in Connecticut. The first adults emerge the middle of May, and a generation from egg to adult requires approximately 6 weeks during the period of most active development. The overwintering generation seems to take about 9 months, of which the

FIGURE 158.—Mines of *Fenusa pusilla* in leaves of gray birch. (Courtesy Conn. Agr. Expt. Sta.)

greater part is spent in hibernation in a cell in the ground (Friend, *168*). The eggs are laid in the leaf tissue, the larvae hatch in a week or 10 days and usually complete feeding within the leaf in 1 to 2 weeks. Full-fed larvae drop to the ground and go through their transformation in earthen cells constructed 1 or 2 inches below the surface of the soil. Larvae completing their development late in the year (August and September) may produce adults the same year, but usually they hibernate over winter to produce adults the following May.

Insect parasites affecting the control of this sawfly have not been thoroughly investigated. Picking infested leaves from ornamental trees would hardly be practical, except possibly in very light infestations and then would be effective only while the larvae are within the leaves. It should be borne in mind that this species does not cocoon or pass the winter within the leaves. Friend (*168*) found that nicotine sulfate (without soap) diluted in water at the rate of 1 : 1,000 killed the eggs and many young larvae which had just begun to mine the leaves, when both surfaces of the leaves were covered with the insecticide. In Connecticut two applications should be made at weekly intervals for the first generation, beginning usually between May 20 and May 25, and three for the second generation, beginning about July 3.

The elm leaf miner (*Fenusa ulmi* Sund.) is legless, flattened, and whitish, with a greenish cast, and the head is brownish. This leaf-mining species is an introduction from Europe and is apparently well established in the northeastern part of the United States and the southeastern part of Canada. Specific records include Vermont, Massachusetts, Connecticut, New York, Michigan, southern Ontario, and southern Quebec. Elm is its food plant, chiefly the English and Scotch elms, the horticultural variety Camperdown elm, and occasionally American elm. The larvae live in mines made between the upper and lower surfaces of the leaves, feeding on the parenchyma between the veins, thus causing large blotch or blisterlike mines (fig. 159). Several larvae may mine in a single leaf. In light infestations the injured epidermis soon dries, turns brown, and drops out, and in severe infestations the mined leaves fall prematurely. Small trees in ornamental and nursery plantings seem to be most seriously attacked, although occasionally heavy infestations occur on the larger trees. There is one generation annually. The adults emerge in May, usually during the first half of the month. The eggs are deposited in the leaf tissue and hatching takes place in about a week. The larvae usually become full grown during the latter half of June when they vacate their mines, drop to the ground, and spin brown papery cocoons in the topsoil. Winter is passed as prepupal larvae in the cocoons, and transformation to the pupal and adult stages takes place in the spring.

The European alder leaf miner (*Fenusa dohrnii* (Tisch.)), closely allied to ***F. ulmi***, is a European species which was accidentally intro-

FIGURE 159.—Mines of *Fenusa ulmi* in elm leaves. (Courtesy Conn. Agr. Expt. Sta.)

duced into the United States sometime prior to 1891. It is now known to occur through the northeastern part of the United States and in the southern part of Canada. The larvae mine the leaves of alder, especially the European alders that have been cultivated in North America. Each larva makes a blotch mine and often several larvae in one leaf may merge them into one large common mine. The mined leaves on the trees or shrubs present an unsightly appearance, and those that are badly mined drop prematurely. There are two generations annually. The winter is passed as prepupal larvae in cocoons in the ground. The adults emerge and deposit eggs in the leaves sometime between the latter part of May and the first half of June, and those of the second generation are active between the latter part of July and the first part of September.

Profenusa canadensis (Marlatt), **the cherry and hawthorn sawfly leaf miner,** has been reported as a serious pest of some of the hawthorns and certain varieties of cultivated cherry in New York and Massachusetts. Its life cycle and habits are somewhat similar to those of *Fenusa ulmi.* It passes the winter as a prepupal larva in an earthen cell in the ground (Parrott and Fulton, *333*).

Scolioneura sp., a leaf miner on Lombardy poplar, is occasionally abundant locally in parts of New England. Its food plants include Lombardy poplar and some of the varieties used for ornamental purposes. The mined areas in the leaves turn brown late in May and in June, and the leaves that are severely mined drop prematurely. There is one generation annually. The adults emerge early in May. The larvae are blotch miners in the leaves and are active during the latter half of May and the first part of June. The full-grown larvae vacate the mines and spin cocoons in the ground in which they pass the summer, fall, and winter.

Subfamily CLADIINAE

The full-grown larva of *Trichiocampus viminalis* (Fall.) is nearly ¾ inch in length, the head is black with yellow markings, and the body is orange-yellow and marked on each side with a subdorsal row of large, more or less rounded black spots, beneath which is another row of smaller spots. It is sparsely clothed with short, white hairs (fig. 160). This species, of European origin, has been present in the United States for more than 50 years. Its known distribution now extends from New Jersey through the Northeastern and Northern States into eastern Canada and west to British Columbia. Records indicate that it feeds on various species of poplar, but in the United States it is usually found on Carolina and Lombardy poplars. These trees when planted for shade or ornamental purposes are occasionally seriously defoliated by this insect.

There may be two generations, or at least one and a partial second generation annually. Adults emerge in May and the first-generation larvae usually become full grown late in June or early in July. Adults of the next generation may emerge in August, but some may not develop and emerge before the following May. The larvae of the second generation may be found from late in August until October. The winter is passed as prepupal larvae in cocoons in the duff beneath the trees. The larvae are generally found in small groups on the foliage, and they eat all but the midrib and larger veins of the leaves.

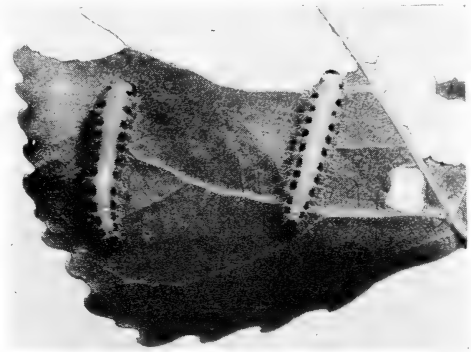

FIGURE 160.—Larvae of *Trichiocampus viminalis* on a poplar leaf. (Courtesy Conn. Agr. Expt. Sta.)

The larva of *Trichiocampus irregularis* (Dyar) is nearly 3/4 inch long when fully grown. The head is almost entirely black. The body is yellow, sparsely hairy, and on each side is a subdorsal row of large black spots, beneath which is another row of black spots, the latter partially coloring the area containing the spiracles. This species has been recorded from Rhode Island and Connecticut and northward into Canada. Willow is its food plant. It has occasionally been reported as abundant locally in Maine, usually on one tree or on a small group of trees. The larvae feed gregariously and the life cycle is very similar to that of *T. viminalis*.

The bristly rose slug (*Cladius isomerus* Nort.) is greenish white and is clothed with long rather stout bristles. It is about 5/8 inch in length when full grown. This species is distributed throughout the northeastern part of the United States east of the Mississippi River, and in California. It is probably the most serious defoliator of wild and cultivated rose bushes. The newly hatched larvae usually begin their feeding on the underside of the leaves, at first eating all but the upper epidermis of the leaflets, later skeletonizing, and finally eating all but the larger veins. According to Middleton (*300*), there may be as many as six generations annually in the vicinity of Washington, D. C.

SUBFAMILY NEMATINAE

The full-grown larva of **the maple petiole borer** (*Caulocampus acericaulis* (MacGillivray), is about 1/3 inch in length and resembles a weevil larva. The head of the young larva is yellowish and the body whitish, but in older specimens the head is light brown and the body straw yellow (Britton, *57*). This species occurs in Connecticut, Massachusetts, New York, and New Jersey, but the limits of its distribution are not definitely known. The larvae bore or tunnel in the petioles or leaf stems of maple, causing the stems to break a short distance from the leaf blade and the leaves to fall late in May or early in June. Although this causes considerable alarm in heavy infestations on shade trees, the sawfly rarely, if ever, becomes abundant enough to cause severe injury to the trees.

There is one generation each year. The adults emerge early in May and the eggs are laid near the bases of the petioles of maple leaves. On hatching, the larvae tunnel in the stems for about a month. After the petioles break and the leaves fall each larva continues to feed for a week or 10 days in that portion of the stem remaining on the tree, when it also drops and the larva vacates the tunnel to enter the ground. Transformation takes place in a cell formed 2 or 3 inches below the surface. Either hand picking of the infested stems as soon as noticed, or spraying the ground beneath the trees with kerosene emulsion about June 15, when the larvae are entering the ground, is the most practical method of control.

The striped alder sawfly (*Hemichroa crocea* (Fourcroy)) has also been designated as *H. pallida* Ashm., *H. dyari* Roh., *H. washingtonia* Roh. & Midd., and *Dineura americana* Prov., but in 1937 Ross (*361*) placed these in synonomy. The full-grown larva is about 4/5 inch long, the head is shiny black. The body is yellowish and marked on each side by a broad dark-brown subdorsal stripe extending from the second thoracic segment to the tenth abdominal segment, and with two broken subspiracular stripes composed of irregular blotches and dashes extending almost to the ninth abdominal segment. The newly hatched larva is pure white, the dark markings becoming visible in the second and third instars. This species was first described from Europe, but has apparently been present in North America a great many years. It is known to occur through many of the Northeastern States and westward into Oregon, and in Canada apparently ranges from Quebec to British Columbia, feeding on various species of alder and occasionally birch. Reports indicate that occasionally it causes severe defoliation of alders in British Columbia and also in some of the Northeastern and Lake States.

There are two generations annually. The winter is passed as a prepupal larva in its cocoon, which is very thin and formed within a cell made by cementing together particles of sand and earth a few inches beneath the surface of the ground. Adults emerge during the latter half of May, and the eggs are deposited on the under surface of the leaves in slits made in the sides of the midribs. Larvae of this generation become full grown in July. Late in July and early in August the adults of the next generation emerge and their larvae may be found in August and September. The larvae are gregarious and usually devour all but the midrib and larger veins of the leaves.

The full-grown larva of **the mountainash sawfly** (*Pristiphora geniculata* (Htg.)) is 5/8 to 3/4 inch in length. The head and legs are yellow orange, the eyes are black, and the body is yellowish, with all segments except the last marked with black spots of uneven size and shape. The spots are arranged in more or less irregular longitudinal rows with four rows on each side of the body (two above and two below the line of spiracles), and two broken rows (spots usually absent from back of abdominal segments 2 to 5, inclusive) down the middle of the back (fig. 161). The young larva is greenish white, with head and legs black, and the body marked with black dots.

This species was first described from Europe in 1840 by Hartig. Although the first definite record of its occurrence in the United States was in 1926 from specimens collected at Haines Falls, N. Y., entomologists differ in opinion as to whether it is of European origin. In 1928 and 1929 it was first reported as seriously defoliating mountain-ash in widely separated localities in Massachusetts, New York, and Vermont. Each year since 1929 this species has been more or less abundant in many localities where mountain-ash commonly grows, and is now known to occur in New Jersey, New York, and throughout New England. In Canada it is found in the Maritime Provinces, Quebec, and Ontario. Field observations indicate that the larvae of this insect will survive only on the foliage of American or European mountain-ash.

The adults emerge during the latter half of May and in June, the dates varying in different localities and with the season. Eggs are deposited in slits cut by the female near the edges of the leaves. Newly hatched larvae may be found from early in June to the middle of July, and they reach full growth from early in June to the middle of August. The newly hatched larvae feed between the veins, skeletonizing the leaves, but after a few days they usually eat all of the leaf except the midrib. They are gregarious and move in small groups, devouring the foliage on one small branch before migrating to another. The cocoons are spun in the duff and topsoil beneath the trees. The winter is passed as prepupal larvae in the cocoons, transforming to the pupal and then to the adult stage in the spring. Laboratory records indicate that occasionally there may be a partial second generation late in August and in September. The adults are rather strong fliers and apparently can find their food plants, even if the trees are widely scattered and growing as individuals in a mixed forest or as shade and ornamental trees.

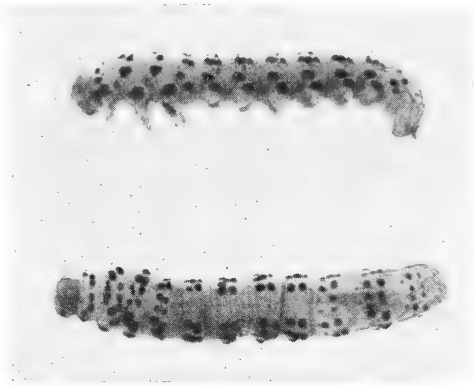

FIGURE 161.—The mountain-ash sawfly (*Pristiphora geniculata*), lateral and dorsal views.

The full-grown larva of **the larch sawfly** (*Pristiphora erichsonii* (Htg.)) is about ¾ inch long, with the head and thoracic legs black and the body dull grayish green above and paler beneath. This species is a serious defoliator of larch in Europe, Asia, and North America. Entomologists differ as to whether this species is an introduction from Europe or a native of America. Packard (*323*) stated that its presence in North America was not definitely recorded until 1882, when severe infestations began to attract attention in Maine. In the same year, serious outbreaks were recorded in Massachusetts, New Hampshire, New York, and eastern Canada. Graham (*194*) recently stated:

> In Minnesota, the first historical record of larch sawfly injury is in the year 1909. The ring pictures of old trees, however, show that reduction from defoliation has occurred periodically throughout the life of the oldest trees. In addition to the recent period of reduced growth that started about 1909, there were at least two other periods of heavy defoliation, one just previous to 1880 and another about 1840. Other minor defoliations occurred about 1855 or 1860, about 1870, and in the late nineties. Whether or not the larch sawfly is a native or an introduced pest can only be shown by further and more extensive studies.

The larch sawfly is now widely distributed through the northern part of the United States and in Canada. Severe outbreaks have occurred at irregular intervals in many localities, sometimes completely defoliating large stands of trees two or more years in succession. In such outbreaks an enormous mortality of trees is usually the result, especially when an infestation of the eastern larch beetle (*Dendroctonus simplex*) is associated with the sawfly infestation. During the outbreaks in the early eighties, widespread destruction of larch, especially in mature stands, occurred throughout the Northeastern States and the eastern provinces of Canada.

The adults emerge from late in May to early in July, and the females lay their eggs in slits cut in the young twigs of the larch. During periods of heavy infestation the oviposition injury causes a marked twisting of the growing twigs. The eggs hatch in about a week. The young larvae feed at first along the edges of leaves that arise from twigs of the previous year's growth, and later devour entire leaves on all parts of the trees. The larvae usually become full grown in July or August, depending on the climatic range. Sometimes larvae are found well into September, and laboratory records indicate that occasionally there may be a partial second generation. When full grown the larvae spin tough, brown cocoons in the duff on the ground beneath the trees, in which they pass the winter (fig. 162).

FIGURE 162.—Larvae and cocoons of the larch sawfly (*Pristiphora erichsonii*). (Courtesy Conn. Agr. Expt. Sta.)

A hymenopterous parasite, *Mesoleius tenthredinis* Morley, a natural enemy of the larch sawfly in Europe, has been introduced into Canada and the United States and is now firmly established in these countries. This species is more fully discussed on page 603. Rodents are important predators on this insect, destroying vast numbers of cocoons. Diseases affecting the larvae and the cocoons sometimes take a tremendous toll, especially when conditions are favorable for epidemics.

The full-grown larva of **the yellow-headed spruce sawfly** (*Pikonema alaskensis* (Roh.)) is about 3/4 inch long and has a chestnut-brown head. The body is dark yellowish green above and lighter beneath, and is marked with a double gray-green longitudinal stripe down the middle of the back, another broad one which sometimes is more or less divided into a double stripe on each side, a broad darker lateral or subspiracular stripe, and a linear spot near bases of the legs on all but the last three segments. This species is distributed from Alaska and British Columbia to Wyoming, and east to New Brunswick, Quebec, and the New England States. Nash (*317*) gave an account of its habits in the Maine forests. Its food plants include white, red, black, Norway, Colorado blue, and Engelmann spruces. The new foliage is preferred until the larvae are about half grown, and in Maine open growth in plantations and natural reproduction was most severely attacked. Heavy infestations seldom occur in stands with a closed canopy. There is one generation annually.

The adults emerge in May or early in June and the eggs are deposited between the new needles as soon as the bud scales are cast off. Hatching takes place in 6 to 8 days, and the larvae become full grown after a feeding period of 30 to 40 days. The cocoons are 2/5 to 1/2 inch long; dark brown, rough, with one end rounded and tapered to a blunt point at the other end. They are spun in the mineral soil beneath the trees in July, but pupation does not take place until spring. For control measures see page 544.

The green-headed spruce sawfly (*Pikonema dimmockii* (Cress.)) has been reported in Canada from Labrador to the Pacific coast, and in many of the Northern States from Maine to Idaho. It feeds on various species of spruce, but apparently never becomes abundant enough to cause serious defoliation.

The larva of **the willow sawfly** (*Pteronidea ventralis* (Say)) is black or greenish black with a row of large yellow spots on each side of the body, the spots becoming lighter and the body a slate black when the larva is full grown. It is then about 3/4 inch long (fig. 163).

FIGURE 163.—Larvae of *Pteronidea ventralis* on a willow leaf. About × 2.

This species is widely distributed over much of the eastern part of the United States and Canada. The larvae prefer willow as food but will attack poplar. They are vigorous defoliators, especially of young trees, and occasionally strip willows in ornamental plantings and in long stretches along the banks of streams. It is considered one of the most injurious pests of basket willow, particularly in the South, where there are several generations annually. There is an overlapping of generations, and the number of generations a year varies in the different climatic ranges.

There is probably one generation a year in the northern limits of its habitat, two and sometimes a partial third in some New England localities, and as many as five in the District of Columbia. Occasionally in New England some specimens remain in a diapause for at least 19 or 20 months. The adults emerge in the spring, the exact dates depending on the climate. The females lay their eggs in pockets cut in the tissue of the leaves. The young larvae at first feed in close colonies, making small holes in the leaves. Apparently the development of a generation requires about 1 month under the most favorable conditions. Cocoons are spun in the litter or topsoil beneath the trees. The winter is passed as prepupal larvae within their cocoons.

The full-grown larva of *Pteronidea odorata* (Dyar) is about ⅝ inch long. The head is shining black, and the body is light green with three longitudinal rows of almost contiguous black spots on the back, but in younger larvae these rows of spots are well separated. The sides of the body are spotted with black, a row just beneath the spiracles and another near the bases of the legs being largest and most conspicuous. The venter has five pale yellow scent glands behind the abdominal legs on joints 6 to 10. The anal plate is black with a pair of terminal spines, and the thoracic legs are black except at the joints. This species occurs through the Northeast and in some years is abundant locally. The larvae feed on species of willow. In New England there may be two generations annually or one and only a partial second. The winter is passed as prepupal larvae in cocoons on the ground. The adults emerge late in May and in June. First-generation larvae may be found in June and July. Adults of the next generation emerge during the latter part of July, in August, and in the early part of September. Second-generation larvae are found in August and September.

In addition to the species of *Pteronidea* already discussed, several others are native to the Eastern States and occasionally become abundant enough to attract attention, at least locally. The larvae of a number of species are somewhat similar in appearance. In some of the more common species the full-grown larva prior to molting into the last instar is about ⅝ to ¾ inch in length. The head is brownish to blackish. The body is generally light green with dark, brown to black markings, those on the back consisting of rows of dots or more or less broken transverse stripes. The sides of the body are more or less speckled but usually have a row of conspicuous spots irregular in shape just below the spiracles and one or two rows near base of the legs. Some have the legs marked with black and others concolorous with the body. A few have a row of black spots on the venter of the abdomen between the legs. *P. alnivora* Roh. feeds on alder, *P. trilineata* (Nort.) on locust, *P. corylus* (Cress.) on hazelnut, *P. populi* (Marlatt) and *P. plesia* Roh. on poplar, *P. harringtoni* (Marlatt) on willow, and **the imported currant worm** (*P. ribesii* (Scop.)) on currant and gooseberry.

The records indicate that these species may have two complete generations or one and a partial second annually in the Northeast. It is possible that farther south some may have a partial third generation. They pass the winter in the cocoon stage either in the duff on the ground or in the topsoil. The adults emerge early in the spring, usually over a period of 2 or 3 weeks, the dates depending somewhat on the climatic range and on the season. The larvae of the first generation hatch out and begin to feed gregariously soon after the leaves of their food plant become fully expanded. Because of the extended period of adult emergence, there is an overlapping of generations, and larvae may be found from early in May until late in September.

The genus *Pontania* has many species and most of those of known habits are gall makers on willow and poplar, although a few are leaf folders and at least one species is known to infest the aments of willow. The adults are small, about 3/16 to 1/4 inch in length, and black or reddish yellow. The larvae are usually white or greenish white with black spots about the eyes, but in some species the head is faintly tinted with brownish. Some species of *Pontania* can probably be found throughout the entire range of the willows and poplars in North America. The gall-making species cause a leaf swelling (fig. 164), usually but not always globular. The galls are fleshy, project at least partially on both surfaces of the leaf, and are usually green, greenish yellow, or tinged with red. These galls result from the punctures made in the leaves by the female sawflies in laying their eggs, the wound closing and becoming invisible to the naked eye. The species that have been observed have one generation annually, and each larva feeds within the gall until full grown. Each species overwinters in a cocoon of delicate texture, which is usually con-

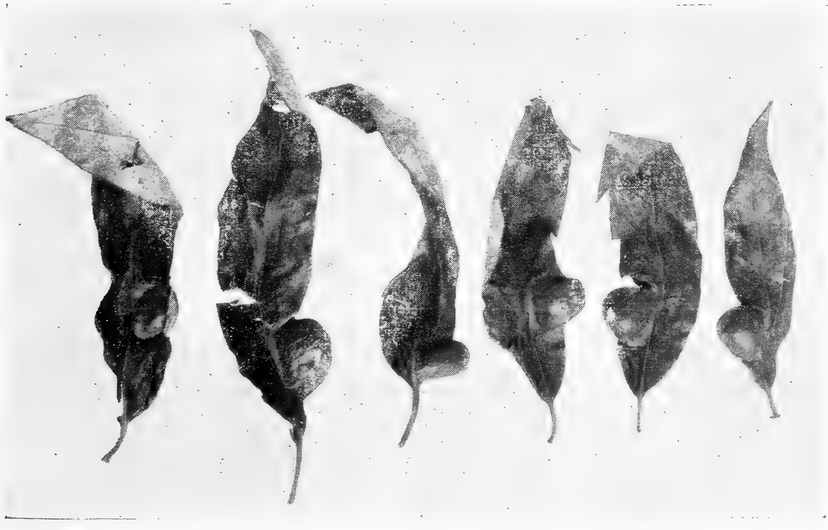

FIGURE 164.—Galls of *Pontania* sp. on willow leaves.

structed in the ground or in decayed wood, although some may occur between leaves or in the galls. The adults emerge in April and May, and the females lay their eggs in the tender leaves. Felt (*153*) listed many gall-making species known to occur in the United States in 1940, together with a key to their galls. The production of the galls on the leaves is the only injury caused by these insects, and apparently this is never of sufficient importance to warrant artificial control measures.

The larva of **the poplar leaf-folding sawfly** (*Pontania bozemani* Cooley) is pale green and is found on the inner surface of a leaf fold, which it skeletonizes. This species occurs in the prairie region of Canada and southward into the United States. The adults emerge in May. In laying their eggs the females injure the tender leaves, thus causing a part of each to fold over. Egg laying continues through July. The larva vacates the leaf fold at certain times and eats holes through the leaf. The injured portions of the leaves become blackened, giving the infested trees an unsightly appearance. When full grown the larva constructs its cocoon within the fold and drops to the ground with the leaf.

Pontania populi Marlatt folds the edge of the leaf of big toothed aspen in May, and *P. robusta* Marlatt is a leaf folder on quaking aspen. The full-grown larva of *P. amentivora* Roh., **the willow-cotton sawfly,** is about ½ inch in length, the head is dark brown, the eye spots are black, and the body is white, with faint grayish spots about the bases of the hairs. The last-named species occurs in some of the Middle Atlantic States and its larvae infest the aments of willow (*Salix humilis* Marsh). The adults appear late in March and early in April. The premature showing of "cotton" by infested aments (fig. 165), a characteristic of attack, generally occurs about the middle of April. The larvae become fully grown during the latter part of April, and drop to the ground to spin their cocoons. Apparently there is one generation annually, and the winter is passed as prepupal larvae in cocoons. Although sometimes abundant locally, its damage probably is of little or no economic importance.

As in the genus *Pontania*, the insects in the genus *Euura* are small and are gall makers. The larva is usually yellowish or greenish white, with the head often tinted slightly with brownish and with the eye spots black. Those species that have been studied attack willow, and it is probable that some species occur throughout the entire range of their food plant. Ross (*361*) and Felt (*153*) listed several species that are found in the United States. The gall is usually a somewhat woody swelling of the twig, sometimes involving the entire shoot in a gradual enlargement and sometimes being an abrupt swelling on one side of the shaft. A few are formed on the leaf or the leaf petiole (fig. 166). Buds may also be enlarged and the interior altered through occupation by these insects. The galls are often smooth surfaced, but are sometimes cracked or seamed, and their color is usually that of the bark of the twig attacked. The inner structure is fleshy at least during the period of development. The growths these sawflies produce on willow shoots can cause economic losses where normal twig development of willow is important.

These sawflies apparently have one generation a year. The adults emerge in the spring, and the species that have been observed lay

FIGURE 165.—Work of *Pontania amentivora* on *Salix humilis*.

FIGURE 166.—Galls of *Euura* sp. on willow leaf stems.

their eggs in the shoots. Since the growth of the gall apparently begins before the larva hatches from the egg, it is probable that the stimulus for abnormal growth is introduced into the plant principally as the egg is laid. A gall develops also when the egg apparently fails to hatch. In some instances the full-grown larvae vacate the galls and construct thin cocoons in the ground in which they pass the winter, whereas in other species they remain in the galls and emerge as adults the following spring. The most practical method for combating these sawflies is to cut and destroy the infested twigs while the larvae are in the galls.

The full-grown larva of **the dusky birch sawfly** (*Croesus latitarsus* Nort.) is about ⅞ to 1 inch in length. The head is shiny black, the body yellowish green shaded with black, and on each side is a subdorsal row of more or less distinct black blotches, and in the subspiracular area a series of black spots. In the earlier instars the larva is fuscous, with few or no distinct dark markings. This species is generally common through New England and the Lake States. Its preferred food plant is gray birch, although other birches (black, paper, red, and yellow) have also been recorded as hosts. Undoubtedly this insect may be found over the entire range of the gray birch. The larvae are gregarious (fig. 167) and often are found defoliating small saplings, but there are no records to indicate that this species has ever defoliated extensive areas. There may be two complete generations or one and a partial second annually. The winter is passed as a prepupal larva in its cocoon in the topsoil. This larva transforms to the adult stage during May or the first half of June. Adults of the next generation may emerge from the middle of July to the middle of September, or in May or June of the following year; therefore the generations overlap, and larvae may be found from early in June until late in the fall.

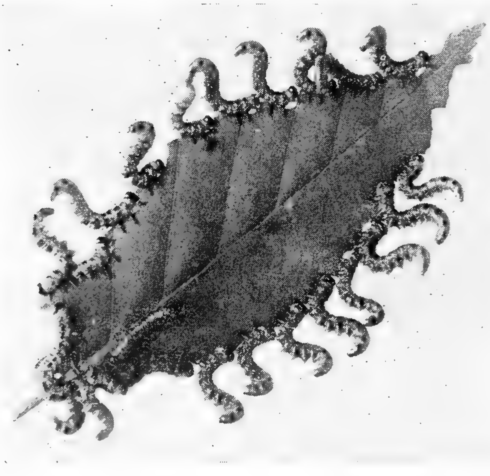

FIGURE 167.—Larvae of *Croesus latitarsus* on birch leaf. (Courtesy Conn. Agr. Expt. Sta.)

SUBFAMILY ALLANTINAE

The full-grown larva of **the curled rose sawfly** (*Allantus cinctus* (L.)) is about ¾ inch in length. The head is yellowish brown, with a brownish-black stripe on the middle of the face, and the eyes are black. The body is metallic green above and is marked with white dots, and the lower surface, including the legs, is grayish white. This species is found from Minnesota to Maine and as far south as northern

Virginia. Its food plants are wild and cultivated roses. The young larvae begin feeding by skeletonizing patches from the underside of the leaflets, later eating so as to cause holes in the leaflets, and finally eating all but the largest veins. The full-grown larvae form cells in the pruned ends of rose shoots or in pieces of soft wood or pith, in which they transform to the adult stage. In its southern range this species has two generations a year, but in its northern range it probably has only one. Middleton (*300*) discussed this species, which was formerly known as *Emphytus cinctipes* Nort., **the coiled roseworm.**

The larvae of *Macremphytus tarsatus* (Say) and *M. varianus* (Nort.) are rather common defoliators of *Cornus* spp. in the Northeastern and Lake States. In each species the larva has a shiny black head, and the body is densely covered with a white powdery secretion. In the early instars the body is whitish, but when nearly full grown the back is creamy yellow marked with grayish-black transverse bands or spots, and the venter and legs are yellowish. They have one generation annually. The adults emerge over a rather long period, from the latter part of May through July. Larvae may be found from July until October. In the laboratory the full-grown larvae bore into and successfully pupate in cork stoppers, so in nature it is probable that they form their cells in pith or in decaying wood on the ground. The winter is passed as prepupal larvae and some may remain in diapause in their cells for one or more years.

Subfamily BLENNOCAMPINAE

The brown-headed ash sawfly (*Tomostethus multicinctus* Roh.) (fig. 168) is about 3/4 inch long as a full-grown larva. It is yellowish white or greenish white, and the head is brownish and much smaller than the thorax. This species is sometimes a serious defoliator of red ash and white ash, particularly of shade trees. It is widely distributed throughout the eastern and central parts of the United States, having been recorded from the New England States, Maryland, the District of Columbia, Virginia, Kansas, and Michigan. There is one generation each year. The adults emerge about the time the leaf buds of the ash show green, which is usually late in April or in May, the maximum emergence in a locality depending somewhat on weather conditions. The eggs are laid in the tissue of the developing leaflets. The young larvae at first eat holes in the leaflets, but later consume entire leaf areas. In the vicinity of Washington, D. C., the larvae may complete their growth by the latter half of May, but in parts of New England it is sometimes the third week in June before they are fully grown. The prepupal larvae pass the summer, fall, and winter in earthen cocoonlike cells constructed in the topsoil.

The larva of **the black-headed ash sawfly** (*Tethida cordigera* (Beauv.)) is whitish with a yellowish tinge. It is about 3/4 inch long when full grown. The head is shiny black and the thoracic legs blackish brown. The head is dark brown in the prepupal stage. Its distribution, food plants, habits, and life history are very similar to those of *Tomostethus multicinctus*, and it also occasionally causes serious defoliation of shade trees.

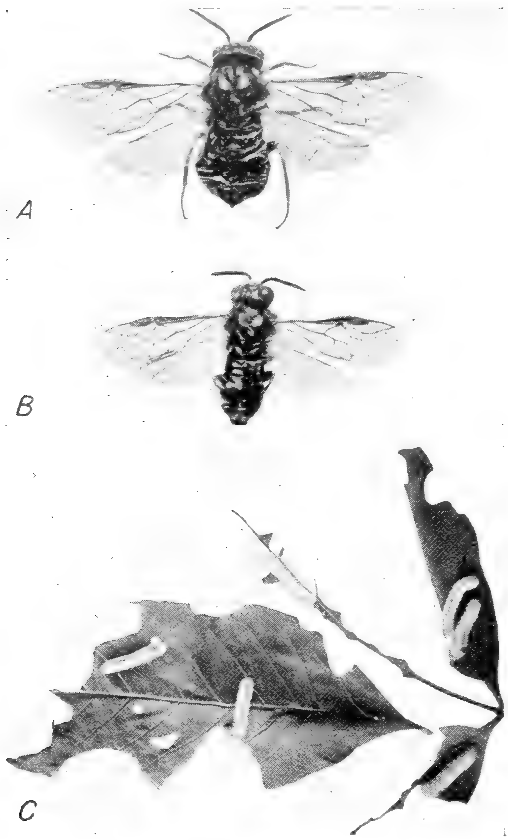

FIGURE 168.—The brown-headed ash sawfly (*Tomostethus multicinctus*): *A*, Adult female; *B*, adult male; *C*, larvae.

The full-grown larva of **the butternut woolly worm** (*Blennocampa caryae* (North.)) is 3/4 inch in length. The body is covered with flocculent white tufts, which rub off on being touched, and the naked larva is then green, darkest on the top, and with indistinct blackish spots on the sides. The head is white with black eye spots. This species occurs throughout the Northeastern States and in the southern parts of Ontario, New Brunswick, and Quebec, Canada. The larvae feed gregariously on the foliage of butternut, black walnut, and hickory in July and August, and occasionally they cause considerable defoliation locally. The cocoon is formed in the ground and is composed of particles of earth and sand cemented together. As far as is known, there is one generation annually and the winter is passed in the cocoon stage.

There are many species in the genus *Periclista*, and those whose biology is known feed on the foliage of hickory or oak. Several species are usually common in the Northeastern States. The larvae of some species are sometimes abundant enough locally to cause the foliage to appear ragged. In general, the larvae are about 1/2 to 3/4 inch in length when fully grown. The head in some species is pale green; in others, black with a pale face or entirely black. The body is usually leaf green, although in some species the back is grayish, and each is armed with rows of small black, green, or white single, two-pointed spines, some being **V**- or **Y**-shaped. The first thoracic segment immediatey back of the head is usually fringed with spines. *Periclista caryicolum* (Dyar) and *P. hicoriae* Roh. feed on hickory, *P. diluta* (Cress.) on white oak and swamp white oak, *P. purpuridorsum* Dyar on red oak and white oak, *P. quercus* Roh. on black oak, scrub oak, and white oak, and *P. similaris* Roh. on white oak and scarlet oak. Each of these species has one generation annually. The adults emerge late in April or early in May and the larvae are active during the latter half of May and in June. Cocoons are spun in the ground in which they pass the winter. Occasionally some individuals remain in diapause for one or more years.

Family XYELIDAE

The family Xyelidae is a small one and, although some 25 species, representing 6 genera, have been described from boreal America, little is known about the biology or habits of most of them. Apparently they seldom, if ever, become abundant enough to attract much attention. *Xyela minor* Nort. is present in the Eastern States, and its larvae feed on the staminate flowers of pine. *Megaxyela major* (Cress.) has been recorded from New York, Kansas, and Texas, where the larvae feed on the foliage of hickory and pecan. *M. aviingrata* (Dyar) is found in New York, Indiana, and Illinois. The larvae feed on butternut and hickory in May. *Macraxyela ferruginea* (Say) occurs from Maine to Idaho and the larvae feed on elm.

Family PAMPHILIIDAE

The adults of the Pamphiliidae are moderately large with long slender antennae; the abdomen is flattened, with sharp lateral margins, and the ovipositor of the female is short. Unlike most species of sawflies, the females of many in this family deposit their eggs more or less exposed. The larvae are medium in size with the body subcylindrical and slightly flattened from the ventral aspect. They have long, seven-jointed antennae and well-developed thoracic legs, but they lack abdominal legs. There is a fleshy protuberance on the venter of the eighth abdominal segment. The tenth segment is depressed, rounded on the caudal margin, usually setiferous, and always has a median hooklike suranal process near the caudal margin, and the subanal lobe has a pair of setiform, three-segmented conspicuous subanal appendages. Yuasa *(439)* included this family in his discussion of the group in 1922. The larvae of some species are gregarious. Some build nests by webbing together leaves of their food plant, by rolling the edge of a leaf, or by spinning silken tubes in which to live.

The full-grown larva of **the pine false webworm** (*Acantholyda erythrocephala* (L.)), an introduced web-making sawfly, is about 3/5 to 4/5 inch in length and pale greenish gray with longitudinal middorsal, lateral, and midventral stripes of purplish red. The head is clay-yellow, with dense, small spots of dark brown above and with black eyes (fig. 169). The prepupa is apple green and the pupa is green with black eyes. Griswold *(204)* gave a short report on this species in 1939. Records show that this species is widely distributed in Europe and it has also been reported from Chosen and Japan. In the United States it was first found in 1925 at Chestnut Hill, Pa., and it is now known to occur in parts of Pennsylvania, New Jersey, Connecticut, and New York. Red pine and white pine are the most favored food plants of the larvae, but they also feed on Scotch, mugho, Swiss mountain, Japanese red, and Austrian pines. In recent years they have severely defoliated some red pine and some white pine trees in New Jersey. Griswold found one generation annually in New Jersey, where the adults emerge from their earthen cells from the middle of April until early in May, and the females usually lay their eggs contiguously in rows of 3 to 10 on the flattened surfaces of the pine needles of the previous year's growth. The eggs hatch in the last 3 weeks in May. The young larvae spin a loose webbing about themselves and feed gregariously, cutting off the needles just above the bundle sheaths and pulling them into the webbing, until the needles are entirely consumed. In the later instars the larvae spin individual silken tubes about themselves along the twig. Considerable frass and needle fragments usually adhere to the outside of these tubes. Larvae may be found from early in May until late in June. The full-grown larvae drop to the ground and construct earthen cells about 2 or 3 inches below the surface, in which they hibernate. Pupation takes place the following spring.

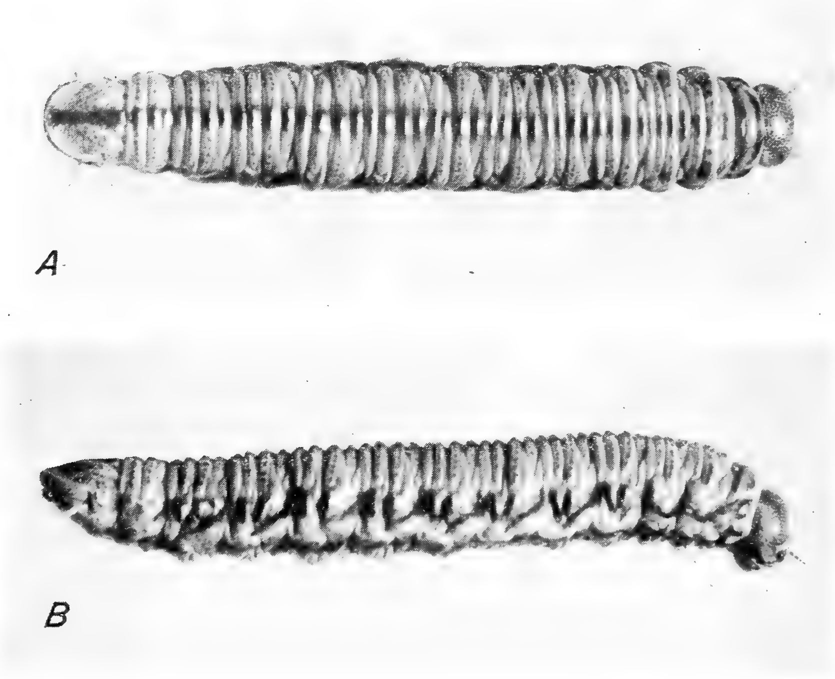

FIGURE 169.—Dorsal and lateral views of larvae of *Acantholyda erythrocephala*, about × 4.

The full-grown larva of *Acantholyda* (*Itycorsia*) *zappei* (Roh.), **the nesting pine sawfly,** is about ¾ to 1 inch in length. The head is brown and the body green, with a dorsal stripe of a darker shade. This species occurs in Connecticut and other Northeastern States, but the limits of its range are not definitely known. Its food plants include Austrian, jack, pitch, red, and Japanese red pines, but thus far it has never been reported as causing large-scale defoliation. The adults emerge late in the spring, and the females lay their crescent-shaped, pale yellowish eggs singly and externally on the developing needles of the new growth late in June or early in July. When a young larva leaves the egg it spins a web about itself on the twig. In feeding it cuts off the needles near the base and feeds on the severed ends, drawing the needles into its web as it eats. The webs are enlarged from time to time, and when the larvae are full grown the webs may be 4 to 5 inches in length (fig. 170). The full-grown larvae drop to the ground and pass the winter in cells in the earth, transforming to pupae and adults in the spring, and thus complete one generation annually (Zappe, *440*).

The full-grown larva of *Neurotoma fasciata* (Nort.) is about ¾ inch in length. Prior to the last instar its head is dark brown or blackish, the body brown with a pinkish dorsal line, and the thoracic legs are slender and tapering. There is a single pair of rather similar leglike appendages on the last abdominal segment, but otherwise the abdomen is legless. The last-instar larva is a deep green. This species is widely distributed and generally common through the Northeastern States. The larvae feed gregariously on wild black cherry, building nests of webbing and frass on the small branches or shoots. They show a decided preference for young, small trees, and the dirty, brown nests present an unsightly appearance. There is one generation annually. The adults emerge late in May and in June, and the females deposit the eggs on the foliage. Apparently the egg laying extends over several weeks, as larvae may be found from the first of June through September. The full-grown larva burrows into the soil and, by cementing together particles of earth, constructs a cell in which it passes the winter as a prepupal larva. Laboratory experiments show that some of the larvae often remain in diapause one or more years.

FIGURE 170.—Work of *Acantholyda zappei* on Austrian pine. (Courtesy Conn. Agr. Expt. Sta.)

The plum web-spinning sawfly (*Neurotoma inconspicua* (Nort.)) occurs throughout the Northeastern States, and westward into the Dakotas, and in Manitoba, Canada. The larvae feed on the foliage of the plums and sand cherries, and sometimes cause considerable injury. They are gregarious and web together the foliage, the webs being somewhat similar to those of **the fall webworm** (*Hyphantria cunea*). There is one generation annually and the winter is passed in the ground in a manner similar to that of *N. fasciata.*

Superfamily *SIRICOIDEA*

The Horntails, or Wood Wasps

The adults of the superfamily Siricoidea are commonly called horntails or wood wasps because the end of the abdomen terminates in a spine or horn directed backward and somewhat upward, and also because many resemble wasps. They are closely related to the sawflies but differ from them by the fact that the abdomen of the female is furnished at the tip with a rather long drill or boring apparatus, instead of the sawlike plates. They further differ in the habits of the larvae, which are borers in solid wood. The female drills a deep hole into a tree and deposits an egg in the bottom of it. Sometimes the boring apparatus becomes caught in the wood, and the female remains a captive until she dies. The larvae are cylindrical and eyeless, and have three pairs of fleshy, unjointed, and poorly formed thoracic legs and no abdominal prolegs.

Both deciduous and evergreen trees are infested by the various species of horntails. The larval galleries through the wood are cylindrical and tightly packed with fine boring dust. The horntails generally attack trees or portions of trees that are dead or in a badly weakened condition. A few species, however, have been reported as attacking trees in a vigorous condition. Transformation to the adult stage takes place in the burrows or galleries, and the holes through which the adults emerge are circular in outline.

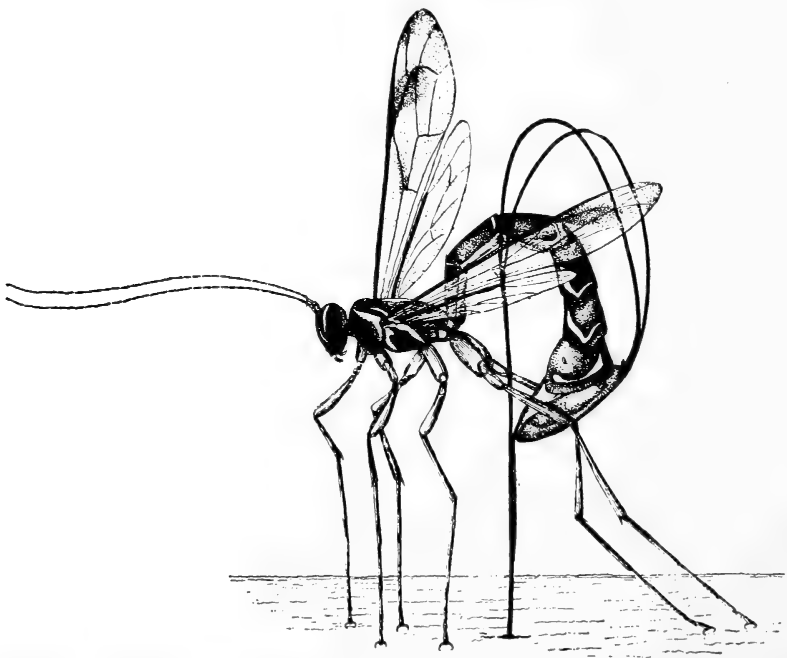

Figure 171.—Female of the parasite *Megarhyssa lunator* ovipositing in a tree infested with horntails.

Horntails are frequently attacked by interesting insect parasites. Two species, *Megarhyssa atrata* (F.) and *M. lunator* (F.), are striking in appearance and usually attract considerable attention whenever observed (fig. 171). These are called "long stings." They are long, slender, wasplike insects with four membranous wings, and the female of each has an extremely long hairlike egg-laying device, which accounts for the common name. This apparatus is, however, not a sting but a drill for laying the eggs within a horntail gallery deep in the infested wood. It is composed of three separate pieces which function together, both in piercing the wood and introducing the egg. The females of the "long sting," like those of the horntails, not infrequently become caught with their ovipositor deep in the wood and remain captives until they die.

Family XIPHYDRIIDAE

The family Xiphydriidae is composed of a small number of species. The adults are ½ to ¾ inch in length and are black and yellowish or reddish, or almost entirely black. The antennae are setaceous and have about 20 segments, the back of the head is separated from the pronotum by an elongate neck, the pronotum is very short medially and not angulate laterally. The front tibia has only one apical spur, which is cleft at the apex, and the sheath of the ovipositor is seldom longer than the last tergite. The larvae are cylindrical, whitish, and about ¾ inch long when fully grown. The thoracic legs are fleshy, not well formed and not jointed, and there are no abdominal prolegs. The abdomen terminates in a distinct brown prong, which is semicircular and concave and ornamented with teeth on the underside.

The larvae bore into and make galleries in moderately sound to partly decayed wood of dead basswood, birch, hickory, American hornbeam, or maple. Their work may aid somewhat in the penetration and distribution of wood-destroying fungi. Little information is available on the biology of these insects; however, the adults are known to emerge from the wood from early in the summer to midsummer, and shortly after emergence to lay their eggs in similar suitable wood. The following species occur in the Northeastern States: *Xiphydria abdominalis* Say attacks basswood; *X. albicornis* Harr., sugar maple; *X. attenuata* Nort., birch; *X. erythrogastra* Ashm., American hornbeam; *X. hicoriae* Roh., hickory; *X. maculata* Say, maple; *X. mellipes* Harr., birch; *X. provancheri* Cress., birch; and *X. tibialis* Say, elm. These insects usually are not abundant, but if for any reason it seems advisable to combat them, the collection and the destruction of the infested wood is recommended.

Family SIRICIDAE

The Siricidae are medium to large cylindrical insects with the head, thorax, and abdomen of equal width. They have long, filiform antennae with about 15 segments, well-developed wings, and the anterior tibiae each with only one apical spur, which is cleft at the apex. The adults are mostly black or metallic dark blue, or have combinations of black, red, and yellow. The females are provided with long ovipositors and sheaths. Eggs are deposited in the bark or wood of many kinds of trees and shrubs. The larvae are usually cylindrical and yellowish white and have a small spine at the posterior end of the body. They are wood borers. Some of the species may have one generation annually, whereas in other species it may take 3 years to complete a generation.

Subfamily TREMICINAE

The adult female of **the pigeon tremex** (*Tremex columba* (L.)) (fig. 172) ranges from $1\frac{1}{2}$ inches to about 2 inches in length. The head, antennae, and thorax are reddish and black, and the abdomen is cylindrical and black, with ochre yellow bands and spots along the sides. The horned tail at the hind end of the body, which is merely a sheath for the boring structure of the ovipositor, is yellowish. The legs are dull yellow. The wings are smoky brown and expand 2 or more inches. The male is reddish, varied with black, $\frac{3}{4}$ to $1\frac{1}{2}$ inches in length, and the abdomen is not furnished with a borer, but ends with a conical horn. The larva is whitish, cylindrical, and about 2 inches in length when full grown. The thoracic legs are fleshy, not well formed and not jointed. There are no abdominal legs. The abdomen terminates in a prominent short brown process which is strongly sclerotized and compressed, and has two pairs of small but distinct teeth.

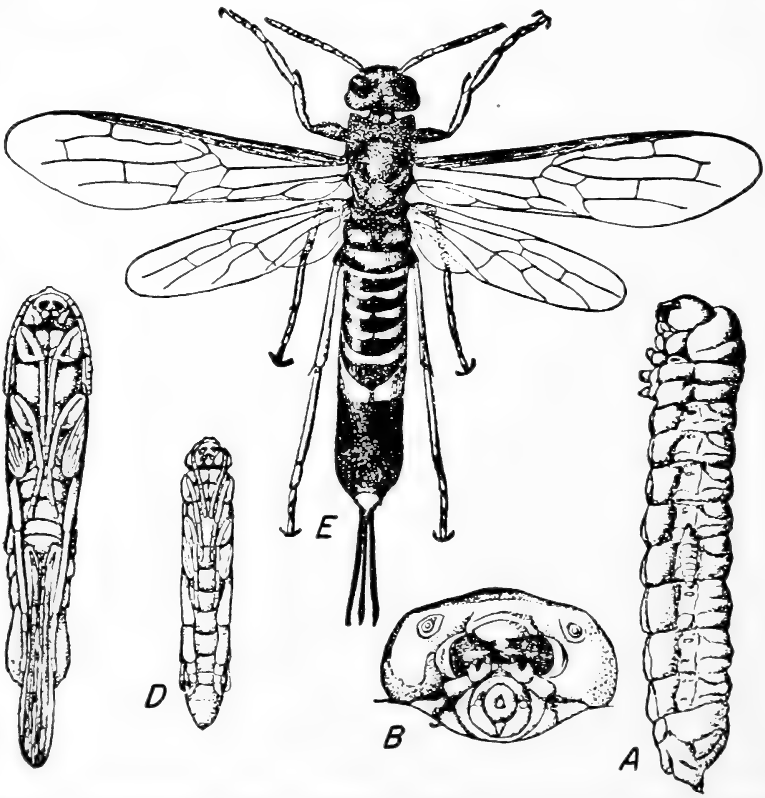

Figure 172.—The pigeon tremex (*Tremex columba*): *A*, Larva; *B*, head of larva, enlarged; *C*, pupa of female; *D*, pupa of male; *E*, adult female.

This species is the most common of our horntails, infesting apple, beech, birch, elm, hickory, maple, oak, pear, and sycamore. It is widely distributed and probably occurs throughout most of the range of its food plants in North America. The insects attack dead, dying, and seriously weakened trees, and injured and dead areas in living trees. The larvae bore galleries through the wood, thus weakening the supporting strength of trunks and branches, and undoubtedly aid in the penetration and distribution of wood-destroying fungi. The adults emerge and are active early in the summer. The females apparently examine the host trees with care before selecting a place to bore into the wood for ovipositing. Although eggs are deposited singly at a depth of ½ inch in the wood, a number may be found near each other in a limited area. The larvae on hatching in the wood make galleries and feed for probably one season. Some authors believe that there is one generation annually. Transformation takes place in the burrow and the adults emerge through circular holes about ⅓ inch in diameter.

Subfamily SIRICINAE

Urocerus albicornis (F.), **the white-horned horntail,** is blue-black or black and measures about 1 to 1¼ inches in length. Most of the antennae, the cheeks, the bases of the tibiae and the tarsi, and sometimes lateral spots on the abdomen are white. The wings are smoky brown and expand nearly 2 inches. The horned tail of the female is shaped like the head of a lance. This species occurs throughout boreal North America and infests cedar, pine, and spruce.

The female of *Urocerus flavicornis* (F.), **the yellow-horned horntail,** is about 1½ inches in length, and is black, with the first and sixth segments and part of the seventh yellow. The male measures about ⅘ inch in length and is black with segments 2 to 5 of the abdomen orange-yellow. This species infests spruce and other conifers throughout northern New England, northward to Labrador, and westward to the Pacific coast. *U. cressoni* Nort., **the black and red horntail,** is widely distributed over New England and has been found on poplar.

The blue horntail (*Sirex juvencus* (L.)) is metallic blue, except for the legs, which are dark red or marked with yellow. It is found in pine, fir, and spruce and has been reported from New England, throughout the Western States, and in parts of Canada. *S. juvencus* race *cyaneus* F. infests spruce and pine in New England. *S. edwardsii* Brulle infests badly weakened pitch pine trees in New England.

Family CEPHIDAE

The Stem Sawflies

The stem sawflies are borers in stems of plants or in the tender shoots of trees and shrubs. The adults are slender-bodied and are mostly black or dark colored, either with or without narrow yellow bands, and are seldom more than ¾ inch in length. The antennae are filiform, slightly spindle-shaped or club-shaped, and with 20 to 30 segments. The anterior tibiae each have only one apical spur, which is cleft at the apex, the inner tooth is small, and the outer tooth large (Yuasa *439*). The larva is generally pale or creamy white; the head semiglobose, moderately large, but narrower than the thorax, pale brown, or concolorous with the body, the body cylindrical, enlarged at the thorax, and never with distinct bright marks. The thoracic legs are vestigial and fleshy and the prolegs are wanting. Lateral lobes are prominent. The ultimate segment has a distinct suranal process and the sternum has a pair of inconspicuous subanal appendages. The larvae are internal feeders and transform to the pupal and adult stages in their tunnels.

The full-grown larva of **the willow shoot sawfly** (*Janus abbreviatus* (Say)), is about ½ inch in length (fig. 173). It is white and cylindrical, with fleshy thoracic legs which are not distinctly jointed,

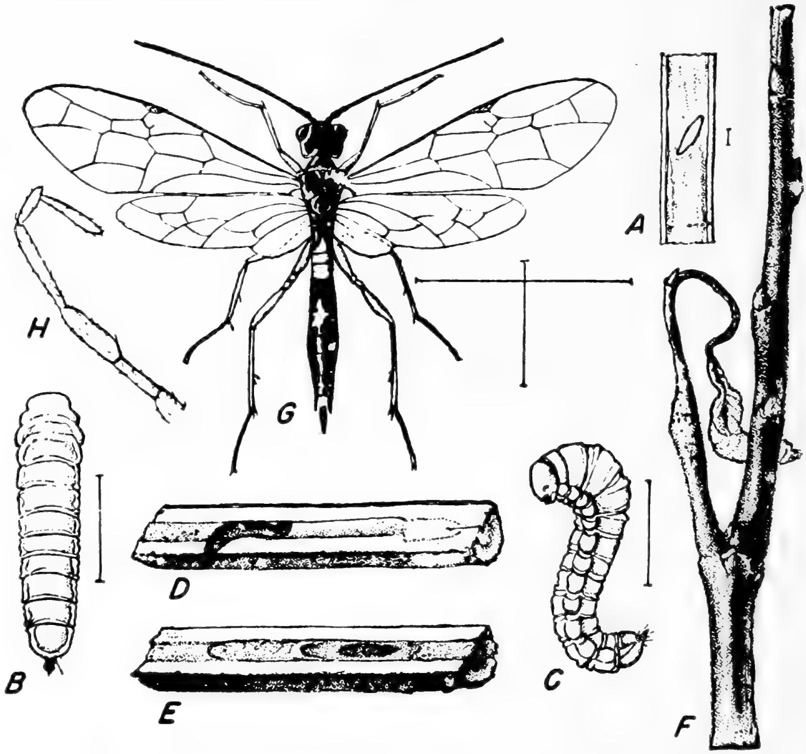

FIGURE 173.—The willow shoot sawfly (*Janus abbreviatus*).

and no abdominal prolegs except a small pair on the underside of the last segment. The tip of the abdomen is furnished with a short, tubular prong. This species attacks poplar and willow, in the Northeastern States, westward into Minnesota, and southward into Texas. The adults emerge late in May and in June, and the females puncture the shoots of willow and poplar in which they deposit their eggs They often weaken or girdle the shoots above the point of egg laying. The larvae, however, cause the principal injury by boring down the shoots through the pith (fig. 174), killing back the shoots for varying distances. The larvae become full grown late in the summer and make cocoonlike structures by lining the occupied portion of the burrows with thin, glazed, transparent membranes. The winter is passed

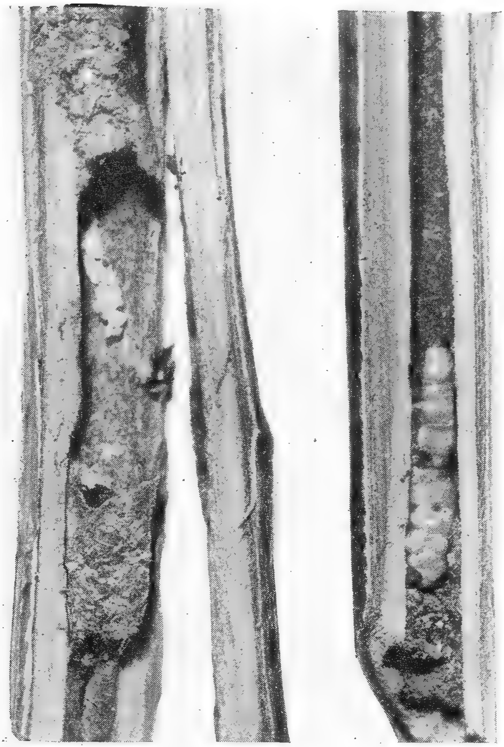

FIGURE 174.—Cocoon and larva of *Janus abbreviatus* in poplar shoot.

FIGURE 175.—Larva of *Hartigia trimaculatus* in a rose stalk.

within the shoot. When control measures seem advisable, cut and burn the infested shoots. **The currant stem girdler** (*Janus integer* (Nort.)) attacks currant in the Northeastern States. *Hartigia trimaculatus* (Say) is also found through the Northeastern States, and its larvae bore in the stems of blackberry and rose (fig. 175.)

SUBORDER CLISTOGASTRA OR APOCRITA

BEES, WASPS, ANTS, AND PARASITES

By PHILIP B. DOWDEN

The greater number of the Hymenoptera, including the bees, wasps, and parasitic forms, belong to the suborder Clistogastra. It is distinguished by a basally constricted or petiolate abdomen and an ovipositor adapted for stinging or piercing. The larva is legless and maggotlike in form. It has a definite head with mandibles or teeth attached, but in certain of the parasitic forms the head is greatly reduced.

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Almost all the adults are highly specialized, and the larval habits vary decidedly. Bees provision their nests with nectar and pollen. The larvae of wasps are largely carnivorous. The feeding habits of adult ants differ greatly in different members of the family. Some are carnivorous, others utilize vegetable substance, and many feed on sweet fluids such as sap or honey dew. Different species of ants adopt different methods of nourishing their larvae. Many feed them on regurgitated liquid, carnivorous species give them portions of other insects, and fungus growers nourish their larvae with fungus hyphae. Many of the Cynipoidea, and a few of the Chalcidoidea are phytophagous. A few Cynipoidea, most of the Chalcidoidea, and all of the Ichneumonoidea are carnivorous, being either endo- or ectoparasites. Because of its feeding habits, the group as a whole has relatively few forms that cause serious economic loss to forests. In fact, most of the bees, predators, and parasites are distinctly beneficial.

KEY TO SUPERFAMILIES OF THE CLISTOGASTRA

(Based on Ashmead, 5)

1. Sting or ovipostor when present always issuing from tip of abdomen, trochanters one or two-jointed ---------- 2
   Sting or ovipositor issuing some distance before tip of abdomen, trochanters always two-jointed ---------- 8
2. Pronotum not extending back to tegulae; trochanter one-jointed -- 3
   Pronotum extending back to tegulae, or the latter absent -------- 4
3. Hind tarsi dilated or thickened, pubescence of head and thorax feathery or plumose ---------- Apoidea, p. 634.
   Hind tarsi slender, not dilated or thickened, pubescence of head and thorax simple, not feathery or plumose ------ Sphecoidea, p. 631.
4. Trochanters one-jointed ---------- 5
   Trochanters two-jointed ---------- 7
5. Abdomen in female greatly elongated, several times longer than head and thorax united; abdomen in male not especially long, clavate ---------- (Pelecinidae) Serphoidea, p. 621 (part).
   Abdomen in female rarely twice longer than head and thorax united, usually much shorter ---------- 6
6. Petiole with one or two scales or nodes ------- Formicoidea, p. 622.
   Petiole simple without scales or nodes ---------- Vespoidea, p. 627.
7. Mandibles large,-4 dentate; hind wings with a distinct venation (Trigonalidae) Vespoidea, p. 627 (part).
   Mandibles never large or 4-dentate; hind wings without a distinct venation ---------- Serphoidea, p. 620.
8. Front wings with a stigma; abdomen with the ventral segments most frequently soft and membranous -- Ichneumonoidea, p. 601.
   Front wings without a stigma; abdomen with ventral segments hard and chitinous without a fold ---------- 9
9. Pronotum extending back to tegulae; front wings with a marginal and basal cell; antennae not elbowed ------- Cynipoidea, p. 592.
   Pronotum not extending back to tegulae; wings with neither marginal nor basal cell; antennae elbowed ----- Chalcidoidea, p. 609.

SUPERFAMILY *CYNIPOIDEA*

Gall Wasps

Most members of the superfamily Cynipoidea are small, dark-colored insects. Biologically they are very interesting for the various species are either gall makers, inquilines, or parasites. The inquilines live in galls formed by another species. The antennae of the cynipids are not elbowed, the wings lack a stigma, the abdomen is strongly compressed, and usually the second abdominal tergite is larger than the remainder. These insects are often regarded as a single family, but Ashmead (*6*) defined two, the members of which exhibit different habits.

Family FIGITIDAE

Most of the members of the family Figitidae are parasites of dipterous larvae. A few are known to attack aphids, coccids, or hemerobiids, whereas others have been recorded from coleopterous larvae.

Family CYNIPIDAE

The family Cynipidae includes not only true gall makers, but also inquilines and a small number of parasites. Most of its members belong to the subfamily Cynipinae, or gallflies, and most of the species produce plant galls, within which their larval development is completed.

Subfamily CYNIPINAE

Although the Cynipinae are known as the gallflies, galls are also produced by many other groups of insects. Galls formed by flies, moths, beetles, and other insects have been described, but most of them are formed by gall midges, mites, plant lice, and true gallflies (Cynipinae). The galls made by mites and plant lice have open mouths from which the young escape, but the gallflies form a closed gall and the insect must make a hole in order to emerge. The forms of galls produced by different species of cynipids differ greatly, and all parts of the plant, from the roots to the flowers, may be affected. In every case the female insect lays an egg in the tissues of the growing plant, where development takes place. The larvae are consequently internal feeders and maggotlike in form. Pupation takes place within the larval cell.

Naturalists have speculated much regarding the phenomenon of gall formation, but the problem appears to be still far from being solved. There appears to be no evidence that cynipid galls are caused by an irritation of the tissues produced by the insertion of the ovipositor or by the injection of fluids at the time of oviposition, although certain sawfly galls are caused as a result of the latter. About all that can be said is that the cynipid galls are produced as a result of reactions of the cambium and other meristematic tissues of the plant to the stimulus produced by the living larva. Their formation and structure have been studied by Cook (*105*), Cosens (*106*), Felt (*151*, *153*), and others.

In many species of gallflies there is a remarkable alternation of morphologically and physiologically different generations. The galls of two successive generations, produced on different parts of the plant, often present entirely different forms; and the insects of the two generations are so different that they have been described as distinct species until, by careful studies of the life cycle, one has been found to be the offspring of the other. In species having an alternation of generations, one generation consists only of agamic females, whereas the other consists of both males and females, which reproduce sexually. The latter is the summer stage, whereas the agamic generation overwinters. In many species males have never been seen, therefore the successive generations are all similar and agamic.

It is remarkable that each species of the gall insects infests a special part of one or more species of plant. Even when the branches of several trees of one species intertwine, one tree may be loaded with galls, while the others are nearly or entirely free of them. Furthermore, the galls produced by different species are of such definite forms that they can be classified according to the species that produced it. Felt (*153*) prepared a useful manual, in which galls of many orders of insects are illustrated.

The cynipids are very restricted in their host relations. Kinsey (*264*) estimated that 86 percent of the known species of gall wasps produce galls on *Quercus* and are confined to that genus. Another 7 percent are restricted to species of *Rosa* and the remaining 7 percent are found on plants belonging to 35 genera of Angiosperms, more especially the Compositae. Felt (*153*) noted that there were 805 species of gall wasps and 731 of these occurred on oaks.

The cynipids are of relatively slight importance from an economic standpoint. A few insect galls are commercially valuable. Some have long been used in the manufacture of ink and in dyeing and tanning, and some provide winter food for bees. Kinsey (*265*) gave an excellent account of their economic importance and estimated that there are not more than 5 or 6 complexes, including possibly 10 species that do any appreciable damage. Three of these species are confined to the Pacific coast area. Appreciable damage is inflicted only by species that produce galls involving a considerable portion of the cambium or young twigs, although some undoubtedly destroy infested acorns. All the species listed by Kinsey in 1935 as causing some economic damage in the eastern part of the United States form twig or stem galls. These, plus a few that form common galls on leaves, stems, flowers, and seeds are described in the following paragraphs. Felt (*153*) listed 41 species that form root galls, but they are of minor importance.

STEM GALLS

The stem swellings caused by *Callirhytis floridana* (Ashm.) are found covered with normal bark in the fall. They look hard and woody, but when cut into they are found to consist of a thick layer of soft, white, parenchymatous tissue which cuts like cheese, the numerous cells being imbedded next to the true wood. Galls range from ½ inch to 3 or more inches long and are not more than ½ inch in diameter. They are formed close to the ground on the lower branches. Galls taken by Weld (*429*) in Missouri contained pupae when examined in November, the adults emerging in the spring. The species is generally distributed over the southeastern part of the United States and westward into Texas. It has been recorded from Chapman oak (*Q. chapmanii*), post oak (*Q. stellata*), and dwarf post oak (*Q. stellata margaretta*). Kinsey (*265*) reported large acreages of *Q. stellata margaretta* nearly killed by this gall wasp in eastern North Carolina in 1935, and damaging infestations as far west as Louisiana. He considers *Q. stellata margaretta* as practically worthless except as a ground cover, and notes that *C. floridana* has not been observed in abundance on the more valuable *Q. stellata.* Where practicable, pruning would probably give effective control.

Callirhytis (*Andricus*) *punctata* (Bassett), **the gouty oak gall** (fig. 176), infests the twigs and smaller limbs of red oak (*Quercus* *borealis*), black oak (*Q. velutina*), and water oak (*Q. nigra*) throughout the eastern part of the United States and westward into Texas. It forms a rough woody swelling on the shaft of twigs and larger branches ranging from ½ inch to 1½ inches in diameter. Frequently several galls fuse together to form a practically continuous mass of abnormal tissue. The gall wasps issue early in the spring and deposit eggs in the starting buds. The young insects develop in small blisterlike leaf galls, usually on or near the veins. Insects of the alternate generation probably issue in midsummer and cause the better-known knotty-branch galls. The species is usually localized on certain trees of a group. At times it becomes numerous enough to cause the death of twigs or good-sized branches. Trees so affected may lose their symmetry, and occasionally whole trees have been killed. The principal economic damage is done to specimen shade trees. Since the insects responsible for these growths are protected within the woody tissue of the galls during their developmental period and for most of their lives, the only practical control consists of cutting and burning the freshly swollen twigs as soon as the galls are observed and before the insects within complete their development and emerge as adults.

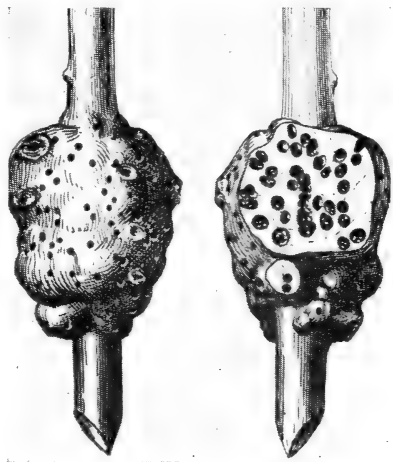

FIGURE 176.—The gouty oak gall (*Callirhytis punctata*). (After Felt.)

The galls formed by *Callirhytis* (*Andricus*) *cornigera* (O. S.),

FIGURE 177.—The horned oak gall (*Callirhytis cornigera*).

the horned oak gall (fig. 177), occur on twigs and branches of pin oak (*Quercus palustris*), scrub oak (*Q. ilicifolia*), blackjack oak (*Q. marylandica*), black oak (*Q. velutina*), and water oak (*Q. nigra* and varieties) throughout the eastern part of the United States and westward into Texas. They differ in appearance from gouty oak galls in having hollow conelike protuberances or "horns," through which the adults emerge early in the spring. The life history of the insect and the damage caused by it, are very similar to what has just been described for the gouty oak gall, and control is the same for both species.

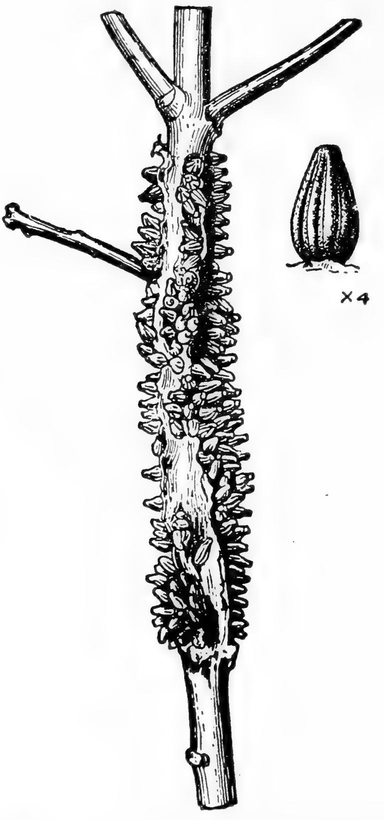

FIGURE 178.—Twig badly infested with the ribbed bud gall (*Andricus gemmarius*), and one gall enlarged four diameters. (After Felt.)

Andricus clavigerus Ashm. is another horned oak gall that is very abundant and is injurious to the southern willow oak (*Quercus phellos*). It is larger than *Callirhytis cornigera* and frequently more abundant. Life history, economic damage, and control are as described for the gouty oak gall. *A. aquaticae* (Ashm.) also forms terminal or subterminal swellings of branches and twigs. It is abundant on black oak (*Q. velutina*) and water oak (*Q. nigra*) in the Southeastern States. It is usually localized on certain trees, and pruning is the most practical method of control.

The galls of *Andricus gemmarius* (Ashm.), **the ribbed bud gall** (fig. 178), are somewhat conical, strongly ribbed and are about 3/16 inch long. They are found in crowded masses along longitudinal cracks in the bark. The species is generally distributed over the eastern half of the United States and has been recorded on red oak (*Quercus borealis*), black oak (*Q. velutina*), and blue jack oak (*Q. cinerea*). A sweetish secretion exudes from the galls early in the summer and attracts hosts of bees and flies. A serious infestation kills twigs and may even kill young trees. In his discussion of the American insect galls, Felt (*153*) included this species as *Callirhytis gemmaria*, and McDaniel (*283*) included this species in a bulletin on the Michigan galls. For control, prune infested twigs, as for *Callirhytis punctata*.

Neuroterus batatus (Fitch), **the oak potato gall** (fig. 179), forms swollen, uneven, stem galls, resembling a potato, about 3/4 inch thick and two or three times as long, on white oak (*Quercus alba*) and related forms. It occurs throughout the northeastern quarter of the United States. Internally this peculiar deformity of the twigs has a dense corky texture, and is composed of numerous larval cells. The insect has two generations annually. The first brood appears early in May from galls of the preceding year's growth, and the second brood in June from green galls. Females of the second brood oviposit in the galls from which they were produced. The early summer brood is made up of both sexes, whereas the overwintering brood is made up entirely of females. The species sometimes causes injuries by deforming young trees. Control is the same as for *Callirhytis punctata.*

Disholcaspis eldoradensis Beut. forms slightly elongated bulletlike galls on twigs of *Quercus lobata*, known locally as river-bottom oak, or California white oak. The galls burst out of cracks in the bark along the internodes. The lower half of the gall is tan colored and rather smooth, whereas the upper side is darker and deeply fissured. During the early stages of growth this rugose surface secretes an abundance of honeydew, which is often a valuable food for bees. About the middle of August the first galls appear. They produce honeydew for several days and are followed by a succession of galls a little farther along the same twig. In California the yield continues until the early rains late in October or early in November. The galls are said to be more plentiful following a mild winter or a very dry summer. Their chief economic value lies in the fact that they appear so late in the season that the bees are encouraged to raise a late brood, and honey produced from such nonfloral excretions is of good quality. The galls usually appear locally, but certain trees are heavily infested year after year.

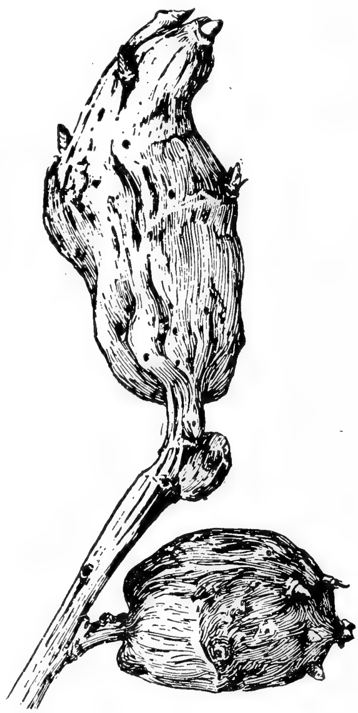

FIGURE 179.—The oak potato gall (*Neuroterus batatus*). Courtesy Amer. Mus. Nat. Hist.)

LEAF GALLS

Amphibolips confluentus (Harr.), **the large oak-apple gall** (fig. 180), is one of the most common and conspicuous oak galls. It is a nearly globular leaf or petiole swelling, from ½ to 2 inches in diameter and greenish or brownish in color, depending on its age. The interior is filled with a spongy mass, in the center of which is a single larval cell. The galls appear on the leaves early in the spring. Some of them produce both male and female adults in June, whereas others produce females in October. It is a common gall on many of the eastern oaks (*Quercus borealis*, *Q. coccinea*, *Q. velutina*, and others), but it cannot be considered injurious.

Galls of the species *Neuroterus floccosus* (Bass.), **the oak flake gall** (fig. 181), are commonly found on the under surface of the terminal leaves of swamp oak (*Quercus bicolor*) in the Eastern States. The galls are small (1.5 to 3.5 mm.), hemispherical, and covered with white hairs. As many as 200 galls may be found on a single leaf. This causes malformation and curling. Adult insects, as well as galls in all stages of growth, are present in July.

Galls produced by *Biorhiza forticornis* Walsh, **the oak fig gall** (fig. 182), have been recorded on the leaves, stems, and twigs of white oak (*Quercus alba*), scrub oak (*Q. ilicifolia*), and dwarf chinquapin oak (*Q. prinoides*) in the Eastern States. These galls are reddish bladder-like growths in dense clusters, and range from 1/4 to 1/2 inch in diameter. The adult female deposits a number of eggs a short distance from one another, apparently sinking them into the wood beneath the bark. A smooth round sweling soon appears above the egg. This swelling bursts and small round granules the size of a pinhead protrude from the opening. As these granules, or galls, grow they resemble small clusters of grapes. The larva lies in a small oval cavity at the base of each gall. Most of the adults emerge before winter, but some of the insects overwinter within the galls and emerge in June.

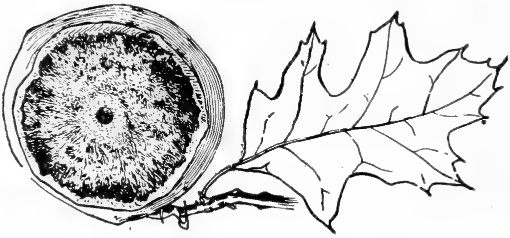

FIGURE 180.—The large oak-apple gall (*Amphibolips confluentus*). (Courtesy Amer. Mus. Nat. Hist.)

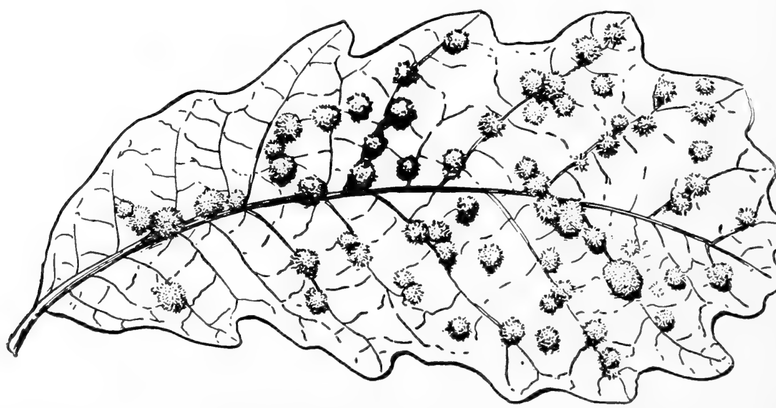

FIGURE 181.—The oak flake gall (*Neuroterus floccosus*). (Courtesy Amer. Mus. Nat. Hist.)

SEED AND FLOWER GALLS

The succulent oak galls formed by *Callirhytis* (*Dryophanta*) *palustris* O. S. (fig. 183) are common early in the spring, appearing on red oak (*Quercus borealis*) and pin oak (*Q. palustris*) in the eastern half of the United States. The growths are somewhat spherical, 3/8 to 1/2 inch in diameter, and consist of a distinctly fleshy wall and a rather

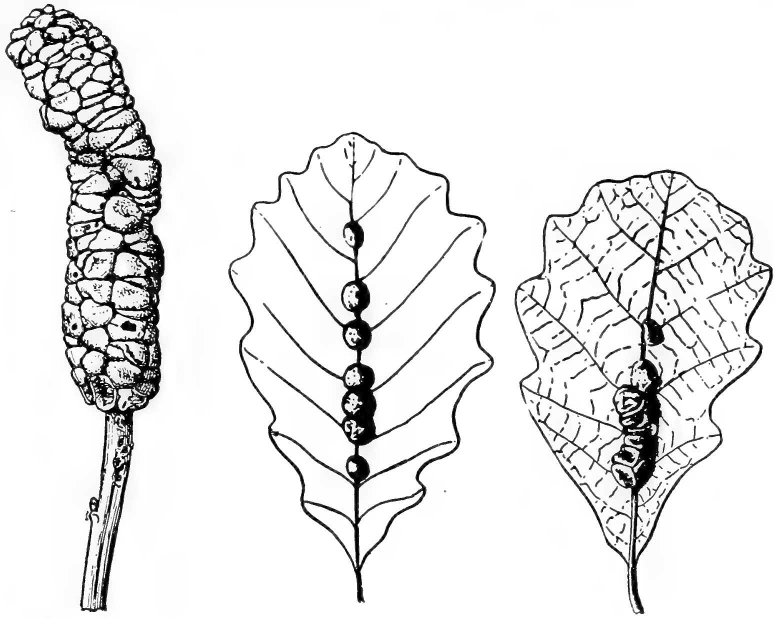

FIGURE 182.—The oak fig gall (*Biorhiza forticornis*). (After Felt.)

large internal cavity, which is hollow except for a single free-rolling cell about $1/10$ inch in diameter. This cell contains the gall-making insect. The adult insect emerges early in May. The galls are usually formed on the leaves, but may also appear on the axis of the staminate flowers. Not long after the adult insects emerge the galls dry up. No injury seems to result from the malformation other than the growth itself, and no remedial measure is advised.

Callirhytis (*Andricus*) *operator* O. S. is well known as one of the first species for which an alternation of generations was shown. It infests red oak (*Quercus borealis*), black oak (*Q. velutina*), scarlet oak (*Q. coccinea*), and scrub oak (*Q. ilicifolia*) throughout the Eastern States and into Texas. The woolly galls on the staminate flowers, which yield the sexual generation, consist of spongy masses of succulent, fibrous, yellowish, whitish, or pinkish material. Within these filaments are seed-

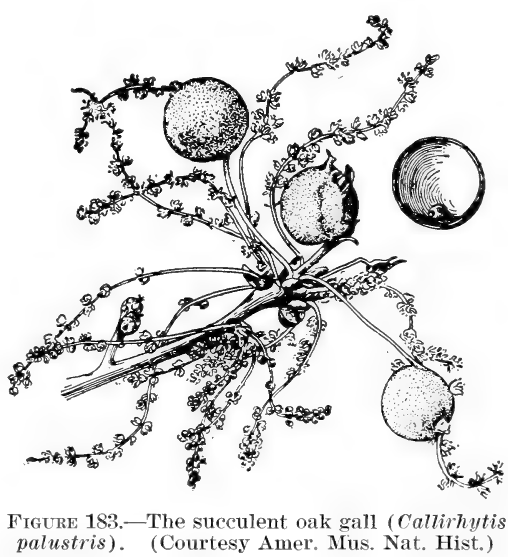

FIGURE 183.—The succulent oak gall (*Callirhytis palustris*). (Courtesy Amer. Mus. Nat. Hist.)

like kernels containing the gall-wasp larvae. Adults emerge early in the summer and oviposit in immature acorns. **The acorn pip galls** of the agamic generation develop in the acorn cup, usually with an aborted acorn. The gall is shaped somewhat like an incisor tooth. From one to five or six may occur in a single cup, and they range in size from that of a flaxseed to ⅓ inch in length. The gall may be important when abundant because of acorn and ament destruction. At the present time the insect, although not rare, does not seem to be numerous enough to constitute a seed problem. If control is desired, collect and destroy the fresh galls.

ROOT GALLS

Bassett (*24*) described *Callirhytis radicis* Bass. as the agamic form of *Callirhytis futilis* O. S., which is a common gall on leaves of white oak (*Quercus alba*) in Connecticut. *C. radicis* forms globose, grayish root galls about 3 by 4½ inches, just below the ground surface on the main roots of young white oak. The bark is covered by a mass of blisterlike swellings and below the surface numerous larvae of all sizes may be found early in the spring. The adult gallflies appear about the first of July.

Subfamily SYNERGINAE

The Synerginae are almost entirely inquilines. They are often mistaken for true gall makers, to which they frequently bear an extremely close resemblance. They usually lay their eggs in cynipid galls on oak, but have also been reared from galls formed by Diptera and other insects.

Subfamily IBALIINAE

The Ibaliinae are a very small group quite distinct from other Cynipinae, and some authorities consider them a separate family. The members are all true parasites that attack larvae of the *Siricidae.*

Ibalia maculipennis Hald. is a fairly common species in the eastern half of the United States. The adults are about ½ inch long and strikingly marked with a yellow and dark-brown pattern. The forewings have two conspicuous fuscous bands. Weld (*428*) reported the capture near Evanston, Ill., of a large number of specimens which were ovipositing in hickory trees that had previously been killed by bark beetles. The *Ibalia* adults were thrusting their ovipositors into the tunnels formed by horntail larvae. The observer believed that the egg was deposited in the tunnel, and, after hatching, the parasite larva probably crawled along until it found its host. Full-grown *Ibalia* larvae were found in the spring in burrows they evidently had made for themselves after they had finished feeding. Pupation took place in these burrows and adults emerged about June 1. Chrystal (*92*) gives a detailed account of the biology of *Ibalia leucospoides* Hochenw. in England. This species is a true internal parasite of the wood wasp *Sirex cyaenus* F., which infests larch, the parasite's eggs being deposited in either the host's egg or the newly hatched *Sirex larva.* Shipments of this species have been made from England to New Zealand for liberation against *Sirex juvencus* L., which is very destructive there in plantations of *Pinus radiata.*

Superfamily *ICHNEUMONOIDEA*

Ichneumon Flies

The superfamily Ichneumonoidea is the largest in the order Hymenoptera, with the possible exception of the Chalcidoidea. About 16,000 species have been described, but undoubtedly there are many times this number. All are parasites, preying on other insects or occasionally on other Arthropods. The group is of great economic importance, since most of the species are beneficial to man. The species exhibit great variety in shape and size and consequently are difficult to classify. The antennae are not elbowed, the pronotum extends back to the tegulae, the trochanters are two-jointed, the forewings possess a stigma, and the ovipositor issues in front of the apex of the abdomen. Ashmead (*5*) grouped them into 6 families and numerous subfamilies. A few representatives of the more important groups are briefly described in the following pages and, where practical, parasites of forest insects are used as examples. It should be borne in mind, however, that the groups are too large and show too great a diversity of habit to be satisfactorily represented by the few examples which space permits in this publication; and, furthermore, the species chosen are rather outstanding examples and generally far more efficient than most of the parasites in the group.

Family AULACIDAE

The Aulacidae is a small family. Many of the species belonging to it are parasites of wood-boring coleopterous larvae, the Cerambycidae being particularly subject to attack.

Family ICHNEUMONIDAE

The Ichneumonidae is a very large family and most of the species are medium-sized to large insects. Most of them are parasitic on Lepidoptera. Next in importance as hosts are the Hymenoptera, more especially the Tenthredinidae, but Coleoptera are frequently attacked, and all groups are preyed upon to some extent.

The genus *Amblyteles* is one of the large genera, and many of the large, varicolored species emerge from pupae of forest insects. *Amblyteles sublatus* (Cress.) is a common parasite of the saddled prominent (*Heterocampa guttivitta*) in the northeast, and *A. velox* (Cress.) is a parasite of **the hemlock looper** (*Lambdina fiscellaria fiscellaria*) in Ontario and Michigan. No comprehensive study has been made of a species of this genus which attacks forest insects in this country, but Eidmann (*143*) gave a good account of *A. nigritarius* (Grav.), an important parasite of the pine geometrid, *Bupalus piniarius* L., in Bavaria. The female of the parasite attacks the host larva. The parasite remains in an early larval instar until the host has pupated. It then develops to the last instar, overwintering in this stage and pupating the following spring. Transformation to an adult takes place within the host pupal shell through which the adult cuts a small opening in the anterior end, in order to emerge. Eidmann believes that the parasite probably completes a summer generation on some alternate host.

Stylocryptus subclavatus (Say) commonly attacks numerous species of tenthredinid cocoons throughout the United States. Furniss and Dowden (*176*) reported that of the cocoons of **the hemlock sawfly** (*Neodiprion tsugae*), which were collected near Sweet Home, Oreg., in 1936 and which produced parasites, about 10 percent had been attacked by *S. subclavatus*. It has also been reared from *N. sertifer* in New Jersey. The adults vary considerably in size depending on the host attacked. The larger specimens are about 5/16 inch long. They have a black thorax, a shiny red abdomen, and red legs. Female antennae are yellowish on the basal half and dark at their tips. Females

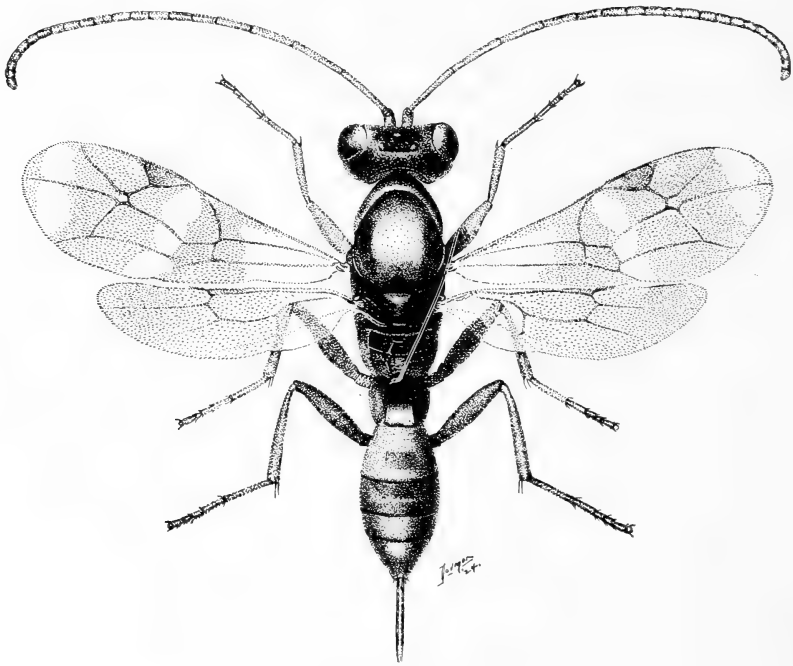

FIGURE 184.—*Hemiteles tenellus*, female.

oviposit through the host cocoon, first paralyzing the host prepupa and then laying a large external egg. The parasite larva feeds externally, completing development and spinning a light cocoon within the host cocoon. The winter is spent in this stage. Pupation takes place in the spring, and the adult parasite emerges after cutting an exit hole in the host cocoon. Two or even more generations may develop in 1 year.

Hemiteles tenellus (Say) (fig 184) is one of the most common of all our hyperparasites, and has been abundantly reared from the cocoons of many species of Ichneumonoidea throughout the whole country. It may occasionally act as a primary parasite of certain Tenthredinidae but its injury as a secondary greatly exceeds its value as a primary parasite. Muesebeck and Dohanian (*310*) gave an excellent account of *H. tenellus* as a parasite of *Apanteles melanoscelus*. The adults vary considerably in size depending on the size of the host attacked. Those reared from *Apanteles* cocoons are about 1/8 inch long.

They are marked with a dark-brown and reddish-brown pattern and the wings have 2 conspicuous fuscous bands. They oviposit in the host cocoon, laying a rather large external egg on or near the host larva. The parasite larva feeds externally. From 15 to 30 days are required for the complete life cycle during the summer months and from 1 to 4 generations may develop in a season. The winter is spent as a mature larva within the cocoon of its host. Males of *H. tenellus* are unknown. Females are invariably produced parthenogenetically, and under laboratory conditions Muesebeck and Dohanian reared several lines of females through 12 generations.

Theronia fulvescens (Cress.) is a very polyphagous species commonly parasitizing a variety of Lepidoptera from New England to Oregon. Evenden (*146*) recorded it as the most important parasite of the pine butterfly (*Neophasia menapia*). Other well-known hosts from which it is recorded include **the Douglas-fir tussock moth** (*Hemerocampa pseudotsugata*), **the gypsy moth** (*Porthetria dispar*), and **the brown-tail moth** (*Nygmia phaeorrhoea*). The adult is a striking, almost unicolorous yellow or brownish-yellow insect from about 3/16 to 1/2 inch long. Evenden states that females oviposit on caterpillars of the pine butterfly which, though weakened, transform to the pupal stage. Other workers have described oviposition as occurring directly in the host pupa, and this would seem to be the more usual procedure. In any case the young parasite feeds internally.

When it has finished feeding it spins a very light cocoon within the host pupa, and the adult *Theronia* emerges by cutting its way out. It spends the winter as an adult, and apparently one or more generations may be completed annually. Occasionally *Theronia* acts as a secondary parasite, but in those instances it seems to have been more a case of development on a parasite already present than a deliberate attempt to search out a parasitized pupa. Fiske (*157*) reared it as a secondary parasite of *Malacosoma disstria* through *Ephialtes conquisitor* Say, and the writer has reared it as a secondary parasite of *Nygmia phaeorrhoea* through the tachinid *Compsilura concinnata* Meig.

Most of the species of *Ephialtes* are parasites of Lepidoptera, but *E. montana* Cush. is an important parasite of the hemlock sawfly (*Neodiprion tsugae*) in Oregon. Furniss and Dowden (*176*) stated that they had found that about 2.8 percent of the cocoons of *N. tsugae* which were formed in exposed places in 1936 had been attacked by this species. The adult is about 5/16 inch long, black, with red legs except the hind tibia, which is black with a white annulus, and the hind tarsal segments, which are white at their bases and black at their tips. The female *E. montana* bores through the host cocoon with its ovipositor and lays an egg inside the prepupal larva. Eggs hatch within a few days, and the first-instar larvae float freely in the body cavity, spending the winter in this stage, but apparently more than one brood may develop during the season, for many cocoons collected in the field during September produced adults of *E. montana* that same fall. Overwintering first instars complete development in the spring and the adult parasites emerge early in the summer.

Mesoleius tenthredinis Morley is an important parasite of **the larch sawfly** (*Pristiphora erichsonii*) in the United States and Canada. It was imported into Canada from England in 1912, and liberations were made near Treesbank, Manitoba. Further liberations were made in Ontario and Quebec in 1916. Graham (*190*) recorded parasitization of 19 percent by this species near Treesbank in 1916, parasitization of 88 percent with an average of 75 percent over a considerable area near Treesbank in 1927, and parasitization of 30 percent at Glen Murray, Quebec, in 1929. In 1917 a small lot of cocoons was sent from Canada to the State entomologist for liberation in Michigan, and small colonies of the parasite were sent from Canada to New England in 1929 and 1931 for liberation in New Hampshire and Massachusetts. Dowden (*135*) noted in 1937 the recovery of this parasite in Montana, Michigan, Wisconsin, and Minnesota, and since then it has been recovered in Connecticut, New York, and Pennsylvania.

Some forest entomologists are of the opinion that the larch sawfly is circumpolar, and has been with us always, in spite of the fact that it was first recorded from the Arnold Arboretum in 1881. The widespread occurrence of *Mesoleius* might be considered further proof of this. Be that as it may, the parasite is a useful member of our fauna. The adult is about 3/8 inch long; black, with a yellow face, and with red legs except the hind tibiae, which have lighter bases and the tips of the tibiae and tarsi brown to black. The females oviposit in larch sawfly larvae. The parasite does not develop beyond the first instar that season, hibernating in this stage within the prepupal larva in its cocoon. Development is completed in the spring, and the adult insect emerges from the host cocoon. There is only one generation a year.

Campoplex frustranae Cush. is an important parasite of **the Nantucket pine tip moth** (*Rhyacionia frustrana* (Comst.)) in New England and Virginia. Cushman (*125*) lists it as second in importance among the parasites reared from this host at Falls Church, Va., in 1924. The adult is about 3/16 inch long, and black, with reddish legs, except the hind coaxe, which are black. The abdomen is petiolate and strongly compressed from side to side. The adult female lays an internal egg in the small tip moth larva. The parasite larva completes development after the host larva has pupated, and a light, white cocoon is spun inside the shattered shell of the newly formed host pupa. In New England adults emerge about June 1, which is about the same time adult moths appear. One generation of both host and parasite is completed in New England. Possibly the parasite completes two generations farther south, where the host has two generations.

In 1925 adults of *Campoplex frustranae* were introduced into a pine plantation in Nebraska for the control of a variety of *R. frustrana*, which was seriously damaging pine plantations in the Nebraska National Forest. Within 5 years this parasite was destroying between 80 and 90 percent of the host over much of the area. Unfortunately a second species of tip moth, in which *C. frustranae* could not develop, became abundant about that time, and since then the plantation has suffered about as much as it did before the parasite was introduced. Nevertheless the reduction of the original infestation by *C. frustranae* was an exceptional case of control of a forest insect by an introduced parasite.

Family BRACONIDAE

The braconids are closely related in structure and habits to the Ichneumonidae. Lepidoptera are the insects most commonly parasitized, but a great variety of hosts are selected and many Coleoptera are attacked. With the exception of certain Alysiinae, practically all the species of the family are primary parasites. Most of the species are small to moderate in size. Various workers have grouped them into about 20 different subfamilies.

Lysiphlebus testaceipes (Cress.) is a common parasite of a number of species of aphids throughout the United States. Among others, it attacks *Myzus cerasi*, which feeds on black cherry and other tree species. The adult is a small black insect, a little less than $1/_{10}$ inch long, with yellowish legs except the posterior pair, which are marked with black. The adult female oviposits directly into the body cavity of the aphid. Usually only one egg is placed in an aphid, but in any case only one parasite develops. When about to pupate, the *Lysiphlebus* larva makes a ventral fissure in the body wall of its host and cements the latter down, applying a thin film of silk. It then pupates within the aphid's body, using the body wall in lieu of a cocoon. After transformation the adult chews a circular hole through the aphid cuticle just large enough to crawl through. During August and September about 2 weeks are required for the development of a complete generation, therefore a number of generations develop each season. The parasites, however, are usually inactive at temperatures below 56° F. The winter is spent as larvae or pupae within the dead and dried body of the host.

Coeloides dendroctoni Cush. is the most important parasite of the mountain pine beetle (*Dendroctonus monticolae*) in lodgepole pine in western Montana and western white pine in eastern Washington and Idaho. De Leon (*130*) discusses the insect's morphology, and gives an excellent account of its biology (*131*). During the course of his studies from 1928 through 1930, parasitization of *D. monticolae* by *Coeloides* averaged 4 to 32 percent, depending on the age of the infestation, and in individual trees it frequently reached 90 percent. The adult insect is about $1/_8$ inch long. The head, thorax, and legs are largely black, while the abdomen is mostly testaceous. It spends the winter as a full-grown larva or prepupa within a cocoon spun beneath the bark in the host larva's mine. Pupation takes place in May and June and the adult *Coeloides* emerge in June. The females fly to a tree that was attacked by beetles the previous August and contains beetle larvae more than half grown. They tap the bark lightly with their antennae to locate a host larva, and then drill directly through the bark to pierce the larva and paralyze it.

The egg is laid on the beetle larva and the parasite larva feeds externally. Development is completed, and a cocoon is spun usually within 2 or 3 weeks. Most of the *Coeloides* remain in the cocoon stage until the next year, but a few (about 5 percent) emerge and complete another generation. The efficiency of the parasite is low, however, probably because the main generation of *Coeloides* remains in the dead trees nearly a year after the host has left, and is thus slow in catching up with the host population.

Phanomeris phyllotomae Mues. is a parasite of *Phyllotoma nemorata*, **the birch leaf-mining sawfly.** It was successfully introduced into this country from Europe in 1931–34, and has become established in Maine. In Europe it was relatively unimportant as a control factor, except in a restricted area, but it was second in importance among the species of parasites recovered from *Phyllotoma*. Dowden (*139*) gave an account of its life history. The adult is a delicate insect about ⅛ inch long, and black, except for its yellowish legs. The female lays an external egg in the host larva's mine, and the tiny parasite larva makes its way to its host, where it feeds externally. Development is rapid and only 8 to 10 days are required for the larva to complete feeding and spin its tough cigar-shaped cocoon inside the host larva's mine. There is only one generation a year, and the winter is spent in the cocoon stage. Pupation takes place in the spring, and adults emerge early in the summer.

Apanteles congregatus (Say) is a very general parasite of sphingid larvae, but has not been recorded from other families of Lepidoptera. It is an important parasite of the catalpa sphinx (*Ceratomia catalpae*) as well as the tomato hornworm (*Protoparce quinquemaculata*), the tobacco hornworm (*P. sexta*), and many others. At times the catalpa sphinx is injurious throughout the Eastern States, and *A. congregatus* is almost invariably found associated with it. Gilmore (*186*) studied its biology as a parasite of the tobacco hornworm.

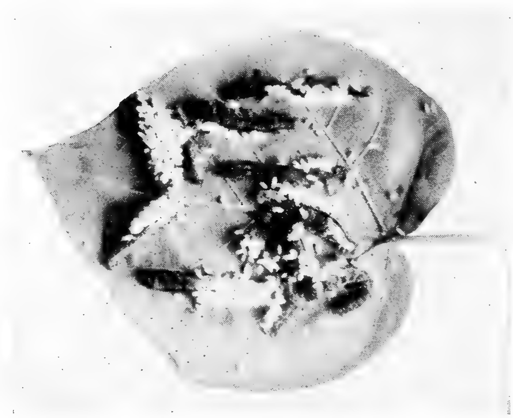

FIGURE 185.—Larvae of the catalpa sphinx bearing coccoons of *Apanteles congregatus*.

The adult is a small, black insect, having yellowish legs, except the coxae which are black. It is a little less than ⅛ inch long. The adult female usually oviposits in the posterior segments of second- and third-instar host larvae. The act of oviposition requires from 20 to 30 seconds, and a number of eggs are laid during one insertion of the ovipositor. The parasite larvae float freely in the lumen of the host. Development is completed in about 10 days. At the end of this time each parasite larva cuts its way through the host larval skin and spins a small white cocoon on the outside. Two hundred or more such cocoons have been seen on the body of one caterpillar (fig. 185). An average of 112 cocoons were formed on 12 larvae of *Protoparce sexta* under laboratory conditions. During the summer about a week is spent in the prepupal and pupal stages, and from two to several generations may be completed in a season. The winter is spent in the cocoon and, since the cocoons are loosely attached to the host larvae, they usually fall to the ground, where they are partly protected by debris. Adults emerge early in the spring.

Bassus pumilus (Ratz.), a parasite of **the larch casebearer** (*Coleophora laricella*), was successfully introduced into the United States from Europe in 1931–36. Recoveries have been made in Maine, New Hampshire, Vermont, and Michigan. In Europe it was found to be an important parasite of the casebearer in Austria and Holland. Collections made in England showed it to be present, but of negligible importance as a control factor. Thorpe (*408*) noted it as a common parasite of the casebearer in southern France, and gave brief biological notes regarding the species. The adults are small black insects, less than ⅛ inch long, with inconspicuous lighter markings on the legs. The wings are fuscous. Probably only one generation develops each year. A very tiny egg is laid internally in a small casebearer larva. The host larva overwinters and the parasite hibernates in the first instar. Development is completed in the spring and *Bassus* adults emerge from host larval cases from about the middle of June until the middle of July. Casebearer larvae suitable for attack are available from about July 15 to the end of the summer.

Apparently all species of *Macrocentrus* are internal parasites of lepidopterous larvae, and in most cases the host larvae live partly concealed as leaf rollers or borers. Most of the species seem to be solitary parasites, but some are gregarious. The latter probably develop through polyembryonic reproduction. At least one gregarious species, *M. gifuensis* Ashm., a parasite of the European corn borer (*Pyrausta nubilalis*) was shown by Parker (*327*) to develop in this manner. Several species are parasites of forest insects, but their life histories are not well known. *M. cerasivoranae* Vier. is a common parasite of *Archips fervidana* and *A. cerasivorana* throughout the United States. The adults are about ⅜ inch long and uniformly dark yellow. A summer generation is completed on these hosts, but it is not known how the parasite overwinters. Probably an alternate host is attacked. *M. peroneae* Mues. is a parasite of **the black-headed budworm** (*Peronea variana* (Fern.)).

The genus *Meteorus* contains a number of species that are important parasites of injurious insects. Most of the species that have been investigated are parasites of lepidopterous larvae, but certain other species attack Coleoptera.

Meteorus versicolor (Wesm.) (fig. 186), a parasite of **the brown-tail moth** (*Nygmia phaeorrhoea*), was successfully introduced into New England from Europe, and definite proof of its establishment was obtained in 1909. As early as 1918 it had spread over the entire area infested by the brown-tail moth, but records do not indicate that it has been of any great importance as an enemy of this insect. In 1926, Brown (*67*) found a species of *Meteorus*, which morphologically and biologically was identical to *versicolor*, acting as an important parasite of **the satin moth** (*Stilpnotia salicis*), in the vicinity of Budapest, Hungary. This *Meteorus* differed from the brown-tail moth parasite only in host selection. From 1929 through 1934 rather large shipments of *Meteorus* cocoons reared from the satin moth near Vienna and Budapest were sent to the United States. Since *M. versicolor* has never been reared from the satin moth in New England, a number of colonies were liberated in that area, and a number were also sent to Washington State for liberation against the satin moth there. The species apparently has not become established on the satin moth in New England, but Jones, Webber, and Dowden (*260*) reported its establishment in Washington, where it has become an important satin moth parasite.

The adults are about $\frac{3}{16}$ inch long, nearly unicolorous yellow, with darker markings on abdomen and propodeum. Oviposition takes place in small brown-tail moth and satin moth larvae in August and

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September, and the winter is spent as a first instar within the hibernating host larva. Development is completed in the spring, and the full-grown larva issues from its host to spin its cocoon. It usually crawls some little distance along a twig or branch and then, suspending itself by a strong thread, which it has made secure, forms an elongate-oval, golden-brown cocoon (fig. 186). Although this habit of spinning a cocoon in midair might be expected to afford some protection from hyperparasites, actually the cocoons are heavily attacked by secondaries.

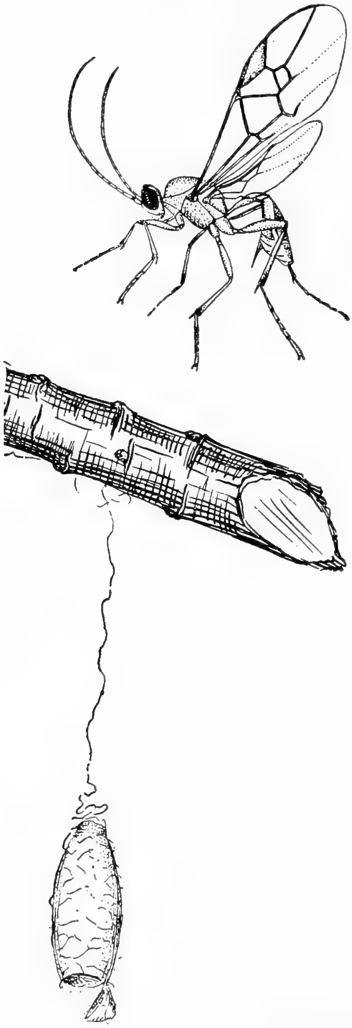

FIGURE 186.—Female of *Meteorus versicolor* and cocoon from which it emerged.

The adult *Meteorus* emerges in about 9 days, and adults of the first generation are present in the field about the middle of June. The later instars of the brown-tail moth and satin moth larvae, as well as some other hosts, are attacked. Adults of the second generation, together with adults of a partial third generation, attack the hibernating larvae.

Orgilus obscurator (Nees) is a parasite **of the European pine shoot moth** (*Rhyacionia buoliana*). It became established in this country with its host, but did not become generally distributed until after liberations were made in the program of parasite introduction against this pest, begun in 1931. In Europe it is an important parasite of the shoot moth in England, Holland, and Austria, but in Holland and Austria its efficiency is greatly reduced by a secondary parasite, *Perilampus tristis* Mayr. The adult is black, about 1/4 inch long, with dusky wings and reddish legs. The female oviposits in small shoot moth larvae, and spends the winter as a first instar within the hibernating host larva. Development is completed early in the summer, and the parasite emerges from the full-grown host larva or pupa to spin a thin, white cocoon inside the host's burrow. Adults emerge from the middle of June until the middle of July. There is only one generation a year.

Spathius canadensis Ashm. (fig. 187) is a parasite of a number of host species, and is commonly reared from **the native elm bark beetle**

(*Hylurgopinus rufipes*) in the Northeast. Kaston (*261*) noted that it was particularly abundant in Connecticut in 1935 and 1936 but had been reported only occasionally since then. The number of parasitized larvae in one family seldom exceeded 25 percent and was more commonly 5 to 10 percent, and that only in certain localities. The adult is a delicate insect, about 1/8 inch long, reddish brown with darker abdomen, and the wings have two dusky bands. Probably two generations develop annually. The winter is spent as a prepupa in a brownish papery cocoon (fig. 187, *A*). In the spring the adult emerges by cutting a circular hole through the bark. Oviposition probably takes place through the bark. The host larvae are paralyzed, and the parasite feeds externally.

Rogas unicolor (Wesm.) is a parasite of minor importance on the satin moth in Europe. Several shipments of cocoons were sent to this country from Hungary in 1933 and 1934, and adults were colonized in New England and Washington. The species has not yet been recovered. The adults are about 1/4 inch long and uniformly brownish yellow. One generation is completed each year. The winter is passed as a first instar within the hibernating host larva. Development proceeds slowly in the spring, and the parasite becomes full grown when the host larva is in the penultimate instar (Dowden, *136*). Host larvae that are parasitized by *R. unicolor* are considerably retarded in growth, and just before the parasite becomes full grown the host larva spins a dense, white web. The parasite cocoon is formed inside the skin of the host larva. Adults emerge the last of June and attack the small hibernating satin moth larvae. Females are produced in parthenogenesis and practically all reproduction proceeds without mating, although an occasional male appears.

Superfamily *CHALCIDOIDEA*

CHALCID-FLIES

The superfamily Chalcidoidea contains a larger number of species than any other superfamily of the order. Many of the species are very small insects and some are minute, measuring not more than 1/4 millimeter in length. The antennae are elbowed, the pronotum does not extend back to the tegulae, the trochanters are two-jointed, the fore wings lack a stigma and closed cells, and the ovipositor issues some distance before the apex of the abdomen. Ashmead (*7*) grouped them into 14 families.

The chalcid-flies are exceedingly important from an economic standpoint. Most of the species are parasites or hyperparasites of other insects, and they are of even greater importance than the Ichneumonoidea in the natural control of noxious insects. The orders most commonly parasitized are the Lepidoptera, Hemiptera-Homoptera, Coleoptera, and Diptera. A few species are phytophagous and, since these forms are found in several different families and some of them cause rather serious damage to the seeds of forest trees, they are sepa-

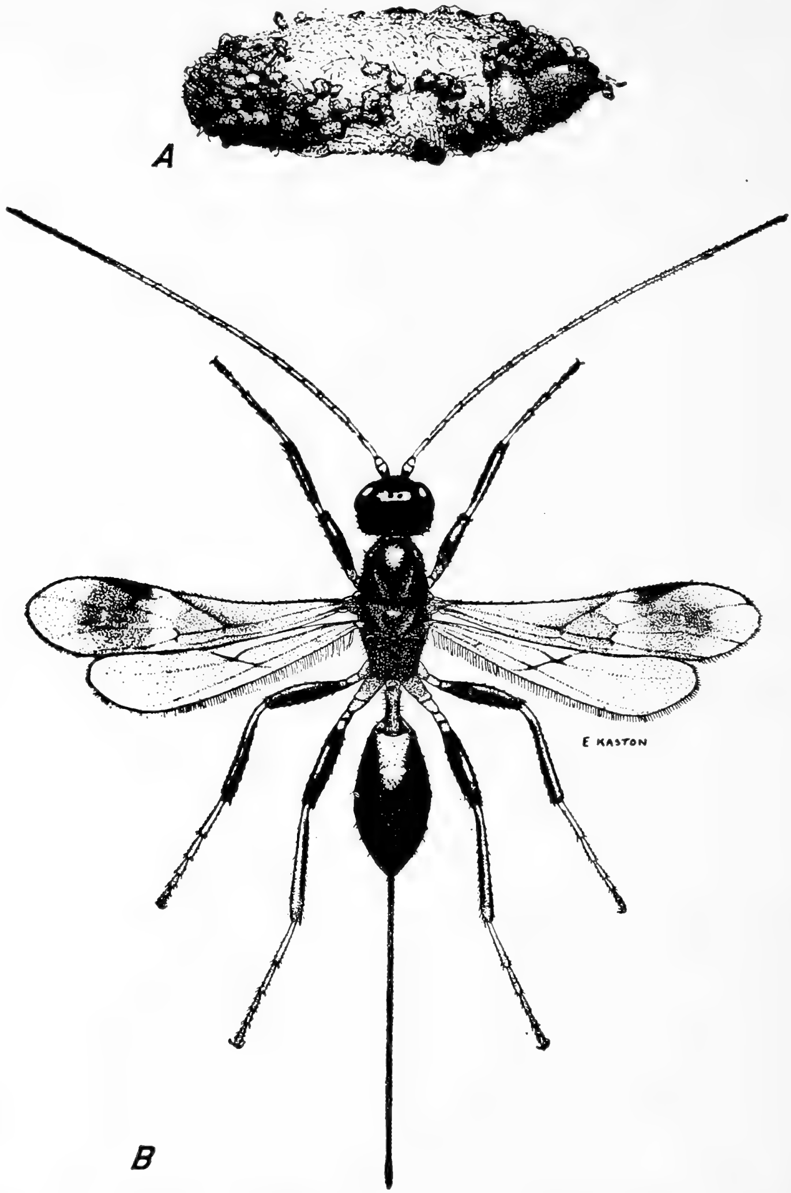

FIGURE 187.—*Spathius canadensis: A*, cocoon,; *B*, female. Greatly enlarged. (Courtesy Conn. Agr. Expt. Sta.)

rated from the entomophagous forms in the following discussion. As in the Ichneumonoidea, a few examples of the more important families have been briefly described. Here again, however, each family contains a wealth of species showing great diversity of habit, and the few examples chosen can by no means satisfactorily represent the whole taxonomic group to which they belong.

ENTOMOPHAGOUS CHALCID-FLIES

Family CALLIMOMIDAE (TORYMIDAE)

Most of the species belonging to the family Callimomidae are parasites of gall-forming insects. Nevertheless, insects of many orders are parasitized and a number of species are phytophagous.

Monodontomerus dentipes Dlm. is a European species that is also present in the Northeastern States. It may have been introduced with its European host, *Diprion simile*. It has proved to be one of the most effective natural enemies of the introduced pine sawfly in New Jersey, Pennsylvania, Connecticut, and Ontario, and frequently a very high percentage of cocoons are parasitized. It has also been reared from the cocoons of a number of other species of sawflies in the Northeast.

In Europe it has been recorded from a number of hymenopterous and lepidopterous hosts and frequently as a secondary parasite on various ichneumonids and braconids. It has been bred commonly from *Diprion pini* and is one of the most important parasites of *D. hercynia* in Europe (Morris, Cameron, and Jepson *305*). The adult is dark, metallic, greenish blue, about 1/8 inch long. The wings are faintly clouded with brown, and the stigmal area has a distinct brown patch. The ovipositor is prominently exserted. A female always lays more than one egg, usually 5 or 6, in a sawfly cocoon. The larva feeds externally on the prepupa and may take 3 to 4 weeks to reach maturity. The larva hibernates in the prepupal stage inside the host cocoon, pupation taking place in April and the first adults emerging in May. There are probably 2 generations a year. Adults have been found on the wing throughout the whole summer. As many as 12 have been reared from a single cocoon of *D. hercyniae*, but the average is 4½.

Family CHALCIDIDAE

The family Chalcididae contains many primary and secondary parasites of lepidopterous larvae and pupae, while others are parasites of Diptera and Coleoptera.

Brachymeria compsilurae (Cwfd.) is a North American species, which, so far as is known, acts solely as a parasite of tachinid flies. It is particularly destructive to *Compsilura concinnata* Meig. and *Sturmia scutellata* Rond., which are European species successfully established in New England against the gypsy moth. The adult is about 3/16 inch long, black, with prominent yellow tegulae and yellow markings on the legs, and possessing the large swollen coxae typical of the family. Dowden (*134*) wrote on the biology of this species, as well as on that of *B. intermedia* (Nees), a primary parasite of the gypsy moth in Europe. *B. compsilurae* overwinters as a full-grown larva within its host puparium. It develops only one generation in single-generation tachinids, but passes through two or three generations in multibrooded host species. The female oviposits through the primary lepidopterous host pupa or larva, laying an internal egg in the tachinid maggot. The tachinid host larva is probably located through a sense of smell. Development from egg to adult is internal and requires from 3 weeks to about a month during the summer. Adult *Brachymeria* emerge by cutting a circular cap off the anterior end of the host puparium. Spring emergence begins about June 1 in New England.

Family EURYTOMIDAE

Probably no other family of chalcids exhibits so wide a diversity of habits as is met with among the members of the Eurytomidae. Many species are phytophagous. Other members of the family live in the nests of bees and wasps or are parasites of gall-forming Diptera and Hymenoptera. A few are egg parasites of Orthoptera, while several species of *Eurytoma* appear to be almost ubiquitous in their selection of hosts.

Eurytoma pissodis Gir. is one of the most important parasites of **the white-pine weevil** (*Pissodes strobi*) throughout the entire range of its host, and parasitization as high as 50 percent has been recorded. Taylor (*406*) found 6 percent parasitization in about 3,000 weeviled white-pine leaders. He found parasitization limited almost entirely to weevils within leaders from $\frac{1}{4}$ to $\frac{3}{8}$ inch thick, and he believed this was due to the fact that the parasite's ovipositor was too short to reach weevils in thicker stems. The adult is from $\frac{1}{8}$ to $\frac{1}{4}$ inch long, and is black, dull on the sculptured thorax but glossy on the polished abdomen, with conspicuous red eyes. It overwinters as a prepupa within the pupal cell of the host larva. Transformation takes place in the spring, the adult parasite cutting its way out through the xylem of the weeviled leader. Adults emerge shortly before the *Pissodes* larvae complete feeding, which may be from the middle of May until the middle of July, depending on the season. The female oviposits either through the stem or through the host larva's entrance shaft. The egg is laid on the full-grown host larva within its pupal cell. The parasite larva feeds externally, becoming full-fed in about 10 days. Practically all the parasites complete only a single generation, but about 4 percent transform to adults in August. These individuals do not find the *Pissodes* larvae in a stage suitable for parasitization, so they possibly complete another generation on some other host.

Family PERILAMPIDAE

The Perilampidae make up a small family. The North American species, the habits of which are known, are secondary parasites, attacking Diptera, Hymenoptera, and Neuroptera, but certain species from Australia are phytophagous.

Perilampus hyalinus Say is a common species throughout the United States. It is a secondary parasite of numerous Lepidoptera, developing at the expense of many species of Tachinidae and Ichneumonidae. Smith (*383*) reported on its biology as a secondary parasite of the fall webworm (*Hyphantria cunea*). The adult ranges from about $\frac{1}{16}$ to $\frac{3}{16}$ inch long. It is bright, metallic, bluish green. Like all members of the family, it is characterized by a large thorax and small triangular abdomen. It has a remarkable history in that its egg is not laid on or in the host, but at some distance, and in all probability on foliage, as are those of other *Perilampus* species.

The first instar is a minute, mobile larva, which has been called a planidium. It crawls to a caterpillar and bores its way into the body cavity, there swimming about freely until the larva of a primary parasite, either hymenopterous or dipterous, is found. It then bores into its true host, where it remains quiescent until the primary parasite larva is full-fed and has made its exit from the caterpillar to pupate.

The planidium then finds its way to the exterior of its host, where it feeds as an ectoparasite in the normal way. Hibernation depends on the host parasitized. If the primary parasite does not pupate until spring, the winter is spent as a planidium inside the body cavity. If the parasite pupates in the fall, the *Perilampus* apparently overwinters as a planidium on the outside of the pupa, where it begins to feed as soon as the weather becomes warm. One or more generations develop during a year, depending on the host parasitized.

Family EUCHARIDAE

The family Eucharidae is a small group closely allied to the Perilampidae. The adults are characterized by the configuration of the scutellum, which is frequently produced backward in the form of powerful spines. So far as known, they are parasites of ants and are found mainly in the tropics. As in the Perilampidae, the first instar is a planidium, and various places are selected by females of different species for egg deposition. Wheeler (*430*) wrote on the life history of the genus *Orasema*, which is parasitic principally on a harvesting ant, *Pheidole instabilis* Emery, but also occurs not uncommonly on representatives of other ant genera in the Southwestern States and Mexico. Clausen (*94*) made the most complete observations on a member of this group in his study of *Stilbula tenuicornis* (Ashm.), which parasitizes *Camponotus herculeanus japonicus* Mayr, the Japanese carpenter ant. This parasite lays large numbers of minute eggs within the buds of certain trees, and upon emergence the planidia attach themselves to *Camponotus* workers. The planidia are thus carried into the nest, where they attach themselves to ant larvae and feed externally. After the host has pupated the parasite larva, now in the second instar, reattaches itself on the metathorax of the host and finally pupates within the host's cocoon.

Family ENCYRTIDAE

The Encyrtidae is a very extensive family. Although the Hemiptera-Homoptera and Lepidoptera are most frequently parasitized, practically all orders of insects are attacked. Certain genera have a wide range of hosts, whereas others are definitely restricted in the forms parasitized.

Ooencyrtus kuvanae (How.), an egg parasite of the gypsy moth (*Porthetria dispar*), was introduced into the United States from Japan, and is an important enemy of this pest in parts of southern New England. Its periods of abundance have been very irregular, however, and the areas in which it has been plentiful have been scattered. The adult is a minute black insect about 1 mm. long. The fertilized female overwinters as an adult, but there is a heavy winter mortality. Those that hibernate successfully become active during April and oviposit in the overwintering eggs of the host. There may be one or two spring generations.

Adults are ready to oviposit as soon as the new gypsy moth eggs are laid in July, and late in the summer and early in the fall only 21 days are required for development from egg to adult. Females deposit their eggs within the host eggs, and if the host embryo is developed, as is usually the case, the parasite egg is placed within the body of the gypsy moth larva. The parasite egg has a long stalk, which remains attached to the host egg at the point of insertion. The parasite larva does not entirely leave the chorion at the time of hatching, but remains with its posterior end thrust into it, and a funnel-shaped shield develops surrounding the posterior segments of the larva during its early stages of development. Pupation takes place within the host egg, and the adult *Ooencyrtus* emerges after cutting a roughly circular exit hole. From four to five generations develop annually in New England.

Habrolepis dalmani (Westw.) is a parasite of *Asterolecanium variolosum* Ratz., **the golden oak scale.** At times the parasite is fairly common in New England, but its occurrence and importance vary considerably, and it is not considered an important factor in the natural control of this pest. From 1923 to 1928, small shipments of the parasite were sent from Massachusetts to New Zealand where the scale frequently caused extensive injury to the English or golden oak (*Quercus pedunculata* Ehr.). The parasite was definitely established by 1925, and is now controlling the scale effectively in that country. The adult is about 1 mm. long, metallic blue and green, with wings heavily clouded by fuscous markings. The female oviposits directly in the scale insect, and the egg has a stalk, which remains attached to the body wall of the host at the point of insertion. The early larval instars remain attached to this stalk through the development of a chitinized funnel surrounding the posterior segments of the parasite larva. The winter is spent in this stage. Development is completed in the spring, and the adult insect emerges by cutting a circular hole through the test covering the scale.

Copidosoma nanella Silv. is a parasite of a number of needle miners in the Northeastern States. Among others it attacks *Recurvaria nanellae*, *Epinotia nanana*, and *Exoteleia pinifoliella.* The adults are minute insects measuring less than 1 mm. long, black, with yellow markings on the legs. The biology of the species is particularly interesting, for, like that of a number of closely allied species, it is characterized by polyembryonic reproduction (Silvestri, *377*). A single egg is laid in the egg of the host, but the larva of the latter emerges in the normal manner. Embryonic fission takes place in the body cavity of the host larva. Up to 11 normal parasitic larvae complete development in the spring of the following year, forming parchmentlike cocoons in the mummified host larva. In other species of *Copidosoma* that attack larger host larvae, hundreds of adults often develop in this manner from a single egg.

Family EUPELMIDAE

Members of the Eupelmidae parasitize a wide range of insects, including the Rhyncophora, Diptera, Lepidoptera, Hymenoptera, and Coccidae. Many are hyperparasites, and certain ones belonging to the tribe Tanaostigmini are phytophagous.

Anastatus disparis Ruschka (fig. 188) is an egg parasite of the gypsy moth. It was introduced into New England from Europe in 1908 and quickly became established in this country. The females jump short distances, but they do not fly, so natural dispersion proceeded very slowly. Between 1908 and 1927 large numbers of egg masses were collected in the colonized areas, and the parasitized eggs were separated out and placed in new areas. More than 65 million *Anastatus* were thus colonized. The parasite is now generally present throughout the infested area, and in certain years it often parasitizes high percentages of the eggs, particularly in eastern New England. Crossman (*122*) gave an account of work done with this species. The adult female is from 2 to 3 mm. long, strikingly marked green and brown, with two broad fuscous bands on the wings. The male is smaller, about 2 mm. long, greenish black, with hyaline wings. Normally *Anastatus* has one generation each year, although occasionally two generations have been recorded. It spends the winter as a full-grown larva within the host egg. Adults emerge in July, when gypsy moth females are depositing their egg masses, and the parasites are often seen ovipositing in the eggs before the cluster has been entirely deposited. The parasite egg hatches very soon after oviposition, and the larva develops quickly into the hibernating stage, about 3 weeks being required for development from egg to full-grown larva.

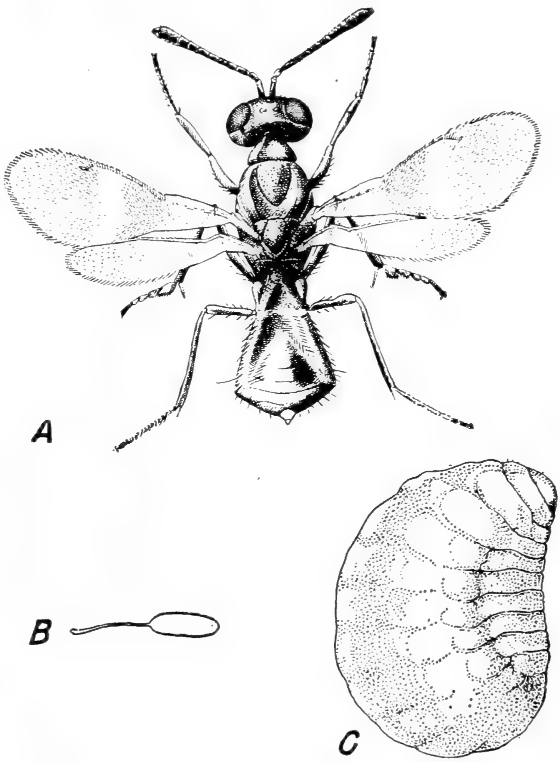

FIGURE 188.—*Anastatus disparis*, a gypsy-moth parasite. *A*, Adult female; *B*, egg; *C*, hibernating larva from gypsy moth egg. All greatly enlarged.

FAMILY PTEROMALIDAE

This is one of the largest chalcidoid families, and its members act as parasites or hyperparasites of almost all orders of insects.

Diorachys cavus (Wlkr.) is a well-known, cosmopolitan hyperparasite. It attacks a great variety of primary parasites including many species of ichneumonids, and it has also been reared from tachinid puparia. Occasionally it acts as a primary parasite, and it has been reared from *Diprion hercyniae*, but it usually is a secondary parasite of this host also. It is extremely destructive to many important beneficial species. Muesebeck and Dohanian (*310*) gave an account of its life history as a parasite of *Apanteles melanoscelus* (Ratz.). The adult is a small dark, almost black insect with a metallic, greenish-blue sheen, and with pale to dark-brown legs and antennae. It ranges from about 1/16 to 1/8 inch long, depending on its host and the number of adults emerging. It is a prolific species. Under laboratory conditions as many as 389 eggs were laid by a single female. They are deposited externally on the parasite larva in its cocoon. Almost always several eggs are laid in one cocoon, although no more than 2 or 3 eggs are laid during one insertion of the ovipositor. The larvae feed gregariously. As many as 14 adults have been reared from an *Apanteles* cocoon and as many as 40 from a cocoon of *Diprion hercyniae*. Development requires from 17 to 34 days, depending largely on temperature, and as many as 5 generations were reared at the laboratory under outdoor temperatures. The winter is spent as a full-grown larva within the host cocoon.

In common with many other parasites *Dibrachys* adults often feed at the puncture holes made by their ovipositor. Feeding may be either direct or by means of a tube constructed with the ovipositor from the larva to the outside of the cocoon, through which the larval juices are sucked. This feeding is probably supplemental to feeding on honeydew and other sweet juices, but it may be an important source of nitrogenous material essential to egg laying. A great many host larvae that are not parasitized are killed in this manner.

Schizonotus sieboldi (Ratz.) is a primary parasite of **the imported willow leaf beetle** (*Plagiodera versicolora*) and some other closely allied chrysomelids. It is well distributed throughout the eastern half of the United States and apparently is present wherever *Plagiodera* occurs in this country. Dowden (*137*) reported high percentages of parasitization over a 3-year period in the vicinity of Boston, Mass., but believed about the same intensity of host infestation was maintained during that time. The adult is from 1/16 to 1/10 inch long, metallic green, with darker highly polished abdomen, and yellow legs. The winter is spent as an adult. Activity is resumed in the spring, and eggs are laid on the first host pupae appearing in the field. This is about June 10 in Massachusetts. The eggs are laid singly on the venter of the pupa, and one female laid as many as 424 eggs under laboratory conditions. The parasite larvae feed externally, and an average of 2 parasites develop per pupa. About 15 days are required from egg deposition to adult emergence. Two, and sometimes three, generations develop during the summer.

FAMILY EULOPHIDAE

The Eulophidae make up a very large family, and many are minute insects. They attack practically all orders of insects, but certain subfamilies and smaller groups frequently attack only closely related hosts. The Eulophinae are principally primary or secondary parasites of leaf miners. The Tetrastichini, on the other hand, attack a wide variety of hosts.

Chrysocharis laricinellae (Ratz.) (fig. 189) is an important parasite of the larch casebearer (*Coleophora laricella*) and of *Phyllotoma nemorata*, **the birch leaf-mining sawfly,** in Europe. It has recently been successfully introduced into New England as a parasite of both these pests, and Dowden (*139*) gave an account of its biology as a parasite of *P. nemorata*. The adult is from 2 to 3 mm. long, bright, metallic green with pale-yellow legs. Females oviposit in the body of the host larva, and the parasite develops internally. When feeding is completed the parasite pushes its way out of the host larva's skin and makes its way to the extremity of the mine. It spends the winter as a full-grown larva in the host larva's case or mine. Pupation takes place in the spring, and the adults emerge by cutting their way out. Pupation may occur during the summer, giving rise to two generations, or the larva may remain in diapause until the following spring. The larvae of *P. nemorata* bleed a little when jabbed with the ovipositor, and the female laps up this fluid. Often the process is repeated many times and larvae fed on in this manner invariably die.

Tetrastichus brevistigma Gahan is an important parasite of the elm leaf beetle (*Galerucella xanthomelaena*) wherever the beetle occurs throughout the Northeastern States. It had not been reared on the

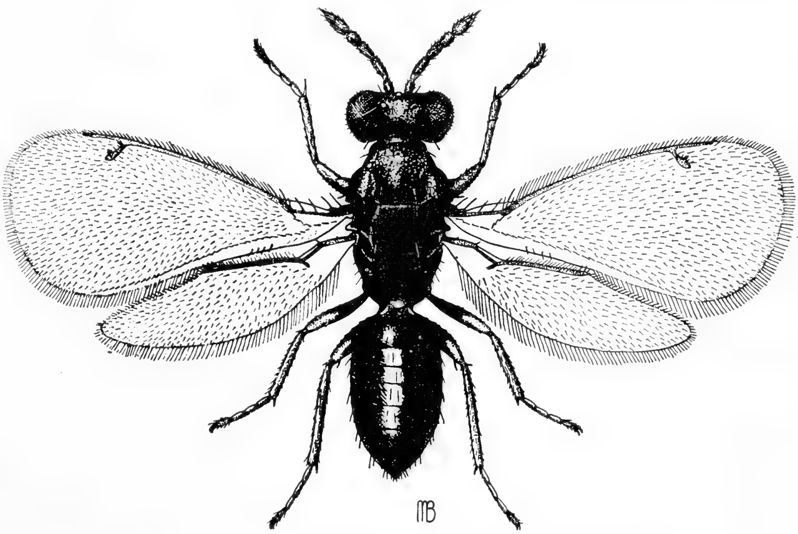

FIGURE 189.—*Chrysocharis laricinellae*. About × 5.

Pacific coast, however, so two shipments were sent to California for liberation in 1934. Later collections the same year indicated that it had passed through one generation in the field. The adult is about 1 mm. long, black with a slight, metallic, greenish tinge, all coxae and the hind femora are mostly black, with the rest of the legs testaceous. Berry (*28*) gave an account of the species in 1938. It spends the winter as a full-grown larva within the host pupal skin. Adults emerge about July 1, or when host pupae first become available in the field. Females oviposit freely in pupae or prepupae and may begin to oviposit within a few minutes after emerging, whether or not mating has taken place. From 1 to 8 eggs are deposited at each insertion of the ovipositor, but the same pupa is often attacked more than once, and an average of 12 larvae develop per parasitized pupa. Females are produced in parthenogenesis. From 3 to 4 generations develop annually, but there are a considerable number of holdover larvae in each generation. In the vicinity of Boston, Mass., parasitization as high as 50 to 80 percent is common during the latter part of the season.

Family APHELINIDAE

Most members of the family Aphelinidae are minute insects that parasitize the diaspine coccids or aphids, although occasionally other orders are attacked. Many species are very important from an economic standpoint.

Aphytis mytilaspidis (LeB.) is the most common parasite of the oystershell scale (*Lepidosaphes ulmi*) in the United States and other parts of the world, and it also attacks many other diaspine coccids. Griswold (*205*) studied this parasite at Ithaca, N. Y., where high percentages of parasitization were obtained. The adult is a minute insect less than 1 mm. long and is bright lemon yellow, with blackish eyes. The winter is spent as a full-grown larva beneath the scale of the host, and adults emerge during the first 2 weeks in June, or at the proper time to oviposit on second-stage host larvae. The female pierces the scale and usually deposits one egg on the surface of the host. The larval stage, during which the parasite feeds externally, lasts about a month. The pupal stage is passed in the same position. Second-generation adults emerge during August and deposit eggs on the surface of sexually mature hosts or lay their eggs among those of the scale insect. The resulting larvae complete feeding and overwinter. Male parasites are very rare.

Family TRICHOGRAMMATIDAE

The Trichogrammatidae are a small family of extremely minute insects, all of which are egg parasites.

Trichogramma minutum Riley is such a well-known egg parasite of many species of Lepidoptera, and has been so extensively propagated for biological-control work in this country, that only very brief notes will be made regarding it. The adults are extremely minute insects, measuring a litttle less than 0.5 mm. long. Two strains or varieties are commonly recognized, a yellow strain (*pretiosa*) occurring in the colder regions, and a dark one (*minutum*) in the warmer parts of the country. This parasite spends the winter as a partly developed larva in the host egg. The number of individuals that may develop in 1 egg depends upon the size of the egg. Patterson (*346*) recorded a maximum of 37 and an average of 29.5 adults emerging from eggs of the pandora moth (*Coloradia pandora*). Eggs are inserted directly into the host eggs, and normal development of the host embryo ceases immediately. The parasite larva hatches within a few hours, and lives free within the liquid contents of the egg. Temperature is an important factor in determining the life cycle. During warm weather from 9 to 16 days is usually sufficient for development from egg to adult. Approximately 13 generations occur per season in New Jersey. Early in the summer the parasite is usually scarce, whereas late in the summer it may be abundant.

Family MYMARIDAE

The species of the family Mymaridae are all exceedingly minute, and, as in the Trichogrammatidae, all are egg parasites. The Hemiptera-Homoptera, Corrodentia, and Rhyncophora are commonly attacked, whereas Orthoptera, Odonata, and other orders are also parasitized. The species are mostly black or yellowish and devoid of metallic colors.

Polynema straticorne Gir. is a parasite of **the buffalo tree hopper** (*Ceresa bubalus*). This host is known best as a pest of apple, but conspicuous damage is also done to willow, cottonwood, maple, and elm. Balduf (*18*) published on the host and the parasite in Illinois and Ohio. The adult is from 1 to 1.6 mm. long, reddish black to brown, with an elongate slender body. Females oviposit directly in host eggs. Development is completed as an internal parasite, and the adults emerge by cutting out a small hole in the chorion. Three generations develop during a year. The winter is spent as a larva, and the first adults appear in May. About 31 percent of the eggs of *C. bubalus* examined by Balduf were parasitized by *P. straticorne*.

PHYTOPHAGOUS CHALCID-FLIES

Many families of chalcid-flies contain species that are phytophagous. The family Agaonidae is composed of remarkable insects that live within figs and fertilize them, but it is represented by only a few species in the United States. Gahan (*179*) listed the phytophagous chalcidoids, except the fig insects. The principal phytophagous forms in the United States are found in the family Callimomidae, which contains a number of seed-infesting species, and the family Eurytomidae, which contains some seed-infesting species, but many more that infest grains and grasses, often forming galls or swellings on the stems. Although chalcidoid gall makers are sometimes injurious to trees in other parts of the world, the phytophagous forms that cause serious damage to the forest trees in this country are the seed-infesting species. Most of them belong to the genus *Megastigmus*, and most of them attack the seeds of coniferous trees.

These seed chalcids are of economic importance. In certain localities a considerable proportion of the seed crop of a tree species may be destroyed in some seasons. This destruction not only seriously affects natural reproduction but is also an important factor in seed collecting, since a high percentage of cleaned commercial seed is often found to have been ruined by these insects.

The life history of all the seed chalcids, so far as known, is essentially the same. The egg is laid in the seed late in the spring or early in the summer. The larva completes feeding and hibernates. Transformation to adult takes place early in the spring, and the adults emerge by cutting a smooth round hole in the seed coat. Some larvae hold over and emerge the second or third year, and frequently as many as 50 percent of the brood may fail to emerge the first summer. Undoubtedly this is an important adaptation in the life cycle. The intermittent character of seed production of conifers is well known, and is apt to be common in other species. The seed chalcids attacking conifers emerge early enough to oviposit when the young cones have soft scales and the seed coats are unhardened (fig. *190*). At this time the interior of the seed is occupied by a milky or jellylike substance.

The adult seed chalcids are almost always black with yellowish markings, are from about 1/8 to 1/4 inch long, and possess strongly exserted ovipositors, usually about as long as their bodies. Our more important species occur on the western coast and were listed by Keen (*262*). Seed chalcids are reported to have killed 50 percent of the Douglas-fir seed crop at Ashland, Oreg., in 1913, although in most years no more than 2 to 10 percent of the annual crop is destroyed. In some years 40 percent of the white fir seed crop in Oregon and California have been destroyed.

Control of seed chalcids appears to be impractical in the growing seed crop. Fumigation of stored seed will not prevent the damage that has already developed during the growing period, but it has been recommended as a measure to prevent carrying the infestation into localities where the seeds are to be planted.

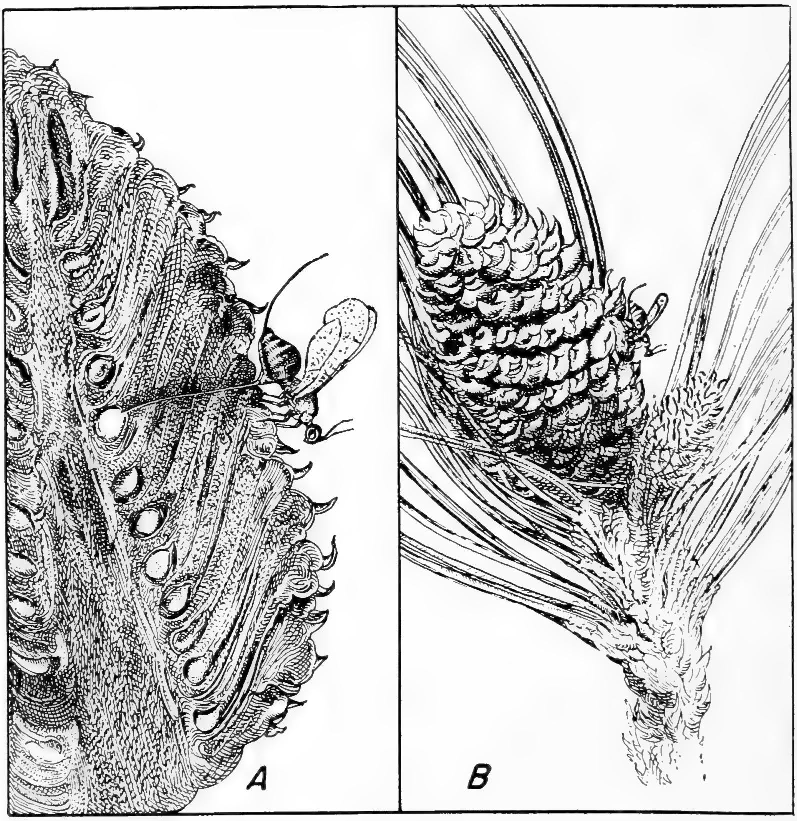

FIGURE 190.—*Megastigmus albifrons:* *A* and *B*, Adult ovipositing through small green cones into seeds. (After Edmonston.)

SUPERFAMILY *SERPHOIDEA*

Most of the members of this superfamily are small insects, black or brown without metallic luster. The pronotum extends back to the tegulae, the trochanters are two-jointed (except in the Pelecinidae), and the ovipositor issues from the apex of the abdomen. The wings exhibit great diversity of venation, many forms are almost veinless, and apterous species are common. Ashmead (*4*) gave a general classification of the group in 1893. Nine or ten families are usually recognized in our fauna. Some of the species are of considerable economic importance because they are valuable parasites, some are hyperparasites, and a small number are inquilines. Comparatively few species, however, are known to parasitize forest insects, and therefore only the two largest families and one small family are treated in the following discussion.

Family SCELIONIDAE

This is a very large and widely distributed family. Its species are egg parasites, infesting the eggs of all orders of insects, those of forest insects being commonly attacked.

Many species of *Telenomus* have been reared from the eggs of forest insects, but comparatively little information exists regarding their life history. Eggs of *Lambdina fiscellaria lugubrosa*, **the western hemlock looper,** collected in the spring of 1930 in British Columbia by Hopping (*237*) and referred to as *Ellopia somniaria*, proved to be 25 percent parasitized by a *Telenomus* sp. Second-generation egg masses of **the catalpa sphinx** (*Ceratomia catalpae*), reared by Baerg (*12*) in Arkansas during 1928 and 1930, were heavily parasitized by *Telenomus catalpae* Mues. *T. clisiocampae* Ashm. is a parasite of the eggs of **the eastern tent caterpillar** (*Malacosoma americana*) and **the forest tent caterpillar** (*M. disstria*). The adults are tiny insects a little less than 1 mm. long, and dull black, except their legs, which are brownish. A small percentage of the eggs of the forest tent caterpillar in New England and the Great Lakes States are attacked by this species. The winter is spent as a larva within the host egg, and adult emergence is delayed until several weeks after hatching of the unparasitized eggs takes place. Adults, therefore, appear shortly before fresh egg masses are available. There is probably time for the development of two annual generations on this one host, but it is possible that there is only one generation.

Family PLATYGASTERIDAE

This is the largest family of Serphoidea. Its species are principally parasites of Cecidomyiidae. Their eggs are usually laid within those of the host, but the development of the latter is not affected, because the parasites do not develop until the cecidomyiid larvae have hatched. A number of species have been reared from cecidomyiid galls found on various forest trees in this country, but apparently none of these species have been studied in any detail.

Family PELECINIDAE

The Pelecinidae is an exceptional family in many ways. It is distinct from the other families of the Serphoidea, and is represented in our fauna by only a single species, *Pelecinus polyturator* Drury and its subspecies *P. brunneipes* Patton. The female is a common North American insect, parasitic on May beetles of the genus *Phyllophaga*, but the male is extremely rare. The female is a large black insect often 2 or 2½ inches long, with a long slender abdomen, which is about five times as long as the head and thorax.

Superfamily *FORMICOIDEA*

Family FORMICIDAE

THE ANTS

The ants are generally considered to constitute a single very large family, the Formicidae. They are among the most common and widely distributed of insects, occurring under almost all conditions, and in number of individuals they probably outnumber all other terrestrial animals. They are easily recognized by the form of the abdominal petiole which bears one or two scales or nodes which are known, respectively, as the petiole and postpetiole. All ants are social, and, except for a few slave-making and inquilinous forms, have a well-differentiated worker caste of modified females, males, and females or queens.

Their nests, or formicaries, present extreme variation in architecture. The number of ants in a fully developed colony may range from only a few dozen individuals in some species to hundreds of thousands in others. Their feeding habits differ greatly. The adults of some are strictly carnivorous, feeding on insects and other small animals; others are largely vegetarian, feeding on plants and seeds; whereas others feed on honeydew, fungi, fruit, and other substances. Although most species of ants nest in the soil, there are many that build their nests in wood, in timbers, in the trunks of decaying trees, or under the bark. Considering their abundance, they are not especially destructive to our forests. A few species cause considerable damage, but some are distinctly beneficial predators on harmful insects.

Large black ants belonging to the genus *Camponotus* are called carpenter ants, because of their habit of tunneling into wood. They attack cut timber, decayed or partially decayed trees, and even some living trees. The most common American species, **the black carpenter ant** (*Camponotus herculeanus pennsylvanicus* (DeG.)) (fig. 191) was well treated by Graham (*194*). These are large black ants, sometimes ½ inch or more in length. They build their nests in a great variety of places. They may attack the dead heartwood of living trees, logs, house timbers, or almost any wood materials. They do their greatest damage in house timbers, poles, and standing trees with soft wood (fig. 192). In northern white cedar, *Thuja occidentalis*, injury is very common, and in certain locations at least 20 percent of the trees that are cut show ant injury. On infested trees grown on swampy ground there is a loss of about 3 feet from the butt, and the loss on trees on higher ground may be 6 feet. Balsam fir, *Abies balsamea*, in the northeast is also seriously damaged. The ants do not use the excavated wood for food, but they make galleries to form a home for the colony. They are rather general feeders, acting as predators on certain caterpillars and also obtaining honeydew from aphids. Their life history is similar to that of most ants.

Mating takes place early in the summer, during what is termed "the nuptial flight." The impregnated female may be taken into an old nest to replace an old queen or she may seek out a new place to form a colony. Once the new home site is selected, she divests herself

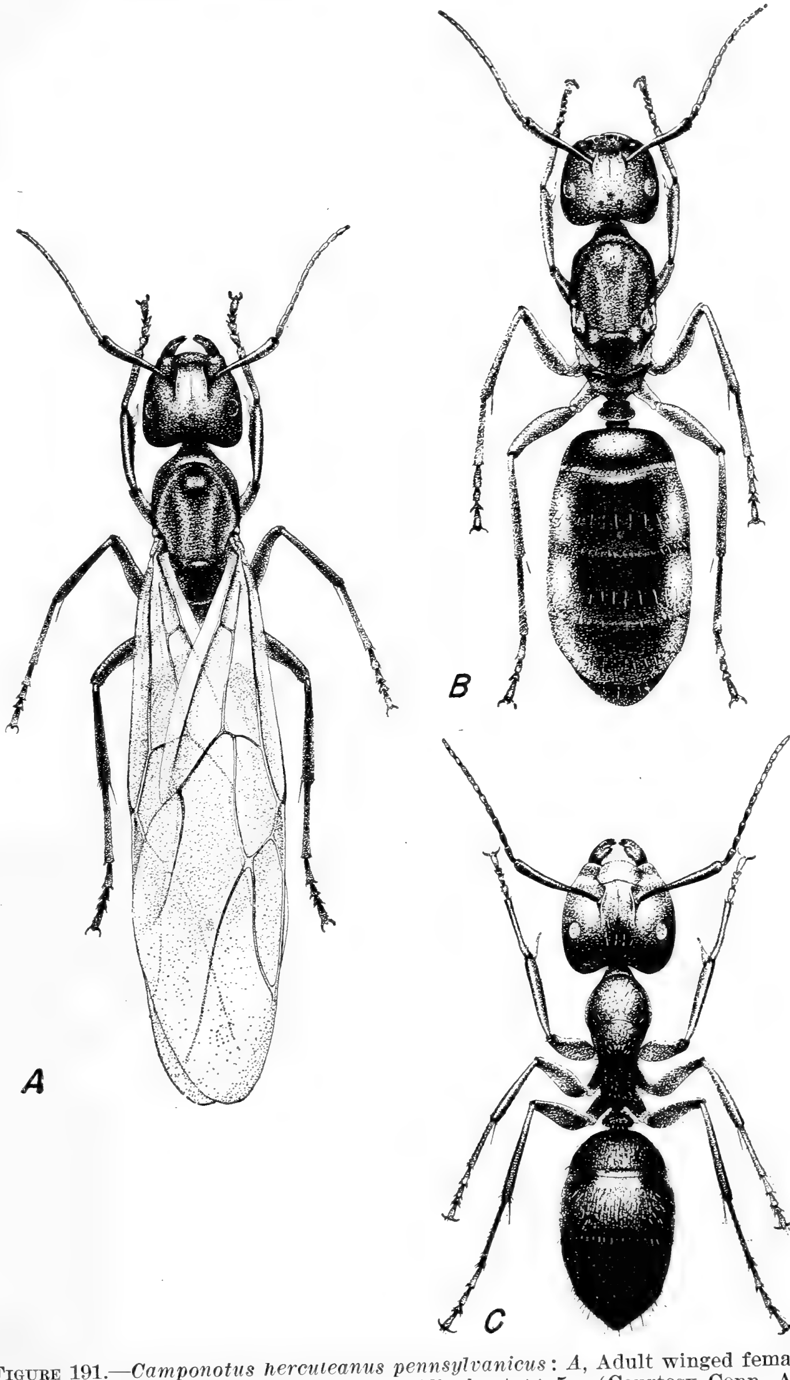

FIGURE 191.—*Camponotus herculeanus pennsylvanicus*: *A*, Adult winged female; *B*, major worker; *C*, minor worker. All about × 5. (Courtesy Conn. Agr. Expt. Sta.)

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FIGURE 192.—Colony of carpenter ants in a 2-foot section of a telephone pole in winter. The arrow indicates ground level. (Courtesy Conn. Agr. Expt. Sta.)

of her wings, and excavates a small chamber within which she seals herself. She remains enclosed during the time her first progeny are developing into adult workers. These she feeds from secretions of her salivary glands. As soon as the workers appear they take over the work of the nest, cutting approximately parallel, concentric galleries running through the wood. Openings, sometimes called windows, are cut to the outside through which food is brought into the nest. The young workers feed the queen and care for her eggs and the young larvae. After the first brood has been reared by the queen, the workers feed the young with secretions from their mouths, and they carry both larvae and pupae from place to place in the nest in an effort to rear them under the most favorable conditions. As the colony grows, more galleries are cut, to enlarge the nest. Early in the summer colonies about 3 years old or older produce winged males and females, which leave the nest to mate and establish new colonies. Either sex may predominate in a colony, and the flights from all the colonies occur simultaneously in the same neighborhood. Means is thus afforded for intercrossing with individuals from different colonies.

These insects may be contolled in several ways (see pages 43 and 44). The simplest method is to inject sodium fluoride, arsenical dusts, carbon disulfide, kerosene, or orthodichlorobenzene into the nests. The sodium fluoride is probably the most satisfactory, for the ants will track through it and carry it to all parts of the nests, whereas the spread of liquids and gases is often blocked in the tortuous, partly frass-filled galleries. Friend and Carlson (*170*) recommended controlling colonies in telephone poles by injecting into the nests coal-tar creosote diluted with an equal volume of gasoline. This is accomplished by boring a hole through the upper part of the nest and injecting the material with a grease gun. Not less than 1 pint should be injected into a cavity 4 feet or less in length and not less than 2 pints into cavities 4 to 7 feet long. Downes (*140*) reported excellent results in controlling carpenter ants with derris powder (4 percent rotenone). No matter where the nest is located or how extensive the infestation, if the powder can be placed where the ants must walk through it and thus get some of it on their bodies, the colony may be exterminated rapidly. A valuable aid in obtaining a good distribution of the dust is the use of an applicator consisting of a bulb (8-ounce capacity) having a cone-shaped metal nozzle. Such an applicator makes it possible to shoot the dust into small crevices. The dust is effective as long as it is dry. Where nests are inaccessible and difficult to find, poisoned-meat bait may be used as an effective means of control. If buildings are set upon stone or concrete foundations, the timbers will usually be kept so dry that they will not provide favorable nesting places. In the forest the ants gain entrance to the trees only through injuries. Fire scars, axe marks, and other surface injuries should be prevented as far as possible, to avoid the entrance of ants and also of wood rots.

The Texas leaf-cutting ant (*Atta texana* Buckley) has long been known as a defoliator of plants in Texas and Louisiana. Walter, Seaton, and Mathewson (*424*) gave an account of its life history and control. These ants have the habit of cutting leaves from a great variety of plants and carrying them to their nests. Each leaf is finely divided and made into small pellets within the nest. The small masses are placed upon a so-called fungus garden, where they supply a medium for the growth of a fungus, which furnishes the colony with food. As the supply of fungus is consumed the ants add leaf pellets to the old mass. Evidently the ants exercise great care in preventing the contamination of the fungus garden by any other species of fungus. In many cases the attack is concentrated on one tree, which may be entirely defoliated in a single night. The nest consists of underground chambers with many openings or craters. The surplus openings seem to be provided for the purpose of ventilating the underground passages. The ants seem to prefer to construct their nests in sandy soil, but nests are by no means restricted to this type. Many of them are constructed near the base of a tree, so that roots help support the soil over the galleries.

In 1934 these ants were recognized as serious pests of young pines on the Kisatchie National Forest, in Louisiana. Smith[36] gave an account of the control work conducted there. The ants attack young planted pine late in the fall and early in the spring, when there is a

[36] SMITH, M. R. THE TEXAS LEAF-CUTTING ANT (ATTA TEXANA BUCKLEY) AND ITS CONTROL IN THE KISATCHIE NATIONAL FOREST OF LOUISIANA. So. Forest Expt. Sta., Occasional Paper 84, 11 pp. [Processed.]

dearth of other green foliage. In longleaf pine the needles are cut off close to the bud of the seedling, and in slash pine both the needles and bud are cut off and the living bark is girdled. The injured longleaf pines are weakened, but the damage resulting from defoliation is not severe unless drought or other factors affect the tree. In slash pine the injury kills the trees. After trees have become 2 or 3 feet high, they seem to have grown beyond the stage of fatal injury. Another type of injury is that to longleaf seedlings in the cotyledon stage under natural reproduction, where total loss has been caused in areas immediately adjacent to the ant colonies.

Colonies can be controlled and, if treated thoroughly at the proper time of year, can usually be eradicated with carbon disulfide. The best kill is obtained from late in February until early in April, when the ground is warm enough for rapid evaporation of the chemical and the ants are concentrated in the nest. In nests treated during the summer the number of ants is reduced appreciably, but only a small percentage of the colonies are eradicated. Success of the treatment with carbon disulfide depends on keeping the chemical in, and the fresh air out of, the passages into the nest. Approximately 2 ounces of carbon disulfide should be poured into one or two holes within each 10-foot square of the nest area, and all passages, both treated and untreated, should be stamped shut. The easiest way to pour the chemical into the holes is by means of a 5-foot section of ¼-inch rubber tubing attached to a small funnel. Insert the tube deep down into the passages (by a twisting push) before the chemical is poured in. (See caution on p. 23.) In the Kisatchie National Forest 178 colonies were located and treated during the winter of 1936–37 in fenced areas that aggregated 18,799 acres. The colonies averaged 300 holes each—an average of 74 of which were treated. To treat adequately an average colony required 7.2 pints of the chemical.

Johnston (*259*) showed that methyl bromide was effective and practical for control of the Texas leaf-cutting ant and that its use has many advantages over the use of carbon disulfide. In the winter or early in the spring 1 pound of methyl bromide should be released through a piece of rubber tubing attached to the applicator about 2 feet down in the tunnels in the central part of the colony. This treatment will eradicate or greatly reduce a colony of average size. It is unnecessary to close the entrance tunnels to the colony at the time of application.

The Allegheny mound ant (*Formica exsectoides* Forel) is common throughout the East, and its large mounds, or nests, often 3 feet high and 6 feet in diameter, are frequently seen in wooded areas. The ants in these mounds may destroy almost all the vegetation around the nests for a distance of 20 feet or more, although large trees are rarely affected. The chief damage is done to young trees in plantations or clearings. White pine from 2 to 15 years old, red pine, Scotch pine, red cedar, spruce, and many other species are killed. The ants, however, are not vegetarians. They feed on a wide variety of insects, both living and dead, but their principal food is the honeydew given forth by insects that suck sap from trees. Peirson (*349*) showed that the trees are killed by an injection of formic acid into the tissues of the main stem a short distance above the ground. The acid coagulates the cell contents, thus preventing the downward flow of sap. The lesion appears superficially like a fungus canker. He believes the trees are killed to prevent shade from falling on the mound, and this often seems to be the case. Andrews (*2*) and others, however, believe that the ants use less discrimination, often killing trees that do not and probably would not shade the nest.

To destroy these ants in plantations, MacAloney and Hosley (*281*) recommend either carbon disulfide or ethylene dichloride as a fumigant. A dosage of 1 pound (approximately 1 pint) is sufficient for a small mound less than 18 inches in diameter. For a medium-sized mound less than 2½ feet in diameter 2 pounds should be used, and a larger mound may need 2 or more applications of 2 pounds each. Fumigation should be done late in the fall, after seasonal activity has ceased, or early in the spring. Several inches of the top material should be removed from the mound and a deep hole should be punched in the center and several holes on the periphery. The liquid should then be poured in the holes, and the top material should be replaced and tamped down firmly. (See Caution, p. 23.)

The Argentine ant (*Iridomyrmex humilis* (Mayr)) became established in this country in Louisiana sometime prior to 1891 and has spread over a large part of the Southern States, as well as over a considerable area in California. It has proved to be probably the most annoying of the economic ants and a pest of considerable importance. Although especially obnoxious to housekeepers, it also causes serious losses to orchardists, planters, beekeepers, and others. Out of doors the ants feed on the honeydew produced by scale insects, mealybugs, and aphids, and do direct damage to vegetation by fostering these insects. They also steal seeds from seedbeds and feed on the sap or fruit juices from certain trees and plants, particularly citrus.

It is possible to eradicate Argentine ants by timely and thorough campaigns repeated for several consecutive years. The infested area is first delimited by careful survey, and the fact that the Argentine ant destroys all native ants within the infested area is helpful in this part of the campaign. Poisoned sirup containing sodium arsenite, now known as "Standard Government-formula Argentine ant poison," is put out in paperoid cups 20 to 25 feet apart throughout the area. (See Caution, p. 23.) The best time to conduct a campaign is in the fall or winter since little honeydew is produced at this time of year, and the ants will eat the poisoned sirup greedily. Considerable literature is available regarding this species. Its life history was published by Newell and Barber (*320*), and suggestions for control and eradication were given by Smith (*385*).

Superfamily *VESPOIDEA*

The superfamily Vespoidea includes the true social and solitary wasps, as well as a number of families showing great diversity of habit. Some are true parasites, some are inquilines, while the true wasps are essentially predaceous and insectivorous. The pronotum extends back to the tegulae, trochanters are almost always single-jointed, and the petiole of the abdomen is without a scale or node.

As a whole, the Vespoidea are relatively unimportant from the standpoint of economic damage done to the forests, so only the larger families will be discussed very briefly.

Families SCOLIIDAE AND TIPHIIDAE

The Scoliidae and Tiphiidae families contain closely related wasps, many of which are parasitic on the larvae of white grubs (Scarabeidae). They are medium- to large-sized, hairy insects, prevailingly black, often spotted or banded with yellow or red, and their wings are frequently fuscous.

Tiphia inornata Say is one of the commonest and most important parasites of the grubs of the genus *Phyllophaga* in the United States. Wolcott (*435*) studied the life history of this species in Illinois, and reported that under favorable circumstances *Tiphia* greatly reduced the numbers of grubs and in some cases practically exterminated *Phyllophaga* from limited areas. Since white grubs often cause serious losses in nurseries, and the adults feed heavily on many forest trees, the parasite is of considerable economic importance to our forests. The adult is from ¼ to ⅝ inch long, shiny black, with grayish hairs on head, thorax, and abdomen. The wings are short and fuscous. The female seeks out grub larvae in the soil and has little difficulty in working her way through black, heavy clay soil in good tilth and seems to be successful in finding grubs, even where they are not abundant. The wasp stings the grub until it ceases to resist her attempts to deposit an egg on it, but the effect of the sting is only temporary. In fact, the egg or the young maggot is often brushed off by the grub as it burrows through the soil.

The ventral surface of the thorax appears to be the preferred and safest position for egg deposition. Incubation of the egg and growth of the maggot, which feeds externally, requires several weeks. At first the grub does not seem to be affected, but when the parasite becomes about one-third grown its movements are restricted and it prepares a sort of cell in which the parasite larva spins a tough silken cocoon beneath a loose outer network of silk. The winter is spent within the cocoon, and the adult emerges about the middle of May. A number of factors limit the abundance of *Tiphia*. The females are not strong fliers, and they tend to remain in the field where the immature stages were passed.

White grubs are usually abundant in fields where there are trees on which the adult beetles feed, but in some localities only a single generation of the dominant species of *Phyllophaga* may be present, and most species of *Phyllophaga* require 3 years for the completion of their life cycle. In the year that full-grown grubs are abundant there is an ample supply of hosts, but the next year only beetles, eggs, and very small grubs are present. Therefore, in certain years *Tiphia* finds no suitable host material and must disperse to new territory, unless large numbers are to perish without depositing eggs. Other factors affecting *Tiphia* abundance are parasites, fungi, and unsuitable soil conditions, but when soil conditions are unsuitable for *Tiphia*, another parasite, the scoliid wasp *Myzine quinquecincta* (F.) is frequently abundant.

Family BETHYLIDAE

The Bethylidae are a large family of parasitic wasps widely distributed throughout the world. Our species are of small or moderate size. Those of known habits prey upon either coleopterous or lepidopterous larvae, and before pupating most of them spin cocoons. The females are often apterous and different in appearance from the males, therefore the sexes are not easily correlated. Apparently few species are parasites of forest insects, but Cushman (*125*) recorded in 1927 rearing small numbers of *Goniozus longiceps* Kieffer from pine tip moth larvae from Louisiana. He considered the species probably gregarious on full-grown or nearly full-grown larvae.

Family CHRYSIDIDAE

Members of the family Chrysididae are beautiful insects, usually a brilliant metallic green. They are known as cuckoo wasps, for most species lay their eggs in the cells of solitary bees and wasps, and the chrysidid larvae either feed on the rightful occupants of the nests or occasionally eat the food provided for the host larva. One species, *Chrysis shanghaiensis* Smith, is a parasite of the oriental moth (*Cnidocampa flavescens*) in Japan. It has been liberated against this pest in the vicinity of Boston, Mass., but has not become established in this country. Parker (*326*), writing on the biology of *C. shanghaiensis* in 1936, stated that the female parasite chewed a hole in the oriental moth cocoon, laid an external egg on the host larva, and then sealed up the hole. The parasite larva fed externally, and, when feeding was completed, spun a cocoon within which it hibernated. One generation was completed during the year. Species of the genus *Cleptes* are exceptional in that they parasitize Tenthredinidae.

Family VESPIDAE

Subfamily EUMENINAE

The members of the subfamily Eumeninae differ from the Vespinae in being true solitary wasps. They exhibit many variations in their nest-building habits. Certain species dig tunnels in the ground, others construct oval or globular vaselike nests of mud or clay fastened to twigs or other objects, while others construct tubular nests in wood or stems, partitioning the tunnels into cells divided by mud walls. The species are predaceous on small lepidopterous larvae or, more rarely, on larvae of the family Tenthredinidae, and for this reason are of economic importance. They paralyze their prey and store it in the cells of the nest to provide food for their offspring.

Subfamily VESPINAE

The subfamily Vespinae includes those wasps commonly known as hornets and yellow jackets. They live in communities and build two different types of nests. The nest built by hornets is roughly spherical or urn-shaped, and is formed of grayish paper made from fibers of weather-worn but not decayed wood. These nests are familiar objects attached to bushes, trees, or the eaves of buildings. They inclose a series of horizontal combs, suspended one below the other, in which the brood is developed. Large nests may contain as many as 5,000 individuals toward the end of the summer. The other type of nest is built by yellow jackets (fig. 193) in a hole in the ground, in a stump, or under some object, and is enlarged by the wasps as they need more room. The paper forming the nest is made of partly decayed wood, and is therefore very fragile. It is brownish and the enveloping layers are made up of small overlapping shell-like portions. Wasps are largely predaceous in habit, and their larvae feed on other insects. Adult wasps are very partial to nectar, ripe fruits, and honeydew, and feed this diet to young larvae for a short time. At times they injure fruits, and may often be a considerable nuisance, but on the whole they are beneficial, because they are scavengers and help reduce the numbers of injurious insects.

A number of species of *Vespula* are difficult to distinguish from one another. They are the small, black and yellow wasps, commonly

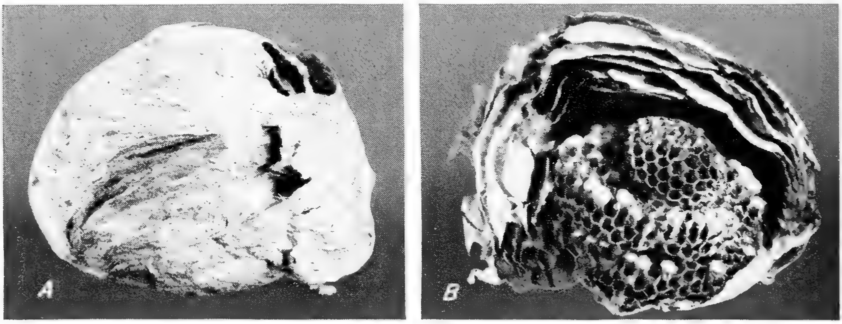

FIGURE 193.—Nest of the common yellow jacket (*Vespula diabolica* (Sauss.)): *A*, Side view; *B*, same with section of shell removed to show interior. (Courtesy Conn. Agr. Expt. Sta.)

known as yellow jackets or hornets, which nest in or above the ground. **The bald-faced hornet** (*V. maculata* (L.)) is the common white-faced hornet, which usually attaches its nest to trees or bushes.

The giant hornet (*Vespa crabro* L.) is our largest species, about an inch long. It builds its nest in hollow trees, or suspends it from the roof within buildings. It is found in the East, particularly in New York and Connecticut, and occasionally attracts notice by the removal of bark from the stems of lilac, ornamental box, birch, and other shrubs. The hornets appear to feed on the sap flowing from the wounds, and they use the bark tissues in the construction of their nests. They tear the bark away down to the cambium, and the injury frequently results in nearly girdling the stems. On account of the insectivorous habits of wasps, they should not be destroyed unless they are in places where they are likely to be disturbed, or unless they are injuring trees and shrubs.

The following control measures are recommended: [37]

When it is necessary to deal with large nests of hornets it is desirable to destroy the entire colony. In the case of nests in buildings or trees, this can be done by carefully observing the nest in the daytime, then at night plugging the entrance holes with cotton soaked in chloroform or benzol. A box or garbage can containing an additional wad of cotton soaked in the anesthetic is next put up so as to enclose the nest, which is then cut down with a long-bladed knife. A tight cover should be applied to the container immediately after the nest has dropped into it, so as to destroy the entire colony.

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[37] THE DESTRUCTION OF WASPS AND YELLOW JACKETS OR HORNETS. U. S. Bur. Ent. and Plant Quar. E–333, 2 pp. 1935. [Processed.]

Where wasps nests are built in inaccessible places, as in walls, the various entrances of the wasps should be noted. At night the openings are plugged, with the exception of the main one. Through this opening benzol or carbon tetrachloride is sprayed, and it is then tightly plugged.

Yellow-jacket nests in the ground may be destroyed by pouring about a teacupful of carbon tetrachloride or carbon disulfide in the hole and covering it with earth or wet sacks. This should be done at night when the wasps are all in the nest.

Open lights, lighted cigarettes, etc., should not be brought around if carbon disulfide is used, because the vapor of this chemical is explosive.

Fly sprays, if applied with a compressed-air or bucket sprayer sometimes can be used to advantage in cleaning out wasp nests. If the nest is kept well enveloped in a droplet spray, the wasps have little chance to escape or to sting the operator.

Downes (*140*) reported that excellent control could be obtained with derris powder (4 percent rotenone). In treating wasp nests built in the wall of a building, throw a handful of derris in the crack through which the wasps emerge, and if it can be made to lodge where the wasps will get it on their bodies, as they pass through, the insects will usually be exterminated in 24 hours. It may sometimes be necesssary to block all entrances except one. Hornets and yellow jackets may also be killed within the nest by throwing in derris powder. A valuable aid in obtaining good distribution of the dust is the use of an applicator consisting of a bulb (8-ounce) having a cone-shaped metal nozzle. The dust is effective as long as it is dry.

Family **PSAMMOCHARIDAE**

The family Psammocharidae is mentioned because it is an extensive group, many species of which are commonly encountered. These insects are remarkable for their extreme activity and ability to run. Most all are predatory, and their prey consists almost exclusively of spiders.

Superfamily *SPHECOIDEA*

The superfamily Sphecoidea includes the Ampulicidae, which prey on cockroaches, the Dryinidae, which parasitize nymphs of Homoptera, and the Sphecidae, which include all of our common nest-building sphecoid wasps. The pronotum does not extend back to the tegulae, except in some Dryinidae and Ampulicidae, the trochanters are single-jointed, the hind tarsi are not dilated, and the pubescence of the head and thorax is simple, not plumose. The Sphecoidea are relatively unimportant as forest insects, and therefore they are treated very briefly.

Family **DRYINIDAE**

The members of the Dryinidae are all parasitic on nymphs of Homoptera, and especially on those of the families Membracidae, Jassidae, Fulgoridae, and Cercopidae. Their biology is exceptionally interesting. During the larval stages they are internal parasites in the abdomen of the host, and usually one or several external gall-like cysts develop on the integument of the attacked insect. These cysts contain the parasite larvae. Many of the cysts are as large as the abdomen of the host. Pupation takes place either on the food plant of the homopteron or in the soil. *Aphelopus theliae* Gahan is a parasite of the membracid *Thelia bimaculata* F., which feeds on young black locust in the Eastern States. The adult is about 1/8 inch long, and black. The mouth parts, except the mandibles, are pale yellow, the mandibles are piceous, and the front tibiae and tarsi more or less reddish. Gahan (*178*) published brief notes on the insect's biology. Oviposition takes place early in June, a single egg being deposited in the *Thelia* nymph. Polyembryonic development takes place, and from 50 to 70 larvae emerge from 1 *Thelia* nymph by boring through the sternites, and then drop to the earth to pupate.

Family SPHECIDAE

The Sphecidae contain many common, small to large wasps. Among them the Sphecinae, or thread-waisted wasps, attract particular attention because of the peculiar shape of their bodies. Although an occasional member of the Sphecidae is an inquiline, most of them are solitary nest-building species that provision their nests with Lepidoptera, Coleoptera, Hemiptera Homoptera, Orthoptera, Diptera, Hymenoptera, or spiders. As a rule, they prepare the nest, accumulate a supply of food sufficient to enable the young to develop to maturity, lay an egg on the food, and then close the cell before the egg has hatched. A few species, however, feed the young from day to day until the larvae have completed development. The prey is stung when captured, so that it is either paralyzed or killed in such a manner that it remains fresh for a considerable period. Members of the family differ greatly in their nesting habits. Some are mason wasps, building cells of earth; many burrow in the ground; and others burrow in the stalks of pithy plants or make use of cavities. Some of the thread-waisted wasps are mud daubers, making nests of mud attached to the lower surface of flat stones or to the ceilings or walls of buildings. These nests usually consist of several tubes about 1 inch long, placed side by side and provisioned with spiders.

Crossocerus parkeri (Banks), syn. *Crabro davidsoni* (Sandh.) (fig. 194), provisions its cells with adult leafhoppers. In 1938 Davidson and Landis (*126*) found that 32 different species of leafhoppers, belonging to the 3 genera, *Typhlocyba*, *Erythroneura*, and *Empoasca*, were preyed upon by *C. parkeri* in Ohio. Some of these leafhoppers are known to feed on forest trees. The wasps form long, winding galleries in dead wood. Each gallery contains many cells, and from 4 to 46 leafhoppers, with an average of 20, are stored in each cell (fig. 195). Apparently the leafhoppers are rendered immobile by being stung before they are placed in the cells, for some individuals retain their original coloration and limp condition for 6 months or longer. An egg is laid in each cell and the larva feeds on the leafhoppers. The wasp cocoon (fig. 194, *B*) is formed within the gallery and consists largely of the exoskeletons of the leafhoppers. The winter is passed in the cocoon, and the adults emerge in the spring.

Sphecius speciosus (Drury), **the cicada-killer,** is a large, formidable-appearing wasp that provisions its nests with cicadas. The adult females are frequently 1½ inches long. They are black or rusty, with prominent yellow bands or spots of yellow on the abdomen. The wings are fuscous. These wasps are frequently seen in August, stinging their prey and carrying the unwieldly cicadas to their nests. The nest consists of a tunnel in the ground, from 6 to 8 inches deep.

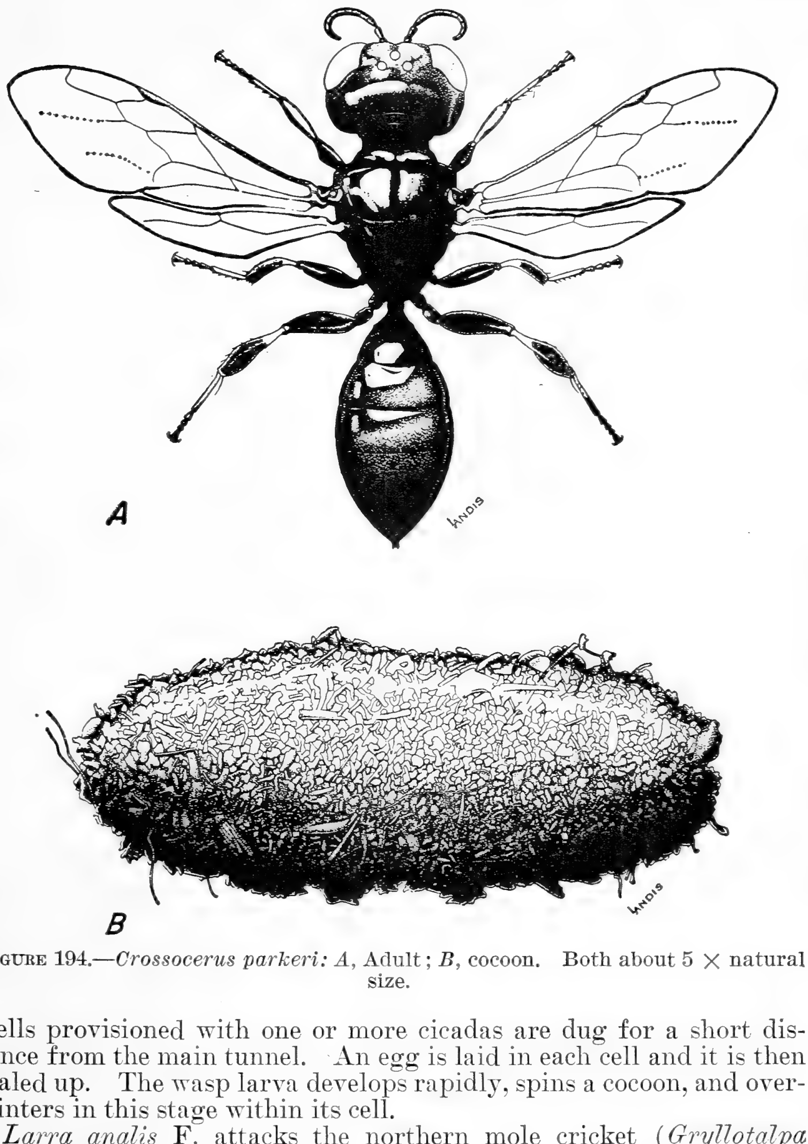

FIGURE 194.—*Crossocerus parkeri: A*, Adult; *B*, cocoon. Both about 5 × natural size.

Cells provisioned with one or more cicadas are dug for a short distance from the main tunnel. An egg is laid in each cell and it is then sealed up. The wasp larva develops rapidly, spins a cocoon, and overwinters in this stage within its cell.

Larra analis F. attacks the northern mole cricket (*Gryllotalpa hexadactyla*), and is found over most of the United States east of the Rocky Mountains. Its biology was studied by Smith (*382*) in Louisiana. The adult insect is about 5/8 inch long, black, with dark, brownish-black wings having shining bronze reflections. At Baton Rouge, La., there are at least three generations a year, with most of the adults present in the field in June, August, and October. The wasps feed on various nectar-producing plants. The females catch most of their victims while the mole crickets are occupying surface burrows. When contact is made the mole cricket fights desperately with its forefeet, but is soon subdued with stings applied about the junction of the abdomen and thorax. In contrast to the effects of the stings of other

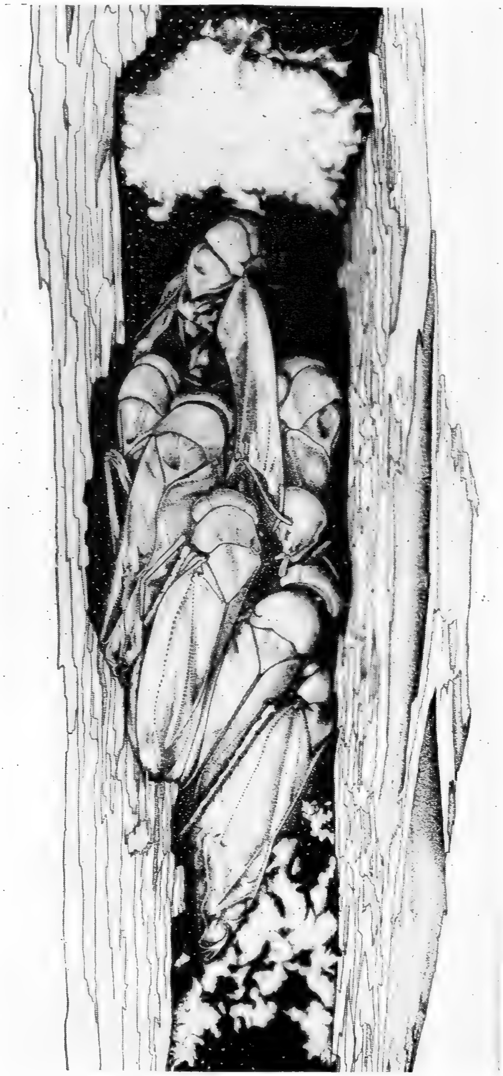

FIGURE 195.—Leafhoppers stored in a piece of rotten log by *Crossocerus parkeri*.

members of the family, this paralysis lasts just long enough to permit deposition of the parasite egg, which is securely attached to the mole cricket's body just back of a hind leg. Normally only one egg is placed on a host. The mole cricket, upon recovering, reenters the soil, makes burrows, and acts in a more or less normal manner until killed by the developing larva. During the first four larval instars the parasite feeds on body juices obtained through an aperture in the body wall. Upon completion of this feeding, and just before molting, the fourth-instar larva kills the host. During the fifth and last stadium, the larva feeds on the muscular parts of the host's body. The cocoon is formed in the midst of the host's remains, or not more than 1 or 2 inches away. The winter is spent in the cocoon stage.

SUPERFAMILY *APOIDEA*

BEES

The bees constitute a very large group of insects, including not only the truly social honey bees and bumble bees, but also many solitary bees. It has been estimated that there are 20,000 different species of bees in the world and 2,500 species in North America. The bees differ from other nest-building hymenopterons in that most of them provision their nests with pollen and honey, instead of animal food. Some, however, live as inquilines or parasites, laying their eggs in the cells of others, and their progeny feed on provisions stored by their hosts. They have a pronotum that does not extend back to the tegulae, and they have single-jointed trochanters, dilated or thickened hind tarsi, and plumose or feathery hairs on the head and thorax. The bees are, of course, extremely important from an economic standpoint, because they act as important agents in pollinating flowers and because of the value of their honey. They are not often considered injurious to forest trees, forest products, or shade trees; nevertheless the families Megachilidae and Xylocopidae sometimes cause light damage.

Family MEGACHILIDAE

Leaf-Cutting Bees

The bees of the genus *Megachile* make their cells out of neatly cut pieces of leaves (fig. 196). Leaves cut by these insects are conspicuous and fairly common. Rose leaves are used more frequently than any other kind, but the work of *Megachile brevis* Say has been reported [38] as common on both maple and rose in Columbus, Ohio. *Megachile* sp. was reported as very injurious to shade trees in north-central Montana in 1932.[39] The nests are made in various places. Sometimes holes are bored into wood, or a cavity already present is used. Frequently any easily adapted place, like a hole in the ground beneath a stone or a crevice between shingles, is used.

Family XYLOCOPIDAE

Large Carpenter Bees

Some of the largest known bees are included in the family Xylocopidae, but most of them inhabit the warmer parts of the United States and the Tropics. They tunnel by means of their mandibles into the solid wood of beams, rafters, telephone poles, or other structural timber, dividing their burrows into a series of cells. These bees deposit a single egg in each cell, which is largely provisioned with pollen. Superficially the adults resemble bumble bees, but they are usually shiny black and without yellowish or reddish markings.

The carpenter bee (*Xylocopa virginica* (Drury)) is the only species found in the northeastern part of the country. It is a large insect, about an inch long, and resembles a bumblebee. It has been reported as causing considerable damage in Ohio by boring in exposed beam ends in houses, and has been reported from Kansas as boring in garage timbers. It sometimes excavates a tunnel a foot in length, which it divides into several cells. The partitions between the cells are made of chips of wood, securely cemented together and arranged in a closely wound spiral. *X. orpifex* Smith and *X. brasilianorum* (L.) are found in the southwestern part of the United States. The former bores in sound redwood and occasionally in Oregon pine, the latter prefers partly decayed live oak, pepper, and eucalyptus. Injury to cut juniper logs from Arizona by *Xylocopa* sp. has been illustrated by Snyder (fig. 197). Ordinarily, damage done by carpenter bees is of little or no consequence, but structural repairs may be necessary if colonies are formed year after year in the same timbers. Dwellings are usually protected by frequent applications of paint. Dusting partially constructed tunnels in wood, either with derris powder (4-percent rotenone) or 10-percent DDT powder; or packing them with absorbent cotton saturated with carbon disulfide and sealing the entrance hole with putty, will kill the adult bees and check the damage.

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[38] U. S. Dept. Agr., Insect Pest Survey Bul. 9: 256. 1929. [Processed.]
[39] U. S. Dept. Agr., Insect Pest Survey Bul. 12: 327. 1932. [Processed.]

FIGURE 196.—Leaf cocoons of *Megachile* sp. in the pith of a woody stem.

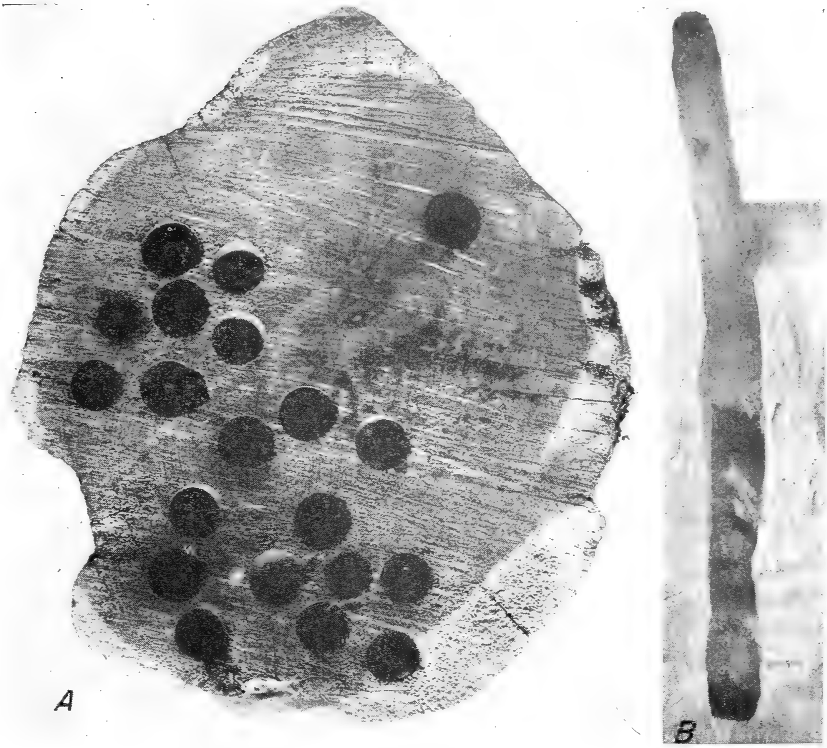

FIGURE 197.—Juniper wood damaged by: *A*, Grub holes made by the carpenter bee *Xylocopa* sp.; *B*, burrow of the carpenter bee.

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