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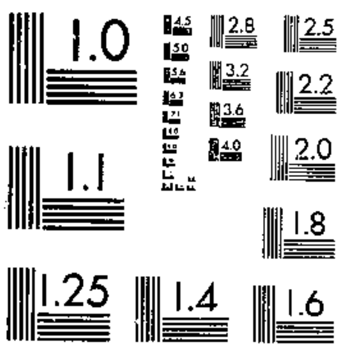

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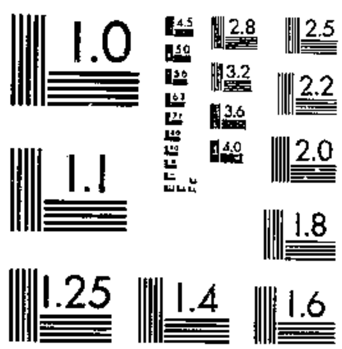

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TECHNICAL BULLETIN No. 86 AUGUST, 1929

UNITED STATES DEPARTMENT OF AGRICULTURE
WASHINGTON, D. C.

IMPORTED INSECT ENEMIES OF THE GIPSY MOTH AND THE BROWN-TAIL MOTH

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CONTENTS

INTRODUCTION

More than twenty years have elapsed since active work was begun to import from their native homes and liberate in the United States the parasites and natural enemies of the gipsy moth, *Porthetria dispar* Linnaeus, and the brown-tail moth, *Nygmia phaeorrhoea* Donovan.

1781°—29——1

At the time this work was initiated, many of the towns in eastern Massachusetts within a radius of 30 miles of Boston were swarming with caterpillars of these insects, and hundreds of thousands of acres of forests, as well as most of the parks and residential sections of the cities and towns, were overrun with these pests. To make conditions far more serious, there were known to be vigorous colonies of these insects throughout southeastern New Hampshire and in York County, Me., in Providence, R. I., and in the towns surrounding.

The statements of multitudes of citizens who suffered material loss as well as personal inconvenience were fully as emphatic as were those of the entomologists who were called upon to review the situation and to attempt some measure of relief from the ever-increasing hordes of these pests. For a few years hand-control measures, although vigorously applied, resulted in little relief, except in limited areas where the most intensive work was done, and completely defoliated areas in late June and July bore witness to the dangers which threatened the tree growth of New England.

The idea of bringing to this country the natural enemies of these pests was hailed with enthusiasm, and hope was frequently expressed that speedy relief would result.

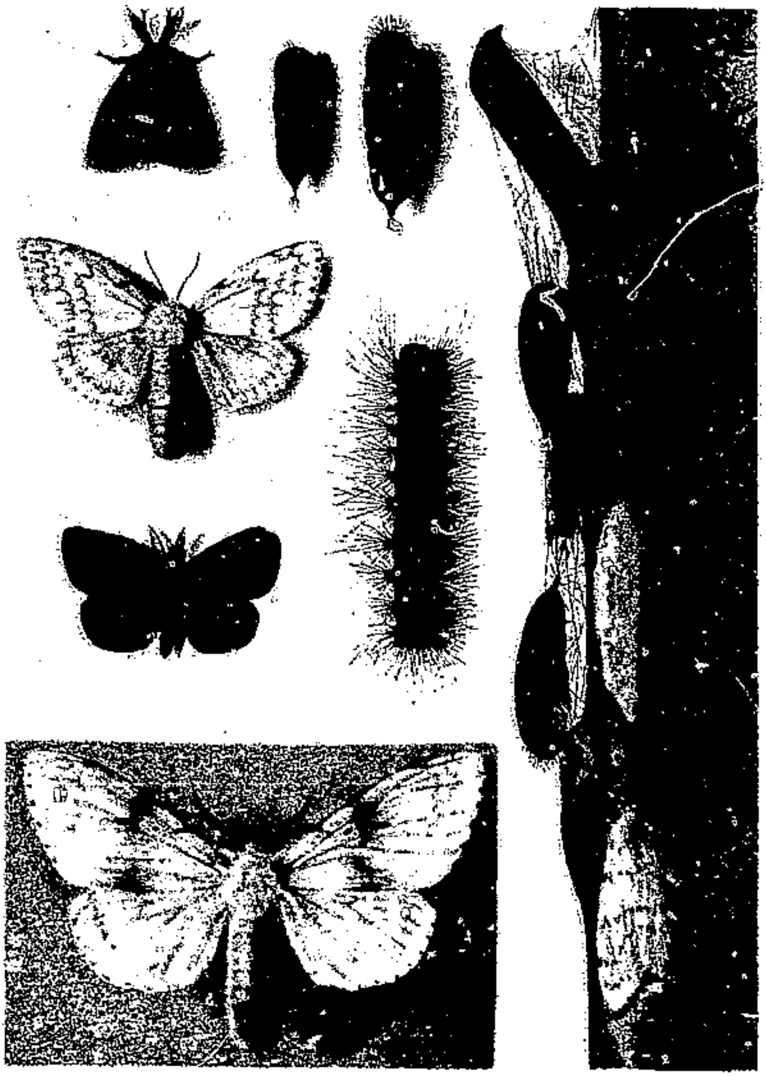
In 1911 a report on this work was published by Howard and Fisk (*14*)[1], which reviewed the efforts made and the results obtained up to that time.

This attempt to introduce parasites and natural enemies to control two closely related foreign pests was the largest in scope that had ever been planned and executed, and no appreciable relief was evident at the time this report was published. The gipsy and brown-tail moths had continued to spread and enormous areas were defoliated each year in outlying territory, in spite of the fact that some of the most promising parasites had begun to obtain a foothold and that intensive control work had been undertaken by all the States concerned and by the Federal Government.

The difficulties of securing parasites and of establishing them successfully in a new country were not fully realized at the time the work began, and the period which was required to make even a slight reduction in the swarms of their fecund hosts could not be estimated. Many of the basic facts relating to the habits of the beneficial species which it was sought to introduce, as well as to the proper methods for the handling and successful transportation of these delicate and in some cases minute species, were to be learned by years of constant experiment and study. Furthermore, the popular idea that a single species of parasite might suffice in effecting control proved to be fallacious for this does not happen in the native homes of these two pests. The difficulties of the problem were further enhanced and the final results were somewhat clouded because of the fact that in many countries in Europe, as well as in northern Africa and Japan where parasites are present and are periodically effective, there are periods when the hosts become excessively abundant.

The work on the introduction and colonization of natural enemies has been continued even more intensively since the bulletin cited was published, and it is being pushed at the present time. As the years passed by, more knowledge was obtained by experience and from

[1] Reference is made by italic numbers in parentheses to "Literature cited," p. 145.



DIFFERENT STAGES OF THE GIPSY MOTH (PORTHETRIA DISPAR)

Egg mass on center of twig; female moth just below; female moth, Japanese variety, lower left; male moth immediately above; female moth immediately above; male moth with wings folded, upper left; male chrysalis at right of this, female chrysalis again at right; larva at center. All about four-fifths natural size. (Howard and Fiske) experimental work, and it is the purpose of this bulletin to review briefly the results obtained.[3]

In order that the relation of the imported parasites to their hosts may be understood, a brief description of the life history and habits of the gipsy moth and the brown-tail moth is given.

LIFE HISTORY AND HABITS OF THE GIPSY MOTH, PORTHETRIA DISPAR LINNAEUS

EGGS

During 9 or 10 months of the year the gipsy moth is in its egg stage (fig. 1). Most of the eggs are laid during July, although some are

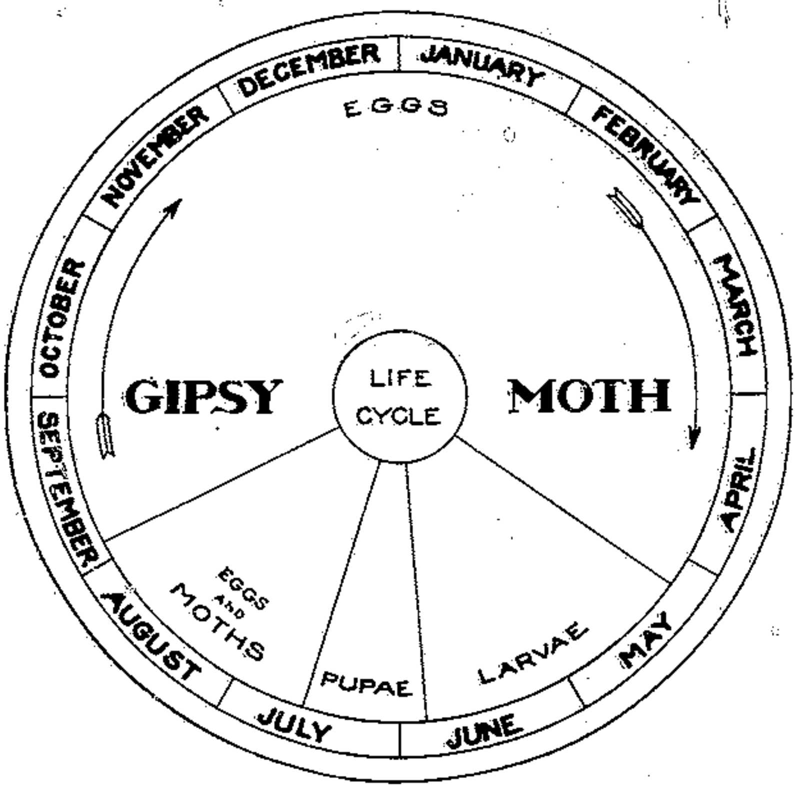


FIG. 1.—Life cycle of the gipsy moth

not laid until August. They are laid in layers protected by buff-colored hairs from the abdomen of the female as shown in the lower

[3] During the progress of the work on gipsy moth and brown-tail moth parasites hundreds, perhaps thousands, of men have assisted in making possible the results set forth. They include not only the men directly employed in this work at the gipsy-moth laboratory at Melrose Highlands, Mass., but a host of other State, Government, and town officials, as well as many citizens whose suggestions and information concerning local conditions have been invaluable. Entomologists and other officials in many foreign lands have afforded every help within their power and many of the embassies and consuls of the United States in foreign countries, and the United States Dispatch agent in New York City, have smoothed the way for foreign investigations and made possible the expeditious dispatch and delivery of shipments of parasites when time was the vital factor and when a slight delay might have meant the death of the delicate material in the shipments and the possible failure of an entire season's work. To all who have assisted this work in any capacity grateful acknowledgement is extended.

right corner of Plate 1. The number of eggs varies considerably, but averages from 300 to 400 for each cluster. They are deposited on the tree trunks and on the under sides of the branches. Sometimes they are found on the leaves and often on a great variety of objects on the ground near trees. Hatching starts in the spring when the new leaves begin to appear, which is usually during the first two weeks of May. It continues over a period of several weeks, but the height of hatching occurs within a week.

LARVAE

Newly hatched caterpillars measure only 3.5 millimeters in length. They feed on the leaf hairs and later perforate the opening leaves. The larvae develop rapidly, and the quantity of food they consume increases very materially as they approach maturity. Sixth-stage caterpillars immediately after molting measure from 30 to 35 millimeters in length. Their bodies are creamy white marked irregularly with black which gives a grayish appearance, and they have a pair of blue dorsal tubercles on each of the segments from the second to the sixth, inclusive, and a pair of red ones on the seventh to twelfth segments, inclusive. These are characteristic of the large larvae and are quite conspicuous. The caterpillars become full grown early in July. Female moths develop from sixth-instar caterpillars (*18*), and males from the fifth instar.

A study of the food plants has been made (*17*), which resulted in their arrangement into four classes according to the degree of favorability as food for this insect. Among the most favored food plants are oak, apple, some of the birches, linden, beech, aspen, and willow. Several of the conifers are favored as food by the larger caterpillars, and the blueberry, cherry, elm, hickory, and maple are often freely eaten.

PUPAE

The caterpillars pupate early in July. The pupae are chestnut brown and are often found in clusters attached to trees, or other objects, by fine silken threads. Many female pupae are an inch or slightly more in length. The male pupae average somewhat smaller. The pupae are provided with characteristic tufts of ocher-yellow hairs. About 10 days after pupation the moths emerge.

ADULTS

The male moths emerge before the females and fly about in a zigzag course. They measure from 1½ to 2 inches from the outside point of one expanded wing to that of the other and are dark brown with darker markings on the wings. The females are larger than the males, measuring from 1½ to 2½ inches between the tips of the spread wings. They are of a light cream color with dark wing markings, and their abdomens are greatly distended with eggs, which makes them clumsy, and as a result they are unable to fly. Mating occurs very soon after the females have emerged. Egg laying begins soon after fertilization and the majority of the eggs are deposited during the first day of oviposition, although several days may be required. As the eggs are deposited the abdomen of the female shrinks, and she usually lives only a short time after laying.

DIFFERENT STAGES OF THE BROWN-TAIL MOTH (NYGMIA PHAEORRHOEA)

Winter nest at upper left; male and female moths, lower right; cocoon in leaf, upper right; male and female chrysalides above, male at left; full grown larva in center, to left small larvae feeding on leaf; below, female ovipositing on leaf; lower left corner, egg cluster broken open showing eggs. Web and full-grown larva X [illegible], chrysalides and egg clusters X [illegible], adults X 1. (Howard and Fiske)

LIFE HISTORY AND HABITS OF THE BROWN-TAIL MOTH, NYGMIA PHAEORRHOEA DONOVAN

EGGS

The eggs of the brown-tail moth are usually laid on the under side of a leaf. They are placed in a cluster, usually smaller than the gipsy-moth egg cluster, measuring about one-half inch in width and two-thirds of an inch in length. The average cluster contains about 300 eggs and is given a reddish-brown color by the hairs from the abdomen of the female, in which the eggs are packed. At the lower left of Plate 2 a brown-tail moth is shown in the act of depositing an

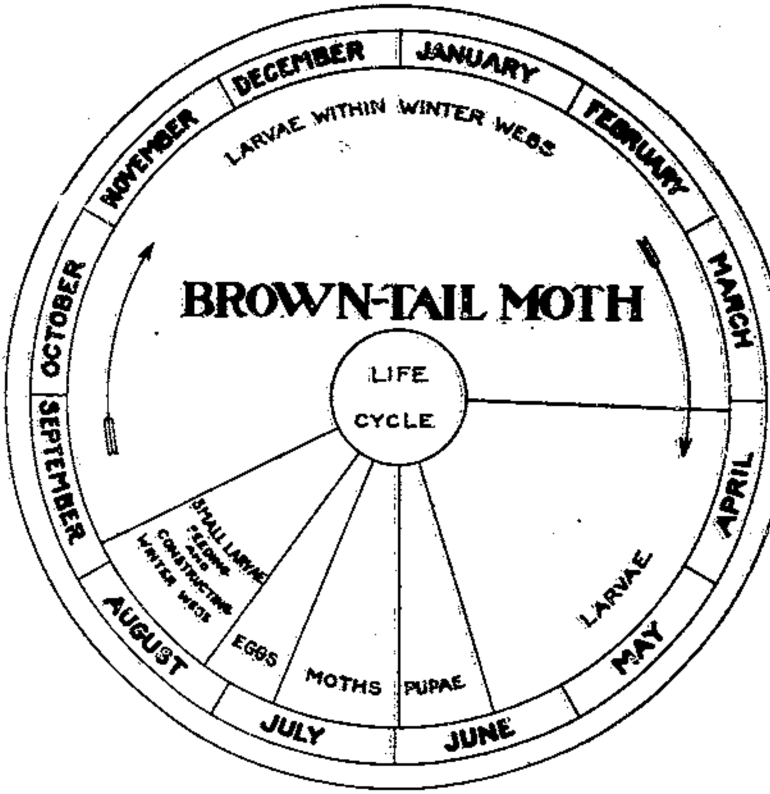


FIG. 2.—Life cycle of the brown-tail moth

egg cluster, and also a completed egg cluster on the same leaf. Just below is seen one of the clusters broken open. They are usually deposited during the middle or last of July (fig. 2). In contrast to the gipsy moth, which remains within the egg during the winter, the brown-tail moths hatch during August and the small caterpillars feed before entering their hibernating quarters.

LARVAE

The newly hatched larvae are smaller than the young gipsy-moth larvae. They feed in groups on the upper surface of the leaf and after molting begin the construction of their hibernating web.

This web is constructed by the small caterpillars drawing together several terminal leaves, often near the egg cluster, and securely fastening them with silk. The larvae from one or more egg clusters often feed together until cool weather sends them into their hibernating webs. The web is very tough and full of pockets in which small groups of the caterpillars pass the winter. The webs are gray and from 3 to 6 inches in length.

The larvae issue from the webs usually in April when the early leaf buds are beginning to open. The small caterpillars feed on the leaves and fruit buds and later, as they develop, devour practically the entire leaf, often completely defoliating the trees. The larvae become full grown about the middle of June, at which time they are about 2 inches long. They have a general brown appearance with a broken white stripe on each side of the body. A conspicuous orange-red tubercle is located dorsally on the sixth and on the seventh abdominal segments.

Apple and pear are especially favored food plants of the brown-tail moth larvae, although plum, oak, willow, and wild cherry are often attacked. The larvae sometimes feed on elm, maple, and rose and occasionally attack hickory, ash, chestnut, and birch, but never conifers.

PUPAE

The full-grown caterpillars spin loosely woven cocoons and in these they pupate. The cocoons are found, clustered or singly, in leaves and on the trunks and under sides of the branches. The pupae are dark brown, and about five-eighths of an inch long. Approximately two weeks after pupation the adults emerge.

ADULTS

Emergence usually occurs during the first week of July, but varies with the season. The moths are pure white except the tip of the abdomen, which is thickly studded with brown hairs. The abdomen of the male is slender, that of the female much stouter. The female measures between the tips of the expanded wings about 1½ inches, which is slightly greater than the wing expanse of the males. Both sexes are strong fliers and are attracted to bright lights, near which they are often seen in large numbers during the first half of July.

INTRODUCTION OF THE GIPSY AND BROWN-TAIL MOTHS AND THE EARLY WORK AGAINST THESE PESTS

The gipsy moth was brought to America in 1868 and was accidentally established in Medford, Mass. The insect had become so destructive by 1890 that the State of Massachusetts began active field operations for the purpose of exterminating it. After the discovery of the brown-tail moth in the same territory measures were taken for its control also.

The brown-tail moth was discovered in Somerville, Mass., in 1897 and had probably been imported a few years before on nursery or florists' stock. At the time this insect was first noticed, fruit and shade trees were being seriously defoliated.

From May, 1891, to February, 1900, admirable control work against the gipsy moth and the brown-tail moth was conducted. In fact the work was so successful in bringing about a scarcity of these insects that those responsible for making continued appropriations considered that further work was unnecessary, and the project was abandoned. With the present knowledge of control and eradication work it seems reasonable to believe that both the gipsy moth and the brown-tail moth could have been exterminated if the work had been continued. There were only 359 square miles sparsely infested by the gipsy moth. The area infested by the brown-tail moth probably was greater, but the eradication of this insect would have been more easily accomplished than the eradication of the gipsy moth. The amount of money necessary to finance such an extermination project would have been only a small portion of the sum that has subsequently been expended.

THE ABUNDANCE AND SPREAD OF THE GIPSY MOTH AND THE BROWN-TAIL MOTH FROM 1905 TO 1927

The abandonment of the eradication project for five years allowed the moths to increase enormously and to spread to such an extent that when the work was started again in 1905 the gipsy moth was found over an area covering 2,224 square miles, and the brown-tail moth over an area even greater. The gipsy moth had become established in Maine, New Hampshire, and Rhode Island, while the brown-tail moth had spread the entire length of the Atlantic coast line from Nantucket, Mass., to Eastport, Me., and St. John, New Brunswick.

There are many published records depicting the abundance of these insects. The following statement by A. H. Kirkland (*15, p. 12*), superintendent of the work in Massachusetts, prepared during the late fall of 1905, gives an idea of the seriousness of the situation:

> As would have been expected, during the years 1900 and 1901 but little notable damage was caused by the gipsy moth, although evidence was not wanting to the trained observer that it was rapidly multiplying in woodlands and on neglected private estates. It was apparent that nonresident property owners particularly paid practically no attention to the increase of the insect, and that farmers and others owning infested woodland areas were unwilling, because of the expense, to fight the pest. In 1902 numerous estates were severely injured throughout the central district, while woodland colonies of some magnitude had developed from which the insects were swarming in all directions. The summer of 1903 showed that the moth had established itself again in alarming numbers in various parts of the infested district. Serious colonies had developed in the woods of Arlington, Medford, Saugus, and Malden, and the Lynn Woods colonies had assumed notable proportions. In 1904 it was apparent to all that the gipsy moth had developed to a remarkable degree, reinfested the areas from which it had been cleared and even extended its bounds into previously non-infested territory. The caterpillar outbreak was sufficient to convince every tree lover of the necessity of concerted action against the moths. While in many places in the afflicted district the trees under the charge of municipal authorities were cared for with considerable success, private estates and woodlands in June and July presented shocking scenes of devastation. In many places the work of fire could not have been more thorough or alarming. From Belmont to Saugus and Lynn a continuous chain of woodland colonies presented a sight at once disgusting and pitiful. The hungry caterpillars of both species of moths swarmed everywhere; they dropped on persons, carriages, cars and automobiles, and were thus widely scattered. They invaded houses, swarmed into living and sleeping rooms and even made homes uninhabitable. Thousands of cases of poisoning of human beings resulted from the swarming of the brown-tail caterpillars. Real estate in the worst infested districts underwent a notable depreciation in value. Worst of all, pines and other conifers—altogether too scarce in eastern Massachusetts—were killed outright by the gipsy moth caterpillars, while shade trees and orchards were swept bare of foliage. Property owners who were disposed to care for their own estates suffered and became discouraged from the neglect of their neighbors. It was evident that the moth pests were in the ascendency, and that they could be controlled only by prompt, thorough and systematic effort.

Many of the conditions just described continued for several years, although, in general, the suppression work prevented a great deal of such devastation in residential sections and along the main thoroughfares. In spite of the artificial control work which was done the insects continued to spread, and as the years passed they gradually became abundant over the greater part of the eastern half of Massachusetts, the northeastern corner of Rhode Island, the southeastern half of New Hampshire, and the southwestern quarter of Maine.

The gipsy moth spread far beyond these sections, and several rather serious infestations were found in Pennsylvania, New Jersey,[3] and Ohio. All of these have been exterminated excepting a severe infestation in New Jersey, which was located in 1920 and found to have spread over approximately 400 square miles. Work is being conducted jointly in this area by the State and Federal forces. The area infested and the intensity of the infestation have been greatly reduced, and extermination of the insect in New Jersey seems probable if the work is continued for a few years longer. In 1924 a gipsy-moth infestation was found by the Canadian entomologists a few miles north of the international border near the New York and Vermont State lines. This infestation seems to have been eradicated, but work is being continued there to make positive the absolute extermination of this colony.

In the older infested area conditions had begun to improve by 1920, and during the following four or five years less defoliation was caused by the gipsy moth than for any period since the work was begun in 1905. In 1925, however, a serious infestation sprang up over a considerable area on Cape Cod which in 1926 increased in area and intensity. A careful survey of conditions there showed that about 60,000 acres were completely or partially defoliated. This year also showed a marked increase of the gipsy moth over a considerable part of the older infested area in New England. The insect continued to increase in abundance in 1927 over a large part of the older infested territory, and a survey including the heaviest infested areas in all of the New England States showed partial to complete defoliation in about 140,000 acres. Over half of this area was from 75 to 100 per cent defoliated.

The brown-tail moth infestation increased in a similar manner, but its decrease in abundance over the area as a whole began a few years sooner than it did in the case of the other insect. It has been persistently abundant in a section in southeastern New Hampshire and southwestern Maine during most of the period. The reports for the year 1927 indicated that this species also was somewhat more abundant than during the previous years.

In recent years the field-control work to prevent further spread of these insects undertaken by the Bureau of Entomology of the United States Department of Agriculture has been confined to an area, known as the barrier zone, in western New England and eastern New York, to prevent the westward spread of the gipsy moth. The infested New England States are confining their efforts to the control of this insect east of the zone, and the State of New York is working in close cooperation with the Federal Government in the border zone. The reduction of infestation in the older infested territory caused by the increase of parasites and field-control operations has contributed materially to the excellent results that have been obtained

[3] This is a separate introduction, not spread from New England.

in the barrier zone. Long-distance spread has been prevented by the enforcement of quarantine regulations, and shipments originating

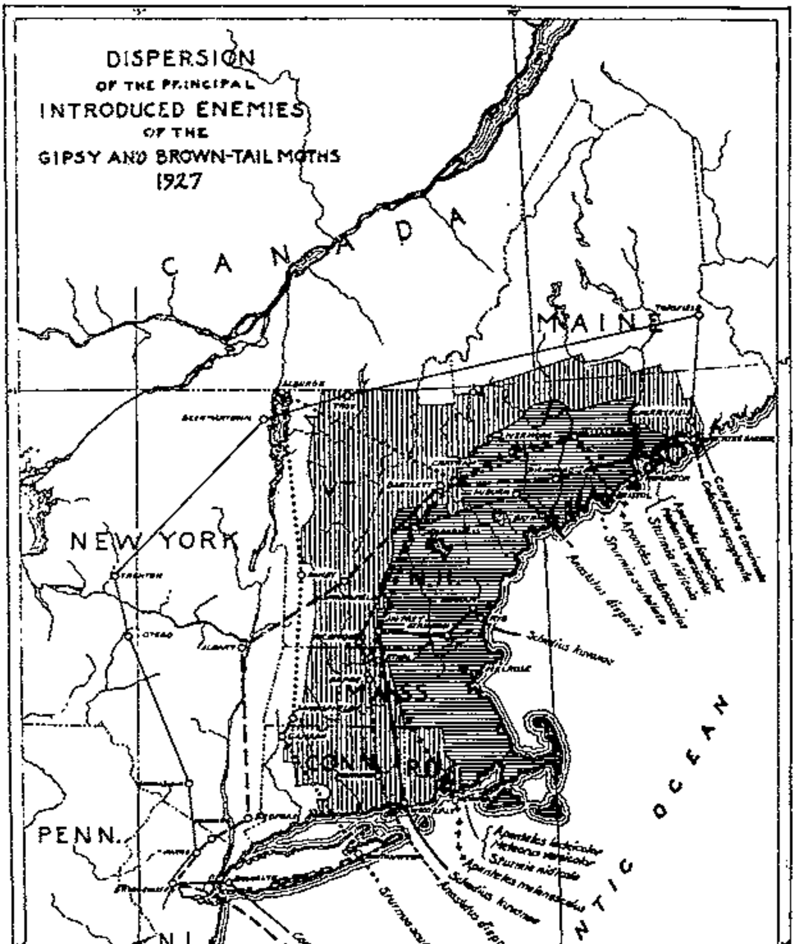


FIG. 3.—Dispersion of introduced enemies of the gipsy moth and the brown-tail moth, 1927. The horizontally lined section is the area quarantined because of the brown-tail moth. This area together with the perpendicularly lined section is the area quarantined for the gipsy moth. The limits of the present-known dispersion of the principal introduced enemies of the gipsy moth and the brown-tail moth are shown by the lines on the map

in the infested territory of products likely to carry infestation are carefully inspected before movement is allowed to points outside.

The present dispersion of these insects, as indicated by the area quarantined because of them. is shown in Figure 3.

EARLY FOREIGN WORK

In the spring of 1905 the Massachusetts Legislature passed a bill declaring the gipsy moth and brown-tail moth public nuisances and providing for their suppression. A. H. Kirkland was appointed superintendent, in general charge of the work of suppressing these moths. In addition to the appropriation of funds to meet the expenses incurred by the moth-suppression work, an appropriation was made for the purpose of experimenting with the natural enemies of the moths. The latter appropriation was used, with a small appropriation made by Congress, for the purpose of studying and importing the natural enemies of the moths. Very soon after the beginning of the work the superintendent enlisted the advice and services of L. O. Howard, Chief of the Bureau of Entomology, United States Department of Agriculture, to supervise the study and introduction of the natural enemies of the moths. Doctor Howard immediately corresponded with several entomologists in regard to sending to this country the natural enemies of the gipsy moth and the brown-tail moth, and on June 3 he sailed for Europe and held consultations with many officials and entomologists of several countries. This resulted in the receipt of a number of shipments of parasite material during the season.

In Doctor Howard's first report (*15, p. 125*) to the superintendent for suppressing the gipsy moth and brown-tail moth he refers to the fine cooperation of the "official entomologists of Europe," and says:

> * * * all have expressed a hearty desire to cooperate with the United States government and with the government of the State of Massachusetts in their work. Their personal endeavors have been at our service, and their expert advice has been of much assistance. In many cases they have been good enough to select and recommend agents, who have been paid for their services from the State appropriation. The personal services of the official entomologists, however, have been gratuitous.

Mention is made here of this early cooperation of foreign entomologists in this work, since their interest and hearty cooperation from the beginning to the present time have made the work possible.

The State of Massachusetts and the Federal Government cooperated in this investigation from 1905 to nearly the end of 1911, when a reorganization was arranged, and the Bureau of Entomology took over the laboratory and importation work in its entirety.

During these years Doctor Howard made several European trips, and at first arranged with a number of European entomologists and agencies to send to America large collections of the various stages of the gipsy moth and the brown-tail moth, and their natural enemies. Prior to 1912 this work was enlarged, and several experts employed by the Bureau of Entomology went to Europe and Japan to study these pests in their native lands and to send their natural enemies to this country. In 1914 the foreign work had to be abandoned because of the outbreak of the World War, and no further investigations were made until 1922.

RECENT FOREIGN WORK

Since the spring of 1922 the Bureau of Entomology has been conducting the foreign work; endeavoring to introduce several natural enemies of the gipsy moth which apparently did not become established during the former importation work. In the earlier work several of the species were never received and liberated in satisfactory numbers; and others, although colonized in large numbers, were liberated under conditions which were not favorable to their establishment.

The foreign parasites which have been received at the gipsy-moth laboratory (fig. 4) during the last few years have been obtained, for the most part, by rearing them in their native countries from gipsy-moth caterpillars.

During the spring of 1923 the junior author, accompanied by R. T. Webber, made a search for gipsy-moth infestations in France, Spain,

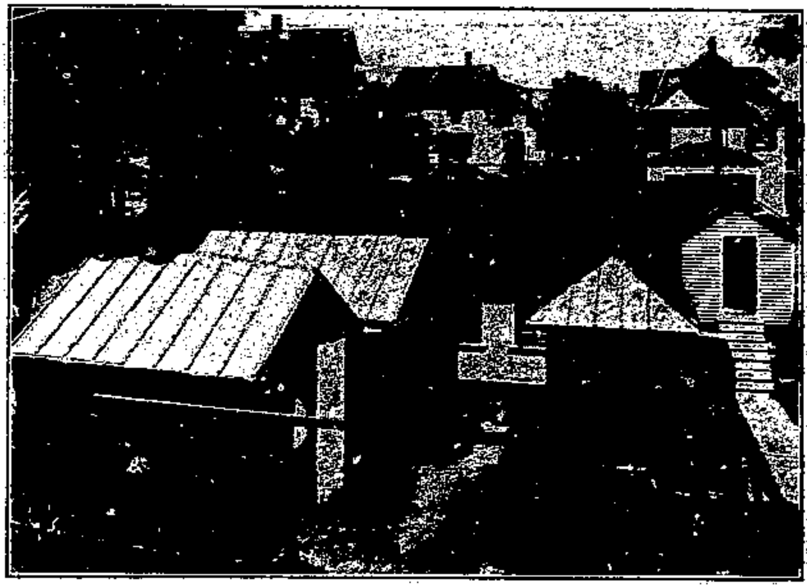


FIG. 4.—The gipsy-moth laboratory yard and insectary at Melrose Highlands, Mass. (Burgess)

Italy, Germany, Austria, Hungary, Rumania, and Poland. In only two of these countries were gipsy-moth infestations found which were of sufficient size to warrant establishing temporary laboratories where caterpillar collections could be made. An indication of the scarcity of the gipsy moth over a large part of Europe was shown the previous year when the junior author searched for gipsy-moth infestations over much of the territory of the first four countries named, and, excepting in Spain, was unable to locate an infestation of sufficient size to make possible large collections of the caterpillars.

After a search had been made in several countries without success, a gipsy-moth infestation of medium intensity was located at Debrecen, Hungary (*11*), a town about 120 miles east of Budapest. Here arrangements were made for laboratory quarters (fig. 5, B), a large number of wooden trays with cloth bottoms were made, and the collection of large numbers of caterpillars was begun. During the season over 100,000 caterpillars were obtained, from which about 44,000 parasites were reared. A few small trays containing 100 caterpillars each were also kept. From these it was possible to gather more accurate information on the degree of parasitism than could be obtained from the large trays, each of which contained several thousand gipsy-moth caterpillars. The records obtained from the small trays showed that about 70 per cent of the caterpillars were parasitized. More than one-half of this parasitism was caused by the two tachinids *Phorocera agilis* and *Sturmia scutellata.*

Caterpillars were collected almost every day as long as it was possible to find them. Each day the caterpillars in the trays were supplied with fresh oak foliage, and the remains of the previous day's feed removed. Tachinid parasites were practically the only ones reared in this work. The maggots were removed each day as they issued, and placed in a large box containing fine damp sawdust,

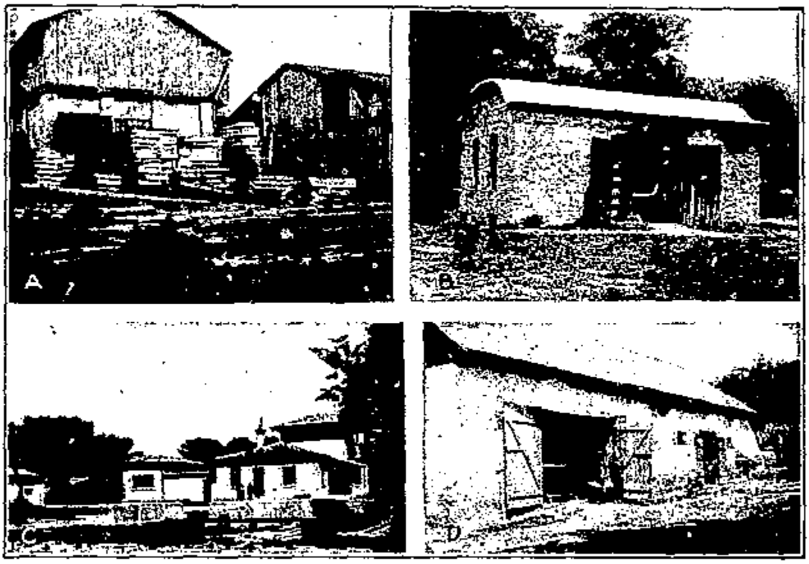


FIG. 5.—Buildings used as temporary insectaries during the recent European parasite investigations: A, At Baja, Hungary; B, Debreceu, Hungary; C, Madrid, Spain; D, Galgamacsa, Hungary

in which they formed their puparia. Several times during the season these puparia were separated from the sawdust and packed in boxes with new sawdust for shipment to the United States. Wooden boxes, about 6 inches long, 4 inches wide, and 3 inches deep, served well for shipping tachinid puparia. These boxes were then packed in larger ones of convenient size for transportation in the cold-storage room of a steamer going to the United States.

In 1924 the work was enlarged, and conducted in two laboratories in Spain, and one each in Poland, Yugoslavia, Bulgaria, and Hungary. That year S. M. Dohanian accompanied the junior author and Mr. Webber. Mr. Dohanian remained in Spain and carried on the work there. About 75,000 gipsy-moth caterpillars and pupae were handled. Most of the caterpillars were kept in Spain to obtain the parasites. The majority of the pupae were sent to Melrose Highlands, to be held there for the issuance of the parasites. The studies in Spain were conducted in two separate areas, one at Madrid, and the other about 150 miles south of Madrid, at Villanueva de Cordoba. Through the kindness of Manuel Aulló, director of the laboratory of the forest fauna of Spain, also chief of the service for the study and extinction of forest plagues, space in Government laboratories at both of these places was given for these investigations.

In Poland arrangements were made to collect large numbers of gipsy-moth caterpillars, but the gipsy-moth colony selected for the work was so greatly depleted in the second larval instar by an extraordinary abundance of the braconid parasite *Apanteles porthetriae* that only about 19,000 of the fifth and sixth instar caterpillars could be collected. The majority of these died in the trays in the insectary from an epidemic of disease similar to "wilt," so only a few tachinids were obtained from Poland.

Here was an example of a heavy gipsy-moth infestation, which apparently had developed to severity almost within a year, being overcome by natural agencies the first season of its abundance. In this case the intensity of the infestation was greatly reduced early in the summer by *A. porthetriae* and later most of the remaining caterpillars and pupae died of disease. *A. liparidis* was also present, as were several tachinids. Only a few more than 1,000 tachinid puparia were obtained, but dissections of the caterpillars indicated that many more would have been secured had the caterpillars not died of the disease.

Considerable difficulty was experienced in Yugoslavia in locating a gipsy-moth infestation of sufficient intensity for parasite-rearing work. During the early spring a location was found in the northern part of that country where a light to medium infestation of egg clusters was found. On the trees were both old and new clusters, with the old ones predominating. The conditions here indicated that this infestation was subsiding, and it was supposed that the few thousand caterpillars which might be collected would be highly parasitized. Later in the season, however, when it was time to make collections of caterpillars for the rearing of tachinids, it was found that this infestation had been so greatly reduced that caterpillar collections could not be made. It was evident that *A. porthetriae* had played an important part in the reduction. *A. liparidis* also was found but there was little evidence of disease. Another small infestation was finally located, limited in area and of light intensity, where about 20,000 large gipsy-moth caterpillars and pupae were collected. It was possible to collect this number only through the perseverance of Madame Anna Bragina (Mikrina), of the laboratory for the study of tropical diseases at Belgrade, whose services had been obtained for the summer. Over 60 per cent of these were parasitized, *Phorocera agilis* and *Sturmia scutellata* being the principal parasites, the former the more abundant.

After a survey of most of Bulgaria, there was found in a small town near its center the only gipsy-moth infestation in that country which was of sufficient intensity to furnish parasites for shipment to America. The infestation was medium to heavy in intensity, but limited to a few thousand fruit trees. Near the infestation was an old mill, part of which was at once converted into an insectary. About 120,000 gipsy-moth caterpillars were collected and from these over 20,000 tachinids were obtained.

At Debrecen, Hungary, the same building was used for an insectary that had served in 1923. The location of the gipsy-moth infestation was somewhat different from that of the previous year. The area where the caterpillars had been collected that summer was relatively free from that insect this season. Several other places, only a few miles distant, were found for the caterpillar collections. About 300,000 gipsy-moth caterpillars were obtained and fed in the trays. These yielded a large number of tachinid puparia, 32,000 of which were placed in hibernation at the gipsy-moth laboratory at Melrose Highlands. The decrease in the gipsy-moth infestation at Debrecen during the summer of 1923 was due largely to the parasitism of *P. agilis* although several other tachinids were recovered, *S. scutellata* being next in importance. *A. porthetriae* and *A. liparidis* were present, the former being much more abundant. *Calosoma sycophanta* played a small part in the natural control of the gipsy moth at this place. The wilt disease was very scarce throughout the season and was not an important factor in the control. In 1924 the infestation had a similar history, although in that year *A. porthetriae* was much more abundant than in the previous year. Because of the scarcity of the gipsy moth at Debrecen in 1925, a new place in which to carry on the work in Hungary had to be found. Only one station in Spain (fig. 5, C) was continued in the 1925 work, but a new one was opened in Portugal. The work at these stations was cared for by Mr. Dohanian, who handled some 60,000 gipsy-moth caterpillars and pupae at the former place. and 98,000 at the latter station. Mr. Webber, with P. B. Dowden, of the gipsy-moth laboratory, continued the work in central and southeastern Europe, and a temporary laboratory was established at Belki, Czechoslovakia, and one at Baja (fig. 5, A) in the southern part of Hungary.

Before the customary rearing work of the season was begun in central Europe, Messrs. Webber and Dowden found several places where attempts might be made to get large numbers of *A. porthetriae* for quick transportation to the United States. Previously only a very few of these parasites had ever been received alive at Melrose Highlands. A few living caterpillars or cocoons of the parasite had been shipped in the cold room of the steamer, but the Apanteles obtained from these were not strong and vigorous and did not mate readily. As they were never received in sufficient numbers for colonization they had to be increased at the gipsy-moth laboratory by reproduction work, through one or two generations, before liberation. This procedure was not entirely satisfactory, for by the time a sufficient supply was on hand for liberation, the gipsy-moth caterpillars in the field were advanced beyond the stages preferred by this parasite.

To obtain a sufficient number of *A. porthetriae* for colonization in New England, while the gipsy-moth caterpillars were still small and suitable to serve as its host, it seemed necessary that the Apanteles and the caterpillars parasitized by it should be collected at the proper time in Europe and started immediately on their way to the United States. This was accomplished by having the living parasites taken directly to the United States and cared for en route. They arrived early enough in the season for at least one generation to reproduce in the field under natural conditions.

As soon as the European work with *A. porthetriae* was completed for the season, a temporary laboratory was established at Belki, Czechoslovakia, near a severe gipsy-moth infestation. Over 300,000 gipsy-moth caterpillars were collected and fed at this station, and about 10,000 puparia were obtained from them, although a disease of the caterpillars interfered seriously with the work. At the laboratory at Baja, Hungary, over 30,000 tachinid puparia were reared from about 400,000 caterpillars.

In 1925, the tachinid puparia, mostly *P. agilis* and *S. scutellata*, were packed in sawdust and shipped to Melrose Highlands more often than had been done during the previous year. With these were mixed puparia of summer-issuing tachinids only the freshest of which had much chance of getting to Melrose Highlands before the adults issued. As soon as the tachinid maggots began issuing from the caterpillars, their puparia were sent to the United States, several shipments being made each week. As time was one of the factors in establishing the multibrooded species, some of the collections were sent by airplane mail to Paris and thence by rail to Cherbourg, where they were placed in the vegetable room of the first steamer sailing for the United States. In this manner the species mentioned were received alive at Melrose Highlands in sufficient numbers for biological studies of them to be made, and several species were colonized in small numbers.

Another innovation was the obtaining of a large number of *Sturmia inconspicua* for colonization. During the spring of 1924 Antoni Czarnecki *(9)*, of Bochnia, Poland, collected large numbers of hibernating cocoons of the sawfly *Lophyrus pini* L., which were very abundant that year. From them he reared several parasites among which was a tachinid, which was later recognized as *Sturmia inconspicua*. Accordingly, early in the spring of 1925 Mr. Dowden went to Bochnia and arranged for the collection of large numbers of cocoons of this sawfly. About 8 bushels were obtained and shipped in four large grain sacks, to a temporary laboratory at the seaport. Unfortunately, many of them had been damaged by heating when they were delayed several days because of frontier regulations. The good cocoons were spread in trays, and as the Sturmia maggots issued they were packed in boxes in damp sawdust and shipped to the United States. Upon arrival at Melrose Highlands they were placed in rearing cages where the adults could issue and mate before colonization.

Early in 1926 Mr. Webber again went abroad to continue the work of gathering gipsy-moth parasites in central Europe. Later in the spring he was joined by C. F. W. Muesebeck and R. C. Brown, of the gipsy-moth laboratory. Two temporary summer field stations were established in Hungary, one at Baja in the southern area, and the other (fig. 5, D) in a small town named Galgamacsa, about 30 miles northeast of Budapest. During the summer Mr. Brown assisted Mr. Webber. Mr. Muesebeck established a temporary laboratory in Budapest, where studies are being made of the gipsy moth and its natural enemies, many of which have not been established in this country.

A special attempt was made again in 1926 to send the puparia often, so that as many as possible of the multibrooded tachinids might arrive before the adults issued. During the height of the parasite issuance the puparia were removed from the trays and shipped to the United States daily, and on some days more than one shipment was made. These packages were sent direct by mail to Cherbourg, France, where they were placed in cold storage on the steamer. As a result of the frequent sendings many summer-issuing tachinids were received alive and approximately 20,000 were liberated. To obtain these, together with over 85,000 tachinid puparia which were placed in hibernation at Melrose Highlands, considerably over half a million gipsy-moth caterpillars were collected and fed at the stations at Baja and Galgamacsa that season.

At the close of the rearing work Mr. Brown remained in Europe to assist Mr. Muesebeck in his biological studies; and Mr. Webber made a trip into southern Europe and northern Africa, to locate gipsy-moth infestations which might provide more species of parasites for introduction into the United States.

Early in 1927 Mr. Webber returned to Europe, and at Budapest with Mr. Muesebeck made arrangements for the season's work in Europe. He then proceeded to several of the Mediterranean countries and established a temporary laboratory at a heavy infestation near Oran, Algeria. In Europe, in addition to the laboratory at Budapest, summer insectaries were established at Moscenica, Yugoslavia; Rembertow, Poland; and Simontornya, Olaszliszka, and Doboz, Hungary. Over 1,000,000 gipsy-moth caterpillars and pupae were collected and cared for at the foreign laboratories during the summer, resulting in the liberation of approximately 42,000 adult tachinids, consisting of 7 species, only 1 of which is known to be established. Moreover, 53,424 puparia were placed in hibernation and 10,000 hymenopterous parasites were liberated. After the season's importation work was finished Mr. Webber returned to Melrose Highlands, and Mr. Muesebeck and Mr. Brown remained at the Budapest laboratory to continue the investigations.

During the years 1922 and 1923 J. N. Summers, of the gipsy-moth laboratory, carried on similar work in Japan for about six months of each of these years. The introductions and colonizations which have resulted from these investigations are given under the discussion of the parasites concerned.

RECEIVING AND HANDLING THE FOREIGN MATERIAL AT THE GIPSY-MOTH LABORATORY

A detailed discussion of the methods used in handling the various parasites will be found, as a rule, under the treatment of the various species. There it will be seen that the actual gathering of suitable material in foreign countries, and landing it at our shores, are only small parts of the procedure necessary for the establishment and dispersal of the beneficial species in this country.

All possible precautions are being taken to prevent any injurious forms from becoming established in this country, especially those hyperparasites which prey upon the useful insects which are being introduced. During the early work when material was received at the laboratory the packages were opened with the greatest care, and the parasite material was removed and assorted according to species. The host material often had to be given the best attention in order to rear any beneficial insects which it might harbor. In recent years a room in one of the laboratory-yard buildings has been especially prepared where all packages containing insect material from foreign countries are opened. This room is in a fram building with wooden floors, sides, and roof. The outside walls are clapboarded, and the roof is covered with tarred paper. The inside dimensions of the room are approximately 26 by 8 by 8 feet. Over the floor is tightly fitted a good grade of linoleum. The wooden walls and ceiling are covered with plaster board the joints of which are sealed by nailing over them strips of ¼-inch stock, 1½ inches wide. Between the ceiling and the roof is a large closed-in air space. In the center of the ceiling is a tightly screened area which permits the circulation of air. The walls and ceiling are painted with white enamel to make the room light. The building runs east and west and is entered on the east

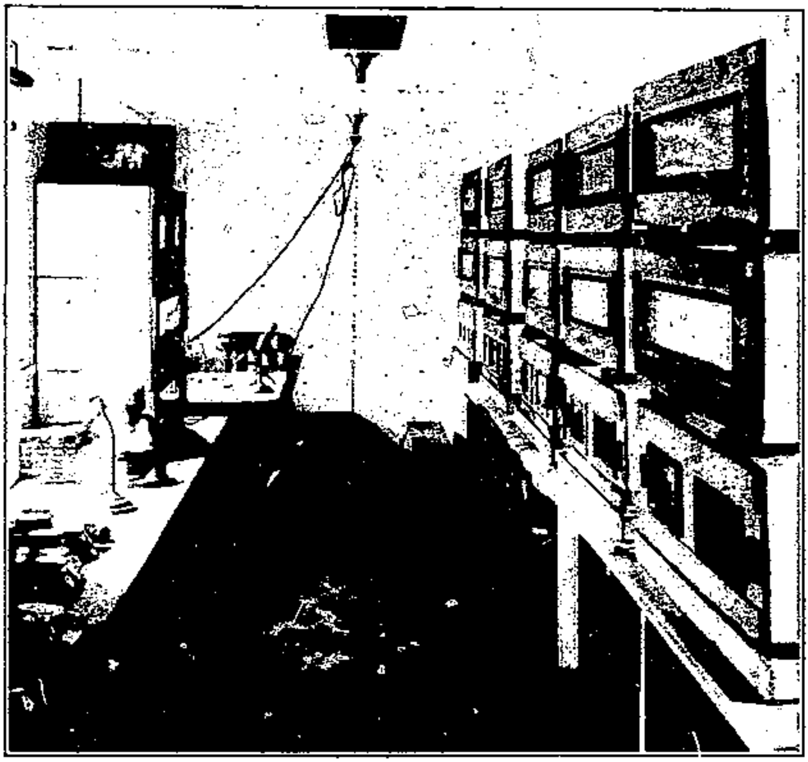


FIG. 6.—Room in one of the laboratory yard buildings at Melrose Highlands, where the foreign packages of insects are opened. This room is also used for rearing work with foreign material. Note the emergence and mating cages for tachinids at the right of the picture

end by two doors between which is a closed space about 3 feet deep and the width of the room. On the south side are three ordinary-size windows spaced equally distant from the ends of the room and from one another. In front of them are working tables. Along the entire north wall of the room about 3 feet from the floor is a screened opening 30 inches wide, in front of which is a long bench on which the emergence and mating cages rest. The screening over this space and over the windows is 60-mesh copper wire netting through which no insect can escape. Special methods, based on their habits of life, are employed in handling the different species received.

HANDLING OF MULTIBROODED TACHINIDS

The multibrooded tachinids are usually received at the laboratory during July, coming as puparia, and special cages are used in handling them. When the curtains are drawn over the windows on the south side of the room the light enters through the screens on the opposite side. It shines through the cloth backs of the tiers of cages (fig. 6), and attracts the parasites away from the cage doors which must be opened occasionally to remove the parasites or replace the food. This equipment can be used with a number of species of Tachinidae which have rather similar habits.

The puparia are received in sawdust in small boxes (fig. 7), and upon arrival at the laboratory the packages are opened in the room just described. With small shipments, the puparia may be taken from the sawdust by hand, but great saving of time results, particu-

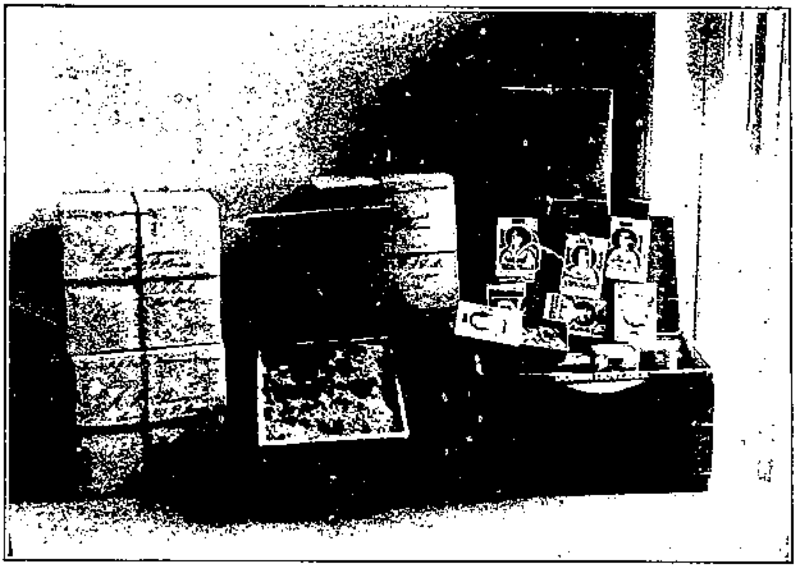


FIG. 7.—A shipment of tachinid puparia received at the gipsy-moth laboratory during the summer of 1926. The puparia are packed in sawdust in boxes measuring 3½ inches deep, 4½ inches wide, and 7 inches long, seen at the center of the picture. At the right is shown similar material packed in match boxes

larly with large shipments, if the winnowing apparatus (fig. 12, *d*) is used. When this device is properly adjusted the puparia may be separated from the sawdust very rapidly. Most of them are then examined individually under a binocular microscope in order to separate the various species, for several multibrooded tachinids come with the single-brooded ones. The puparia of the multibrooded tachinids are placed in cages (fig. 8), for emergence. The lower cage (fig. 8, B) has a bottom of 14-mesh copper-wire netting, the top, ends, and back are covered with cotton cloth, and the front is of wood or wall board and has a sliding door. The cage is set on damp sand in a galvanized-iron tray (fig. 8, A), and sometimes a small quantity of damp sand is spread over the bottom of the lower cage, B, which keeps it in contact with the larger quantity of sand in the iron tray. The puparia are placed in cage B.

The first flies to emerge are males, but the females begin to emerge before the male issuance is completed. As the flies come out they crawl up on the cloth sides of the cage. The males are removed and placed together, in cage C or D. They are easily removed by placing a 4 by 1 inch test tube over them. As the tube touches them they crawl into it and are kept there by placing the thumb over the open end. As the females issue they are removed and placed with the males in C or D. The males in C and D are older than the females and the freshly emerged females mate with them more readily than with males which have recently issued. The females which happen to become mated in the lower or emergence cage (B) are removed to a colonization cage. (Fig. 9.) During the emergence and mating period the cages are watched carefully, and as pairs are observed in coition they are removed, while still together, in glass tubes in the same manner as are the individual flies. The tubes containing the mated pairs are laid aside and left undisturbed until the pairs have separated. The males are then returned to the mating cages (fig. 8, C and D), and the fertilized females are placed in the colonization cages.

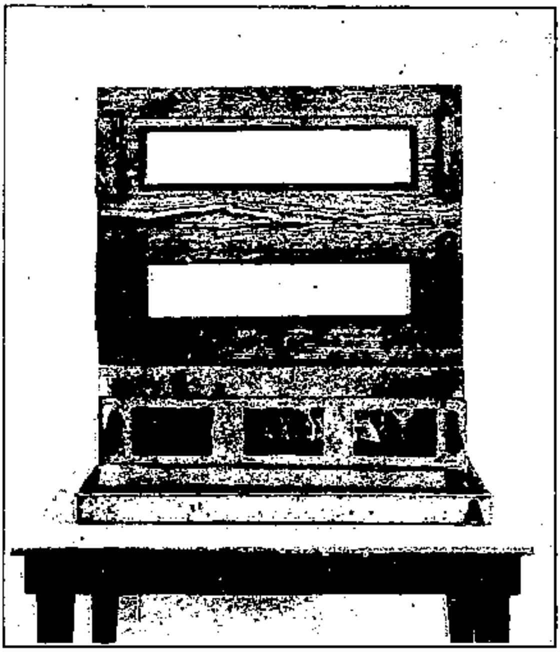


FIG. 8.—A rack of emergence and mating cages for tachinids: A, A galvanized-iron tray, 3½ by 19 by 40 inches, in which sand is placed and kept moist; B, the emergence cage, 14 by 16 by 30 inches, on the wire-netting bottom of which the puparia are placed; C and D, mating cages, which are the same size as cage B, and are constructed in a similar manner except that they have cloth bottoms instead of wire-netting bottoms

In this manner the males are used several times in the mating cages. As soon as a sufficient number of fertilized females have been obtained they are liberated, and as the end of the mating and colonization period approaches the males are liberated with the females.

The parasites are fed in the emergence and mating cages by attaching numerous pieces of dry loaf sugar to the sides and top of the cages. The loaf sugar is held in place on the cloth by setting it in small quantities of melted paraffin which hardens quickly and holds the sugar firmly in place. In the wire colonization cages (fig. 9), the pieces of sugar are tied in place. Clean water is placed in the cages on pieces of sponge, and several times daily the flies and inner sides of the cages are lightly sprayed with clean water. There is always some mortality of flies in the cages so that it is necessary to liberate them as often as a sufficient number are on hand for a colony. The feeding of the flies appears to be very important, and more experimental work is necessary in order that this may be done under ideal conditions and in the best possible manner. It is likely that proper feeding is a factor not only in the length of time that the flies live but also in connection with mating and egg development. In some cages, in addition to the loaf sugar and water diet, pieces of fruit, vegetables, and flowers have been supplied, but these have not seemed to prolong the life of the tachinids to any extent.

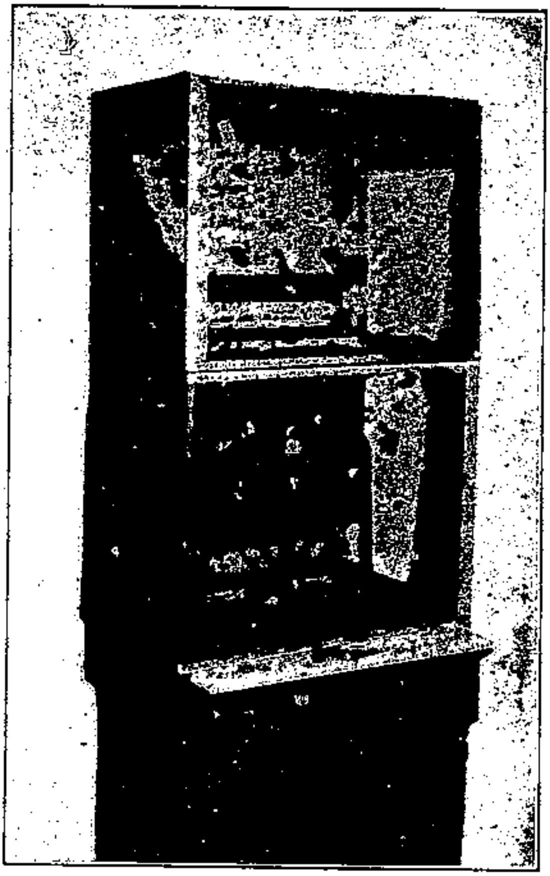


FIG. 9.—Two tachinid colonization cages 18 by 24 by 36 inches, covered with copper-wire mosquito netting. The flies and loaf sugar used for their food are shown in the picture

The colonization cages, while being stocked, are kept under one of the buildings in a cool and shaded place, where the flies are less active than they would be in the bright sunlight. In liberating the flies it is merely necessary to remove a portion of one side of the cage to allow them to escape.

HANDLING OF SINGLE-BROODED TACHINIDS

Several methods have been tried for carrying through the winter the single-brooded tachinids *Phorocera agilis* and *Sturmia scutellata*, which pass the winter in the ground within their puparia. The method which seems to serve best is described below.

Most of the puparia which are received are placed in hibernation without attempting to separate the living ones from the dead ones. The puparia are packed in light sandy loam, in trays 14 inches square and 3 inches deep (fig. 10), for hibernation. The bottom of each tray is of 60-mesh copper-wire screening. In filling these trays about one-half inch of soil is placed in the bottom of the tray, then a layer of puparia is placed in it, so spaced as not to allow the puparia to touch one another. These are covered with about one-half inch of soil, then another layer of puparia is placed in the tray, and the process continued until the tray has been filled. It is then covered with the same type of copper-wire screening as was used on the bottom of the tray. The trays are set into earth which has previously been well spaded and leveled in the laboratory yard, and covered with 3 or 4 inches of soil and the whole is protected with a light layer of straw or leaves.

In the spring, just before the time for the adults to issue, the trays are taken up and the puparia removed from the soil. The puparia are then placed in rearing cages and handled the same as are the multibrooded species.

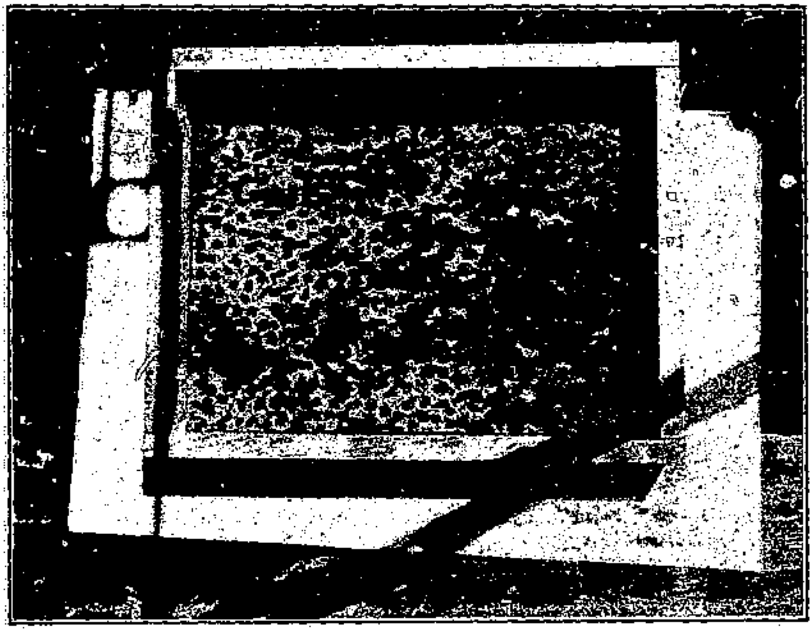


FIG. 10.—A layer of *Sturmia scutellata* puparia being prepared for hibernation

HANDLING OF HYMENOPTEROUS LARVAL PARASITES

The hymenopterous parasites of the gipsy moth and the brown-tail moth larvae vary so greatly in their habits that different methods, described in detail under the several species, have had to be used in handling them. In some cases the best results have been obtained by rearing the parasites for liberation from foreign collections of their hosts. In other cases, especially when only a few specimens of some species could be obtained, they have been increased through reproduction at the laboratory before liberation. In the case of one species, large numbers of its hibernating cocoons were collected, sent to this country, and held until the adults emerged the following spring, whereupon the adults were liberated. Another species was collected in Europe and brought to this country in the adult stage. This lot required special attention and care en route. Most of these adults were liberated upon arrival here, but some were retained at the laboratory and used in reproduction work, which resulted in the rearing of large numbers of this parasite for liberation.

After the parasites became established, and when further colonization was necessary, they were collected in this country. Some species can be obtained in large numbers by collecting the proper stages of their hosts and caring for them until the parasites issue. With other species it is best to collect the hibernating cocoons of the parasites, and use the adults, when they issue, in reproducing large numbers for colonization.

HANDLING OF EGG PARASITES

Two species of hymenopterous egg parasites of the gipsy moth have been established in this country. These are handled by entirely different methods from the larval parasites. One species, which has several generations each year, is obtained in small numbers from collections of gipsy-moth eggs. These are then increased to large numbers for liberation each season by rearing them through several generations at the laboratory. The other species, which has a single generation each year and passes the winter within the gipsy-moth eggs, is obtained in large numbers by collecting the host eggs and separating the parasitized from the nonparasitized eggs.

HANDLING OF PREDACIOUS BEETLES

The adults of predacious beetles have been collected in their native countries and shipped here. They have arrived in this country in good condition when each beetle was placed in a small match box with damp sphagnum moss. In some cases adult beetles of foreign origin have been liberated here, but in most cases they have been held at the laboratory and increased through reproduction. After suitable numbers have been obtained by this method, adults as well as their larvae are liberated.

FOREIGN INSECT ENEMIES OF THE GIPSY MOTH POSITIVELY ESTABLISHED

Over 93,000,000 enemies of the gipsy moth and the brown-tail moth have been liberated in this country. Some 47 species have been liberated, 15 of which are known to be positively established, and 9 or 10 of these have become of considerable importance as enemies of these insects in New England. Several other important species, which have been liberated during recent years, may be established, although absolute records to show this have not been obtained.

In the following discussion the parasites have been arranged in the order in which the stages of the host are attacked. Those parasites attacking the eggs are treated first, then those which parasitize the small, the medium, and the large-size caterpillars, respectively, and finally those which kill the pupae. They have been arranged in two groups—those that are positively established and those that are not. Only the species which have been encountered in the recent investigation are discussed in the text, as the status of the others reported in the earlier work by Howard and Fiske (*14*) has not changed. All of the species, however, which have been liberated, are included in the summary of the total colonizations of imported enemies of the gipsy moth and brown-tail moth.

EGG PARASITES

ANASTATUS DISPARIS Ruschka[4]

Anastatus disparis (fig. 11) is a parasite of the gipsy-moth egg. It attacks eggs other than those of the gipsy moth with reluctance, but has been bred in laboratory experiments in eggs of *Hemileuca oliviae* Ckll. and *Hemerocampa leucostigma* S. & A. The species has also been recorded as acting as a hyperparasite on *Apanteles melanoscelus* Ratz. Extensive collections of cocoons of this Apanteles, however, show that the rôle played by Anastatus as a hyperparasite is very inconsequential. It has a single generation each year, passing the winter as a larva within the gipsy-moth egg. It is now firmly established and is rated as one of the most important of the introduced enemies of the gipsy moth. It disperses slowly and this has necessitated a large amount of colonization in order to hasten its establishment over the entire area infested by the gipsy moth.

Foreign Distribution and Abundance

This parasite is widely distributed in Europe and in Japan. It has been recovered at the gipsy-moth laboratory at Melrose Highlands from gipsy-moth eggs collected at Akabane, Fukuoka, Funakimura, Gifu, and Nishigahara, Japan; Crimea, Schiriga, Kiev, and Kishenev, Russia; Lipova (Lippa),[5] Dorgos, and Sistarovat, Rumania; Huszt, Poland; Schlesien, Germany; and Nantes, France. Recent investigators from the gipsy-moth laboratory have found this parasite at Yokohama, Japan; Hyères, France; Madrid, Talavera de la Reina, and Salamanca, Spain; Caltagirone in Sicily, Italy; Dahlem, Germany; Beli Manastir, Yugoslavia; Bělki, Czechoslovakia; and Vetrén, Bulgaria.

Examinations made at Melrose Highlands of gipsy-moth egg clusters which were collected in foreign countries, and field examinations made by the bureau men, indicate that, although this parasite is distributed over much of Japan and Europe, its abundance is variable and periodical. The records of the parasitism of gipsy-moth eggs which have been gathered from Japan and Europe indicate that this parasite is more abundant in some of the European countries than in Japan.

During the winter of 1908–9 approximately 1,000,000 gipsy-moth eggs were received from the towns listed in Rumania and Poland. The value of this parasite in Europe that winter is well demonstrated by the fact that approximately 25 per cent of these eggs contained Anastatus. Recent work carried on in Spain by the department of investigations and extermination of forest plagues, under the direction of Manuel Aulló, has shown that this parasite is an important enemy of the gipsy moth in that country. The Spanish authorities are transferring Anastatus from areas of abundance to other parts of the country where it is absent. In this work they have found the parasitism by Anastatus to run from none to 35 per cent, and in some locations where large collections of gipsy-moth eggs have been made an average of 15 per cent were parasitized by Anastatus. The experts of the Bureau of Entomology, while carrying on parasite investigations in Spain from 1922 to 1925, found Anastatus present in gipsy-moth egg clusters in many places, and records of from 10 to 20 per cent of parasitism were obtained.

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[4] In previous American literature referred to as *Anastatus bifasciatus* Fonscolombe (*1a, 22a*).
[5] The towns listed in Rumania and Poland were in Hungary when these importations were made.

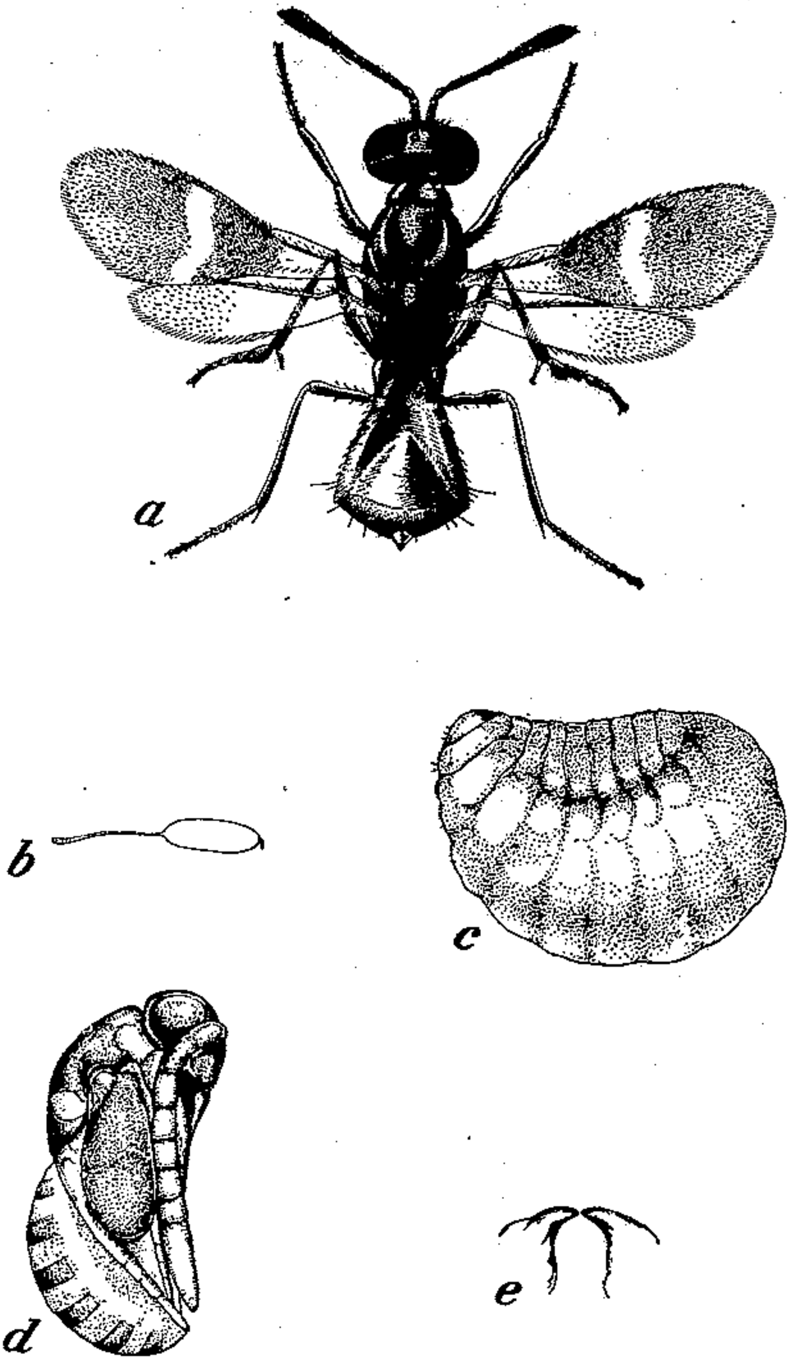
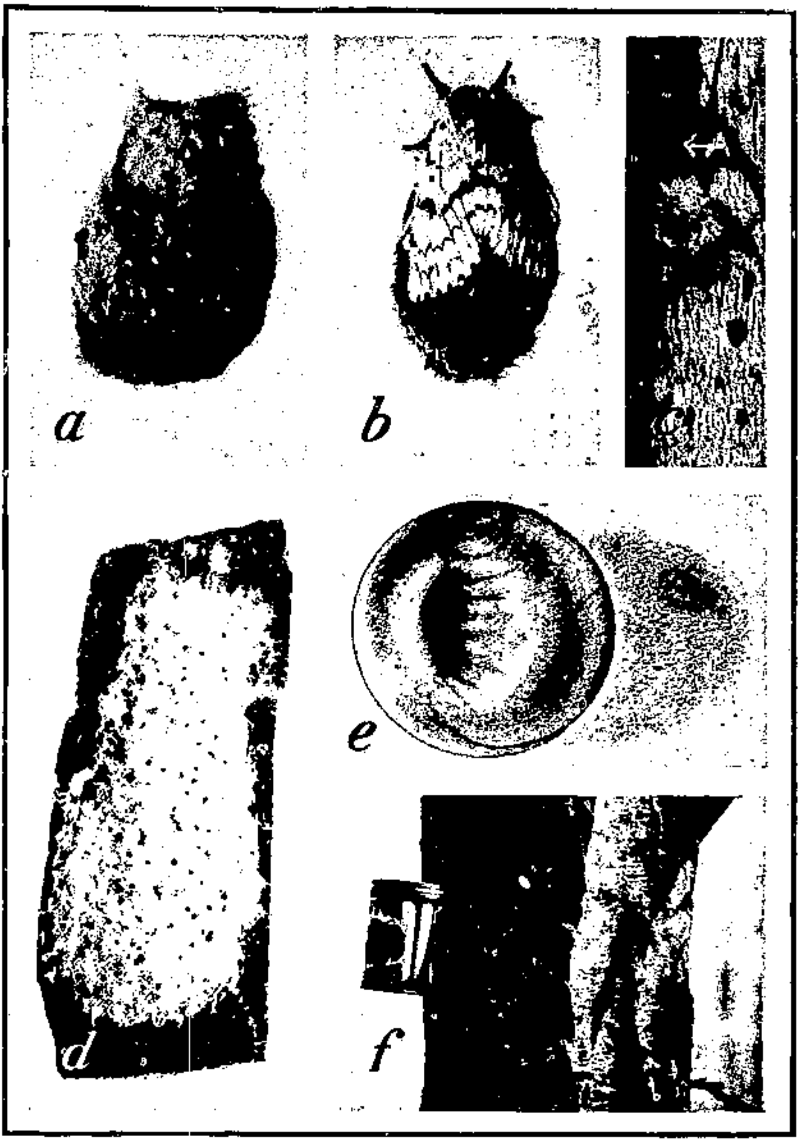


FIG. 11.—*Anastatus disparis*: *a*, Adult, × 19; *b*, uterine egg; *c*, hibernating larva removed from egg, × 45; *d*, pupa, × 47; *e*, mandibles, × 19. *b* and *e*, greatly enlarged. (Howard and Fiske)



SCHEDIUS KUVANAE AND ANASTATUS DISPARIS

a, Gipsy moth egg cluster with adult Schedius on it, × 1½; *b*, female gipsy moth depositing egg cluster, with female Anastatus on cluster, life size; *c*, Anastatus colonization mark on roadside tree; *d*, gipsy moth egg cluster showing exit holes of Schedius, × 2; *e*, hibernating larva of Anastatus as seen within host egg, × 34; *f*, Anastatus colonization can in position on tree trunk. *d* and *e*, Howard and Fiske; *a*, *b*, *c*, and *f*, Crossman

Life History and Habits

Normally Anastatus has a single generation each year, although occasionally two generations have been recorded in one season. Usually nearly 12 months are spent by the parasite within the gipsy-moth egg. This period ranges from 10 to 13 months. Records have also been obtained of Anastatus living within gipsy-moth eggs for two years when these eggs were placed in cold storage at a temperature of about 30° F. and kept there a year after the normal time of issuance of the parasite (*10*). Most of the Anastatus emerge from gipsy-moth eggs, after hibernation, during the last two weeks of July. This period varies somewhat with the season, but occurs at the time when the majority of the female gipsy moths are depositing their egg clusters. The female parasites are often seen on the gipsy-moth eggs before the cluster has been completely deposited. The parasite egg and larva develop quickly, requiring only two weeks to develop from egg to full-grown larva.

The males fly, but the females are unable to do so, and the adult life is rather short in confinement—10 days to 2 weeks being the average when they are kept in cages and fed a mixture of 40 per cent of honey in water.

Importation

Anastatus for colonization in New England were originally obtained from gipsy-moth eggs which were collected in Europe and Japan. Large shipments of gipsy-moth eggs were received in bulk, in cloth bags inclosed in wooden boxes. In the case of smaller lots, the egg clusters were often wrapped individually in paper and packed in layers between blotting paper. The shipments were received by both mail and express in a satisfactory condition. In shipping large collections of gipsy-moth eggs, it is advisable to divide them into packages of about 2 quarts each. This avoids heating, which is apt to occur when larger quantities are confined in tight packages for several weeks. Some shipments came in the steamer's cold storage, but this is not necessary unless the eggs have been exposed to freezing temperature before they were collected.

Gipsy-moth eggs parasitized by this species began to arrive during the winter of 1907–8. At first they were kept in the laboratory to hasten the issuance of the parasites, in the expectation that the adults would parasitize large numbers of the gipsy-moth eggs which had been held in cold storage since the previous fall. No reproduction was obtained from these experiments, and the remainder of the foreign eggs were placed in cold storage until the appearance in the field of new gipsy-moth egg clusters. They were then removed and the adults which issued at this time were liberated. During the winter of 1908–9 large shipments of gipsy-moth egg clusters were received, mostly from Hungary. These eggs were placed in trays for the non-parasitized ones to hatch, the parasitized eggs being left for use in colonization.

Colonization

The first few individuals of Anastatus liberated in New England were adults released during the summer of 1908. They were obtained from gipsy-moth eggs collected in Japan and Russia. In 1909 the species was colonized in much greater numbers as mature larvae within the host eggs. Most of this material came from Hungary, although some was from Japan. The species quickly became established so that all of the Anastatus colonized after 1909 were obtained in New England.

As Anastatus disperses very slowly it has been necessary to colonize the species each year in large numbers, in order to hasten the time when it would become well distributed, and thus to derive as quickly as possible the benefit of its presence. Table 1 gives a summary of the numbers of Anastatus which have been liberated in this country.

TABLE 1.—*Numbers of Anastatus disparis colonized in New England*

Year	Number liberated in—						
	Massachusetts	New Hampshire	Maine	Rhode Island	Connecticut	Vermont	Total
1908	513						513
1909	128,180						128,180
1910	105,000						105,000
1911	227,500	26,000					253,500
1912	621,000						621,000
1913	851,000	571,000					1,422,000
1914	1,047,000	514,000					1,561,000
1915	6,877,000	1,501,000	813,000				9,191,000
1916	8,227,000	3,522,000	942,000				12,691,000
1917	1,722,000	4,376,000	1,357,000	573,000	51,000		8,079,000
1918 [1]	645,000	575,000	377,000	93,000	55,000		1,745,000
1919	2,111,000	6,273,000	1,675,000	135,000	144,000		10,338,000
1920		1,214,000					1,214,000
1921	[2] 500,000						500,000
1922	3,708,000	816,000	242,000	258,000	430,000	112,000	5,566,000
1923	333,000	225,000	167,000		200,000	5,000	930,000
1924	291,000	494,000	200,000	41,000	257,000	100,000	1,383,000
1925	492,000	1,068,000	500,000		330,000	25,000	2,435,000
1926	1,046,000	207,000	[3] 425,000	196,000	400,000	59,000	2,333,000
1927	[4] 2,527,000	1,369,000	650,000		596,000	6,000	5,148,000
Total	31,459,193	22,771,000	7,348,000	1,296,000	2,463,000	307,000	65,644,193

[1] Enough eggs of the gipsy moth were collected during the winter of 1917–18 to yield 8,000,000 Anastatus, but unusually low temperatures caused heavy mortality of both host and parasite.
[2] Estimated. The greater part of the material was used for a large reproduction experiment.
[3] 50,000 of this number estimated to have been the number in one colony.
[4] 1,000,000 of this number used in an experiment in a heavily infested area.

A total of 65,644,193 Anastatus have been released. For the most part these have been liberated in colonies, each consisting of 1,000 parasitized gipsy-moth eggs. They were placed in small tin cans (pl. 3, *f*), provided with several small holes near the top, through which the adult parasites escaped as they issued. These cans were fastened to trees. In the older infested towns, where the gipsy-moth infestation was general, each town was colonized thoroughly. The one who liberated the colonies was provided with a blue-print map showing all the roads in each town. Where the gipsy-moth infestation was sufficient to warrant the liberation, colonies of parasites were placed one-fourth of a mile apart on both sides of all roads, in woodland, a few hundred feet in from the roadside. As each colony was liberated, its location was marked on the blue print. Two colonies in each town were marked in the field so that they might be easily found for later observations. Reference to Figure 3 will show that most of the colonization which remains to be done is in the border area generally considered lightly infested. In much of this area it is not practicable to colonize solidly, as has been done in the older infested territory. Here the infestations are often several miles apart. In these infestations 2,000 or more parasites of Anastatus are liberated in each colony.

APPARATUS AND METHODS USED TO OBTAIN ANASTATUS FOR COLONIZATION

In the early work, before Anastatus was generally distributed, there were a few strong Anastatus colonies where the parasitized gipsy-moth eggs were gathered. Using the center of a colony as a starting point, 8 lines were run out, 4 to the cardinal points of the compass and 4 midway between these. In the fall sample collections of gipsy-moth eggs were made at designated distances along these lines. These sample collections were examined at the laboratory to determine the

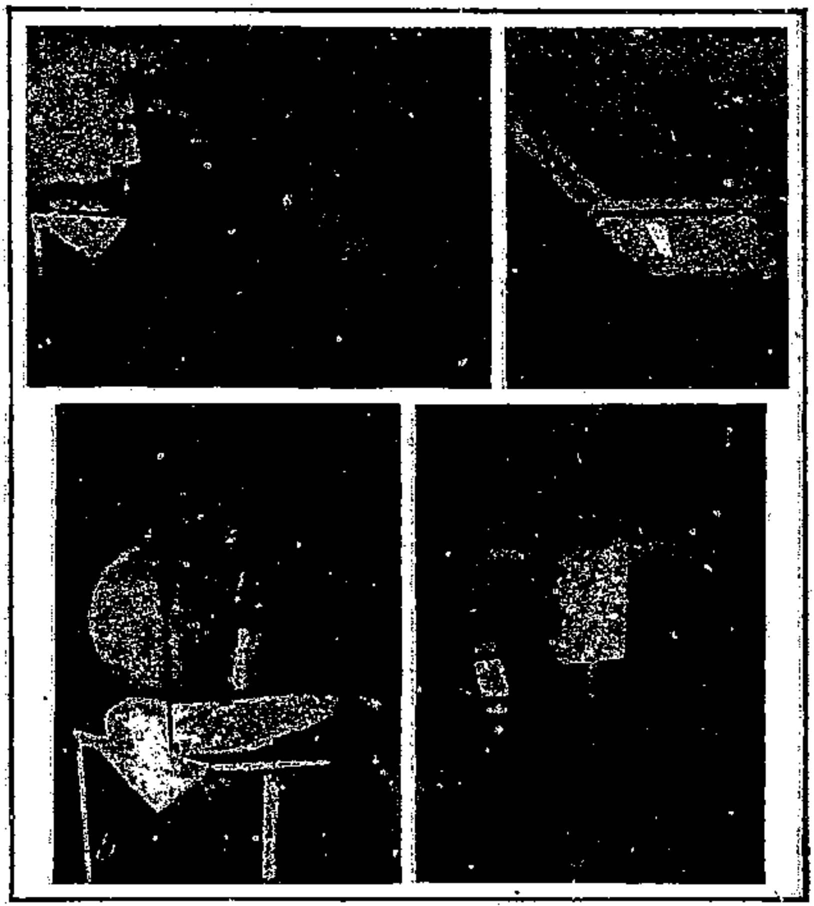


FIG. 12.—Apparatus used in gipsy-moth egg-parasite work with *Anastatus disparis*: *a*, Separating apparatus used to separate gipsy-moth eggs from the hair; *b*, showing inner surface of disks of separating apparatus; *c*, bouncing apparatus used to separate nonparasitized eggs from eggs containing Anastatus larvæ; *d*, winnowing apparatus used for separating the eggs containing Anastatus larvæ from the eggshells, dead eggs, and other material removed from the hatching trays. (Crossman)

percentage of parasitism of the eggs. In this manner it was possible to determine the area in which the parasitism was greatest and, where large collections of gipsy-moth eggs could be made, to furnish a supply of Anastatus for the spring colonization.

In recent years Anastatus has become so evenly distributed over a large part of the gipsy-moth-infested area that it has not been necessary to select a limited area in which to collect the material. A few sample collections of gipsy-moth eggs are made each fall from various locations. From examination of these collections the best places from which to obtain the general collections of Anastatus for colonization are determined.

During the winter large collections of gipsy-moth egg clusters are made at the points which have been selected. At the laboratory these egg clusters are broken up, and the eggs separated from the hairs by means of an apparatus developed for this purpose. (Fig. 12, *a* and *b*.) It consists of two circular wooden plates which are padded on the surfaces that are in contact. The lower one is stationary and the upper plate revolves on a spindle by power from a small motor, its inner surface lightly touching the upper surface of the stationary plate. The egg clusters are fed to the apparatus at an opening near the center of the upper plate. As this plate revolves, the egg clusters are drawn between the plates, gradually broken up, and worked between the surfaces of the plates until the eggs reach the circumference, where they fall off, separated and clean, and are caught in a jar beneath. The hairs and dust are removed from the apparatus by means of a suction blower attached to a galvanized-iron pipe which leads from the center of the apparatus to the outside of the building.

After the eggs have been separated from the hairs, the parasitized eggs are separated from the nonparasitized ones by allowing them to run by gravity over an inclined plane, at the bottom of which is a small piece of metal placed in a horizontal position. As the eggs hit this horizontal surface they rebound into different compartments of a box which is placed at the bottom of the inclined surface. (Fig. 12, *c*.) The eggs containing Anastatus larvae drop into the first compartments of the box, while the nonparasitized ones rebound farther into the compartments beyond. When the parasitized eggs have been separated from the nonparasitized ones they are measured; and each measureful, containing approximately 1,000 parasitized eggs, is placed in a small envelope and held until spring for colonization.

Collections of Gipsy-Moth Eggs to Determine the Parasitism by Anastatus

Each year, since the liberation of Anastatus, collections of gipsy-moth eggs have been made to determine the presence of the parasite, the amount of parasitism caused by it, and its dispersion. The results shown by the examinations of these collections have recently been published (*10*), and only two sets of records will be included here to bring these up to date.

For the last eight years small collections of gipsy-moth egg clusters have been made from the different sections of each town shown in Table 2, and the figures obtained by the examination of them show the degree of parasitism of the gipsy-moth eggs by Anastatus in the area represented.

TABLE 2.—*Average percentage of parasitism of gipsy-moth eggs by Anastatus disparis as indicated by representative collections made in five towns in Massachusetts*

Year	Burlington	Dover	Lynnfield	North Reading	Wilmington	Average parasitism
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1919-20	14	14	11	16	16	14.2
1920-21	24	34	19	23	26	25.2
1921-22	35	37	31	35	34	34.4
1922-23	32	31	28	25	30	29.2
1923-24	28	24	14	11	18	19.0
1924-25	17	9	12	6	6	10.0
1925-26	6	10	7	7	2	6.4
1926-27	8	22	16	13	18	15.4

In Table 3 are given data which represent a much greater area than is considered in Table 2. These data have been gathered during the last 15 years and show the yearly average abundance of Anastatus.

TABLE 3.—*Summary of examinations of gipsy-moth eggs collected around the "observation points"*

Year	Number of collection points	Number of clusters collected				Eggs parasitized						Total parasitized		Total parasitism
						By Anastatus			By Schedius					
		Large	Medium	Small	Total	Large clusters	Medium clusters	Small clusters	Large clusters	Medium clusters	Small clusters	By Anastatus	By Schedius	
						Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1912-13	77	1,131	1,127	1,102	3,360	0.207	0.19	0.28	0.33	0.50	0.64	0.21	0.43	0.64
1913-14	73	1,068	1,090	1,053	3,211	.718	.87	.23	1.09	1.19	1.54	.85	1.20	2.05
1914-15	69	1,069	1,067	1,048	3,184	.93	1.13	.93	.83	.97	1.16	.99	.93	1.92
1915-16	66	1,037	1,050	1,046	3,133	2.33	2.86	2.91	1.36	1.21	1.57	2.62	1.35	3.97
1916-17	64	921	1,015	1,001	2,937	4.36	6.27	6.46	2.36	2.77	3.31	5.01	2.66	7.67
1917-18	68	792	1,034	981	2,807	6.19	7.69	9.54	2.30	2.83	4.18	7.26	2.78	10.04
1918-19	64	890	913	852	2,655	9.25	10.22	10.75	.11	.00	.21	9.83	.12	9.95
1919-20	49	430	739	731	1,900	9.75	11.16	12.53	.50	.58	.92	10.84	.61	11.45
1920-21	49	667	742	694	2,103	15.57	17.85	19.56	.03	.07	.13	16.98	.06	17.04
1921-22	51	357	708	695	1,760	25.03	28.60	31.20	.09	.12	.23	27.86	.13	27.99
1922-23	49	351	758	333	1,442	17.22	24.25	30.10	.98	.85	1.12	21.94	.93	22.87
1923-24 [1]	17	119	359	104	582	18.51	23.02	30.35	.71	.52	.17	22.18	.55	22.73
	60	560	1,403	389	2,352	16.32	20.00	26.78	.33	.32	.21	20.96	.29	21.25
1924-25	17	96	111	69	276	10.6	11.8	13.06	.47	.05	.17	11.10	.28	11.38
	61	392	493	281	1,166	7.8	10.5	13.0	.19	.13	.26	10.10	.18	10.28
1925-26	17	73	161	68	302	14.7	14.5	20.9	.11	.08	.06	15.36	.09	15.45
	60	368	541	200	1,169	9.8	12.5	18.0	[2] T	T	T	13.1	T	13.1
1926-27	17	40	226	88	354	6.3	7.1	10.2	0	T	0	7.4	T	7.4
	61	153	816	271	1,240	5.3	5.7	8.1	T	T	T	6.3	T	6.3

[1] A uniform method of collecting and examining the eggs was followed from 1912 through the spring of 1923. Since that date the collections have been made, when possible, from approximately the same locations as previously, but over a larger area. The eggs from 17 of the points have been examined in the same manner as previously. A slightly different method has been used in examining collections from the other points. These data have been kept separated in the table. They show that the method used for the 17 points is more accurate than that used for the larger number of points. However, the difference in the total parasitism shown by the two methods of examination is not very great, and the method of examination used for the majority of the collections is much more rapid.

[2] T used in the Schedius column indicates that only a trace of this species was found.

Each year the egg-cluster collections have been made, so far as possible, in the same towns scattered over eastern Massachusetts and southern New Hampshire. The collections have not been made with reference to parasite colonizations, and the data show the actual average degree of parasitism caused by this species each year in the area under consideration. These eggs have been collected with considerable care, and an attempt has been made to obtain an equal number of large, medium, and small egg clusters in each collection. The examination of egg clusters separately has shown a considerable difference in the degree of parasitism of large and small-size clusters. These examinations have shown that the percentage of parasitism in some years of the small egg clusters was nearly twice as great as it was of the large clusters. This is an important factor in the parasitism of the gipsy-moth eggs, for during certain years the gipsy-moth egg clusters average medium and small in size.

The data obtained from the egg-cluster collections given in these tables show an increase in the abundance of this parasite until the fall of 1922. The decrease, which was first apparent in the eggs collected that fall, continued until the fall of 1925.

In addition to the records pertaining to the degree of parasitism of the gipsy-moth eggs, data have been gathered showing that there is practically no difference in the degree of parasitism of the eggs in relation to their position on the trees. Other data have been gathered in regard to the winter mortality of Anastatus which indicate that during the mild winters there is practically no mortality over the eastern half of Massachusetts, southern New Hampshire, and southwestern Maine. There is some mortality in the colder sections of the area during a severe winter, such as the winter of 1917–18. A high percentage of the parasites survive in the gipsy-moth eggs which are laid in protected situations or are covered with snow or ice.

Recovery and Dispersion

Because of an epidemic of wilt disease which killed practically all of the gipsy-moth larvae and pupae in the immediate vicinity, no recoveries of Anastatus were made during the spring of 1909 at the site of the colony that was liberated in 1908. During the summer of 1909 many adult Anastatus from the parasite colonies which were liberated during the spring of that year were found working on the gipsy-moth eggs. The first records of Anastatus having passed a New England winter successfully under natural conditions were obtained in 1910.

A study of the yearly dispersion of Anastatus was carried on for several years. Collections of gipsy-moth egg clusters were made at points 50 feet apart along eight lines which ran from the centers of several colonies. Later, beginning 600 feet from the colony center, the collections were made at 100-foot intervals, and as the dispersion continued the egg collections were made along the lines 100 yards apart. These studies showed that Anastatus is a slow-spreading parasite, but that as the parasite increases in abundance and the colony in area the yearly spread becomes much greater. They showed that during the year that the parasite was liberated it spread out only 200 feet, but that five years later it had spread 4,800 feet from the point of liberation.

The dispersion of Anastatus has been greatly accelerated by an enormous amount of colonization. It is now generally present within the Anastatus line as indicated on the map (fig. 3). A few liberations have been made beyond this line but there is still a considerable amount of colonizing to be done with this species.

Value of Anastatus disparis

The data which have been given in the discussion of *Anastatus disparis* clearly show that it is an important enemy of the gipsy moth. Many collections of gipsy-moth egg clusters were made in which over 40 per cent of the eggs had been killed by this parasite. In fact, as far as it has been possible to obtain data, Anastatus appears to be of more value in this country than in the countries from which it was originally obtained. It is thoroughly established, and although it suffers some mortality during the severe winters in New England, it appears to withstand them as well as, or better than, its host. It is now present over most of the area which is considered generally infested by the gipsy moth, and although the degree of parasitism is not at present as high as it has been, a rapid recovery to its earlier status is expected.

SCHEDIUS KUVANAE Howard

The gipsy-moth egg parasite *Schedius kuvanae* Howard has several generations each year, and at times, since it became established, it has been very abundant in many sections of eastern Massachusetts. Its periods of abundance have been very irregular, and the areas in which it has been plentiful have been scattered. In some seasons it has parasitized a remarkably large percentage of the gipsy-moth eggs in rather small sections of the territory, and it appears to be better adapted to the milder parts of the infested area.

Foreign Distribution and Abundance

Schedius kuvanae (fig. 13) was introduced from Japan and is not known to exist in any of the European countries. At the gipsy-moth laboratory it has been reared from gipsy-moth eggs collected at Akabane, Fukuoka, Funakimura, Nishigahara, and Tokyo, Japan. The data which have been gathered as to the distribution and value of Schedius in Japan were obtained by the examination of gipsy-moth eggs, most of which were sent to this country by S. I. Kuwana; and by observations made in that country by J. N. Summers, of the Bureau of Entomology, while studying the natural control of the gipsy moth there. Examination of these eggs showed that this parasite was plentiful in some locations and entirely absent in others. As high as 33 per cent of one lot of egg clusters were killed by Schedius, indicating its value in some areas.

Life History and Habits

After many experiments, satisfactory proof was obtained that Schedius passes the winter as an adult in the forest debris. There is a large mortality each winter, and only strong fertilized females well laden with eggs have been recovered in the early spring. The females which live through the winter first become active on the warm days of April. Many of them do not leave their hibernation quarters until the middle or last of this month. These adults live, in experimental cages, for from three to five weeks and oviposit read-

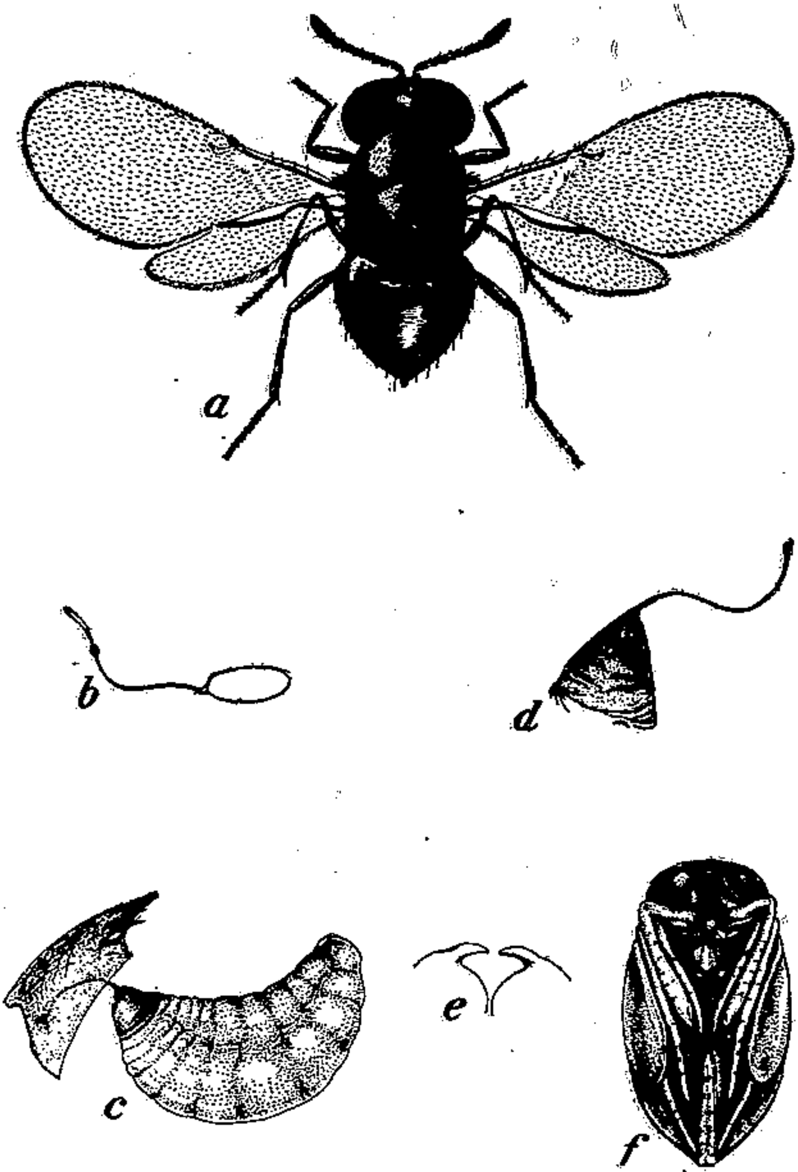


FIG. 13.—*Schedius kuvanae*: *a*, Adult female, × 40; *b*, egg; *c*, third-stage larva still retaining egg stalk and anal shield, × 40; *d*, egg stalk and anal shield of larva as found in host eggs of the gipsy moth from which the adult Schedius has emerged or in which the Schedius larva has been attacked by a secondary parasite; *e*, larval mandibles; *f*, pupa, × 42; *b*, *d*, and *e* greatly enlarged. (Howard and Fiske)

ily in the overwintering gipsy-moth eggs. This generation requires approximately six weeks to mature, but later in the season the generations mature in about three weeks.

In the spring some of the Schedius pass through two generations whereas others have only one. Adults are ready for oviposition in the new gipsy-moth eggs as soon as they are laid in July, and occasionally one will be found parasitizing an egg cluster before it is completely deposited by the moth. The fall generations overlap so that adult Schedius are present in the field from the time of gipsy-moth egg laying until early in November. During the late summer and early fall only 21 days are required for a generation, but as the cool weather approaches a longer time is necessary. During an average season, from the middle of July to early November, there is ample time for this parasite to complete four generations in the new eggs, and there is often a partial fifth generation. In some seasons a part of this fourth generation, and usually most of the fifth generation, are killed within the gipsy-moth eggs when severe temperatures are first recorded. When this occurs many of the active adults enter hibernation, although evidence has been obtained that some adults enter their hibernating quarters earlier in the season.

This parasite will reproduce readily, in laboratory experiments, in a greater variety of lepidopterous eggs than Anastatus. It has been reared in such experiments from nine different species, including the the gipsy moth, the brown-tail moth, and the satin moth, *Stilpnotia salicis* L. It has also been occasionally reared from cocoons of *Apanteles melanoscelus;* but this host does not appear to be a favorable one, and often adults which have matured within the Apanteles cocoons are unable to bore their way out. It is interesting to note that when Schedius reproduces in large eggs, such as those of *Hemileuca oliviae* Ckll., several parasites will mature within a single egg, and in one case 17 Schedius were recovered from a single *melanoscelus* cocoon (*21*). A distinct preference is shown for gipsy-moth eggs, and only rarely does more than one Schedius mature in one of these eggs.

Considerable anxiety was felt during the early studies of Schedius and Anastatus for fear that Schedius would act as a parasite of Anastatus. This anxiety was increased when a study of gipsy-moth eggs from Japan revealed that this actually had happened. Fortunately laboratory experiments indicate it to be a rare occurrence, and no records have been obtained of its successful occurrence in the field. Each year many thousands of gipsy-moth eggs are examined with a binocular microscope; and although occasionally Anastatus and Schedius larvae have been found within the same egg, neither parasite has developed in the cases that have been observed. In the field these parasites do not often conflict; usually one or the other greatly predominates locally, although occasionally collections of gipsy-moth egg clusters are obtained which show about equal parasitism by both species.

Importation

The story of the introduction and colonization of this parasite has been told so often that it will be given only briefly here. Evidence of the presence of an egg parasite was first found in the Japanese eggs in 1907, but the specimens found were badly damaged and no living parasites were obtained. In 1908 many egg clusters were received from Japan, but all of the Schedius that the packages contained were dead excepting one male which was obtained in December. In January, 1909, a living female Schedius was obtained which reproduced parthenogenetically, a generation of males resulting. In April, 1909, 12 Schedius were reared. One of the females died early, but from the 11 remaining 100 adults were reared, this being the first generation in this country. Twenty-one more adults from Japanese eggs were added to these, and a second generation was developed containing 643 adults. These produced 1,350 Schedius in the third generation. In the meantime 1,671 more Japanese Schedius were obtained, and these were added to the stock already developed. The reproduction work was continued throughout the year and into the winter of 1910. From this stock and its progeny all of the colonizations have been made.

Colonization

The first colonies of Schedius were liberated during the summer of 1909, stock being used which had been developed as described above, together with about 1,000 Schedius which had issued from Japanese eggs. Several more colonies were liberated during the fall. The material in the breeding trays was kept developing until early in 1910, when it was estimated that the trays contained approximately 1,000,000 Schedius. They were then placed in a cool cellar until March, when most of the material was divided into lots containing about 10,000 Schedius each and distributed over the eastern part of the area. Colonization has continued each succeeding year, established stock being used to rear large numbers. Table 4 gives the total number of Schedius which have been liberated.

TABLE 4.—*Summary of the colonization of Schedius kuvanae*

Year	Number of Schedius liberated in—					
	Massachusetts	New Hampshire	Rhode Island	Maine	Illinois	New Jersey
1909	46,415					
1910	889,120					
1911	68,486					
1912	93,368	19,807				
1913	382,645					
1914	1,120,536	944,725	21,855			
1915	455,146	182,308				
1916	1,477,963	1,161,929	57,200			
1917 [1]	9,120	1,006,279		232,260	5,000	
1918	3,844,500	932,000				
1919		1,540,000				
1920			440,000			270,000
1921	496,000		124,000		12,000	
1922	200,000	516,000				212,000
1923			472,000			
1924	92,000	80,000	64,000			146,550
1925	1,121,000					
1926	1,132,000		88,000			
1927	991,000		112,000			
Total	12,419,299	6,383,048	1,379,055	232,260	17,000	628,550

[1] A few eggs of *Hemileuca oliviae* parasitized by *Schedius kuvanae* were sent to Maxwell, N. Mex.

TABLE 4.—*Summary of the colonization of Schedius kuvanae*—Continued

Year	Number of Schedius liberated in—						
	Connecticut	Vermont	District of Columbia	Spain [1]	Morocco [1]	Algeria [1]	Total
1909							46,415
1910							889,120
1911							68,496
1912							113,175
1913							382,645
1914							2,067,116
1915							637,454
1916							2,697,092
1917 [2]							1,252,659
1918							4,776,500
1919							1,540,000
1920							710,000
1921	1,638,875		20,000				2,290,875
1922	904,000						1,832,000
1923	804,000			200,000			1,476,000
1924	668,000	80,000		50,000	25,000		1,205,550
1925	102,500				8,000	8,000	1,239,500
1926					55,000	40,000	1,315,000
1927				15,000			1,116,000
Total	4,117,375	80,000	20,000	265,000	88,000	48,000	25,677,587

[1] Numbers of Schedius sent to Spain, Morocco, and Algeria are estimated.
[2] A few eggs of *Hemileuca oliviae* parasitized by *Schedius kuvanae* were sent to Maxwell, N. Mex.

It will be noted that several large colonies of Schedius have been liberated outside of the area infested by the gipsy moth. Laboratory experiments showed that Schedius would reproduce in confinement on the eggs of a variety of hosts, and readily on the eggs of the white-marked tussock moth, *Hemerocampa leucostigma* S. and A. The Schedius which were sent to Washington, D. C., and to Illinois were liberated in tussock-moth infestations. A few were sent to Maxwell, N. Mex., after it was found that this parasite would reproduce in the eggs of *Hemileuca oliviae* Ckll. Several shipments have been made to Madrid, Spain; Rabat, Morocco; and Algiers, Algeria, where attempts are being made by the Government entomologists to establish this species in gipsy-moth infestations.

Schedius are colonized in the fall, in contrast to Anastatus, which are colonized in the spring. The Schedius are bred at the laboratory and the adults liberated, while Anastatus are colonized as mature larvae within the gipsy-moth eggs.

Approximately 4,000 Schedius are liberated in each colony. The colonies are placed about 2 miles apart, in woodland, along each road where there is sufficient gipsy-moth infestation. The locations of the colonies are marked on a blue-print map of the town, and in the field with white paint on a roadside tree.

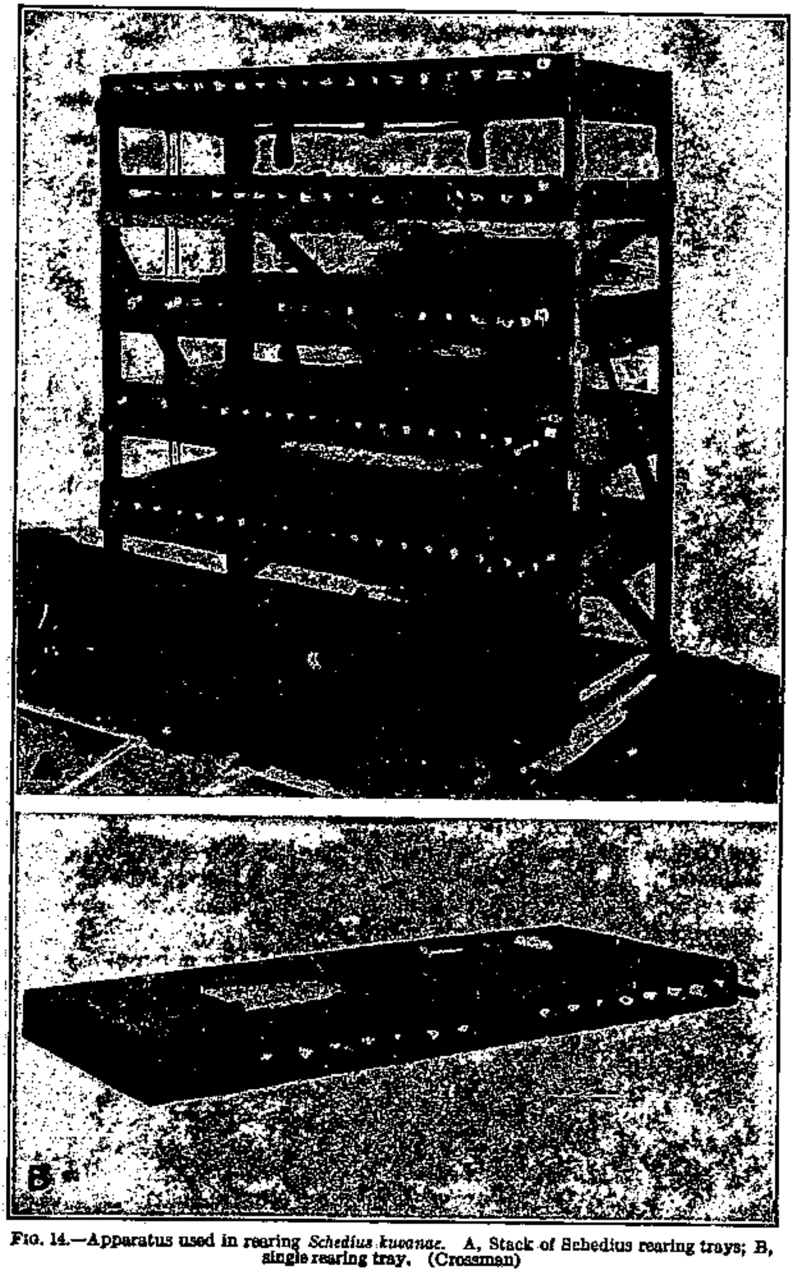


FIG. 14.—Apparatus used in rearing *Schedius kuvanae*. A, Stack of Schedius rearing trays; B, single rearing tray. (Crossman)

Reproduction Work to Obtain Schedius for Colonization

The trays (fig. 14, B) used for rearing Schedius at the laboratory are 5 feet long, 2 feet wide, and 5 inches deep. They are made of half-inch matched cypress, dovetailed at the corners and painted on the inside with a flat black paint. Two openings, 12 inches square, are left in the top; these are placed equally distant from the center and from the ends of the tray. In the front side of each tray are several holes 1 inch in diameter. These are kept closed with cork stoppers until ready to be used. Over the bottom of the trays are spread evenly a quantity of gipsy-moth eggs mixed with a few parasitized gipsy-moth eggs and adult Schedius which have been collected from the field. A mixture of 40 per cent of honey and 60 per cent of water, for food for the parasites, is sprinkled on several pieces of white blotting paper and placed in the trays. Glass plates are placed over the two openings in the top. As the trays are stocked they are placed on a rack (fig. 14, A) and kept at a temperature of from 75° to 80° F. During the cool evenings of the early fall this is maintained by means of electric lights. A few thousand adult Schedius are placed in each tray to supplement those already there and those which develop from the parasitized eggs which were put in the trays. The adults oviposit readily in the gipsy-moth eggs in the trays. As soon as a new generation of Schedius develops, which is in about three weeks, the light is excluded from the trays by placing black paper over the glass covers in the tops. The cork stoppers in the front side of the trays are removed and paper cones are inserted in which closed glass tubes 1 inch by 4 inches are placed. The Schedius in the trays are attracted by the light into the glass tubes, from which they are removed and placed in mailing tubes for colonization. About 4,000 Schedius are placed in each tube with a piece of paper on which is smeared a mixture of honey and water for their food. The tube is then covered with a piece of cotton cloth held in place by a rubber band. Each day the tubes containing the day's output are sent to the field for colonization.

Collections of Gipsy-Moth Eggs to Determine the Parasitism by Schedius

The collections of gipsy-moth eggs which have been made each year since 1912, at or near the observation points, are tabulated in Table 3, under the discussion of the parasitism caused by Anastatus. The apparently slow increase and low rate of parasitism credited to Schedius in these collections may be explained to some extent by the fact that many of the points where these collections were made are in towns where this parasite has never been abundant. Schedius does not appear to be well adapted to a considerable part of the area that is infested by the gipsy moth. There are, however, certain sections, especially in southeastern Massachusetts and on Cape Cod, where climatic conditions are favorable, and this parasite has increased and attacked a very appreciable percentage of the gipsy-moth eggs.

The mortality caused by this parasite has varied considerably over a period of years owing to a number of controlling factors.

Studies which were made to determine the degree of parasitism of gipsy-moth eggs in various parts of the trees showed, as do similar data in connection with Anastatus, that the location of the egg clusters on the trees has little or no effect upon the percentage of parasitism caused by Schedius.

Recovery and Dispersion

Schedius was recovered in 1909, soon after it had been liberated. It increased rapidly and was soon found in abundance on the egg clusters in the immediate sites of the liberations. It was recovered until cold weather in December, after which no more could be found or reared from the gipsy-moth eggs. All trace of it was lost and it was feared that the species could not survive the New England winters. During the spring and summer of 1910 occasional Schedius were recovered, but in very limited numbers, and under conditions which indicated that they might have been individuals which had dispersed from some of the spring colonizations. It was not until the summer and fall of 1911 that Schedius was recovered under conditions which left no doubt that it had survived the winter.

Although Schedius is a slow-dispersing parasite it spreads more rapidly than Anastatus. The data which have been gathered show a spread of about 400 yards for a single generation and a little over half a mile for the first year. Records obtained in colonies the second year after liberation have shown a spread of nearly 2 miles at the end of the second season. The dispersion of this parasite has been accelerated by the large amount of colonization which has been done. The present known dispersion is shown on the map (fig. 3). It has been colonized considerably north of this line in New Hampshire and southwestern Maine, and occasionally has been recovered in parts of New Hampshire, north of the line, but only sparingly; and continued observations indicate that it will not increase satisfactorily much north of the dispersion line shown on the map.

Value of Schedius as an Enemy of the Gipsy Moth

Schedius is an important egg parasite of the gipsy moth in the milder parts of southern New England. In Massachusetts it has been found abundant in many sections within 50 miles of the seacoast and especially in towns along the south coast and on Cape Cod. There is often a large winter mortality which may account for its uneven distribution and periods of scarcity, but as it has several generations each year it increases rapidly under favorable conditions.

LARVAL PARASITES

APANTELES MELANOSCELUS Ratzeburg

Apanteles melanoscelus Ratzeburg, a braconid parasite (fig. 15) of the gipsy-moth larvae, has two generations each season, the first generation developing in first and second instar caterpillars and the second generation in third and fourth instar caterpillars. In general the two generations are confined to the stages as mentioned above, although many third instar gipsy-moth caterpillars are destroyed by the first generation, and large numbers of fifth-instar caterpillars and a few sixth-instar caterpillars are killed by the second generation of this parasite. The parasite passes the winter as a full-grown larva within a very tough, strongly woven, yellowish cocoon. The cocoons are attached to tree trunks, particularly on the underside of the branches, as well as on the underside of fence rails, and on articles (pl. 4) on the ground to which the parasitized caterpillars have crawled.

FOREIGN DISTRIBUTION AND ABUNDANCE

This parasite is found over most of Europe, especially in the southern area. In recent observations it has been recorded from southern France, Spain, Portugal, northern Africa, Italy (being especially abundant in Sicily), Germany, Poland, Czechoslovakia, Hungary, Yugoslavia, and Bulgaria. In addition to these locations specimens have been received at the gipsy-moth laboratory from Vienna, Austria; and Bendery, Russia.

Although this parasite has a wide European distribution it has been found abundant in only a few locations. Under the conditions which have prevailed during the recent European work of the Bureau of Entomology, this parasite has not been obtained in sufficient numbers to indicate that it is a parasite of primary importance as an enemy of the gipsy moth. Exceptions to this condition were found in Sicily by the junior author, and in Spain at Alcala in the province of

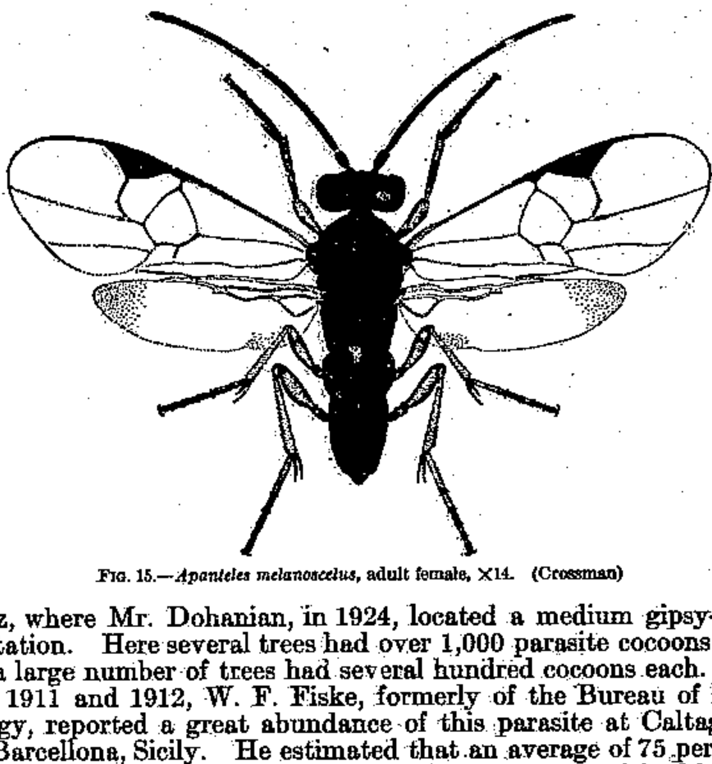


FIG. 15.—*Apanteles melanoscelus*, adult female, ×14. (Crossman)

Cadiz, where Mr. Dohanian, in 1924, located a medium gipsy-moth infestation. Here several trees had over 1,000 parasite cocoons each, and a large number of trees had several hundred cocoons each.

In 1911 and 1912, W. F. Fiske, formerly of the Bureau of Entomology, reported a great abundance of this parasite at Caltagirone and Barcellona, Sicily. He estimated that an average of 75 per cent, and in some places more, of the caterpillars were parasitized by this species. In one place he estimated as high as 10,000 cocoons on a single large tree. The junior author visited this area in 1922, at which time the gipsy-moth infestation was much lighter than during 1911 and 1912, but cocoons of *A. melanoscelus* were very abundant. Judging by the number of the previous year's gipsy-moth egg clusters present and the abundance of the cocoons of this parasite, there must have been in this forest a medium gipsy-moth infestation during the preceding year. The new gipsy-moth egg clusters were scarce, and the evidence obtained strongly indicated that this parasite was the primary cause for the decrease of the moth.

Life History and Habits

The adults issue from their cocoons about the time that the gipsy-moth eggs are hatching. The first are mostly males, the females appearing a few days later. A few hours after the females have issued from their cocoons they are ready to begin ovipositing. If they have not been fertilized they reproduce parthenogenetically, the resulting progeny being males. The females work rapidly in the bright sunlight, flying from one caterpillar to another. There is no apparent examination of the prospective host, merely a quick insertion of the ovipositor and the deposition of a single egg. Occasionally a female lays more than one egg in the same host, which is a waste of eggs, for very rarely does more than one parasite larva issue from the same host. The females which have issued from the hibernating cocoons prefer first and second instar gipsy-moth caterpillars for oviposition. The egg may be inserted in any part of the body of the caterpillar, but more often it is inserted in the posterior half. The number of eggs deposited by an individual varies, but records at the gipsy-moth laboratory indicate that each female is capable of laying approximately 1,000 eggs (*8*).

The egg stage lasts from four to six days, depending upon the temperature. There are three larval instars, the first one lasting from two to three days in the spring generation and from six to eight days in the summer generation. The second larval instar of the spring generation occupies from two to three days, and of the summer generation from five to seven days. The time spent in the host by the third-instar larvae of the spring generation is from a few hours to two days, and as long as three days by the summer generation. The third-instar larva, when ready to issue, bores its way through the body wall of the caterpillar.

The construction of the cocoon is started before the larva is entirely out of its host. The spring-generation larva requires about two hours to make its cocoon, while nearly four hours are consumed by the summer-generation larva. The cocoons of the first generation are light and delicate, constructed of a yellowish white silk, but those of the second generation are strong and densely woven, and are of a light sulphur yellow. Within the cocoon the larva transforms to the mature insect. The adults of the spring generation issue in from five to nine days; the summer-generation larvae contract somewhat and become quiescent, and in this condition they remain until the following spring, when they pupate, the adult issuing at about the time when the gipsy-moth eggs begin to hatch.

Importation of the Parasite

The original colonization stock of this species was obtained in 1911 by W. F. Fiske, in Sicily. Arrangements were made at Portici, Italy, for the use of a room where the material could be handled during the summer. Large collections of gipsy-moth caterpillars were made in Sicily and transported to the Portici laboratory, where they were placed in trays, fed, and cared for. As the first-generation parasites issued from the caterpillars and spun their cocoons in the trays, the cocoons were removed and placed in a refrigerator to retard their development. In addition to the material obtained in this manner, large numbers of cocoons of this parasite were collected in the forests of Sicily. These were placed in specially constructed

HIBERNATING COCOONS OF APANTELES MELANOSCELUS containers in a compartment which was surrounded by snow or ice. They were then taken or sent to Portici for repacking, and, together with the cocoons obtained from the rearing trays at Portici, were shipped to the laboratory at Melrose Highlands. The shipments were made as often as possible, to avoid retarding the development of the parasites any longer than necessary. Some of these packages were arranged so that the cocoons were in compartments which were surrounded by an iced chamber, and upon arrival in New York City the packages were reiced and sent to Melrose Highlands. Other packages were sent without ice, the development of the parasite being retarded by keeping the packages in the steamer's cold-storage room.

As a result of this work about 125,000 first-generation cocoons were received at Melrose Highlands during June, 1911. Later in the season 17,000 cocoons of the second generation were received. During the summer of 1912 the work in Sicily resulted in the shipment of 22,000 cocoons of the second generation.

Colonization

In this country the first-generation cocoons introduced in 1911 were placed in darkened containers, into which glass tubes were inserted to draw out the adult parasites and any secondary insects which they might contain. By this method the injurious insects were separated and destroyed, and the beneficial ones liberated. The 17,000 second-generation cocoons received during 1911 were placed in gelatine capsules and kept in an outdoor insectary at the Melrose Highlands laboratory. The 22,000 second-generation cocoons of 1912 were cared for in a similar manner. The adult Apanteles which issued during the succeeding springs were liberated.

The total liberations of this parasite which have been made in this country are shown in Table 5.

Table 5.—*Number of Apanteles melanoscelus liberated in the United States, 1911–1927*

Year	Number of individuals liberated		Number of colonies liberated in—								Total number of colonies
	Sicilian stock [1]	Colonized New England stock	Massachusetts	New Hampshire	Maine	Connecticut	Rhode Island	Vermont	New Jersey	New York	
1911	[2]23,000		1								1
1912	203		1								1
1913	273		1								1
1915		1,500	2	1							3
1916		5,541	11								11
1917		3,500	7								7
1918		8,100	9	7							16
1919		930	2								2
1920		10,100	11	9			1				21
1921		1,000	2								2
1922		27,837	19	21	5	4	5				54
1923		32,558	13	16	21	12	2	2	1		67
1924		12,000	11		2	6		4			23
1925		[1]4,600	4			4		1			9
1926		17,400	12	3	3	2	3	4		2	29
1927		7,105	7	3							10
Total	23,476	132,177	113	60	31	28	11	11	1	2	257

[1] Adults.
[2] Probably a part of these should be credited to *A. porthetriae* Mues.
[3] During 1925, 1926, and 1927 adult Apanteles were colonized. Previous to 1925 the cocoons were colonized.

It will be noted that only 23,000 adults were liberated from the 125,000 first-generation cocoons which were introduced, and that only a small percentage of Apanteles issued from the second-generation cocoons received during 1911 and 1912. The mortality in all three cases was very high. In the first case it was probably due largely to the long exposure to cold-storage conditions. Subsequent experiments have shown that such unnatural conditions are often harmful to insects, especially to the braconids during the period when normally they would transform in a few days from larvae to adults. In the case of the second and third shipments, which were second-generation cocoons, a very high percentage of the Apanteles were killed by hyperparasites. In addition to this the cocoons were kept in sealed gelatin capsules without any ventilation before the parasites emerged and were liberated, a condition which in later work has been avoided by pricking each capsule with a needle.

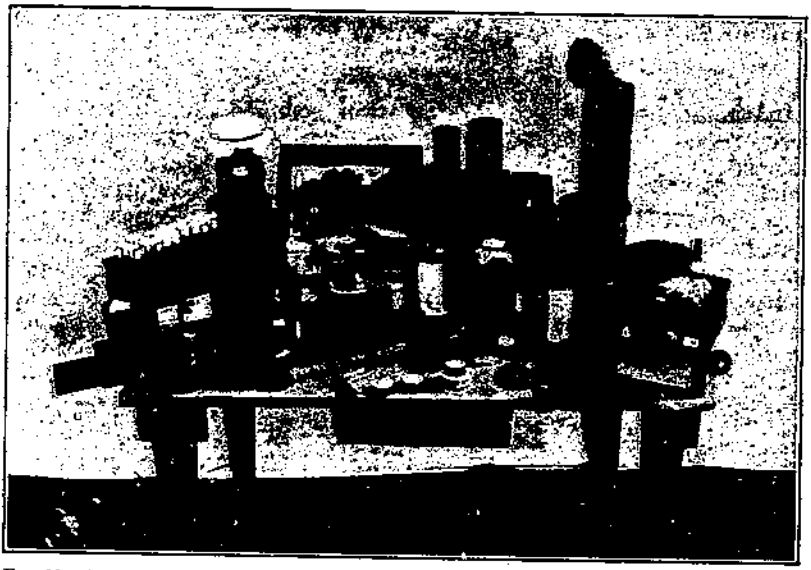


FIG. 16.—Apparatus used for rearing and colonizing parasites and beetles. A, Colonization cans; B, glass vials 1 by 4 inches; C, glass vials 2 by 8 inches; D, pasteboard boxes 4 by 5 by 7½ inches; E, rearing cans; F, collecting box; G, glass rearing jars; H, small rearing can with glass cover; I, galvanized-iron cylinders used for carrying insects through the winter; J, cylindrical cages for carrying Calosoma beetles through the winter; K, wooden box with sliding glass top.

All of the parasites liberated after 1913 were obtained from stock established in New England. Groups of towns for colonization sites were chosen each year, just outside of the known dispersion of the parasite, and in each of these towns were placed approximately 500 first-generation cocoons. The liberations were made by placing the cocoons in small cylindrical tin cans (fig. 16, A) 2½ inches high and 2 inches in diameter. These cans have holes in the side near the top through which the adults can escape. The cans were nailed to trees in the woodlands where there were gipsy-moth infestations of medium intensity. After placing the cocoons in the can, the cover was put on to keep out the rain and protect them from birds and other enemies. A band of sticky material was then placed around the can to prevent ants from getting to the cocoons, for they would very quickly destroy a colony.

In 1925, 1926, and 1927 the Apanteles cocoons were held at the laboratory until the adult parasites issued. These were then placed in containers to ensure the fertilization of the females before they were liberated. Although the liberation of fertilized females requires more attention than the colonization of the parasite in the cocoon stage, there is less danger of females dispersing before fertilization takes place. This method is considered much better than the colonization of cocoons, as the colony has a better chance of becoming established.

Up to and including 1927, 257 colonies, usually of about 500 each and totalling 155,653, had been liberated as follows: 113 in Massachusetts, 60 in New Hampshire, 31 in Maine, 28 in Connecticut, 11 in Rhode Island, 11 in Vermont, 1 in New Jersey, and 2 at Brooklyn, N.Y. The colonies placed at Brooklyn were liberated in an area where the white-marked tussock moth is abundant.

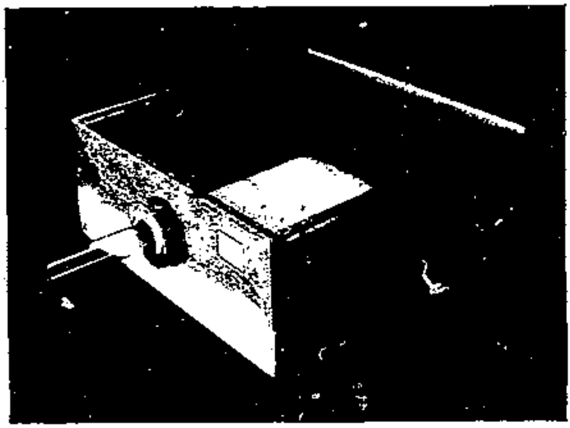


FIG. 17.—Reproduction tray used in life-history experiments with several of the parasites. (Culver)

APPARATUS USED IN LIFE-HISTORY STUDIES AND LARGER REPRODUCTION WORK

The glass-covered tray shown in Figure 17, and described under the title "Apparatus used in Compsilura life-history studies," which was developed and used in the Compsilura life-history work, is very useful in connection with the Apanteles breeding work and has been used to a considerable extent in similar work with several parasites. Glass vials 1 by 4 inches (fig. 16, B) and larger ones 2 by 8 inches (fig. 16, C) are also useful in small breeding experiments. The smaller ones are often used while exposing individual caterpillars to Apanteles, and the larger ones are very satisfactory for keeping the Apanteles confined and fed. When they are not being used the parasites should be kept in a dark, cool place where they will remain quiet.

In order to rear large numbers of this species a wooden breeding chamber (fig. 18) has been constructed. It is 5 feet long, 2½ feet wide, and 10 inches deep, with glass top and bottom. Trays, the proper size to be inserted easily in this chamber, are used. After the trays have been stocked with approximately 10,000 first-instar gipsy-moth caterpillars they are placed on racks where the caterpillars are fed and allowed to develop a few days before being exposed to the parasites. After a supply of adult Apanteles has been placed in the chamber a tray of gipsy-moth caterpillars is inserted.

It is important to control the light entering the chamber, so that in manipulating the trays the parasites will not be injured or lost. By

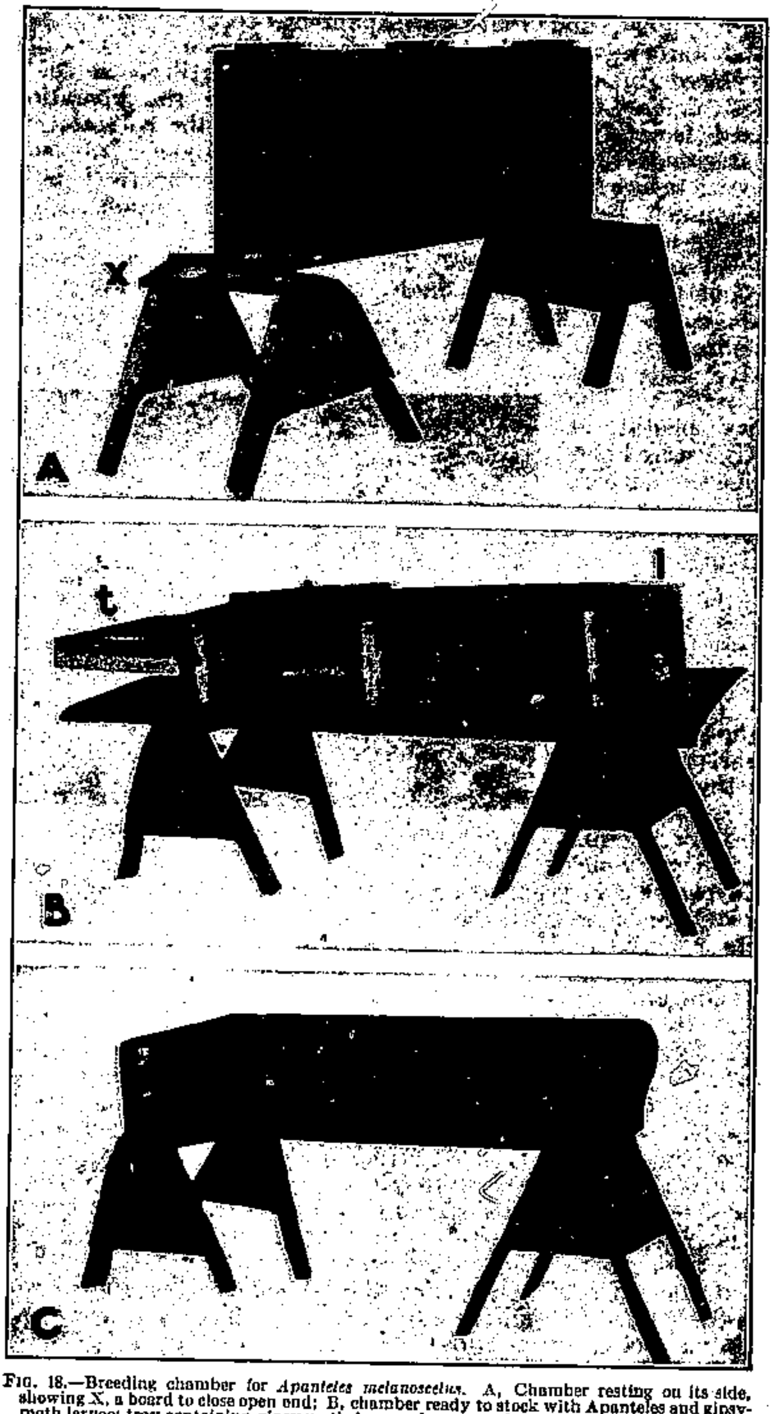


FIG. 18.—Breeding chamber for *Apanteles melanoscelus*. A, Chamber resting on its side, showing X, a board to close open end; B, chamber ready to stock with Apanteles and gipsy-moth larvae; tray containing gipsy-moth larvae shown partly inserted at *t*, light being admitted at *l*; C, chamber resting on horses with light entering from bottom only. (Crossman)

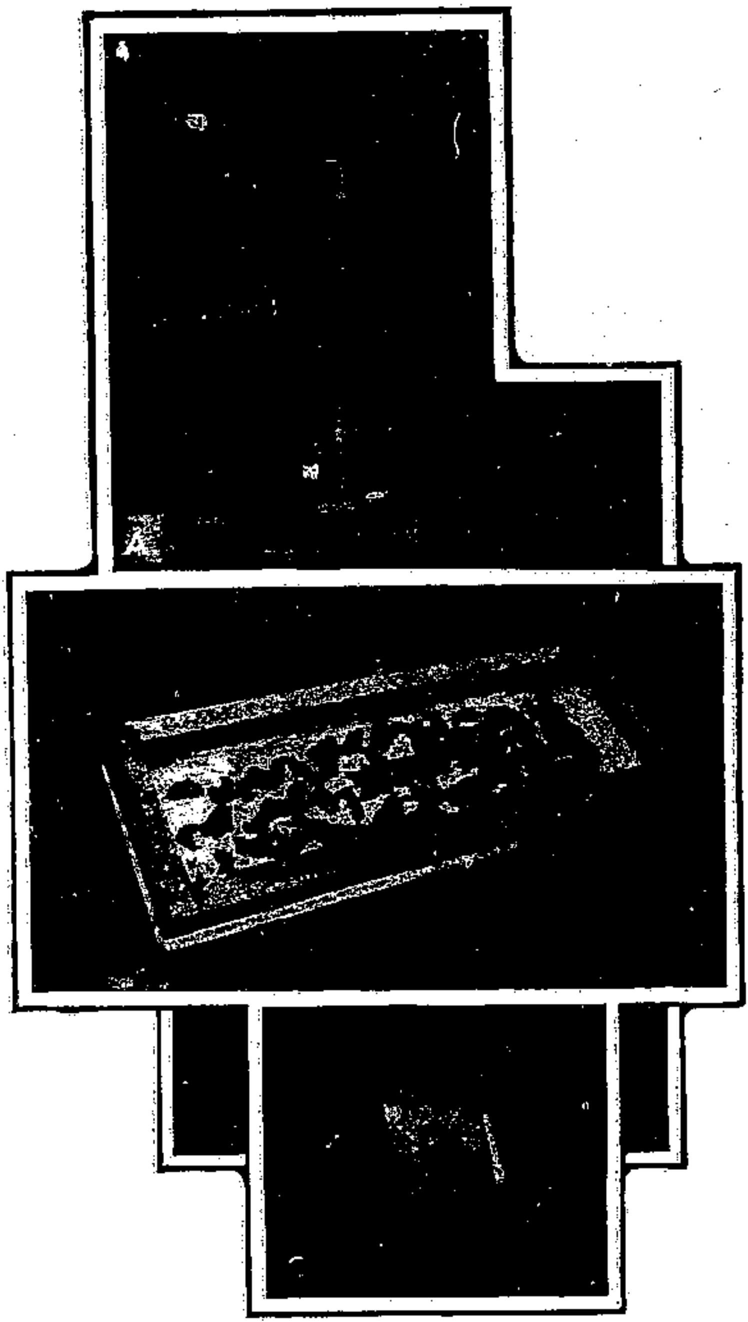


FIG. 19.—Some apparatus used in rearing parasites of the gipsy moth and brown-tail moth. A, Large wooden cage 30 by 24 by 24 inches, called tube cage, used for rearing parasites from imported brown-tail moth webs (Howard and Fiske); B, large rearing tray 24 inches wide, 60 inches long, 5 inches deep, with cloth bottom designed by Fiske in which brown-tail-moth and gipsy-moth caterpillars are fed until parasites issue, webs being shown on bottom of tray; C, small rearing tray made of heavy paraffined paper pressed so as to fit a 14-inch square wooden frame, containing brown-tail moth web

allowing the light to enter the chamber from the top, near the end farthest from the opening through which the tray is inserted, the parasites are drawn to the light area at the top of the chamber while the tray is inserted or removed. While the tray containing the caterpillars is in the chamber, all light is excluded, excepting that which enters through the cloth bottom of the tray, which draws the parasites to the bottom where the caterpillars are feeding. When the caterpillars have been exposed for a sufficient time the tray is withdrawn and another one put in its place. This process is continued as long as the supply of Apanteles is available. The parasitized caterpillars in the trays are fed and cared for until the parasite larvae issue. The Apanteles cocoons are then removed and colonized or held to rear the adults for liberation.

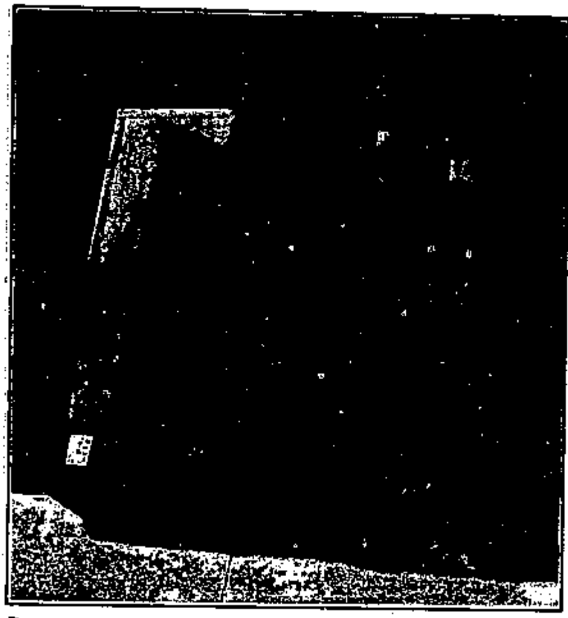


FIG. 20.—Small Fiske tray for feeding gipsy-moth caterpillars. Section at the top has been sawed out and bent back to show the sticky band which prevents the caterpillars from escaping. (Burgess)

The following method of rearing Apanteles in large numbers for colonization has also been satisfactory, although it has not replaced the chamber method, for it is not quite so dependable, and there is more or less loss of the parasites. An ordinary rearing tray with a cloth bottom is used, well stocked with small gipsy-moth caterpillars. By covering the top with black paper all light is excluded from the tray except that which enters through the cloth bottom. The parasites are inserted through a small opening and allowed to remain in the trays for several days, after which the paper tops are torn off, and the adult Apanteles allowed to escape. The trays are then cared for in the usual manner.

The breeding work to obtain Apanteles for colonization is supplemented by collections of gipsy-moth caterpillars from areas in New England where this parasite is plentiful. Such collections are placed in wooden trays (fig. 19, B), with cloth bottoms, where they are cared for until the parasites issue. To prevent the escape of the caterpillars, a band of sticky material is placed on the underside of the horizontal edges which project around the top of the tray. (Fig. 20.)

COLLECTIONS OF HOST CATERPILLARS TO DETERMINE THE PERCENTAGE OF PARASITISM

In an endeavor to ascertain the percentage of gipsy-moth caterpillars killed by *Apanteles melanoscelus* each year, collections of the host have been made several times a week for a number of years.

Because of the time involved such collections must of necessity be made relatively near the laboratory. These collections have been made at Melrose and Stoneham when possible. Collection of the caterpillars is begun soon after the first-instar gipsy-moth caterpillars are present in the field. One hundred of these caterpillars are collected on each collecting day as long as that number of first-instar caterpillars can be obtained. As soon as enough second-instar caterpillars are in the field to make a collection of 100 possible the collections of this instar are started. This system of collecting is continued through the caterpillar season; consequently two or more collections are often made on the same day at the same point.

A much abridged table showing the data obtained from these collections is Table 6. The dates indicate when the first and last caterpillar collections were made from which Apanteles were recovered. In the columns "First generation" and "Second generation" are given, for each season, the lowest and highest percentage of parasitism obtained in the series of collections. In all cases there were many collections showing a percentage of parasitism between these extremes.

TABLE 6.—*Per cent of gipsy-moth caterpillars killed by Apanteles melanoscelus, 1915–1927*

Year	Collected in town of—	Dates of collections	Percentage of parasitism of gipsy-moth larvae caused by—			
			First generation		Second generation	
			From—	To—	From—	To—
1915	Stoneham	May 28 to July 9	0	8	0	4
	Melrose	May 28 to July 19	0	6	0	18
1916	Stoneham	May 29 to July 10	0	10	0	10
	Melrose	May 29 to July 23	1	[1] 17	0	20
1917	Stoneham	June 6 to July 23	0	8	0	28
	Melrose	June 9 to July 23	0	11	0	36
1918	Stoneham	May 23 to June 19	1	13	0	4
	Melrose	May 17 to June 20	3	[2] 24	1	16
1919	Stoneham	May 28 to July 11	0	21	0	2
	Melrose	May 23 to July 10	5	16	0	19
1920	Melrose [3]	June 3 to July 6	0	1	0	2
	Melrose	May 27 to July 13	0	4	0	4
1921	Stoneham	May 17 to June 27	0	3	0	2
	Saugus [4]	May 20 to June 23	0	14	0	4
1922	Saugus [5]	May 13 to July 3	0	7	0	[6] 33
1923	Saugus	May 17 to July 17	0	25	0	22
1924	Saugus	May 22 to July 8	0	24	0	38
1925	Melrose	May 14 to July 1	0	1	0	36
1926	Saugus	May 25 to July 29	0	1	0	8
1927	Saugus	May 16 to July 28	0	4	0	[7] 67

[1] There were three collections in which 17 per cent of the larvae were parasitized, and one collection in which 16 per cent were parasitized. The other collections showed a lower percentage parasitized.
[2] There were three collections in which 24 per cent of the larvae were parasitized, and one collection in which 22 per cent were parasitized. The other collections showed a lower percentage parasitized.
[3] In 1920 gipsy-moth larvae were so scarce in Stoneham that collections in Melrose were substituted.
[4] In 1921, because of the scarcity of the gipsy moth in Melrose, Saugus was substituted.
[5] During the years from 1922 to 1927, inclusive, only one set of collections was made.
[6] There were three collections in which over 30 per cent of the larvae were parasitized. The other collections were lower.
[7] There were four collections in which over 40 per cent of the larvae were parasitized. The other collections were lower.

Practically all collections contained 100 gipsy-moth caterpillars, excepting in the last four years, when the size of each collection was decreased to 50 each. Although these collections were made over a limited area they are representative of conditions in many towns in the older infested territory. In addition to the serial collections of gipsy-moth caterpillars recorded in Table 6, small collections of caterpillars have been made in scattered localities throughout the moth-infested area. The data obtained from such collections, together with field observations, have shown that this parasite is often very abundant in limited areas, and collections of gipsy-moth caterpillars are often obtained which show from 20 to 30 per cent of parasitism caused by this species.

Recovery and Dispersion

Apanteles melanoscelus was recovered the first year following its liberation in this country; sparingly at first, but in greater numbers each successive year. The dispersion of this parasite has been augmented each year by liberating new colonies outside the area in which the species was known to be present. The natural spread has been in a northeasterly direction, and this fact has influenced the locations in which the new colonies have been liberated. The dispersion of the parasite in New England as determined by the laboratory records is shown in Figure 3. Further colonization of this parasite is necessary in order that it may more quickly become established over the entire territory that is infested by the gipsy moth.

Value of Apanteles melanoscelus

As indicated in Table 6, this parasite is of considerable value as a parasite of the gipsy-moth caterpillars. It has two generations annually either one or both of which may make appreciable inroads on a gipsy-moth infestation. Although *A. melanoscelus* was first liberated in 1911 it did not become noticeably abundant until 1916, and then only in a few locations. Nearly every year since then it has been observed in large numbers (pl. 4, A, B, C, and D), in many small, widely separated areas. The benefit derived from the establishment of this parasite in the United States is not confined to the control of the gipsy moth alone, for field records have been obtained of its attacking the satin moth, *Stilpnotia salicis* L., a foreign insect which has recently become established in the United States and Canada, as well as the white-marked tussock moth, *Hemerocampa leucostigma* S. & A. In addition it has been reared in laboratory experiments from *Malacosoma americana* Fab., *M. disstria* Hübn., *Olene basiflava* Pack., and from the brown-tail moth, *Nygmia phaeorrhoea* Donovan.

Like many of the introduced parasites and like the hosts themselves, it has its periods of abundance and scarcity. There are various reasons for this periodicity. In the first place the host must be present in suitable numbers to allow for its rapid increase. Secondly, climatic conditions are of very great importance, especially during the period when the parasites are ovipositing, for at this time during warm bright days the females are very active, but they do not oviposit readily when the weather is cold or rainy. The third and most serious handicap to *A. melanoscelus* is the enormous mortality caused by hyperparasites.

The hyperparasitism of this insect by species occurring in this country is much higher than that of the other parasites which have been introduced as enemies of the gipsy moth and the brown-tail moth. Records obtained at the laboratory show that over 95 per cent of the overwintering brood of *A. melanoscelus* are frequently destroyed by hyperparasites. Muesebeck and Dohanian (*21*) have reared some 35 species which attack this parasite and have cited 14 species which are particularly harmful. They list these in the order of their importance as follows:

Eurytoma appendigaster (Swed.)	*Hypopteromalus tabacum* Fitch
Dibrachys boucheanus (Ratz.)	*Habrocytus dux* Girault
Hemiteles tenellus (Say)	*Hemiteles fulvipes* Grav.
Dimmockia incongruus (Ashm.)	*Eupelminus saltator* (Lindm.)
Gelis bucculatricis (Ashm.)	*Dimmockia pallipes* Mues.
Gelis apantelis (Cushm.)	*Pleurotropis tarsalis* (Ashm.) } Principally tertiary.
Eupelmus spongipartus (Foerst.)	*Pleurotropis nawaii* (Ashm.) }

This heavy hyperparasitism, however, is not likely to be fatal, for comparable conditions exist in Sicily where this Apanteles was obtained. The junior author visited this area during the spring of 1922 and found *Apanteles melanoscelus* very abundant, yet in the examination of 100 cocoons hardly one could be found which had not been killed by hyperparasites or destroyed by ants.

There is a close relationship between the abundance of the gipsy moth, of this Apanteles, and of its hyperparasites, any one of which often increases rapidly under favorable conditions. In several cases in this country where the gipsy-moth infestation was increasing there has been noted a remarkably rapid increase of this parasite, which, in turn, has been overtaken by the hyperparasites; not, however, until it had had its effect on the gipsy-moth infestation.

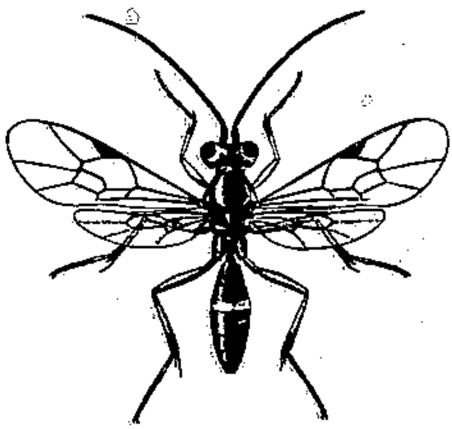


FIG. 21.—Adult male, × 4, of *Hyposoter disparis*. (Howard and Fiske)

Such hyperparasitism is an extraordinary handicap to overcome. Fortunately Apanteles has two generations annually, which gives it a reproductive capacity considerably greater than that of its host. The first or spring generation is exposed to the hyperparasites for only the few days while it is in its cocoon, and it is not parasitized to a serious extent. In spite of the great mortality of this species it is one of the most valuable introduced enemies of the gipsy moth.

HYPOSOTER DISPARIS Viereck

Although *Hyposoter disparis* Viereck (fig. 21), a parasite of the small gipsy-moth caterpillars, was recovered in very satisfactory numbers in 1913, it has never increased to any appreciable extent. It has a single generation annually and hibernates within its cocoon. It has been recovered sparingly nearly every year since its introduction.

Foreign Distribution and Abundance

The records at the gipsy-moth laboratory do not show it as a widely distributed species. In 1907 this parasite was first discovered in a small collection of gipsy-moth caterpillars imported from Kiev, Russia. The number obtained, in comparison with the number of caterpillars in the box, indicated that the percentage of parasitism was considerable; but an expert traveling in Russia for the Bureau of Entomology in 1909, who searched for this parasite especially, was able to find only a few cocoons. In 1910 another search for it was made in several Russian forests but to no avail. In Gioia Tauro, Italy, it was found abundantly in 1911.

During the recent gipsy-moth parasite investigations in Europe nothing comparable to the great abundance of this species in Italy in 1911 has been found. Several new distribution records have been obtained, but so far as these investigations have shown Hyposoter has been only an incidental enemy of the gipsy moth. During this

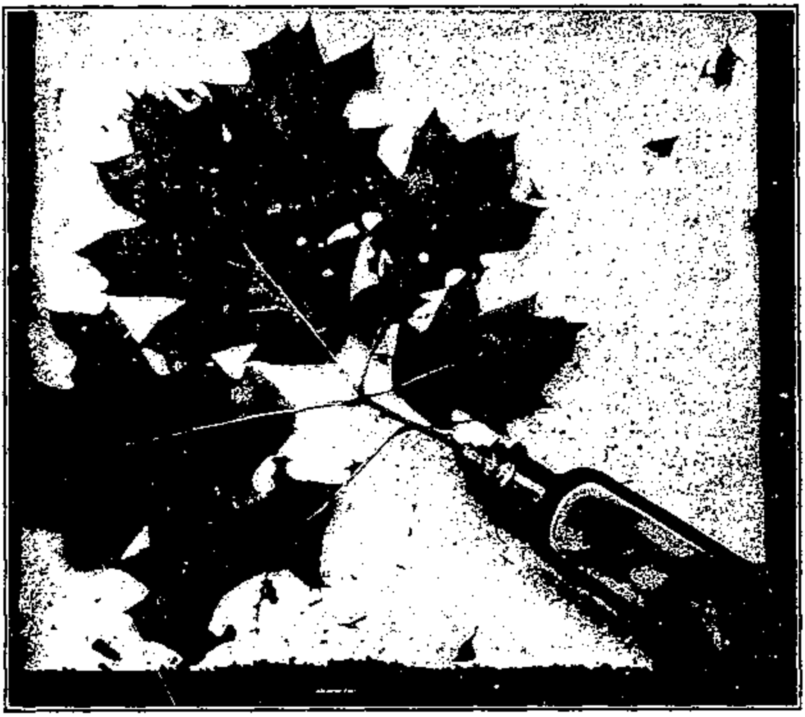


FIG. 22.—Cocoons of *Hyposoter disparis* on leaves in gipsy-moth feeding tray. Note the caterpillars from which the parasite maggots issued

work a few have been recovered in Spain, Hungary, Poland, Yugoslavia, Bulgaria, and Czechoslovakia.

LIFE HISTORY AND HABITS

Because of the great scarcity of this parasite in New England it has not been possible to make a detailed study of its life history and habits. At the time of its colonization in 1912 the chief object was its liberation and establishment. Since that time so few have been recovered each year that, until 1926, its life history had received little attention. For several years large collections of gipsy-moth caterpillars were made near the sites where this parasite had been liberated. In many cases the parasite was not recovered, and on several occasions when a few cocoons were obtained the parasites died during hibernation, or only a single sex issued the following spring. Curiously enough, only males have been recovered in some seasons and only females in others.

Several cocoons were obtained during the summer of 1926, and about 65 more came with the parasite introductions from Europe. During the spring of 1927, for the first time since 1912, adults of both sexes emerged after hibernation at the laboratory. Apparently fertilization occurred, but only males were obtained from the resulting cocoons.

The species has a single generation and is entirely dependent on the gipsy moth. The adults issue from their cocoons about the first week in May, according to R. Wooldridge, who is investigating the life history of this species. They insert their eggs in first-instar and second-instar caterpillars, and the mature larvae issue from fourth-instar caterpillars. In nature most of the larvae drop to the ground, and here the cocoons are formed and the winter is passed. Some cocoons have been found on tree trunks and leaves but they are easily dislodged. In laboratory rearing trays the cocoons are found in the bottom of the trays or attached to the foliage (fig. 22) which was placed in the tray as food for the caterpillars.

Introduction and Colonization

As stated, Hyposoter was found in great abundance at Gioia Tauro, Italy, in 1911. About 125,000 cocoons of it were gathered in the field, placed in boxes, and shipped to Melrose Highlands. Most of these cocoons were picked up from the leaf mold on the ground where the species normally passes the winter.

When the cocoons were received at the Melrose laboratory they were divided into small lots and placed in stout pasteboard boxes (fig. 16, D), on which were placed tight-fitting covers. A glass vial 4 inches long and 1 inch in diameter was inserted in a paper cone in the end of each box to draw off the adults or any hyperparasites which might issue. The cocoons contained a great variety and abundance of hyperparasites which continued to issue throughout the summer and early fall. Later, after this issuance ceased, a large number of the cocoons from which no hyperparasites had issued were colonized. These were placed on sphagnum moss in a cage in the ground. More sphagnum moss was placed over them, and the cage was then covered with heavy wire netting coarse enough to allow the parasites to escape and strong enough to protect the material from enemies. The remainder of the material was carried through the winter at the laboratory and about 12,000 adults issued the following spring and were liberated. About 500 cocoons were received during the summer of 1927. These have been placed in hibernation cages.

Recovery and Dispersion

Hyposoter disparis was recovered in 1913, the year following its liberation. It is recovered each year but only very sparingly and not more than a few miles from the area where it was originally liberated.

Value of Hyposoter disparis

Up to the present time it has not been an important enemy of the gipsy moth in New England. Its annual recovery, although in small numbers, indicates that it is firmly established. In the European investigations it has been recovered from several countries but only abundantly one year, in southern Italy. It may be that this parasite is able to increase to advantage only in a milder climate than is found around Boston.

A beginning was made in 1926 to increase this species by rearing it at the laboratory, but several seasons may be required to rear a sufficient number for a satisfactory liberation. As soon as enough are on hand it is the intention to place a strong colony in southern Massachusetts, the climate there being milder than it is in the Boston area, where this parasite is now merely existing. It is hoped that when this has been done the parasite will be under more favorable conditions and become the important gipsy-moth enemy that it was in 1911 in Italy.

COMPSILURA CONCINNATA Meigen

One of the first parasite enemies of the gipsy moth and the brown-tail moth to be obtained from Europe was *Compsilura concinnata.*

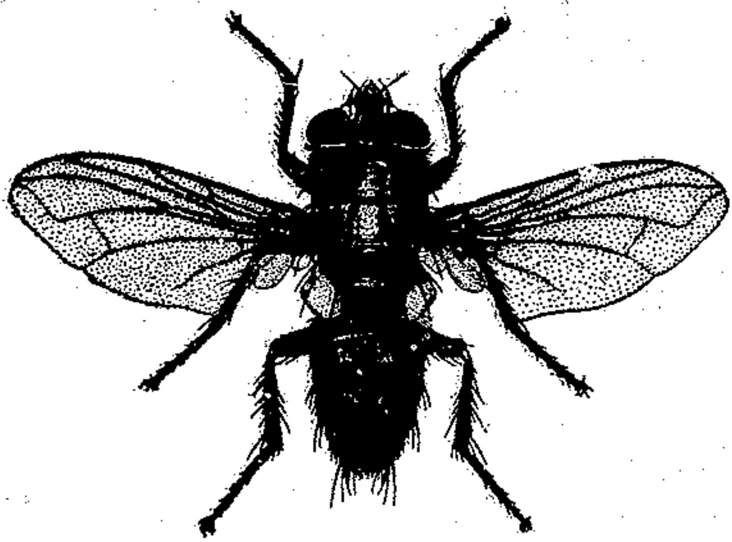


FIG. 23.—*Compsilura concinnata;* adult female, × 6½

(Fig. 23.) It was first received in 1906, and then in each successive year up to and including 1911, but it was not until 1909 that it was considered "as of particular importance as a gipsy-moth parasite" (*14, p. 220*). This tachinid passes the winter as an immature maggot within hibernating lepidopterous pupae (*26*), and has three, and possibly four, generations annually. In New England it has been one of the principal checks on the increase of the gipsy moth and the brown-tail moth, as well as an important enemy of native insects.

FOREIGN DISTRIBUTION AND ABUNDANCE

This species has a wide distribution and has been recovered from the following countries: France, Belgium, the Netherlands, Germany, Poland, Czechoslovakia, Austria, Hungary, Bulgaria, Yugoslavia, Switzerland, Portugal, Spain, Italy, Russia, and Japan. During the recent foreign work it has been found often in Europe, but not in abundance in the areas where experts of the Bureau of Entomology have carried on their investigations until the summer of 1927. It has been reared from collections of gipsy-moth larvae made by them in Hungary, Czechoslovakia, Poland, Bulgaria, Yugoslavia, Spain, and Portugal. The data obtained from the recent European work of the bureau up to 1927 would indicate that this species is not an important enemy of the gipsy moth. It will be remembered, however, that during the early years of the importation work this species was received only sparingly for three years, and it was not until the fourth year of the work that it was considered of importance as a gipsy-moth parasite.

The number of Compsilura received from Europe during 1909 indicated that it must have been an important parasite of the gipsy-moth caterpillars that season. It was found in many locations, especially in southern France and Germany. The large number of European insects recorded as hosts of this parasite is also indicative of its importance. The records show that in Europe there are years when Compsilura is of considerable importance as an enemy of the gipsy moth and the brown-tail moth. Evidently it has periods of abundance and scarcity, as is the case with many insects.

Its value as a gipsy moth and brown-tail moth parasite is largely dependent upon the abundance of suitable hibernating hosts, and this accounts to a large degree for its periodicity of abundance.

Life History and Habits

Compsilura concinnata passes the winter as an immature maggot within its host. About 25 species of hibernating hosts in this country have already been discovered in the investigations (*26*) carried on at the gipsy-moth laboratory at Melrose Highlands, Mass.

From the middle to the last of April the full-grown parasite maggots issue from their overwintering hosts and pupate, the adults appearing about 10 days later. There are from three to four generations annually, the first one attacking the small brown-tail moth and gipsy-moth caterpillars. Other records show that this generation is not confined to these two species but attacks many native insects also. The adult parasites live from 18 to 20 days, so there is an overlapping of generations in the field, and adults may be collected in the field from May 1 until November 11.

The female is provided with a long curved sheath which is very sharply pointed. It is used for piercing the bodies of the caterpillars, and guides the larvipositor as a living maggot is inserted into the host. According to Culver (*12*), and Tothill (*24*) the reproductive capacity of Compsilura ranges from 90 to 119 maggots. In nature the females are presumably more fecund than in confinement.

There are three larval instars within the host, requiring an average of 13 days for their development. The mature third-instar maggot bores through the skin of the host, usually in the caterpillar stage, and pupates outside of it, but occasionally it does not issue until its host has pupated. If the host of Compsilura is a brown-tail-moth caterpillar the maggot usually issues while the caterpillar is spinning its loosely woven cocoon and may pupate within the cocoon. When the host is a gipsy-moth caterpillar the maggot upon issuing usually drops to the ground and enters the soil for pupation, but it may pupate in masses of molted skins or pupae. The puparia (fig. 24) are often found in crotches of trees where the hosts are resting or under débris and stones on the ground where the parasitized caterpillars have crawled. In from 10 to 14 days after the parasites have left their hosts the adults of the next generation appear.

Reproduction continues during the summer, and as the hosts prepare for hibernation the Compsilura maggots within them become quiescent until the following spring.

Importation

During the first years of the introduction work large numbers of brown-tail moth and gipsy-moth caterpillars were collected from many areas in Europe. These were sent to the gipsy-moth laboratory, first at Saugus, Mass., and later at Melrose Highlands, Mass. For shipment, the caterpillars were placed in light wooden boxes about 8 inches long, 5 inches wide, and 3 inches deep. In one end of each box was a hole about 1 inch in diameter covered by fine copper-wire netting. Each box was well supplied with foliage for the caterpillars and covered with a wooden top. The boxes were then made up into packages of size convenient for shipment. There was usually a very

Fig. 24.—*Compsilura concinnata*: Lateral view of puparium, about 10 times natural size

heavy mortality of the caterpillars while in transit to this country, but in many cases the Compsilura maggots issued from the caterpillars en route and pupated successfully in the boxes. From 1906 to 1908 most of the Compsilura were obtained in this manner from shipments of full-grown brown-tail moth caterpillars. In 1909, 1910, and 1911 many Compsilura were recovered from shipments of gipsy-moth caterpillars as well as from brown-tail moth caterpillars.

Colonization

Compsilura was first received and liberated in 1906 with some other tachinids. The identification of these parasites was not possible at the time, so the exact number of Compsilura which were liberated in that and the following year will never be known. It is known, however, that the liberations made in 1907 were much greater than those of the preceding year. In 1908 no liberations were made although the species was received from several European countries. The numbers of Compsilura which have been liberated are given in Table 7.

Table 7.—*Colonization of Compsilura concinnata in the United States*

Year	Number of Compsilura liberated in—								
	New England	District of Columbia	Canada	New Mexico	Arizona	California	New Jersey	Florida	Total
1906	Few.								
1907	(1)								
1909	6,121								6,121
1910	749	437							1,186
1911	555		615						1,170
1912	[2] 3,125		2,357						5,482
1913	4,565		4,238	250					9,053
1914	14,488		5,000	3,150					22,638
1915	9,582		4,013	2,005	2,000			896	18,496
1916	9,518		[3] 15,725					2,125	27,368
1917	1,900								1,900
1918					10,625				10,625
1919	4,400								4,400
1920									
1921							4,882		4,882
1922	780						983		1,763
1923						1,000	4,000		5,000
1924						1,500	5,145		6,645
1925							2,896		2,896
1926							2,000		2,000
1927	13,384						2,750		16,134
Total	69,167	437	31,948	5,405	12,625	2,500	22,656	3,021	147,759

[1] Many more than previous year.
[2] All of the Compsilura liberated previous to 1912 were of foreign stock. Since 1912 all of the Compsilura for liberation have been obtained in the New England States except 13,384 in 1927 which came from Europe.
[3] Most of the Compsilura which have been sent to Canada were obtained by experts from the staff of the Dominion entomologist who made their headquarters, while obtaining this material, at the gipsy-moth laboratory at Melrose Highlands, Mass.

In New England this parasite has been colonized in the adult form as well as in the puparial stage. When the puparia have been colonized they have been placed on the ground in protected places and lightly covered with a layer of earth and leaf mold. In recent years the practice has been to hold the puparia at the laboratory and allow the adults to issue and mate before being liberated. This method of colonization is considered better than the colonization of puparia.

Although there is usually considerable mortality of tachinids when held as adults in confinement, the liberation of fertilized females has enough in its favor to counterbalance this mortality. When the tachinids are colonized as puparia, the adults as they issue may spread so rapidly that in many cases the sexes are not able to meet, and a generation of males is produced parthenogenetically. When fertilized females are liberated the number of parasites in each colony need not be so great as when the colony is put out as puparia. This permits the liberation of more colonies and makes for a quicker dispersion over the infested territory. When puparia have been colonized, 500 or more were placed in each colony. In liberating colonies of fertilized females 250 to 300 parasites in each colony are considered sufficient to insure its establishment. It should be noted, however, that in attempting the establishment of a foreign tachinid not present in this country much larger colonies should be liberated.

Apparatus Used in Compsilura Life-History Studies

A wooden tray (fig. 17) about 14 inches square and 5 inches deep, covered on the bottom with white cotton cloth and on the top with glass, was found to be very useful in breeding work with this species. One-inch holes bored in three sides of the tray and covered with fine copper-wire netting allow ventilation. Another 1-inch hole, near the top of one of the sides, closed with a cork stopper, is convenient for introducing adult parasites. A 2-inch hole bored in the side of the tray not containing ventilation holes is used for inserting and removing the foliage for the caterpillars. This hole is closed by means of a large wooden stopper. Often, in this large wooden stopper is a 1-inch hole into which a glass tube full of water is inserted. The stems of

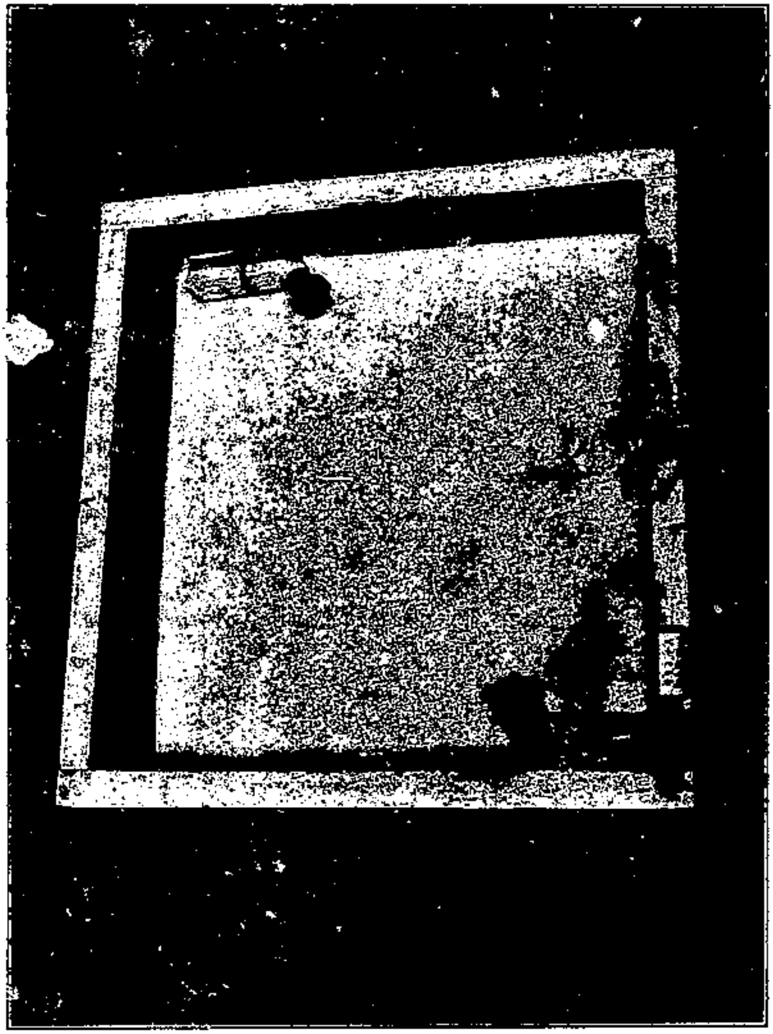


FIG. 25.—Paraffined paper tray used for feeding small collections of caterpillars. Note that the bottoms and sides are made of one piece of heavy paper which has been treated with paraffin. This sets into a wooden frame. (Mosher)

the foliage pass into this tube of water through a small hole in a cork stopper which fits into the open end of the tube. In this manner the foliage in the cage is kept fresh. Another method of keeping the foliage fresh is to insert the stems in the same way into the open end of a small crook-necked bottle of water. Seepage of water from the tube or bottle is prevented by wrapping the stems of the foliage with small pieces of newspaper before inserting them in the cork stopper. The foliage should be changed each day.

The adult parasites are fed by slightly moistening pieces of sponge with a mixture of 1 part of honey to 2 parts of water. These pieces of sponge should be placed on a piece of paraffin paper so that they do not foul the cage and should be thoroughly cleansed and moistened with a fresh mixture of honey and water each day. Within such a tray gipsy-moth caterpillars and Compsilura are easily kept and observed.

Glass vials 8 by 2 inches were found very useful for securing larviposition in individual caterpillars for study. A fertilized female and a caterpillar are confined in such a vial until the host is attacked. The caterpillar is then removed and placed in a small tray (fig. 25), for rearing. In cases where the study necessitated the keeping of a parasitized caterpillar isolated, small cans (fig. 16, E) were found to be very satisfactory. These cans are easily kept clean and the foliage remains fresh in them longer than in open containers.

Methods Used to Obtain Compsilura for Colonization

By the year 1912 this species was firmly established, but further colonization to assist in its dispersion was necessary. The procedure has been to make small sample collections of gipsy-moth caterpillars from many locations, and from those showing the highest percentage of parasitism large numbers of caterpillars were collected. Mainly fifth-instar and sixth-instar caterpillars are collected for the bulk recovery of this parasite. These are put in wooden boxes, 3 by 5 by 8 inches. (Fig. 16, F.) In each box with the caterpillars is placed a small quantity of foliage and a note indicating the location from which the collection was made. The boxes are then sent by mail to the laboratory or brought in by the collectors. On arrival at the laboratory the caterpillars are placed in large wooden trays and fed. As the parasites issue they are removed from the trays and put up in colonies of 500 each and kept in a cool place until ready for colonization. If adults are to be liberated the puparia are placed on soil in emergence cages (fig. 8, B) and handled as described on page 18. After mating has taken place the females are put into a colonization cage (fig. 9), to be taken to the field for liberation.

During the last few years, in addition to the Compsilura obtained for liberation from gipsy-moth caterpillars, many have been reared from large collections of caterpillars of the satin moth. This recently introduced foreign insect is rather heavily parasitized by Compsilura and, being abundant in many locations in eastern Massachusetts, is a convenient host to collect in large numbers for bulk recovery of Compsilura.

Collection of Hosts to Determine the Percentage of Parasitism

As this parasite attacks a great variety of hosts the collections of host caterpillars are not confined to the gipsy moth and the brown-tail moth, but the satin moth and a large number of native insects are collected annually.

PARASITISM OF NATIVE INSECTS

Compsilura has been reared at the gipsy-moth laboratory from approximately 100 different species of insects (*26*), in most cases lepidopterous caterpillars and pupae. With some species the parasitism has been very high.

This information has been obtained through the handling annually of from 50 to 150 different species, involving the care of from 18,000 to 60,000 native insects each season. These insects are from many collections, some of which contain only one larva, others several thousand. They not only require daily feeding, but many of them must be successfully carried through the winter in order that the desired information may be obtained. The handling of so many species requires the use of a large variety of rearing cages and a careful system of recording the data. The material is collected by members of the laboratory force when they are in the field, and also by members of the field force who are provided with small mailing tubes for this purpose. Many of the local moth superintendents in Massachusetts,

FIG. 26.—Type of ordinary tray used at the gipsy-moth laboratory for feeding small collections of caterpillars. Note the band of sticky material on the inside of the sides and ends of the tray to prevent caterpillars from escaping

and interested people all over New England, contribute to these collections. As the host material arrives at the laboratory, it is assorted according to the species and placed in containers suitable for rearing the insects. The ordinary gipsy-moth rearing tray (fig. 26) is used for many species. For some species the glass-covered tray shown in Figure 17 is better adapted. Another tray, useful for some species, is a modification of the one shown in Figure 25. It has a wire bottom instead of cloth, and may be placed on the ground or may have a small quantity of earth put in it for the larvae, which pupate in the soil. Many types of small cans and jars, some with cloth tops, held in place by elastic bands and others with tin or glass tops, are used. (Fig. 16, C, E, G.)

Recently a cylindrical can 2 inches in diameter and 2 inches long (fig. 16, H) with a glass top has been found very useful for rearing individual caterpillars and their parasites. The cover is made by cutting out most of the top of the tin cover of the can, leaving enough of the tin around the circumference to retain a circular piece of glass placed behind it. The glass is held there by means of three small metal clips soldered to the tin. With the glass fitted into the cover the hosts or their parasites can readily be seen without removing the top; and if a parasite has issued the can may be opened with less danger of the parasite escaping. When there are many containers to observe each day the cans with glass covers save much time in the routine handling of this material.

Some of the collections which arrive at the laboratory are placed in containers in which they are to pass the winter. Jars partly filled with earth serve the purpose satisfactorily for many species. Other types of hibernating cages for insects which pass the winter in the soil are shown in Figure 16, I. One of these is a galvanized-iron cylinder about 10 inches long and 5 inches in diameter. The bottom is covered with fine-mesh copper-wire netting and the top may be covered with the same material or with cloth. Another one made of a strong heavy wire netting is used for the hibernation of Calosoma beetles.

PARASITISM OF GIPSY-MOTH LARVAE

Many collections of gipsy-moth caterpillars are made annually to determine the percentage of parasitism of this species by Compsilura. In general these collections may be divided into three series, namely, the semiweekly collections, the annual collections from 25 specified towns, and a large number of miscellaneous collections.

The semiweekly collections have been made during the caterpillar season for several years at Melrose or surrounding towns. They are merely a continuation of similar collections made of the smaller caterpillars for data in regard to the parasitism caused by *Apanteles melanoscelus*, and are described in the part of this bulletin pertaining to *A. melanoscelus* on page 46. The collections for recovery of Compsilura consist of third, fourth, fifth, and sixth instar caterpillars. Usually not many caterpillars which have been collected while in the third instar have been in the field long enough to become parasitized by Compsilura. High percentages of parasitism are sometimes obtained from caterpillars collected while in the fourth instar, but the highest percentage is found in caterpillars of the fifth instar. A decrease in the percentage of parasitism is usually shown in caterpillars collected as sixth instar. Occasionally Compsilura maggots issue from gipsy-moth pupae, but the great majority of them issue from the caterpillars.

Tables 8, 9, and 10 show the percentage of mortality of the gipsy-moth caterpillars caused by Compsilura in collections of caterpillars made in Melrose, Stoneham, and Saugus. In most cases each collection consisted of 100 caterpillars, all of the same instar. These were placed in trays and here they were cared for throughout the season. The trays were examined daily and careful records were kept of the observations made. Each tray was confined in a screened compartment (fig. 27) to prevent the occurrence of any parasitism at the laboratory after the collections had been made.

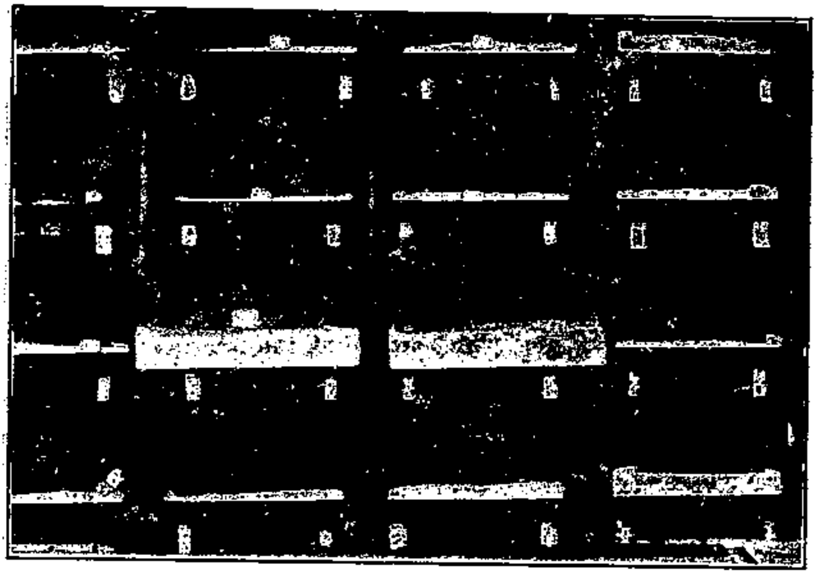


FIG. 27.—Screened-in rack for holding trays of gipsy-moth larvae collected to determine the amount of parasitism. Two trays are partially withdrawn to show the doors over each compartment

TABLE 8.—*Semiweekly collections of gipsy-moth caterpillars made at Melrose, Mass., to determine the percentage of parasitism caused by Compsilura concinnata*

Year	Number of collections made and stage of larvae collected							Percentage of parasitism		
	3d	3d and 4th	4th	4th and 5th	5th	5th and 6th	6th	Lowest	Highest	Average
1915	2							0	0	0
		4						0	5	2
				2				17	33	25
						7		0	20	11
1916	7							0	5	1
			8					2	24	7
					2			0	30	15
						6		0	10	5
1917	2							0	0	0
			4					0	5	4
					5			2	8	5
							3	0	7	5
1918	10							0	2	1
			3					1	3	2
					9			0	42	12
							9	0	45	24
1919	7							0	11	4
			6					4	20	15
					17			1	[1] 58	35
							20	3	26	9
1920	6							0	1	1
			9					7	[2] 31	19
					17			3	[3] 67	40
1925 [4]	8							0	1	1
			11					0	3	1
					17			0	3	1
							12	0	6	1
1925 dissections	3							4	18	5
			10					0	16	6
					8			0	8	4
							2	0	4	2

[1] Of the 17 collections made, 9 showed from 10 to 44 per cent of parasitism.
[2] Of the 9 collections made, 6 showed over 20 per cent of parasitism.
[3] Of the 17 collections made, 2 showed between 50 and 60 per cent of parasitism, 2 of them between 60 and 70 per cent, 2 of them between 70 and 80 per cent, and 2 between 80 and 87 per cent of parasitism.
[4] During this year most of the collections contained 50 caterpillars each. Half of these were cared for in trays and the other half were dissected.

These collections were made each year from 1915 to 1920 inclusive. The figures obtained show clearly a very high percentage of parasitism of the gipsy-moth caterpillars in 1919 and 1920. In 1920 the mortality was so great that no collections of sixth-instar caterpillars could be be made at the collection point in Melrose. *Compsilura concinnata* was the chief cause for the decrease of the infestation in this locality, although *Apanteles melanoscelus* accounted for the death of a considerable number of the earlier stages of this host. *Calosoma sycophanta* also was present and killed many larvae. Since 1921 the gipsy-moth infestation in this area has been so light that semiweekly collections of caterpillars could not be made until 1925, so the semiweekly collections to represent this section were made at Saugus, Mass. Some of these years it has not been possible to find the full number for each of the collections at the collecting point in Saugus, and the collections have been completed in many cases in Melrose or other surrounding towns as near to the collecting point as possible.

In 1925 there was a slight increase in the gipsy-moth infestation in Melrose and semiweekly collections of the larvae were made. Each collection contained 50 caterpillars instead of 100 as in previous years. Part of these collections were handled in the usual manner and a part were placed in a preservative for dissection. The data obtained for 1925 are given at the bottom of Table 8. The parasitism was relatively low.

TABLE 9.—*Semiweekly collections of gipsy-moth caterpillars at Stoneham, Mass., to determine the percentage of parasitism caused by Compsilura concinnata*

Year	Number of collections made and stage of larvae collected							Percentage of parasitism		
	3d	3d and 4th	4th	4th and 5th	5th	5th and 6th	6th	Lowest	Highest	Average
1915		6						0	1	0.3
				2				11	13	12
						6		0	8	5
1916	8							0	11	7
			8					6	[1] 45	21
				2				43	62	53
						4		10	26	20
1917	3							0	0	0
			4					6	18	10
				5				4	50	23
							3	2	18	11
1918	4							1	3	1
			2					11	20	16
				5				9	30	19
							6	2	37	19
1919	5							4	30	13
			8					24	[2] 48	41
				15				1	41	14
							21	0	16	1
1921	8							7	41	20
			9					39	[3] 65	53
				11				7	63	28
							3	0	4	2

[1] Of the 8 collections made 5 showed over 20 per cent of parasitism.
[2] Of the 8 collections made 6 showed over 30 per cent of parasitism.
[3] Of the 9 collections made 8 showed over 40 per cent of parasitism.

The Stoneham collections were made and handled in a manner similar to those made at Melrose. The parasitism of the caterpillars caused by Compsilura was very high in 1919, and although the table shows that 21 collections of sixth-instar gipsy-moth caterpillars were made, it should be stated that many of these collections did not contain the usual quota of 100 caterpillars, for the infestation was greatly reduced by Compsilura. Calosoma also was present and *Apanteles melanoscelus* killed many caterpillars in the early instars. The infestation was so thoroughly reduced that it was not possible to make the semiweekly collections in Stoneham during the following year. However, in 1921 the gipsy-moth infestation had increased enough so that semiweekly collections could be resumed, and the data given in Table 9 show Compsilura very abundant. It was, again, chiefly responsible for a big reduction in this infestation. Since 1922 the infestation at Stoneham has been too light to support semiweekly collections.

Collections of gipsy-moth caterpillars have been made at Saugus each year since 1921 and handled in a manner similar to those made at Melrose and Stoneham. Collections were started at Saugus, a neighboring town, because of the scarcity of the gipsy moth at Melrose and Stoneham during these years. The infestation at the location in Saugus, where the collections were made, has not been heavy during the period covered by these collections. The percentage of parasitism by Compsilura at this collecting point has not been so high as those recorded at Melrose in 1919 and 1920, and in Stoneham in 1919 and 1921. However, as shown in Table 10, it has been consistently high each year, excepting in 1925, when there was a marked decrease in the percentage of parasitism.

TABLE 10.—*Semiweekly collections of gipsy-moth caterpillars made at Saugus, Mass., to determine the percentage of parasitism caused by Compsilura concinnata*

Year	Number of collections made and stage of larvae collected				Percentage of parasitism		
	3d	4th	5th	6th	Lowest	Highest	Average
1921	6				1	11	3
		6			2	15	7
			10		4	35	14
				9	0	13	4
1922	8				0	7	1
		11			0	19	4
				16	0	24	11
			16		0	25	6
1923	7				3	28	13
		7			15	40	24
			12		8	49	19
				10	2	14	9
1924	8				0	11	4
		10			0	27	26
			13		1	35	20
				9	0	12	8
1925		7			0	4	1
			16		0	11	3
				12	0	5	1
1925 dissections		4			8	12	10
			9		4	12	7
				4	4	4	4
1926	7				0	16	4
		9			8	44	19
			13		0	68	23
				13	4	52	20
1926 dissections	7				0	0	0
		9			0	20	6
			13		0	44	16
1927	11				0	22	7
		11			10	32	20
			19		4	64	29
				16	9	60	29

The semiweekly collections of gipsy-moth larvae which have been made at Melrose, Stoneham, and Saugus demonstrate clearly the great benefit that has been derived from the importation of this parasite. Because of the labor involved it has not been possible to make such a thorough study of the parasitism caused by Compsilura in other locations.

In 1915, 25 representative towns were chosen in which to make an annual collection of gipsy-moth caterpillars for the recovery of Compsilura. These towns are scattered over the eastern half of the gipsy-moth-infested area, and although collections of this nature do not give an accurate figure of the percentage of parasitism of the host, they are indicative of the general abundance or scarcity of the parasite. The area involved in these collections and the percentage of parasitism recorded for Compsilura for 1923 are shown in Table 11.

TABLE 11.—*Collections of gipsy-moth caterpillars made to determine the abundance of Compsilura concinnata and Sturmia scutellata, 1923*

Locality	Number of larvae collected	Percentage of parasitism for—		Locality	Number of larvae collected	Percentage of parasitism for—	
		C. concinnata	S. scutellata			C. concinnata	S. scutellata
Melrose, Mass.	100	36	35	Hopkinton, Mass.	100	27	13
Saugus, Mass.	100	38	6	Candia, N. H.	100	7	3
Stoneham, Mass.	100	10	10	Rye, N. H.	100	10	31
Wakefield, Mass.	100	17	3	Stratham, N. H.	100	35	7
Revere, Mass.	100	38	24	Leominster, Mass.	82	40	2
Beverly, Mass.	100	8	5	Medfield, Mass.	100	18	6
Middleboro, Mass.	100	14	1	Biddeford, Me.	100	7	7
Wilmington, Mass.	100	62	7	Warner, N. H.	100	0	4
Lexington, Mass.	100	29	4	Plymouth, Mass.	100	42	1
Boston, Mass.	100	50	0	Ashburnham, Mass.	100	4	38
Weymouth, Mass.	100	17	6	Worcester, Mass.	100	25	3
Derry, N. H.	100	10	24				
Pelham, N. H.	100	8	5	Total	2,482		
Acton, Mass.	100	87	7	Average		25	10

TABLE 12.—*Summary of annual collections of gipsy-moth caterpillars from 25 towns to determine abundance of Compsilura concinnata and Sturmia scutellata from 1915 to 1927*

Year	Number of gipsy-moth larvae collected	Percentage of parasitism for—					
		Compsilura			Sturmia		
		Lowest	Highest	Average	Lowest	Highest	Average
1915	2,291	0	29	4	0	0	0
1916	2,438	0	45	9	0	7	1
1917	4,278	0	45	8	0	4	1
1918	2,712	0	48	9	0	6	1
1919	2,486	0	36	7	0	1	1
1920	3,147	0	46	8	0	12	2
1921	3,179	0	21	4	0	2	1
1922	2,500	0	54	14	0	8	3
1923	2,482	0	87	25	0	38	10
1924	2,352	0	51	10	0	8	2
1925	2,240	0	16	4	0	18	2
1926	2,485	0	53	8	0	3	0.2
1927	2,503	0	35	11	0	1	0.2

When possible each collection contained 100 fourth-instar to sixth-instar gipsy-moth caterpillars. These were collected from any area within each town. The caterpillars were fed at the laboratory in trays until the parasite maggots issued or until the caterpillars pupated; the pupae were then removed to separate containers to be held for the issuance of *Sturmia scutellata*.

A summary of the records obtained from similar collections of gipsy-moth caterpillars which were made at the towns listed in Table 11 each year from 1915 to 1927 appears in a much abridged form in Table 12.

Fourth-instar to sixth-instar caterpillars were collected in this series of collections. In most cases each collection contained 100 caterpillars taken promiscuously from any location within each town. The data indicate that Compsilura was most abundant in the areas involved in 1923. That year the collections showed an average of 25 per cent of the larvae parasitized by this species. It also shows the fact that during the last few years this parasite has been less effective. This is very evident for 1925, for 16 per cent, which was the highest parasitism recorded for the entire list of towns, was the lowest high percentage obtained since the collections were started in 1915, and the average percentage of parasitism of the caterpillars by Compsilura was only 4.

It will be noted that the table contains some data on parasitism by *Sturmia scutellata*. Reference will be made to these under the discussion of this species.

Besides the semiweekly collections and the annual collections recorded in Tables 8, 9, 10, 11, and 12, a great many miscellaneous collections of gipsy-moth caterpillars are received at the laboratory each season. Many towns scattered over practically the entire gipsy-moth-infested area are represented in these miscellaneous collections. In Table 13 are listed the towns from which collections of gipsy-moth caterpillars were received in 1923. This list of towns indicates the area from which similar collections are received each year.

It should be noted that many of these collections were made where the gipsy-moth infestations are extremely light and scattered, in the area farthest from the older gipsy-moth-infested territory. The records given in Table 13 are for 1923, when Compsilura was more abundant over the entire gipsy-moth-infested area that it has been since its establishment. It is very gratifying to obtain relatively high percentages of parasitism from many of the collections made in the area which is only lightly infested. Such parasitism undoubtedly occurs in many places where light gipsy-moth infestations are present, just east of the westerly dispersion line, and must be of inestimable value in preventing a rapid increase of this insect in these isolated gipsy-moth colonies.

The data obtained from these collections during the last few years are rather similar in nature to those in Table 13, except that the average percentage of parasitism has not been so high as for that year. It is not necessary for these detailed data to be included here, but a brief summary of them is given in Table 14 and is indicative of the conditions during this period.

TABLE 13.—*Parasitism of fifth-stage and sixth-stage gipsy-moth caterpillars by Compsilura concinnata and Sturmia scutellata in 1923, as determined by miscellaneous collections, especially in the outer area*

State and town	Number of gipsy-moth larvae collected	Percentage of parasitism: Compsilura	Percentage of parasitism: S. scutellata
New Hampshire:			
Barrington	38	3	5
Bath	41	7	-------
Charlestown	53	11	23
Chesterfield	109	12	4
Concord	109	-------	5
Cornish	20	-------	-------
Danbury	24	50	4
Enfield	151	[1] 7	1
Grafton	62	11	11
Hampton	100	2	19
Hanover	53	[1] 19	9
Haverhill	118	74	-------
Hinsdale	116	[1] 2	3
Langdon	84	[1] 21	-------
Lebanon	123	9	16
Lisbon	111	[1] 47	5
Lyme	111	[1] 11	-------
Milton	24	-------	13
Monroe	5	-------	-------
New Durham	34	-------	9
Oxford	7	[1] 29	-------
Piermont	135	[1] 91	4
Plainfield	65	[1] 5	[1] 2
Rochester	162	2	4
Wakefield	20	10	-------
Walpole	158	[1] 53	8
Westmoreland	152	[1] 11	3
Massachusetts:			
Abington	220	24	4
Ashfield	23	29	4
Ashfield	23	-------	20
Brockton	3	-------	-------
Charlemont	41	17	5
Chesterfield	41	-------	6
Colrain	19	[1] 5	-------
Conway	23	[1] 100	-------
Deerfield	63	5	-------
Dedham	100	10	27
Easthampton	52	-------	4
Falmouth	105	[1] 7	-------
Greenfield	65	43	-------
Goshen	3	-------	-------
Lanesboro	7	[1] 14	-------
Marion	124	1	[1] 2
Montgomery	22	[1] 5	[1] 9
Nantucket	1	-------	-------
Northampton	29	7	[1] 7
Raynham	208	[1] 8	10
Shelborne	12	[1] 9	33
Southampton	73	-------	5
Southwick	30	[1] 3	-------
Massachusetts—Contd.			
Shrewsbury	162	4	1
Tolland and Grandville	90	19	[1] 10
Wareham	98	13	[1] 10
Whately	100	3	-------
Westfield	50	[1] 2	34
Williamsburg	90	[1] 1	[1] 7
Williamstown	10	[1] 20	-------
Worcester	154	28	1
Worthington	16	-------	[1] 13
Maine:			
Lebanon	31	-------	29
Sandford	26	-------	-------
Vermont:			
Athens	36	-------	-------
Barnet	5	-------	-------
Brattleboro	50	4	-------
Dummerston	63	4	[1] 2
Essex	208	4	5
Fairlee	18	[1] 17	-------
Grafton	31	[1] 29	3
Groton	3	-------	-------
Guilford	90	31	-------
Hartford	48	-------	-------
Hartland	52	2	-------
Marlboro	14	-------	-------
Norwich	43	-------	-------
Newbury	84	4	-------
Putney	37	-------	-------
Rockingham	239	59	4
Ryegate	2	-------	-------
Springfield	10	-------	-------
Strafford	1	-------	-------
Thetford	73	13	3
Topsham	110	85	36
Vernon	75	-------	-------
Wardsboro	25	60	8
West Fairlee	76	[1] 1	-------
Westminster	122	32	7
Connecticut:			
Bloomfield	34	-------	[1] 9
East Granby	71	[1] 3	[1] 37
New Hartford	4	-------	-------
Plainfield	8	25	-------
Salisbury	20	-------	-------
Suffield	79	[1] 32	3
Thompson	13	8	23
Weathersfield	60	[1] 12	2
Windsor	15	-------	-------
Total	6,199	-------	-------

[1] Species recovered for the first time in the town.

TABLE 14.—*Summary of miscellaneous gipsy-moth caterpillar collections to show abundance of Compsilura concinnata, 1915 to 1927*

Year	Number of localities represented	Total number of gipsy-moth larvae received	Percentage of parasitism by Compsilura
1915	50	56,865	13
1917	4	4,000	5
1918	50	113,207	8
1919	86	5,186	15
1920	58	5,651	8
1921	138	24,536	3
1922	100	4,656	11
1923	96	6,199	18
1924	53	3,858	9
1925	53	4,439	6
1926	81	7,092	6
1927	68	7,765	7

1781°—29——5

The caterpillar collections shown in this table contained from a few to several thousand caterpillars from each town, depending upon the abundance of the gipsy moth in the area.

The data given in Table 14, together with those shown in the previous tables, are conclusive evidence that Compsilura is a very important factor in the biological control of the gipsy moth.

PARASITISM OF OTHER CATERPILLARS

Compsilura concinnata is an important parasite of the brown-tail-moth caterpillars as well as of the gipsy-moth caterpillars, satin-moth caterpillars and many native insects. The satin moth has proved to be a favorite host for Compsilura in this country. Records were obtained of high parasitism of the large caterpillars by this tachinid the first year that this insect was found in New England. The parasitism of the satin moth by Compsilura has been briefly treated in a recent publication (*7*) by the authors. The data which have been obtained show that this parasite has become the most important insect enemy of the satin moth in New England. In many collections of large caterpillars from 50 to 70 per cent of the caterpillars have been killed by Compsilura. Records obtained from collections of satin-moth caterpillars, made over the entire area infested by this insect, show that Compsilura is attacking this host wherever it occurs in New England.

RECOVERY AND DISPERSION

Compsilura was doubtfully recovered in 1907, the year following its first liberation. The next year it was not recovered but the following year and each succeeding year it has been recovered in considerable numbers.

The dispersion has been hastened by the liberation of new colonies beyond the area in which it was known to be present. Records have been obtained indicating that it may spread as much as 25 miles in a single season, and this has been considered in determining the locations for new liberations. For the most part Compsilura has been recovered by rearing it from gipsy-moth and brown-tail moth caterpillars collected from over the entire area infested by these insects. In addition to the recovery records obtained in this manner many valuable new dispersion records have been made by rearing it from native insects.

As Compsilura is not dependent for its existence upon the gipsy moth or the brown-tail moth it has spread far beyond the dispersion of these insects and has been recovered from 33 towns outside of the area infested by the gipsy moth. Many of the native collections of larvae from which these data have been obtained were made by field men employed on gipsy-moth work by the New York State Conservation Commission and the New Jersey Department of Agriculture, and valuable data have been furnished by the entomological department of Syracuse University. Without such splendid cooperation by those interested, several of these recoveries would not have been made. The territory over which this parasite is now known to be present is shown in Figure 3. Its natural westward spread of approximately 125 miles beyond the gipsy-moth dispersion line is remarkable and indicates that this beneficial insect will eventually spread over a large part of the United States without further assistance or cost.

Value of Compsilura concinnata

This parasite is certainly one of the most beneficial introductions that have been made. It has already demonstrated the important place it occupies among the insect enemies of the gipsy moth and the brown-tail moth. In addition to the benefits derived from its parasitism of these insects, it is causing high parasitism of the satin moth, a recently introduced pest. The high percentage of parasitism of this host by Compsilura is of special value because it is the only parasite that has attacked the satin moth in New England to any appreciable extent. Only rarely are collections of large caterpillars of this insect obtained which do not show some parasitism by Compsilura. Sometimes the collections show over 70 per cent of the caterpillars killed by this tachinid.

The value of Compsilura in this country is still further increased because of its attack on a great variety of native injurious insects. It has already been reared at the gipsy-moth laboratory from over 100 different species, and undoubtedly records of its successful parasitism of other species will be obtained.

The records obtained of the parasitism of the gipsy moth by Compsilura over the entire infested territory, and especially along the border of this territory, show conclusively that this parasite has assisted in checking the increase of the insect and in curtailing its westward spread. Such parasitism is particularly valuable in small isolated gipsy-moth colonies in the sparsely infested regions.

There are many foreign insects listed as hosts of this tachinid which are not present in this country. Should some of them ever become established here this parasite undoubtedly will attack them as well as the gipsy moth, the brown-tail moth, and the satin moth.

STURMIA SCUTELLATA Robineau-Desvoidy

Sturmia scutellata (fig. 28), formerly referred to as *Blepharipa scutellata* R. D. in American literature, was among the first tachinid parasites of the gipsy moth to be received from Europe. At first considerable difficulty was experienced in obtaining sufficient specimens for colonization, but later satisfactory liberations were made. The adult fly is much larger than Compsilura and is a stronger fly, although during the spring it is often so sluggish that it may easily be captured with the hands. This species has a single generation each year and passes the winter within its puparium in the soil. It can exist and reproduce only upon the gipsy moth but has a very great reproductive capacity. It ranks among the best enemies of the gipsy moth which have been successfully established in this country.

Foreign Distribution and Abundance

This tachinid appears to be present in Europe over much of the area where the gipsy moth survives. It has been received at the gipsy-moth laboratory from many parts of France, Belgium, The Netherlands, Germany, Austria, Hungary, Czechoslovakia, Russia, and Italy.

During the last few years it was observed by the experts of the Bureau of Entomology while they were carrying on gipsy-moth investigations in Spain, France, Germany, Czechoslovakia, Hungary, Poland, Yugoslavia, and Bulgaria. During the period covered by these investigations *S. scutellata* has not been of great importance in Spain, Portugal, northern Africa, or Poland. Heavy gipsy-moth infestations have been found in these countries, but this parasite was relatively scarce and in some instances it was not even recovered. During the same period the gipsy-moth infestations in France, Belgium, The Netherlands, Germany, Austria, Rumania, and Italy have been too light to warrant carrying on investigations with the purpose of importing parasites into the United States. In Hungary, Bulgaria, Czechoslovakia, and Yugoslavia a large number of *S. scutellata* have been reared from collections of gipsy-moth caterpillars and pupae. The rearings in these countries have shown that this parasite is one of the important European enemies of the gipsy moth. An allied species known as *Crossocosmia sericariae* Corn. is a parasite of the silkworm and of the gipsy moth in Japan, often being very abundant and of primary importance.

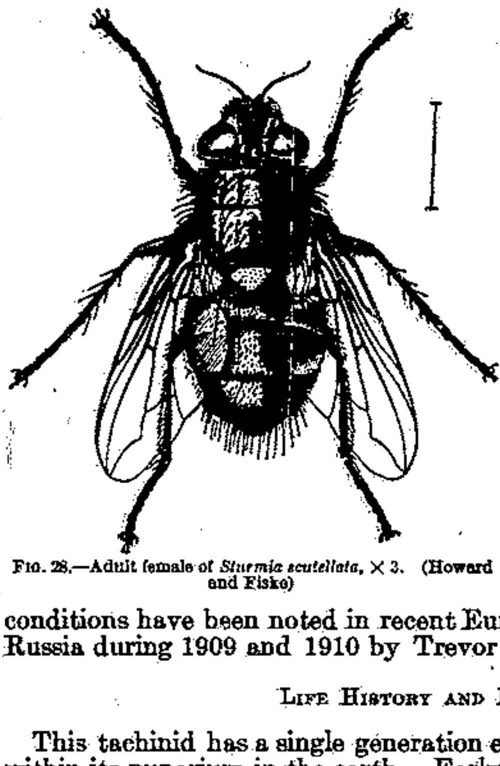


FIG. 28.—Adult female of *Sturmia scutellata*, × 3. (Howard and Fiske)

In the earlier parasite-introduction work the Sturmia which were introduced in large numbers for colonization came mostly from France, Germany, Austria, Hungary, Italy, or Russia. From some of these collections Sturmia issued in numbers suggestive of great abundance. Like most of the parasites, *S. scutellata* is found in great abundance in some areas during certain years, yet examinations made in other locations often not far distant fail to show its presence. Such conditions have been noted in recent European investigations, and in Russia during 1909 and 1910 by Trevor Kincaid and W. F. Fiske.

Life History and Habits

This tachinid has a single generation each year, passing the winter within its puparium in the earth. Early in the spring, a week or two before the gipsy-moth hatching is general, adults of this fly begin issuing from the soil. The females deposit their tiny black eggs on the foliage (fig 29), to be swallowed by the host caterpillars. As is the case with most leaf-ovipositing tachinids (*25*), *S. scutellata* has a large reproductive capacity. Dissections of female flies of this and allied species show that as many as 5,000 eggs may be deposited by a single individual. The eggs are chitinized, indicating an ability to withstand exposure. They are covered with a fine sculpture which presumably strengthens them, making them less liable to injury while being swallowed by the caterpillars. Soon after the egg is in the alimentary canal of the caterpillar the maggot issues, bores through the wall, and attaches itself in the host tissue. The early development of the parasitic maggot within the caterpillar is rather slow, but as the gipsy-moth caterpillar approaches the period of pupation the parasite develops quickly, sometimes issuing from the caterpillars, but usually not killing the host until it has pupated. Then the maggot tears a hole in the pupa, issues, and enters the earth for pupation and hibernation.

Importation

The successful establishment of this species was brought about after several unsuccessful attempts. A number of its puparia were obtained in 1905, the first year of the parasite-introduction work. They were sent in boxes containing shipments of full-grown gipsy-moth caterpillars and pupae, but the following spring not a single fly was obtained from these puparia. During the next few years many shipments of large gipsy-moth caterpillars and pupae were received from Europe, but most of them arrived in very poor condition. In many cases the Sturmia maggots had developed and issued en route and were forced to form their puparia in the bottoms of the boxes under such unfavorable conditions that only a very few of them ever produced flies. Many methods were tried in an endeavor to carry such material through the winter but none of them proved very successful.

Fig. 29.—Eggs of *Sturmia scutellata* on fragment of leaf, × 10. (Howard and Fiske)

In 1909 arrangements were made to continue the large shipments of full-grown gipsy-moth caterpillars and pupae and to have them transported in cold storage on the steamer. By this method the caterpillars and pupae as well as the parasites they contained were so retarded in their development that many of the parasitic maggot did not issue until after the shipments had been received at the laboratory. Here they were placed in containers that allowed the Sturmia maggots to enter the soil as they issued from their hosts. Under such circumstances the parasitic maggots developed and many of them entered the winter in good condition. The following spring the emergence of the flies was much better than in any previous year.

During the last few years rather large numbers of *S. scutellata* have been recovered in the rearing work carried on by the Bureau of Entomology in several European countries. In these investigations the tachinid maggots issuing in the rearing trays from gipsy-moth caterpillars and pupae were placed in large boxes containing damp sawdust. Such material has been sent to the United States by mail or brought here by the men when returning after the season's work. Although great care has been taken in handling this material before shipment and after arrival at Melrose, there is considerable mortality.

Table 15 lists the number of *S. scutellata* puparia which have been received from Europe during the last five years, and the countries from which they were obtained.

TABLE 15.—*Importation of foreign Sturmia scutellata puparia, 1923–1927*

Year	Number of *S. scutellata* received from—							
	Hungary	Czechoslovakia	Poland	Bulgaria	Yugoslavia	Spain	Russia	Total
1923	8,718						36	8,754
1924	5,055		608	11,885	1,842	1,192		20,582
1925	7,693	40				371		8,104
1926	8,752							8,752
1927	3,734		48		637			4,419
Total	33,952	40	656	11,885	2,470	1,563	36	50,611

This species is a difficult one to handle and transport, being very susceptible to injury under adverse conditions. The constant presence of a considerable degree of moisture seems to be a prerequisite to its successful development and hibernation. Too great a degree of moisture, however, creates conditions unfavorable to the parasite, and heating is apt to occur if the puparia are confined under such conditions very long. The proper moisture conditions are difficult to maintain, especially when the packages containing the puparia are en route for any length of time.

When puparia of *S. scutellata* and *Phorocera agilis* are received at the Melrose Highlands laboratory from Europe, they are separated and placed in containers for hibernation. The method used is the same for the two and is explained in detail for both species under the subject, "Receiving and handling of the foreign material at the gipsy-moth laboratory" (p. 20).

At Melrose Highlands during the last three years the bulk collections of gipsy-moth pupae have been kept in trays with heavy, coarse wire-netting bottoms. The wire is coarse enough to allow the maggots to pass easily through the openings. These trays, placed one over the other, are arranged in racks. (Fig. 30.) As the Sturmia maggots have a natural tendency to work downward, they drop from the upper trays to the lower ones and finally into boxes, placed below, which are full of earth composed of leaf mold and fine root fibers. *S. scutellata* has been relatively scarce since these racks have been in use but the results indicate that this method will be a most satisfactory one for the hibernation of tachinids which pass the winter as do *P. agilis* and *S. scutellata*. The maggots go into the soil unmolested and there form their puparia under nearly natural conditions, never having been touched by the operators. These boxes are afterwards placed in the soil where the parasites pass the winter.

COLONIZATION

S. scutellata for colonization has been obtained by collecting its host and rearing the parasite. The original stock was collected in Europe as described in preceding paragraphs, but since the species became established in this country the material for new colonies has been obtained in New England.

When Sturmia had become sufficiently abundant to furnish material for colonization it was found to have dispersed over a considerable part of the infested area and no concerted efforts to obtain it for further liberation in New England were necessary. The *S. scutellata* which have been obtained and colonized since 1917 were recovered incidentally while making collections of gipsy-moth caterpillars and pupae for other purposes. The majority of them were obtained from large collections of gipsy-moth pupae made for the purpose of gathering female moths, from the abdomens of which an extract was obtained to be used in experiments in attracting male moths. The foreign

FIG. 30.—Two racks of trays with coarse wire-netting bottoms containing gipsy-moth pupae collected for the recovery of *S. scutellata*. As the parasite maggots issue from the gispy-moth pupae they drop through the wire bottoms of each tray and finally into the wooden boxes beneath, which contain leaf mold, earth, and root fiber. The parasites hibernate within their puparia in these boxes

S. scutellata liberated during the last four years were obtained among other tachinid parasites that were being gathered in Europe.

As early as 1907 a few Sturmia were liberated, but under very unsatisfactory conditions. The number of parasites liberated that year is not known, but probably it was less than 100 individuals. The colonization records for the succeeding years are given in Table 16.

TABLE 16.—*Colonization of Sturmia scutellata from 1908 to 1927*

Year	Stage of parasite used	Foreign stock	New England established stock	Year	Stage of parasite used	Foreign stock	New England established stock
		Number	*Number*			*Number*	*Number*
1908	Probably adults	100		1922	Puparia		9,996
1909	do	1,086		1923	do		14,620
1910	do	3,962		1924	Adults	1,325	609
1911	do	224		1925	do	2,087	400
1917	Puparia		475	1926	do	912	
1918	do		1,588	1927	do	501	1,223
1919	do		8,635				
1921	do		30,000	Total		11,007	73,546

Grand total, 84,643.

The actual number of effective *S. scutellata* liberated during the years from 1907 to 1923 may be greater or less than shown in the table, for in the summer of 1909 several thousand Sturmia maggots were allowed to enter the earth naturally in the forests, and the number successfully emerging could not be known. Presumably the emergence occurring in the spring from material which passed the winter under such natural conditions would be much greater than that which would occur from material which was artificially hibernated in cages at the laboratory. The *S. scutellata* puparia colonized from 1917 through 1923 were held in soil in the laboratory yard until spring, when they were placed in forests where the emergence took place. In such cases it was impossible to determine what percentage of the puparia gave issuance to adults. The number of adults which emerged from check lots cared for in a similar manner varied greatly. The issuance of adults in a few of them was nearly 100 per cent, but in most cases it was much lower, and in some practically no adults were obtained.

It is possible to gather this parasite in Europe and in New England in large numbers, but it is exceedingly difficult to handle such material so that a high percentage of adults will issue after hibernation. It seems essential that the maggots upon issuing from their hosts have the proper moisture and soil conditions in order to enter hibernation in a healthy state and develop to mature insects in the spring.

From 1908 to 1911, 5,372 adults of foreign origin were liberated. From 1917 to 1923 inclusive, 71,314 Sturmia puparia were obtained in New England and colonized. During the period from 1924 to 1927, 5,725 adults of foreign origin and 2,232 adults of established stock were liberated, making a grand total colonization of 84,643 *Sturmia scutellata.*

COLLECTIONS OF HOSTS TO DETERMINE PERCENTAGE OF PARASITISM CAUSED BY STURMIA SCUTELLATA

Collections of gipsy-moth pupae are made each year to determine the extent of mortality due to Sturmia. In addition to the data obtained from such collections many new distribution records for this parasite are made from collections of fourth, fifth, and sixth instar caterpillars. The maximum percentage of parasitism is not shown in the caterpillar collections unless the caterpillars have stopped feeding at the time of the collection, for, as previously stated, the eggs of this tachinid are laid on the foliage and are consumed by the feeding caterpillars.

The area from which the gipsy-moth caterpillars were collected and the percentage of parasitism credited to Sturmia are shown in Tables 11 and 13, together with the parasitism caused by Compsilura. In these tables are listed the gipsy-moth caterpillar collections made in 1923. These caterpillars were put in trays for feeding until the parasites issued or the caterpillars pupated. In most cases *S. scutellata* maggots are obtained from the pupae, but occasionally they issue from the caterpillars. When the caterpillars pupated the pupae were removed to other containers and held until the parasites issued.

A large number of similar collections are made each year in the area represented by the towns listed in Tables 11 and 13, many of which are in the area only sparsely infested by the gipsy moth. In some cases the infestations were so light that only a few caterpillars could be found; yet, even under such conditions several very appreciable percentages of parasitism were recorded which showed the abundance and effectiveness of this parasite in the outer gipsy-moth-infested territory. The average percentage of parasitism by Sturmia in these collections was considerably less than by Compsilura, but these were larval collections which do not give the maximum parasitism by Sturmia. Several instances are recorded in the tables where the parasitism by Sturmia was greater than that caused by Compsilura and in some cases it was present where Compsilura was not. A summary of the annual gipsy-moth-caterpillar collections made from 25 selected towns is given in Table 12, but the summary of the annual gipsy-moth pupal collections (Table 18) is a better indication of the benefits derived from this tachinid.

In Table 17 are given the results obtained in 1923 from collections of gipsy-moth pupae made from 47 towns, many of which are in the lightly infested territory.

The parasitism of the female gipsy-moth pupae is in most cases considerably greater than of the male pupae. In the average for the entire collection it is more than twice as great. Although there is often a small amount of superparasitism by *S. scutellata*, this has not been considered in these figures as it is not enough to change the status to any appreciable degree. Each collection was supposed to contain 100 male and 100 female pupae. The fact that most of the collections listed in this table contained less than 100 pupae indicates the scarcity of the gipsy moth in the areas involved. The remarkably high parasitism in many widely separated localities shows the abundance of Sturmia over practically the entire area. Many of the collections were made in areas near the outer border of the gipsy-moth infestation and in some cases from isolated colonies beyond the dispersion line of the gipsy moth. A collection of old gipsy-moth pupae made from a newly discovered isolated infestation at Alburgh, Vt., bore evidence to the fact that this parasite does locate isolated colonies far removed from the generally infested area, and is able to effect a material amount of parasitism in such locations.

Gipsy-moth pupal collections are made each year from towns representing the infested area as shown in Table 17. A summary of the data obtained from such collections from 1918 to 1927 is given in Table 18.

TABLE 17.—*Collections of gipsy-moth pupae for recovery of Sturmia scutellata, 1923*

Towns	Number of pupae collected			Per cent of pupae parasitized	
	Male	Female	Total	Male	Female
Massachusetts:					
Ashfield [1]	14	12	26	0	50
Charlemont [1]	12	12	24	0	17
Conway [1]	46	43	89	28	81
Colrain [1]	8	17	25	0	53
Deerfield [1]	13	21	34	8	24
Goshen [1]	13	35	48	0	17
Greenfield [1]	69	89	158	17	81
Raynham	54	26	80	6	12
Rowe [1]	5	17	22	20	65
Russell	0	8	8	0	0
Sheffield	3	2	5	0	0
Shelburne [1]	25	24	49	8	50
Shrewsbury	27	15	42	4	80
Whately [1]	43	22	65	12	59
Williamstown	1	9	10	0	0
New Hampshire:					
Bath	6	0	6	0	0
Bennington [1]	0	92	92	0	26
Charlestown	1	3	4	0	33
Claremont [1]	38	53	91	5	38
Conway	0	6	6	0	0
Cornish [1]	14	20	34	0	15
Greenfield	0	138	138	0	60
Hampton	38	125	163	26	70
Hanover [1]	10	16	26	0	13
Haverhill	49	49	98	12	20
Lebanon	34	40	74	3	0
New Hampshire—Continued.					
Lyme [1]	11	0	11	36	0
Newfields	224	83	307	42	60
Orford	2	9	11	0	0
Piermont	39	20	59	0	20
Plainfield	3	8	11	0	0
Walpole	24	28	52	4	25
Vermont: [2]					
Essex [1]	100	100	200	24	40
Grafton	1	6	7	0	17
Hartford [1]	6	1	7	17	0
Norwich	5	4	9	0	0
Rockingham	12	5	17	0	0
Salisbury [1]	8	21	29	0	5
Springfield [1]	15	18	33	7	72
Thetford	1	1	2	0	0
Topsham [1]	50	41	91	56	100
Wallingford	0	2	2	0	0
Westminister	19	96	115	11	50
Connecticut:					
Suffield	8	7	15	0	0
Windsor	1	4	5	0	0
Bloomfield	1	6	7	0	0
Total or average	1,053	1,354	2,407	[3] 20	[3] 49

[1] This parasite was recovered for the first time in the town.
[2] At Alburgh, Vt., several old gipsy-moth pupae were found, 30 per cent of which were estimated to have been killed by *S. scutellata*.
[3] These are weighted averages obtained by dividing the total number of parasites that emerged from male and female pupae by the gross number of male and female pupae.

TABLE 18.—*Summary of gipsy-moth pupal collections made annually to obtain records of distributions of Sturmia scutellata, 1918–1927*

Year	Number of towns represented	Number of pupae collected			Average percentage of pupae parasitized	
		Male	Female	Total	Male	Female
1918	51	3,224	3,335	6,559	2	5
1919	35	2,212	2,958	5,170	1	4
1920	50	2,805	4,194	6,999	5	20
1921	78	1,627	2,616	4,243	2	9
1922	65	852	1,286	2,138	5	17
1923	48	1,053	1,354	2,407	20	49
1924	40	997	1,099	2,096	4	16
1925	34	761	1,323	2,084	1	2
1926	43	1,033	1,579	2,612	1	3
1927	43	1,638	1,808	3,446	4	13

The number of pupae in each collection varies considerably each year. Some collections contain over 100 males and 100 females, but many of them contain only a few. The average percentages of parasitism as shown in the table for each year are indicative of the value of this tachinid.

Many pupal collections show a much higher, and often a very much higher, mortality from Sturmia than the average percentages given in Table 18. The reverse of the case is also true, and this lowers the average percentage of parasitism, so that this percentage during a certain year may be 20 or 30, whereas there will be locations where gipsy-moth colonies are practically exterminated by the parasite. Such data are not even indicated in such a summary as is shown in Table 18.

In addition to the annual pupal collections made from the area represented by the towns shown in Table 17, yearly collections of pupae have also been made since 1917 from the 25 towns from which annual collections of gipsy-moth caterpillars are made to determine the extent of parasitism by Compsilura. These towns are scattered over the eastern third of the area now infested by the gipsy moth.

The results obtained from the pupal collections for 1923 are given in Table 19, and a summary of such collections made for the period from 1917 to 1927 appears in Table 20.

TABLE 19.—*Collections of gipsy-moth pupae made at 25 towns to determine the parasitism due to Sturmia scutellata in 1923*

Locality	Number of pupae collected		Percentage of parasitism	
	Male	Female	Male	Female
Melrose, Mass	100	100	28	71
Saugus, Mass	100	100	14	20
Stoneham, Mass	26	100	6	74
Wakefield, Mass	100	100	37	57
Revere, Mass	65	100	21	68
Beverly, Mass	100	100	18	45
Middleboro, Mass	91	100	1	8
Wilmington, Mass	100	100	15	45
Lexington, Mass	100	100	10	20
Boston, Mass	33	57	0	18
Weymouth, Mass	14	27	1	7
Derry, N. H	55	86	17	55
Pelham, N. H	75	100	5	42
Acton, Mass	46	100	6	37
Hopkinton, N. H	20	63	2	33
Candia, N. H	16	33	2	3
Rye, N. H	45	100	6	40
Stratham, N. H	100	100	33	60
Leominster, Mass	36	100	0	28
Medfield, Mass	100	78	4	20
Biddeford, Me	75	100	11	47
Warner, N. H	100	100	27	44
Plymouth, Mass	60	100	3	22
Ashburnham, Mass	82	64	8	30
Worcester, Mass	40	78	1	9
Total or average	1,679	2,186	16	41

TABLE 20.—*Summary of annual collections of gipsy-moth pupae made at 25 towns to determine the parasitism due to Sturmia scutellata, 1917 to 1927*

Year	Number of pupae collected			Average percentage of parasitism	
	Male	Female	Total	Male	Female
1917	1,948	2,040	3,988	1	6
1918	2,100	2,012	4,112	1	5
1919	2,090	2,369	4,459	2	5
1920	2,605	2,407	5,012	3	14
1921	2,068	2,544	4,612	4	12
1922	2,303	2,431	4,734	8	27
1923	1,679	2,186	3,865	16	41
1924	1,043	1,074	2,117	7	22
1925	898	1,296	2,194	1	5
1926	2,040	2,130	4,170	1	6
1927	1,995	2,072	4,067	7	19

The data in these tables are evidence of the great value of Sturmia. As has been shown for *Compsilura concinnata,* the highest average parasitism by *Sturmia scutellata* occurred in 1923. There was a decrease in 1924, a still further drop in 1925, and a marked increase in the percentage of parasitism for 1927.

Recovery and Dispersion

In 1911, four years after the first Sturmia were liberated, they were recovered in a manner which proved that the species had passed through a complete generation in the field. The species was recovered in 1910, but under conditions indicating that the recoveries were from colonies which had been liberated earlier during the same season. The recoveries of 1911 were made from several places, showing not only that the species was established but that it was spreading satisfactorily. It was recovered only sparingly, however, until 1916, when a collection of pupae from Beverly, Mass., showed 15 per cent of parasitism. From this time up to and including the summer of 1923 this parasite increased very rapidly.

Sturmia scutellata has dispersed rapidly, and it has not needed the assistance of artificial colonization as have some of the other parasites. Many interesting dispersal records of this parasite have been obtained. At Alburgh, Vt., some 30 miles from the nearest known gipsy-moth infestation, were found the remains of several gipsy-moth pupae, about 30 per cent of which had been destroyed by Sturmia. This recovery seems especially remarkable as this tachinid is practically dependent upon the gipsy moth for its existence.

S. scutellata was found in the gipsy-moth infestation in Somerville, N. J., in 1920. The manner in which it became established there will never be known, but it is probable that it was brought from Europe in the soil around the roots of imported spruce trees. It is extremely doubtful whether this tachinid can continue to exist in New Jersey, because of the intensive control work which has been conducted against its host.

The present known dispersion of Sturmia in New England is shown in Figure 3.

Value of Sturmia scutellata

Sturmia scutellata has proved itself to be among the most valuable introduced enemies of the gipsy moth. The benefits that have been derived from this tachinid are shown in part in the tables which have been presented. The average percentage of parasitism of female gipsy-moth pupae for the entire infested area in 1923 was 49. In many places the parasitism was much higher than the average and in one case it reached 100 per cent. This shows clearly that this parasite is of great importance in the lightly-infested areas along the border as well as in heavy infestations in the older areas.

S. scutellata is dependent upon the gipsy moth alone for a host. It has a great reproductive capacity, disperses rapidly, and is present over practically the entire area infested by its host.

ENEMIES OF CATERPILLARS AND PUPAE

MONODONTOMERUS AEREUS Walker

One of the first parasites to be liberated in 1906 was the *Monodontomerus aereus* of Walker. Records have been obtained suggesting that at times this species attacks the gipsy moth and the brown-tail moth, but it is certain that this insect has not acted as a primary parasite of either to any appreciable extent.

Foreign Distribution and Abundance

Monodontomerus (fig. 31) has a wide distribution in Europe and Japan, and has been reared at the gipsy-moth laboratory from practically all countries from which brown-tail-moth webs have been received. It has been recovered abundantly from France, Germany,

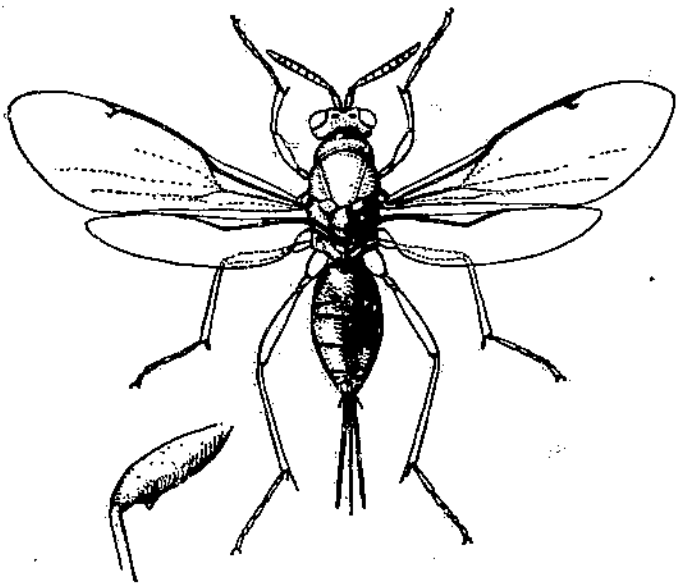


Fig. 31.—*Monodontomerus aereus*, adult female, × 13. (Howard and Fiske)

Austria, Hungary, Czechoslovakia, and, in less numbers, from Italy, from Japan, and from Simferopol and Kiev, Russia.

Life History and Habits

The female adults hibernate. No males have ever been found during the winter or early spring. In the early fall the fertilized females seem to seek out brown-tail-moth webs for hibernating quarters. In laboratory experiments they have hibernated successfully in bunches of curled leaves, and one was found in a bird's nest collected in the field. The experiments indicate that parasites of the brown-tail moth are more likely to be parasitized by Monodonotomerus than are the same parasites when reared from other hosts.

Usually there are two generations annually, but females of the first generation have been successfully carried through the winter (*21*).

The females are sturdy insects and often have been kept alive at the laboratory for 9 and 10 weeks. In the spring, after the females leave their hibernating quarters, several weeks are required for the development of their eggs. When this period is passed, and a suitable host has been located, the development from the egg to the adult requires only three weeks.

The female oviposits in the cocoons of braconids and some other Hymenoptera but prefers tachinid puparia. The eggs are laid on the larvae or nymphs within the cocoons or puparia and here the parasite larvae feed externally on their hosts. When several Monodontomerus develop upon a single host the adults are smaller than when fewer develop on the same host.

Fortunately *Apanteles lacteicolor* and *A. melanoscelus* are not parasitized to a serious extent by Monodontomerus, but *Compsilura concinnata* suffers to a considerable degree, and *Sturmia nidicola* to some extent but not so seriously.

From the European shipments of cocoons of the brown-tail moth many Monodontomerus were obtained. In many cases they undoubtedly issued from tachinid puparia within these cocoons, but in other cases careful examinations seemed to prove that they were also acting as primary parasites. In the laboratory experiments Monodontomerus has been doubtfully reared as a parasite of the brown-tail-moth pupae, but in many experiments where apparent oviposition has taken place no reproduction has occurred.

In large shipments of gipsy-moth pupae from Italy in 1908 many Monodontomerus were obtained. "A large number of the pupæ which were examined was found filled with the larvae or pupæ of the parasite, and even when the larvae were still immature and feeding there was absolutely no trace of any other parasite present in the majority of instances." (*14, p. 246*). If no mistake in identity was made in these observations it is evident that under certain conditions Monodontomerus does act as a primary parasite of the gipsy moth, but the limited experiments which have been carried on during the last few years indicate that this species is almost exclusively a hyperparasite.

During the earlier phase of the parasite-introduction work the primary object was to establish as many species as possible. At that time there seemed to be sufficient evidence that this species and *Eupteromalus nidulans* were more beneficial than harmful, and accordingly both species were liberated and became established. During the last few years further biological studies have been contemplated in order to determine several points which are still in doubt, but during this period these insects have been so scarce that only a small quantity of material could be obtained to make these investigations.

Introduction and Colonization

About 17,000 adult Monodontomerus were obtained from brown-tail-moth webs sent from Europe in 1906. Some of these were liberated in the spring of 1907. Later in the season it was decided that this species was of doubtful value and they were destroyed with the other recognized hyperparasites. In 1908, when many Monodontomerus arrived from Italy in a large shipment of gipsy-moth pupae, they were liberated, since the evidence seemed conclusive that the species would act as a primary parasite of the gipsy-moth pupae. They continued to be liberated through 1910.

Apparatus Used to Recover Monodontomerus

The data regarding Monodontomerus given in Table 33 under the discussion of Eupteromalus are indicative of its increase and abundance, as shown by records of the females which issued from collections of brown-tail-moth webs.

A separating cage used in connection with collections of brown-tail-moth pupae minimized the necessary handling of the webs and cocoons which is always accompanied by a rash on the skin and irritation of the eyes and delicate membranes of the nose and throat of the operator.

The description and illustration of this cage (fig. 32) are taken from Bulletin 91 of the Bureau of Entomology (*14, p. 150–151*). The case is described as follows:

> In carrying on this work several styles of rearing cages were used, of which one was devised for the special purpose of securing the tachinid parasites with the minimum of exposure to the effects of the irritating hairs of the brown-tail caterpillar. This worked very satisfactorily, and since it may possibly be found of service in conducting similar work elsewhere, the following description is presented:
>
> The basis of this cage consisted of a box of stiff pasteboard 8 inches square and 12 inches high. About 4 inches from the top a stiff paper funnel (*a*) was fitted and held in position by the cleats (*b*), which, in turn, were fastened to the sides of the box by broadheaded upholsterer's tacks driven in from the outside. These cleats served to support the tray (*c*), which just fitted into the cage. The bottom of this tray was covered, in some instances with coarse mosquito netting, and in others with a wire screen of ¼-inch mesh. Two holes in the side of the tray corresponded with two 1-inch holes in the side of the box, and these in turn with similar holes in a wooded strip (*d*), which was fastened on the outside. When the tray was in position, paper cones (*h*) and large glass tubes (*g*) were inserted in these holes.
>
> The stiff paper funnel (*a*) had its apex inserted into another hole bored diagonally in a similar wooden strip which was fitted in the bottom of the cage. Inside of this hole a stiff paper cone (formed like *h* by rolling up a section of a strip of paper cut to a circular shape) was held in position by a tack which passed through it into the wooden strip. The end of this cone, passing through the bottom of the cage, permitted a third glass tube (*f*) similar to the two above mentioned, to be held in position. No further support to this tube was needed than that afforded by the cone itself.

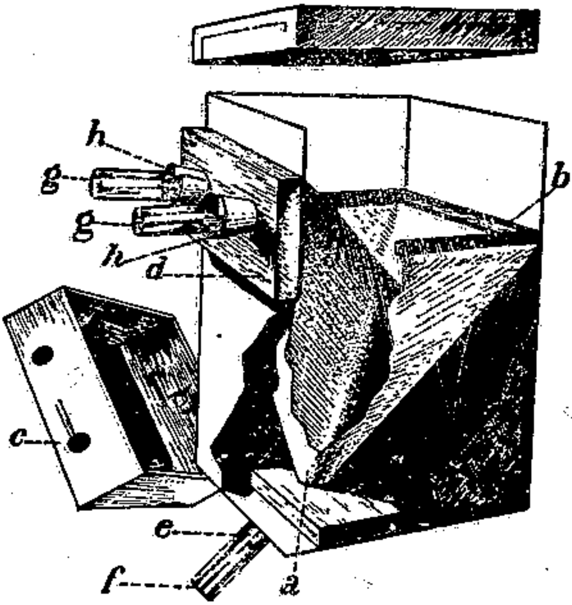


Fig. 32.—Separator cage used for recovering hymenopterous and dipterous parasites from brown-tail moth pupae and webs. *a*, Paper funnel; *b*, cleats holding paper funnel in position; *c*, tray; *d*, wooden strip on outside of cage; *e*, paper cone connecting paper funnel and glass tube, *f*; *h*, *h*, paper funnels supporting glasst ubes, *g*, *g*. (Howard and Fiske)

In using this cage a mass of cocoons of the brown-tail moth was placed in the tray, and the cover was put on with the several tubes in position. Tachinid maggots issuing from the prepupal caterpillars, or pupæ contained in the cocoon mass, in attempting to seek the earth would pass through the bottom of the tray and be conducted by the stiff paper funnel into the lower tube, where they were quickly noticed and easily removed. All other parasites, as well as the brown-tail moths themselves, when they emerged, were attracted by the light into the two upper tubes, and could be similarly removed with little difficulty.

Recovery and Dispersion

During the winter of 1908–09, Monodontomerus was recovered from brown-tail-moth webs in sufficient numbers to indicate that the species was increasing and dispersing rapidly. These records showed a dispersal of approximately 10 miles a year for the three years after the species had been colonized. In the summer of 1909 it was recovered from collections of gipsy-moth and brown-tail-moth pupae under conditions which indicated that it was acting as a primary parasite. The brown-tail-moth web collections of 1909 and 1910 showed a remarkable dispersion, but the summer observations of 1910 did not show it to be increasing as a gipsy-moth pupal parasite. The web collections for the winter of 1910 and 1911 continued to show a great dispersion, but they did not show the expected increase. The dispersion, however, was very remarkable, for in this short time Monodontomerus had spread over practically the entire area infested by the brown-tail-moth. The greatest spread was about 150 miles toward the northeast from the nearest place where the species had been colonized.

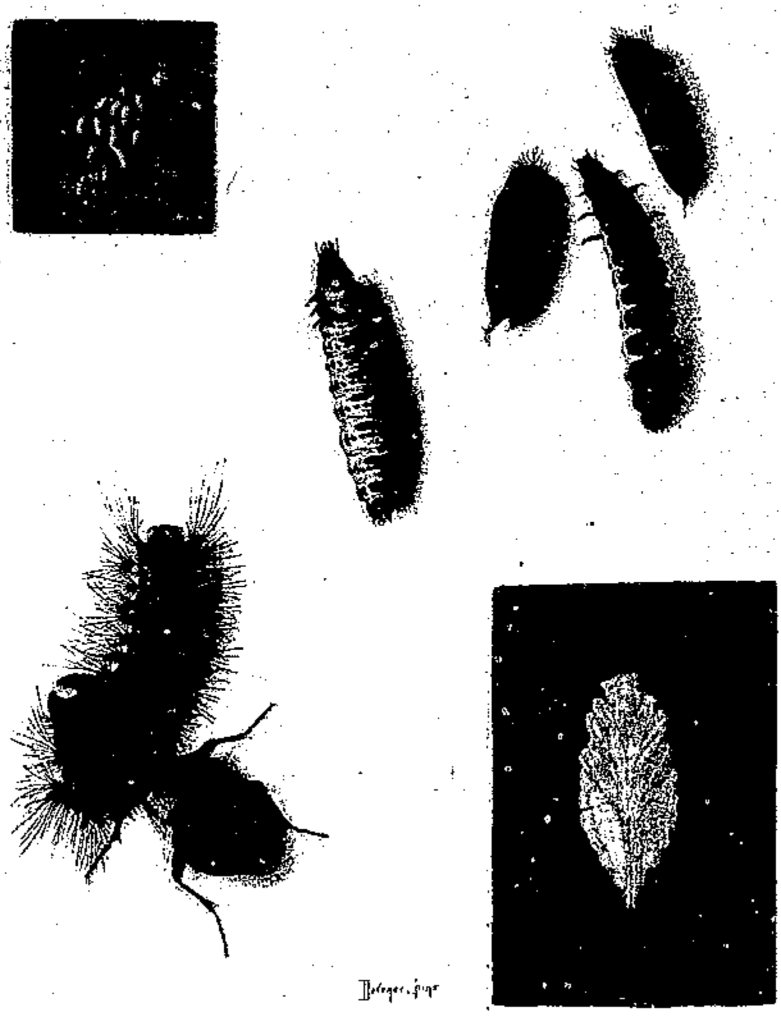
Value of Monodontomerus

Little can be said in favor of the establishment of this species. Its actions in America have been more harmful than beneficial, as it is a rather serious hyperparasite of Compsilura and, to a lesser extent, of *S. nidicola*. Fortunately it has not interfered to any great extent with the increase of *Apanteles lacteicolor*, *Meteorus versicolor*, and *A. melanoscelus*, although occasionally it is reared from these species.

Since its heavy increase as shown by the collection in 1910–11, it has decreased in numbers in the field and is now seldom found unless an extraordinary effort is made to find it.

CALOSOMA SYCOPHANTA Linnaeus

The brilliantly colored carabid beetle *Calosoma sycophanta* L. (pl. 5) is the principal predacious enemy of the gipsy moth that has been introduced into this country. It is now well established over practically the entire infested area and has been recovered from some locations beyond the gipsy-moth dispersion line. The adults are conspicuous during June and the early part of July, when they are often seen on the trees feeding on the gipsy-moth caterpillars. The beetle larvae also are abundant from the last of June to the middle of July, and may be found on the tree trunks and larger branches of rough-barked trees feeding on large gipsy-moth caterpillars and pupae. *Calosoma sycophanta* is considered among the most beneficial of the introduced enemies of the gipsy moth.



CALOSOMA SYCOPHANTA

Adult eating gipsy moth caterpillar, lower left, X [illegible]; pupa, lower right, X [illegible]; eggs, upper left, X [illegible]; eaten chrysalides of the gipsy moth, upper right; full grown larvae from above and from below, X [illegible]. (Howard and Fiske)

FOREIGN DISTRIBUTION AND ABUNDANCE

This beetle has a wide distribution and has been collected in France, Germany, Switzerland, Italy, and Russia. During the last few years experts of the Bureau of Entomology while searching for insect enemies of the gipsy moth and brown-tail moth have observed it in the following countries: Spain, Portugal, Poland, Rumania, Bulgaria, Hungary, Czechoslovakia, and Germany. In Europe it is known to prey extensively (*5*) on the gipsy moth and on the pine sawfly, *Lophyrus pini* L. In 1911 in Italy (*6*) the efficient control of the gipsy moth by *Calosoma sycophanta* in a large forest was observed by W. F. Fiske. The junior author observed it in 1922 in large numbers in the eastern part of Germany, where it was feeding on the nun moth, *Lymantria monacha* L., which was very abundant at the time. In 1923 R. T. Webber located a gipsy-moth infestation in Rumania, where Calosoma was extraordinarily abundant. The following year practically no gipsy-moth infestation was found at this place and Mr. Webber felt confident that Calosoma had been the chief cause of the decrease. In 1925 S. M. Dohanian observed it very abundant in Portugal, and P. B. Dowden found Calosoma larvae very plentiful in a gipsy-moth infestation at Belki, Czechoslovakia.

LIFE HISTORY AND HABITS

The adults of *Calosoma sycophanta* often live four or more years. They are large metallic green beetles measuring about 1¼ inches in length. The winter is passed as adult beetles in the ground. During the first week of June, the date varying with different seasons, most of the adult beetles emerge.

The beetles climb rough-barked trees in search of their food, often going to the smaller twigs, and occasionally they are seen on the leaves. They grasp their prey with their sharp mandibles, breaking the integument and feeding upon the body contents.

They feed for about seven weeks during the period when the gipsy-moth caterpillars are feeding and pupating and begin to go into hibernation soon after gipsy-moth egg laying is started.

Feeding experiments at the gipsy-moth laboratory showed an average of 272 large gipsy-moth and tent caterpillars consumed in a season by a pair of adult beetles (*4*). The older beetles consumed more than the younger ones. When smaller caterpillars serve as the food for the beetles a much larger number are eaten, and an average of 2,000 small brown-tail moth caterpillars were eaten by a pair of beetles in the feeding experiments. A pair of these beetles and their progeny will destroy more than 6,000 gipsy-moth caterpillars and pupae in a single year.

The beetles feed for a few days after emerging from hibernation, then copulation takes place and egg laying is begun. The eggs are deposited in the ground, the older beetles laying a considerably larger number of eggs than the younger ones. Although one instance is on record of a female which laid 653 eggs in a season, it is probable that under field conditions, considering all females both young and old, an average of about 100 eggs per female are laid.

The average time spent in the egg stage is from four to seven days, the longer period being in May and the shorter one in August. These

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data were obtained from laboratory experiments, but under natural conditions oviposition as early as May or as late as August seldom occurs. Soon after emergence the small beetle larvae begin to feed on lepidopterous caterpillars which may be on the ground or to climb rough-barked trees in search of their food. The small beetle larvae attack not only small caterpillars but large ones and pupae as well, especially those pupae not inclosed in a cocoon. In the case of the gipsy moth the number of pupae destroyed is probably as great as that of the caterpillars. The beetle larvae attack the caterpillars and pupae viciously, and feed on the body fluids and contents of their host. In many instances only a small amount of the caterpillar or pupa is consumed and many of those which are not devoured are injured and die as the result of attacks by this beetle or its larvae. In feeding experiments an average of 41 sixth-instar gipsy-moth cat-

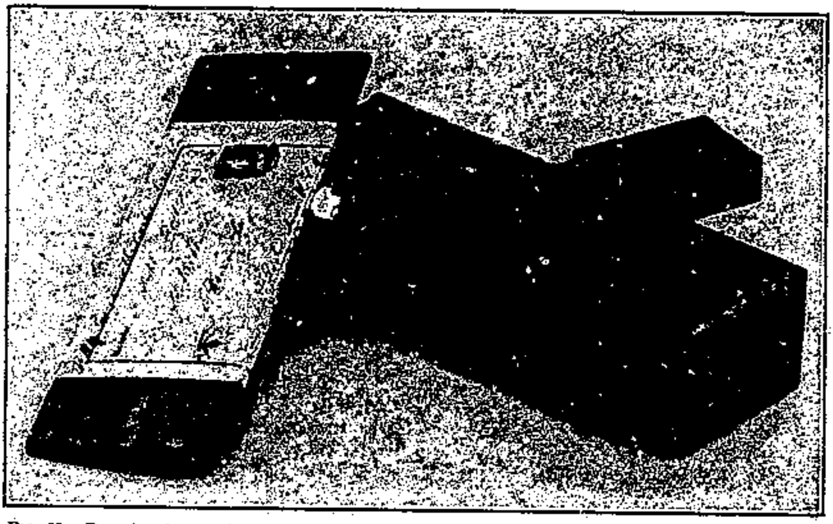

FIG. 33.—Box showing method of packing Calosoma beetles for exportation. Each match box contains a single beetle and a small quantity of sphagnum moss. (Burgess)

erpillars and an average of 13 gipsy-moth pupae were consumed during the development of each Calosoma larva.

During the growth of the Calosoma larvae two molts occur. The molted skins are often found in the crevices of the bark and among the remains of gipsy-moth caterpillars and pupae. When the beetle larvae become full grown, about the time the female gipsy moths are laying their eggs, they enter the soil, construct a pupal cell, and pupate. A little less than two weeks is usually required for this stage but the adult beetle remains in the pupal chamber during the winter.

Importation of the Beetles

The first living beetles of *Calosoma sycophanta* were received at the gipsy-moth laboratory from Europe in 1905. Each succeeding year, up to and including 1910, specimens were collected and sent to the United States. Several methods of shipping were tried. Ordinary small safety-match boxes were found to serve this purpose best. (Fig. 33.) A beetle was inclosed in each box with wet sphagnum moss and often a caterpillar was included for food, although when the moss was sufficiently moistened no food was necessary. The match boxes were placed in small wooden boxes and sent by mail or express. The shipments from Europe were en route from 12 to 14 days.

Colonization

The first liberations of this beetle were made in 1906. Each successive year, up to and including 1922, beetles have been liberated. No colonies have been liberated since 1922, except a few in 1926 and 1927.

Both adults and larvae have been used for colonization. When larvae are liberated each colony should contain at least 200 specimens to insure the successful establishment of the species. If adult beetles are liberated, smaller colonies serve as well. In liberating colonies, areas have been chosen where there was a plentiful supply of gipsy-moth larvae and, when possible, places not likely to be disturbed by artificial control work.

Table 21 shows the number of colonies and individuals which have been liberated in New England.

In addition to the colonization in New England, *Calosoma sycophanta* has been colonized in several other places in the United States and also in Canada. These colonizations are recorded in Table 22.

Table 21.—*Liberations of Calosoma sycophanta in New England from 1906 to 1927, inclusive*

	Number of colonies liberated		Number of individuals liberated	
	Adults	Larvae	Adults	Larvae
Massachusetts	140	86	15,900	18,123
Maine	93	2	9,730	232
New Hampshire	62	6	7,350	1,375
Rhode Island	24	1	2,292	200
Connecticut	5		510	
Total	338	95	35,880	19,930

Total liberations of individuals in New England, 55,760.

Table 22.—*Liberations of Calosoma sycophanta outside of the New England States*

Years	Locality	Number of individuals	Years	Locality	Number of individuals
1912 to 1918	Canada [1]	5,331	1915	Florida	16
1913 and 1918	California	1,030	1917	Delaware	35
1914	New Mexico	1,750	1919	Washington	200
1915	Colorado	1,010	1921	Alabama	50
1915	New York	180	1921	North Carolina	178
1915	District of Columbia	600			
1915	Arkansas	461	Total		10,821

[1] Most of the Calosoma which have been sent to Canada were obtained by experts from the staff of the Dominion entomologist, who made their headquarters while obtaining this material at the gipsy-moth laboratory at Melrose Highlands, Mass.

The 10,821 individuals recorded in Table 22, together with the 55,760 which have been liberated in New England, make a total of 66,581 liberated. The record of the total colonization is given in Table 23.

TABLE 23.—*Total number of living Calosoma sycophanta imported and number of beetles and larvae colonized*

Year	Number received	Number colonized from importations	Number colonized from rearings and field collections		Year	Number received	Number colonized from importations	Number colonized from rearings and field collections	
			Adults	Larvae				Adults	Larvae
1906	693	389			1918			6,102	
1907	967	578			1919			496	
1908	675	430		2,300	1920			1,332	
1909	405	250		6,100	1921			713	
1910	1,305	1,064	452	6,380	1922			176	
1911			621	1,104	1923				
1912			256		1924				
1913			3,246	2,901	1925				
1914			8,875	629	1926			625	
1915			15,601	516	1927			909	
1916			800						
1917			3,642		Total	4,045	2,711	43,940	19,930

Grand total of individuals liberated, 66,581.

It will be seen from the data in Table 23 that 2,711 beetles which came from Europe have been liberated, and that a few hundred beetles and several thousand larvae were reared at the laboratory and colonized during the early work with this species through 1910. Since that

FIG. 34.—Jars for rearing Calosoma beetles. *a*, Large jar with wooden top and ladder; *b*, small jar with wooden top; *c*, showing construction of top and ladder; *d*, jar with cheesecloth top held in position with rubber band. (Burgess)

year no foreign stock has been received, and most of the liberations have been made from stock collected in eastern Massachusetts.

Apparatus Used in Life-History and Reproduction Work

Glass cylindrical jars 8½ inches high by 6 inches in diameter (fig. 34) have been found very successful for rearing Calosoma. Each jar should contain about 3 inches of soil, which must be kept damp but not wet. The jars are covered with wooden covers grooved to fit the rim of the glass. A circular hole in each top covered with wire netting provides ventilation. A piece of wire mosquito netting is attached to the inside of the cover and projects into the jar, allowing the beetles to climb to the top of the jars in search of the caterpillars which often rest there. Such jars are stocked with a pair of beetles and with caterpillars which serve for their food. The female beetle burrows into the soil and here she deposits her eggs. The beetle larvae when confined in rearing jars attack one another, so it is necessary to examine the earth in the jars daily and remove the grubs soon after they have emerged from the eggs. In order that they may not come in contact with one another they are placed in separate containers, such as jelly glasses half filled with earth, or large breeding chambers with a supply of caterpillars for food. Cylindrical wire-cloth cages 4 by 10 inches, with wooden tops and bottoms, are also used to some extent for rearing Calosoma. The top should be made to fit tightly. Such cages are set 8 inches in the soil. When the larvae become full grown they can go into the soil and there transform to adults. In such cages the larvae can develop without extra handling until the following spring.

Large wooden boxes with wire bottoms and hinged covers provided with wire netting are used for hibernating quarters for the beetles. (Fig. 35.) They are set about 20 inches into the ground and filled with soil to the same level as on the outside. Cylindrical cages (fig. 16, J) made of ¼-inch mesh galvanized-iron wire also have been used with good success as hibernating cages for the beetles. These may also be used for rearing beetle larvae if they are lined with fine-wire screen.

Methods of Obtaining Data From the Field Regarding Calosoma

The beetles are conspicuous and easily observed in the field. The larvae also are found quite readily in masses of caterpillars and pupae on the tree trunks. As the beetle larvae molt twice, evidence of their previous presence is often afforded by their molted skins on the tree trunks. Even if the larvae and beetles have gone into the ground for pupation and hibernation, evidence that they have been present is found in the dead caterpillars and pupae, many of which remain on the trees for several weeks after the beetles and their larvae have left. Caterpillars and especially pupae (fig. 36) which have been attacked by Calosoma are torn in a manner characteristic of the predator, and the cause of their death can frequently be determined by a careful examination of the remains.

To determine the dispersion of Calosoma, the trees outside of the area in which the beetle is known to be present are examined during July and August for the molted larval skins. Many records of the dispersion of this insect have been obtained in this manner.

In addition to the laboratory studies many field observations have been made to determine the number of caterpillars and pupae consumed by the beetles and their larvae. For several years the remains

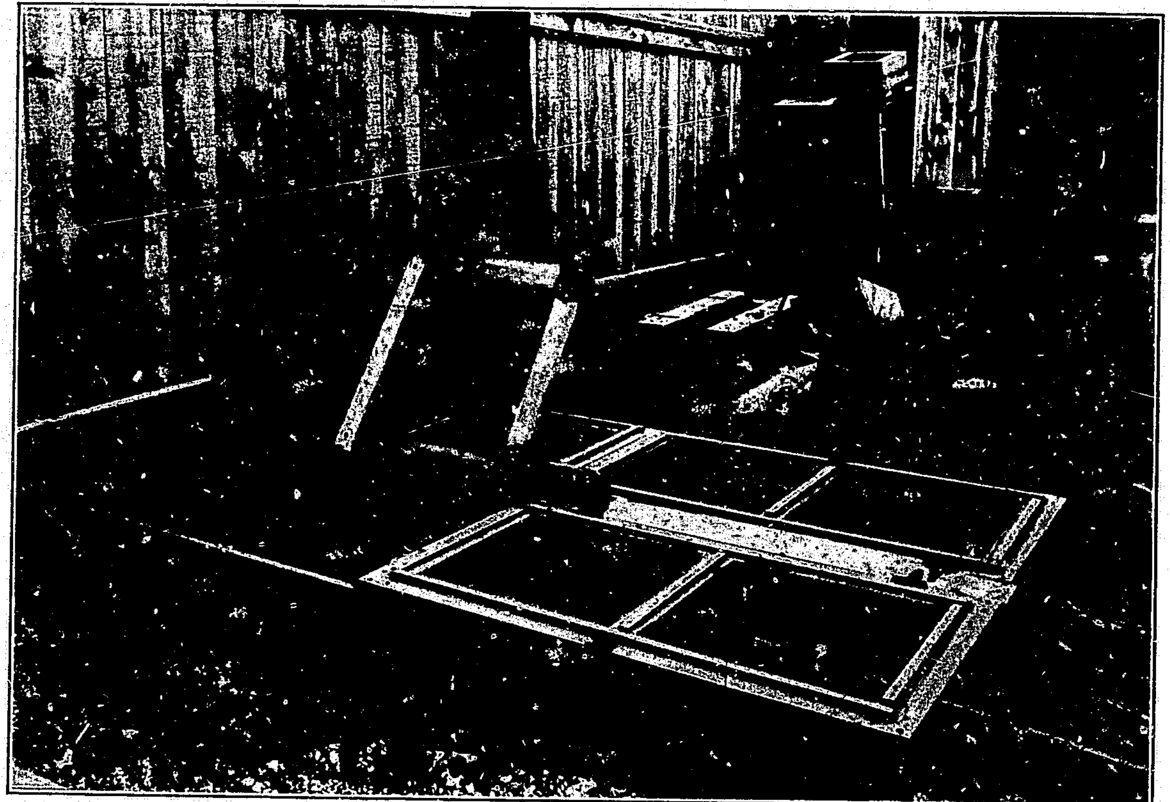

FIG. 35.—Box cages used for rearing Calosoma larvae late in the summer. *A*, coarse-mesh screen top used after the larvae have gone into the ground to transform and hibernate; *B*, cover with fine-mesh screen used in summer

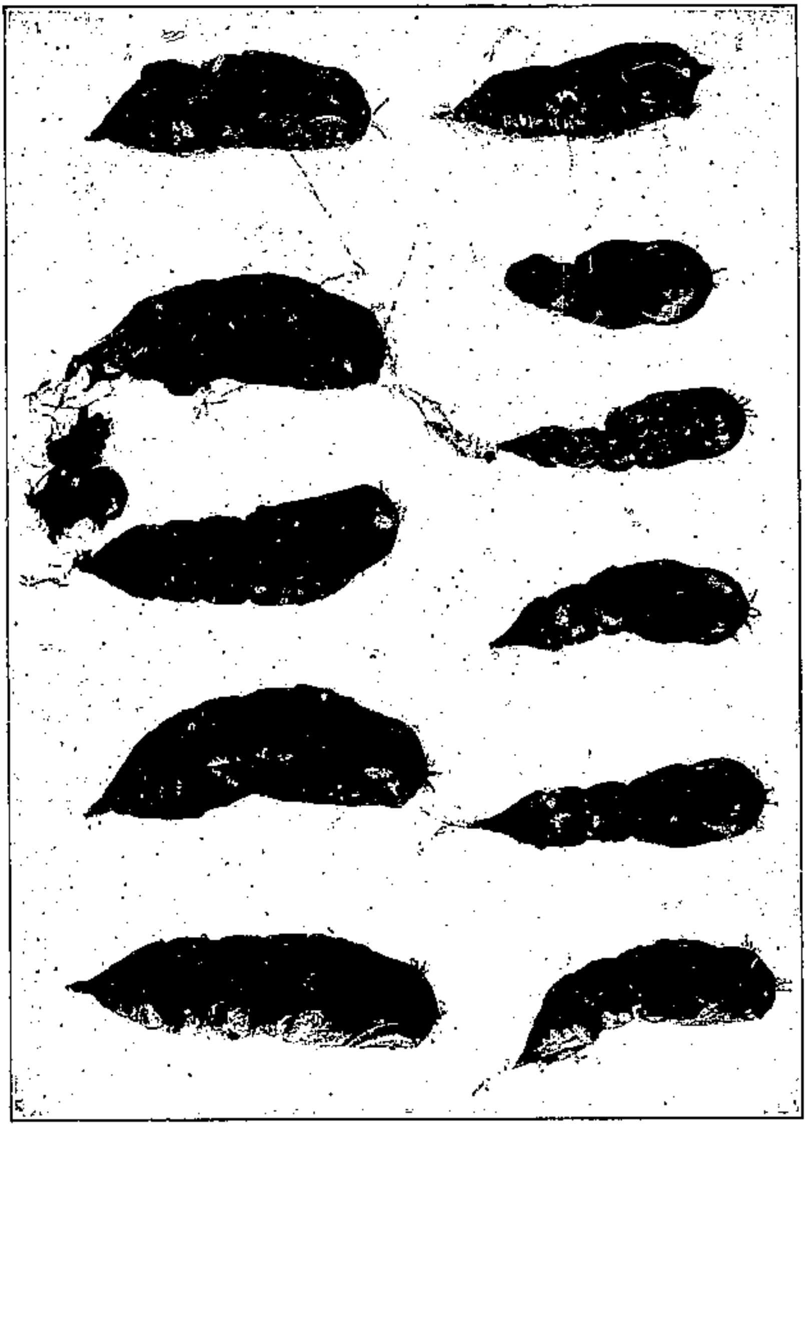

Fig. 36.—Pupae of the gipsy moth that have been destroyed by the larvae of *Calosoma sycophanta*, × 1½. Note the characteristic irregular holes. (Burgess)

of dead gipsy-moth caterpillars and pupae were collected at designated places and examined at the laboratory. The quantity of such material killed by Calosoma is considerable. During later years specific trees in various locations have been examined each year and collections made of the remains of the gipsy-moth pupae. The examination of such material shows the abundance of this predator. Often from 10 to 40 per cent of the gipsy-moth pupae are destroyed, and much higher percentages of destruction are sometimes obtained. These records also show that many more female gipsy-moth pupae than male pupae are destroyed. Such examinations do not show the full destruction of the gipsy moth caterpillars and pupae by Calosoma for the season, for many caterpillars are killed or injured and drop to the ground, and are not recorded. Other evidence, however, has been obtained indicating that the percentage of caterpillars destroyed by the beetles is as high as the percentage of pupae destroyed by Calosoma larvae, and some records have shown it to be two and one-half times as high.

Recovery and Dispersion

Larvae of *Calosoma sycophanta* were found in this country during the summer of 1907, proving positively that this beetle, which had been liberated the previous summer, had successfully passed the winter and begun reproduction. Each succeeding year this species has been recovered and, aided by the establishment of new colonies, it is now present over practically the entire gipsy-moth-infested area. Its present known dispersion is shown on the map in Figure 3. It will be observed that it has been recovered well beyond the gipsy-moth dispersion line and was found at the gipsy-moth infestation in New Jersey.

Value of Calosoma sycophanta

It is difficult to place a definite value on any of the introduced enemies of the gipsy moth and the brown-tail moth. However, extensive data accumulated at the gipsy-moth laboratory show that this beetle is one of the most desirable enemies of the gipsy moth that have been introduced and established

In addition to its destruction of the gipsy moth and brown-tail moth, it is an enemy of several native insects, and the beetles readily attack the caterpillars of the recently introduced satin moth. Since the seasonal history of this Calosoma corresponds closely to that of the gipsy moth, it is particularly adapted to feed on this insect. The fact that the beetles live for several years adds to their value as destroyers of injurious insects.

FOREIGN ENEMIES OF THE GIPSY MOTH NOT POSITIVELY ESTABLISHED

LARVAL PARASITES

APANTELES PORTHETRIAE Muesebeck

The braconid *Apanteles porthetriae* Muesebeck has been confused with *A. vitripennis* Haliday, *A. lateralis* Haliday, *A. solitarius* Ratzeburg, and *A. melanoscelus* Ratzeburg. According to Muesebeck (*21*) it is very similar to *A. vitripennis* and closely resembles *A. liparidis* Bouché.

This braconid has several generations annually. Its first-generation larvae emerge from small gipsy-moth caterpillars, often profusely, but, in contrast to *A. melanoscelus*, the second generation does not develop abundantly in the gipsy moth. It has been colonized in large numbers, but its establishment has not yet been determined.

Foreign Distribution and Abundance

Apanteles porthetriae has a wide European distribution. It has been found each year since 1922 in almost every gipsy-moth infestation which has been observed in Portugal, Spain, France, Poland, Germany, Czechoslovakia, Hungary, Italy, Yugoslavia, and Bulgaria, and in Morocco and Algeria in northern Africa. In most of these countries this parasite has been found generally scattered throughout the gipsy-moth infestations since 1922. In a considerable number of places it has been a very important factor in the control of the gipsy moth.

It was found in greatest abundance during the spring of 1924 in a small village near Bochnia, Poland. Here R. T. Webber, in company with Stefan Kéler, a Polish entomologist, found a very severe gipsy-moth infestation on the few fruit and shade trees of the village.

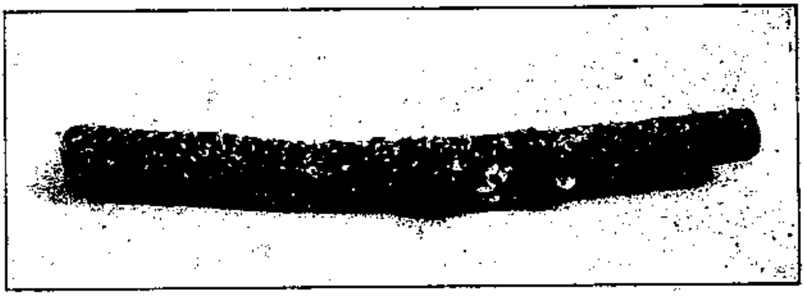

Fig. 37.—A small branch of willow collected near Bochnia, Poland, in 1924, showing many cocoons of *Apanteles porthetriae*. They are scattered singly over the branch. On the right half of the branch are two clusters of the white cocoons of *A. liparidis*, ×¼

The trees were small, hardly more than 20 feet high, and many of them bore 100 or more gipsy-moth egg clusters. Through the kindness of Antoni Czarnecki, the overforester in whose district the infestation was located, arrangements were made for the use of a room in his dwelling in which to carry on the rearing work for the summer. Marjan Numberg, a graduate student of forestry, was employed to make and care for the caterpillar collections.

When the time came to begin collections of gipsy-moth caterpillars to rear tachinid parasites for shipment to the United States, Mr. Numberg found the infestation greatly reduced by *Apanteles porthetriae*. A week or two later the junior author visited this laboratory expecting to find a large number of tachinid puparia to add to others from Hungary and Bulgaria for shipment to the United States. Only a few tachinids had been recovered and the rearing trays contained only a few thousand caterpillars. An inspection at the infestation quickly explained the reason for the small number of gipsy-moth caterpillars in the trays. The caterpillars had become scarce, and everywhere on the tree trunks, on the underside of the branches, and even on the grass were the cocoons of this parasite. A small branch typical of conditions there is shown in Figure 37. In the field the branch bore many more cocoons than are shown in the picture, for during the packing and handling of this specimen many cocoons were dislodged. The adults were already beginning to issue, so it was too late to attempt to introduce the species into the United States that season.

The subsequent rearing work did not produce many tachinids and most of the caterpillars which escaped the attack of the Apanteles died later in the season from a disease, apparently "wilt." The infestation was so depleted that in the following year there were not sufficient gipsy-moth caterpillars in the village to warrant the making of collections to obtain parasites for shipment to the United States.

During the same year this Apanteles was very abundant in gipsy-moth infestations in Debrecen, Hungary; Vetren, Bulgaria; and Beli Manastir, Yugoslavia. In the first and last of these places it rendered useless for collecting purposes some of the gipsy-moth infestations which had been located earlier in the season.

Reports such as the following were received from the bureau men in Europe in 1925: From S. M. Dohanian, Evora, Portugal, "Cocoons very plentiful, *dispar* infestation decreasing." From P. B. Dowden, Beregsas, Czechoslovakia, "A heavy gipsy-moth infestation in 1923, now gone; very many old cocoons present, the most I have seen except at Bochnia, Poland; some trees with many hundreds of cocoons." From Belki, Czechoslovakia, "Trees not defoliated in areas where Apanteles was abundant, defoliated all around this area." From R. T. Webber, Baja, Hungary, "Great many caterpillars parasitized by Apanteles here but not so many as at Bochnia, Poland, last year." At Portalegre, Portugal, this species was very common and on many trees its cocoons were as abundant as shown in Figure 38, which is a piece of cork oak found there by S. M. Dohanian.

Such conditions as those cited above are not true for all of the area. They represent rather local sections. In many places during these years gipsy-moth infestations have been observed where this parasite was recovered only incidentally. The foregoing data are sufficient, however, to show that *Apanteles porthetriae* is, under favorable conditions, an important enemy of the gipsy moth.

Life History and Habits

This braconid probably passes the winter as a small larva within lepidopterous caterpillars. In the field the adults attack the first-instar and second-instar gipsy-moth caterpillars. The great majority of the parasite larvae issue from the second and third instar caterpillars under field conditions. Usually only one larva develops within a single host. In laboratory work the period from the laying of the egg to the issuance of the parasite from its host was from 11 to 20 days, the average being 14 or 15 days. The larva spins a delicate white cocoon, lightly attached to the caterpillar, which may live several days but does not feed after the issuance of the parasite. The cocoons are found on the tree trunks and on the underside of the branches where the parasitized caterpillars usually rest just previous to the issuance of the parasite. The adult issues in from five to nine days after completion of the cocoon, and the males are usually the first to appear.

By the time the adults of this generation have developed in the field, most of the gipsy-moth caterpillars have reached the third and fourth instars, and are seldom attacked by this brood. There is sufficient time for this generation to parasitize another species before attacking the host in which it passes the winter.

Introduction and Colonization

It is surprising that this parasite was not encountered as an enemy of the gipsy moth during the importation work from 1905 to 1911, for in the recent investigations of the Bureau of Entomology it has been the predominating braconid enemy of this insect. An exception to this condition was found in 1922 by the junior author in

Fig. 38.—A piece of cork oak collected at Portalegre, Portugal, in 1925, showing the cocoons of *Apanteles porthetriae*, ×¼

Sicily, where *Apanteles melanoscelus* was the predominating species. There is a strong suspicion that during the early work there was a misidentification of the braconid parasites which were obtained as enemies of the gipsy moth. It seems likely that a part of the 23,000 Apanteles liberated in 1911 as *A. solitarius*, and later (*8*) credited to the colonization of the spring generation of *A. melanoscelus*, were in reality partly *A. melanoscelus* and partly *A. porthetriae*. As there is no way of determining the number of the two species actually liberated, no change will be made in the number credited as *A. melanoscelus*, but it is probably high. The manner in which this parasite was obtained in 1911 has been explained under the discussion of the introduction of *A. melanoscelus*.

There were no more liberations of *A. porthetriae* until 1924. In 1922 W. R. Thompson, of the Bureau of Entomology, sent a few collections of the early instars of the gipsy-moth caterpillars from Hyeres, France, from which a few cocoons of *A. porthetriae* were obtained. The adults which emerged from these evidently did not mate, for only males resulted from the reproduction work with them that season.

During 1924, from 45 cocoons sent to Melrose Highlands from Spain, 8 females were reared and fertilized. These were used in a reproduction experiment and in two generations 2,440 cocoons resulted. Of these one colony of 1,400 was placed at Hampton, N. H., and 1,000 at Rochester, Mass. The remaining 40 were used in reproduction experiments and later liberated at Melrose Highlands.

This parasite proved to be a very difficult one to transport satisfactorily to this country. Several small lots of cocoons have been gathered in Europe and sent to the laboratory at Melrose by mail or express, but in practically every case the adults emerged and died on the way. Similar collections of cocoons have been sent which were kept in the steamer's cold storage while in transit, but in such cases only a few adults were received alive, and these were usually weak and did not mate readily. Many collections of small parasitized gipsy-moth caterpillars have been shipped to the laboratory, but in most cases the parasites and their hosts died before arrival.

This species was observed in great abundance in several European countries in 1924, and it seemed that every possible attempt should be made to establish it here. Accordingly, in the spring of 1925 T. H. Jones of the laboratory went to Europe and met the bureau men who had gone earlier in the year and had located three areas where this parasite could be obtained in large numbers, one at Belki, Czechoslovakia, one at Baja, Hungary, and one at Debrecen, Hungary. As soon as the first cocoons of *A. porthetriae* began to appear, large numbers of first and second instar gipsy-moth caterpillars were collected and placed in pasteboard boxes. The covers of these boxes were sealed to prevent the escape of the caterpillars; but an opening was arranged through which the foliage for the caterpillars' food could be inserted. After the collections were completed the boxes containing the gipsy-moth caterpillars and Apanteles cocoons were assembled and Mr. Jones started with them for the United States. When he boarded the steamer at Bremerhaven, circular holes were cut in the ends of the collecting boxes and into these glass tubes were inserted. As the adult Apanteles emerged from the cocoons which had been placed in the boxes, and from those which were formed in the boxes by the parasite larvae that issued from the caterpillars, they entered the glass tubes. From these they were removed and placed in wooden boxes which had been prepared for them. In these boxes the adults were fed with a mixture of 1 part of honey and 2 parts of water during the remainder of the trip. The boxes were made so as to fit into a large traveling case. (Fig. 39.) The outside measurements of the boxes were 9 inches long by 4½ inches wide by 3 inches deep. A glass cover fitted tightly into a groove in the top. In one end of each box was a hole 2 inches in diameter through which the parasites, and later the food, were inserted.

On May 29, Mr. Jones arrived with about 2,400 living adult Apanteles in good condition. A part (1,500) of these were liberated immedi-

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ately in a gipsy-moth infestation at Barnstable, Mass., and they had time to complete a generation on the gipsy-moth caterpillars in the field. The remaining 900 adults were used in a reproduction experiment to start a generation at the laboratory and were then liberated at the colony site in Barnstable. Thus 2,400 foreign adults in all were liberated at that colony. During the summer, from the start made with the 900 adults before they were liberated, 13,382 cocoons were obtained in two generations. These Apanteles were liberated in Massachusetts and New Hampshire in large colonies after they had had an opportunity to mate.

There were no colonizations in 1926. A better method of shipping this species was developed during the summer of 1927 by Mr. Muesebeck. This resulted in the liberation of 9,665 foreign adults. A few adults from Hungary were used in a reproduction experiment and 6,700 parasitized caterpillars were liberated. Only freshly formed cocoons were sent to the United States during this season and these came in wooden boxes, each one measuring 3 inches deep, 5 inches wide, and 6 inches long. In one end of each box a 1-inch circular opening covered with very fine wire screening permitted circulation of air and the insertion of a glass vial to draw off the adults. Each box would accommodate from 300 to 400 cocoons, and these were held in place with 3 or 4 mm. wire screening. Many adults issued en route and a sugar solution was supplied for food. This was placed in a nickled brass tube 10 cm. long and 2 cm. in diameter. A piece of lamp wick long enough to allow both ends to project was run through each tube and the ends of the tube were plugged with cotton batting. The wick and cotton were saturated with the solution before insertion. Each box contained two tubes held firmly in place with nails. By using this method to ship *A. porthetriae* to the United States it was not necessary to retard the development of the parasites by placing them in cold storage during transportation, and the material arrived in this country in excellent condition.

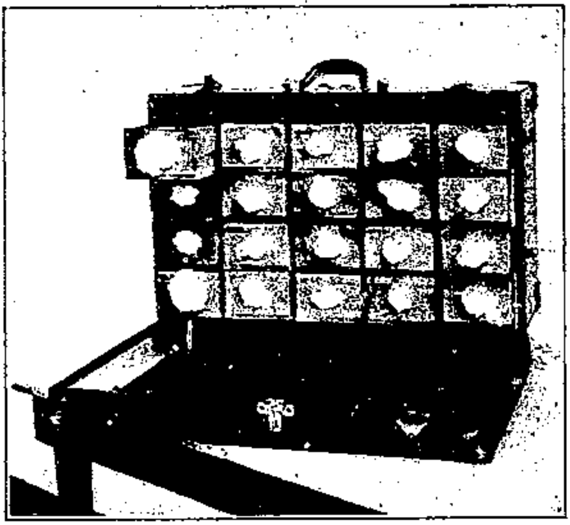

FIG. 39.—Large traveling bag containing 20 boxes with glass tops used in transporting adults of *Apanteles porthetriae* from Europe to Melrose Highlands, Mass., in 1925

The summary in Table 24 shows the area over which this parasite has been liberated and the number of individuals placed in the different colonies.

TABLE 24.—*Total liberation of Apanteles porthetriae in New England.*

Year	Liberated in—	Bred stock	Imported stock, adults	Parasitized caterpillars
		Number	*Number*	*Number*
1924	Melrose, Mass.	40		
	Rochester, Mass.	1,000		
	Hampton, N. H.	1,400		
	Total	2,440		
1925	Barnstable, Mass.		2,400	
	Brewster, Mass.	4,032		
	Dennis, Mass.	3,000		
	Madison, N. H.	3,000		
	Sandwich, Mass.	2,000		
	Saugus, Mass.	1,350		
	Total	13,382	2,400	
1927	Boxford, Mass.		6,165	
	Amherst, Mass.		3,500	
	Westwood, Mass.			6,700
	Total		9,665	6,700

Grand total liberated, 34,587.

In addition to the Apanteles which have been liberated as shown in Table 24 there probably were a few thousand colonized in 1911 as *A. melanoscelus* and *A. solitarius*.

About 230 cocoons of *A. porthetriae* were received at the gipsy-moth laboratory from Spain and Portugal in 1925, but no living adults were obtained from this material.

METHODS USED IN REPRODUCTION WORK

This parasite is not a difficult one to breed under laboratory conditions. The adults are kept in glass tubes, where they are fed a mixture of 1 part of honey and 2 parts of water. The food is usually placed in the tube on a small piece of sponge which should rest on a small can or a piece of paraffin paper so as not to foul the tube. The sponges should be cleansed thoroughly each day and a fresh mixture of honey and water used.

Parasite-free gipsy-moth caterpillars are obtained by rearing large numbers of them from their eggs. A quantity of gipsy-moth eggs is held in cold storage to prevent hatching until the caterpillars are needed. These caterpillars are exposed to the female Apanteles soon after the first molt. They are introduced on a small camel's-hair brush into a glass tube 8 by 2 inches, which contains from 15 to 20 fertilized female Apanteles. The closed end of the tube is kept toward the light, which prevents the Apanteles from escaping. As soon as a caterpillar is attacked once it is withdrawn and placed in a tray. From 100 to 150 of these parasitized caterpillars are confined in paraffin-paper trays which fit inside of wooden frames, 14 inches square. (Fig. 25.) A strip of sticky tree-banding material to prevent the caterpillars from escaping is placed on the inner sides of the paper tray near the top. The small caterpillars are fed each day with fresh foliage which is lightly sprinkled with water before being placed in the trays, to keep it fresh for a longer period. In the bottom of each tray is placed a piece of clean paper. This is removed each day and aids in keeping the tray clean.

About two weeks after the caterpillars have been attacked the Apanteles larvae begin to issue and spin their cocoons in the trays. These cocoons are removed to small glass vials and held until the adults begin to issue. The first to emerge are always males. These are divided equally and placed in several glass-covered boxes, such as are shown in Figure 16, K, and Figure 39. Here they are kept and fed until the females emerge. Freshly emerged females of Apanteles mate more readily with males which are a day or two older. After the females emerge they are put into the boxes which contain the older males, for fertilization. As soon as sufficient adults for a colony are obtained and mated, they are liberated and not held until a large supply is on hand.

Recovery and Value of Apanteles porthetriae

This species has not been recovered in New England except during the summer of its liberation, and then only from the vicinity of the colony site. It was not recovered during the summer work of 1926, the year following what was considered satisfactory colonization. It is not unusual to fail to recover an introduced parasite for a year or two after its liberation, and there is still a chance that this species is established. It has a variety of hosts but apparently requires an overwintering host. Possibly this parasite will find a suitable hibernating host here. The brown-tail moth or the satin moth may serve this purpose.

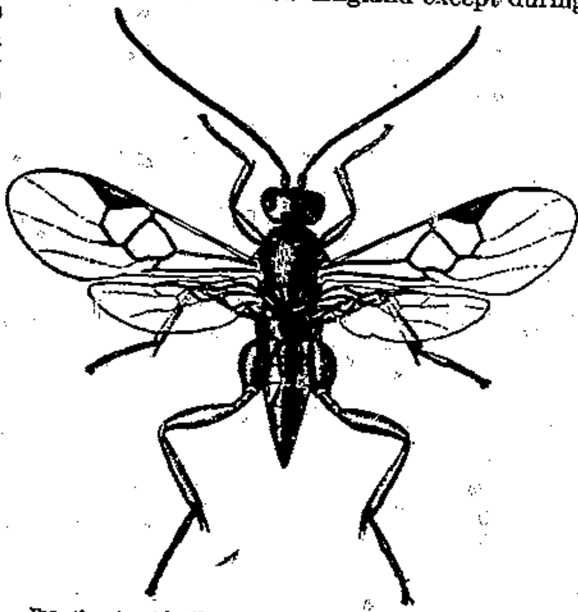

FIG. 40.—*Apanteles liparidis* adult, × 12. (Howard and Fiske)

APANTELES LIPARIDIS Bouché

The braconid parasite of the gipsy-moth caterpillars which was so often referred to during the early work at the laboratory as Glyptapanteles, and later in literature as *A. fulvipes* Hal., is not that species according to C. F. W. Muesebeck, but is *A. liparidis* Bouché. (Fig. 40.) Mr. Muesebeck reports having seen Bouché's type of *A. liparidis* in the museum of the Landwirtschaftliche Hochschule in Berlin and says: "* * * It is certainly the same species that we called *fulvipes*. The true *fulvipes* while structurally very close is nevertheless readily separated, and it apparently is restricted to smooth-bodied host larvae."

A. liparidis has several generations each year, two of which are on gipsy-moth caterpillars. In addition to being one of the most important gipsy-moth parasites in Europe and Japan, it is recorded as a brown-tail-moth parasite. It has been liberated in this country in large numbers and under as favorable conditions as can be expected. It has not been recovered, except during the season of liberation, and its establishment seems very doubtful.

Foreign Distribution and Abundance

This species is widely distributed in Japan and in Europe, and has often been considered one of the most efficient enemies of the gipsy moth in foreign countries. In the earlier work with this species, when several attempts were made to establish it here, specimens were received from several locations in France, Germany, Kiev, Russia, and Japan, and it was observed also in Austria. Since foreign work started again in 1922 this Apanteles has been reported by the bureau experts at Yokohama, Nishigahara, and Tokyo, Japan; Debrecen, Pomaz, Telzogallo, Baja, Galgamacsa, and Budapest, Hungary; Hyeres, France; Madrid and Valencia, Spain; Mugglessee and Zittau, Germany; Belgrade and Beli Manastir, Yugoslavia; Bochnia and Drewnica, Poland; Beregsas, Munkecera, Uzhorod, and Kosice, Czechoslovakia; and Vetren, Bulgaria.

During the period from 1922 to 1927, in many European countries, *A. liparidis* was observed in the field and reared in the trays from gipsy-moth caterpillars, but not in so great abundance as in Japan during 1922 and 1923.

J. N. Summers reported in 1922 that the parasitism of the gipsy moth by the second generation of this parasite was high, and one collection showed 60 per cent of parasitism at Yokohama. H. A. Loomis, an American living in Yokohama, Japan, observed that there the gipsy moth was held in check by natural enemies, and several attempts were made by him and others to introduce this species. In 1908 T. Kincaid was sent to Japan to investigate the natural control of the gipsy moth. His reports in regard to *A. liparidis* were very enthusiastic, for in that season this species was very abundant.

More recent European investigations have not indicated that this braconid is an important enemy of the gipsy moth although there are many earlier records of its great abundance. Professor Kincaid reported from Kiev, Russia, in 1909 in regard to a heavy gipsy-moth infestation which had occurred in 1908 (*14, p. 124*).

> Only a few isolated colonies seem to have survived, the most important of these being at Mishighari, a small place on the river about two hours by steamer from Kief. In this place, which is perhaps 100 acres in extent, the trees are plastered with cocoons of *Apanteles fulvipes*. The attack of the parasite was so thorough that the first generation seems to have been sufficient to wipe out the caterpillars, as I can find no large caterpillars about the place, and a few days will doubtless witness the complete wiping out of *dispar*.

In 1910 W. F. Fiske, after visiting the forest at Mishighari where Professor Kincaid had found Apanteles so abundant, reported as follows (*14, p. 125*):

> Everywhere the gipsy moth was rare or at least uncommon, and everywhere the cocoon masses of *Apanteles fulvipes* were at least as abundant as the egg masses of their host. At Mishighari the conditions remained much as described by Prof. Kincaid, except that the cocoon masses of Apanteles were even more abundant than his letters would indicate. Upon some trees they were literally matted together by the thousands in such semiprotected situations as are selected by the caterpillars at the time of molting.

Such conditions are not universal and other forests were found where the parasite was scarce or not observed at all. This is sufficient to indicate both the abundance and scarcity of this parasite, and to emphasize the necessity of long and continuous investigations in connection with the biological control of insects in order to establish the exact status of the host and its enemies.

According to later reports this species was found abundantly during the summer of 1926 at Drewnica, Poland, where 20, 35, 42, 50, and 100 clusters of cocoons were seen on trees where there had been a serious gipsy-moth infestation during the summer. These counts were made on trees which were typical of conditions there. This is the first record during the recent European investigations of the finding of this Apanteles in abundance.

Life History and Habits

When this parasite has been imported during the rush of the season's work, the chief concern has been its reproduction and colonization. As far as is known it has never lived through a winter here and no specimens have been available for studying it except during the seasons of its introduction.

The gipsy moth alone will not sustain this parasite, for it requires another insect in which to hibernate. During the week of March 4 to 11, 1922, while J. N. Summers was investigating the gipsy-moth situation in Japan, he found Apanteles larvae issuing from caterpillars of *Dendrolimus spectabilis* Butl. at Nishigahara. This discovery established the fact that *D. spectabilis* is the hibernating host of this braconid in Japan. In Europe the species is recorded as a parasite of *D. pini* L.; and in Spain the junior author was told that at times there are bad outbreaks of *D. pini* there, and that *A. liparidis* is an important parasite of this insect. While visiting a pine forest near Valencia, Spain, in March, 1924, nearly all stages of caterpillars and even an occasional pupa of *D. pini* were found, showing the variety of stages which Apanteles may choose as suitable ones in which to pass the winter. Undoubtedly this species is a favorable hibernating host for *A. liparidis* in Europe. It is possible that this Apanteles may hibernate in other hosts, but unless such is the case it can not be established in America, for neither of the hibernating hosts mentioned above is present here.

Adults of this Apanteles attack their hosts in manner similar to that of *A. lacteicolor* and *A. melanoscelus*, the act of oviposition being a quick insertion of the ovipositor for deposition of the eggs. The females oviposit freely in nearly all stages of gipsy-moth caterpillars, but fewer Apanteles develop from small caterpillars than from the larger ones. From 15 to 20 larvae develop from a single oviposition in a medium-sized gipsy-moth caterpillar. Caterpillars are often attacked more than once, so from 80 to 100 parasites are sometimes obtained from large-size caterpillars. In one case Mr. Muesebeck, who conducted the experiments, allowed a large fifth-instar gipsy-moth caterpillar to be oviposited in by several females, and 16 days later 192 cocoons of Apanteles were recovered. They appeared to be of medium size and entirely normal. The time elapsing from the laying of the eggs to the issuance of the parasite

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larvae was from 14 to 21 days, with an average of 16 days, which is about one day longer than for *A. porthetriae*.

Each larva prepares a white cocoon and in this transforms to the adult. When a number of the cocoons are clustered together, as is usually the case, they are quite conspicuous. They are found on the tree trunks, and often the caterpillars from which the larvae issued are found partially entangled over the top of the mass of cocoons. (Fig. 41.) Usually the host does not die for several hours after the issuance of the larvae. The development of the parasite after the larvae leave their hibernating hosts is rather slow in Japan, for according to Doctor Summers the adults do not issue from the cocoons for 24 or 25 days. In the summer generations the period from the time the larvae issue to the emergence of the adults is from 5 to 10 days, with an average of about 8 days. Adults developed from the hibernating generation attack the small gipsy-moth caterpillars and produce the first summer generation, which parasitizes the medium and large gipsy-moth caterpillars, issuing from them in time to pass through another generation before they attack their hibernating host.

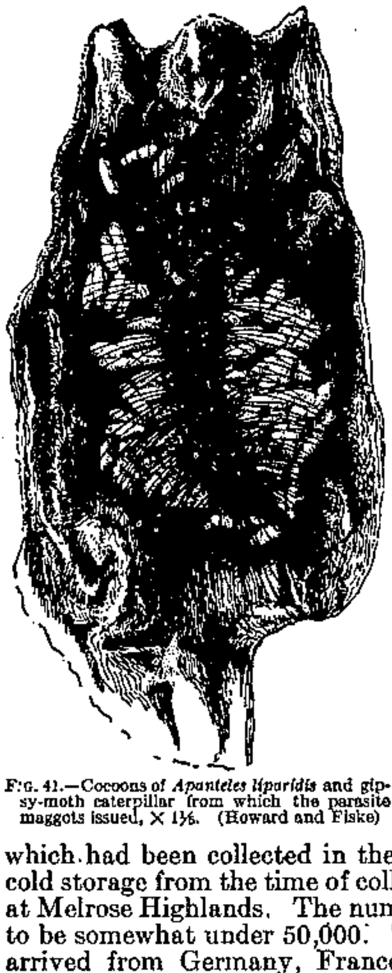


FIG. 41.—Cocoons of *Apanteles liparidis* and gipsy-moth caterpillar from which the parasite maggots issued, × 1⅓. (Howard and Fiske)

INTRODUCTION AND LIBERATION

This parasite was one of the first to attract attention as an enemy of the gipsy moth in Europe and in Japan. It was also among the first to be received at the gipsy-moth laboratory in 1905, although all of the specimens were dead. Considerable difficulty was experienced in transporting it alive to this country, and many unsuccessful attempts were made until 1908, when the first living individuals were received. They arrived in packages containing hundreds of thousands of cocoons which had been collected in the field in Japan and had been kept in cold storage from the time of collection until the packages were opened at Melrose Highlands. The number of living Apanteles was estimated to be somewhat under 50,000. These, together with a few which had arrived from Germany, France, and Russia, were liberated. The spring of 1908 was later than usual in Japan, while in New England it was early; and although a great many adults were liberated here this year the colonization was very unsatisfactory, for practically all of the gipsy-moth caterpillars had pupated at the time the parasites were colonized.

In New England the spring of 1909 was cold and insect development was somewhat retarded. A few thousand Apanteles cocoons of the first generation were received from Japan early enough for about 1,000 adults to be obtained and colonized while a few first instar gipsy-moth caterpillars were still present. Later during the summer many cocoons were received and the parasites were liberated when there was still sufficient time to allow for a generation on the native caterpillars. Approximately 10,000 adults were liberated during the summer.

Next year rather large numbers of adults were liberated from cocoons received from Japan and Germany early enough in the season for one generation to develop on the gipsy moth. The actual numbers colonized that year are not known. One thousand six hundred and seventy-nine adults were liberated, but in addition to this there were two uncounted lots of several boxes, each containing a large number of cocoons which were sent to the field and the adults liberated as they emerged.

In 1912 some 19,000 adults were liberated from large collections of cocoons, most of which came from Germany. During the years from 1908 to 1912 a total of 76,702 of *A. liparidis* were colonized. Positive evidence was obtained that this species passed through two generations in the field in 1909, and another generation developed in the field in 1910. All of these field generations were developed from the adults liberated earlier the same season.

No more attempts were made to colonize this braconid until 1922, when the foreign work was started again. During that year there were received from Japan 995 cocoons, from which 64 adults were reared. These were increased at the gipsy-moth laboratory by reproduction methods to 3,300 in the first generation. Two colonies consisting of 1,000 cocoons each were liberated, one in Massachusetts and the other at Bridgewater, N. J. The colony was released in New Jersey to give the parasite a chance to find some host suitable for hibernation which might not be present in Massachusetts. The remaining cocoons, numbering 1,300, were retained at the laboratory for use in continuing the reproduction work. From them only 13 females were obtained, indicating that the two colonies liberated were not of much value. However, the reproduction work was continued and as a result of it 8,870 more Apanteles were colonized in Massachusetts and Connecticut.

The method used in the reproduction work was the same as described in some detail in the discussion of *A. porthetriae* under the topic "Method used in reproduction work" (p. 94). Both of these species can be readily reproduced by laboratory methods and large numbers of them reared from a small beginning if a few important details are observed. In handling these species the tubes in which they are confined must be kept clean. The tubes are kept on their sides and the insects are fed a mixture of honey and water which is placed on small pieces of sponge or blotting paper. In order to keep the food from touching the sides of the tubes, the sponges or blotting paper are placed in the tubes on paraffin paper or in flat tin cans. Each day when the fresh food is supplied the can should be washed; or if paraffin paper is used, this can be cleansed or renewed. The honey-and-water mixture should be made fresh each day, and the tubes containing the Apanteles should be kept in cool dark places when the parasites are not being used in reproduction work. A crumpled piece of crêpe paper in the tubes serves well for a resting place for the parasites.

In 1923 a further attempt to introduce this Apanteles was made. Two 10-gallon ice-cream tubs, each with a heavy metal ice-cream container, were purchased (*23*) for this purpose. Wooden boxes were made which would fit tightly into each metal container, and small wooden collecting boxes were made to fit inside the large boxes. (Fig. 42.) A top was made for each tub and several improvements were added to prevent injury to the collections by wetting or jarring while en route.

These refrigerators were used for shipping Japanese material from the Pacific coast to the gipsy-moth laboratory at Melrose Highlands, Mass. The collecting boxes were stocked with gipsy-moth caterpillars in Japan and placed inside the wooden boxes, to be put in the refrigerators upon arrival at Seattle. As soon as larvae of *A. liparidis* began to issue from the gipsy-moth caterpillars in Japan, the collections were made. In each box with the caterpillars was placed a small supply of foliage still on the twigs. The two large wooden

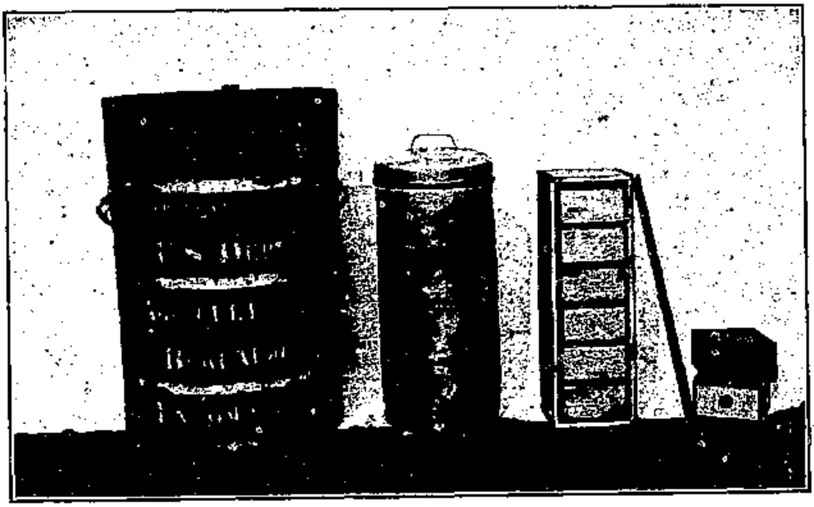


FIG. 42.—Component parts of refrigerator and shipping box used in transporting gipsy-moth larvae from Japan in 1923. (Summers)

boxes containing the collection boxes of caterpillars were shipped in the steamer's cold-storage room. Upon arrival at Seattle they were immediately placed in the metal chambers of the refrigerators, which were surrounded with ice. The refrigerators were then shipped by express to Melrose Highlands. The tubs were repacked with ice once while en route. This lot of material arrived at Melrose Highlands from Japan in 18 days. A few of the gipsy-moth larvae were still alive. Most of the Apanteles larvae had issued from their host, en route, and spun their cocoons, but the adult parasites had not emerged, and 255 cocoons were obtained from which 70 adults issued.

A refrigerating metal hand bag, shown in Figure 43, was made to carry small collections of parasites when their development needed to be retarded during transit. The case is of convenient size and because of its shape it is naturally placed on its bottom with the top up during transportation. The inside measurements of the case are as follows: The base is 9½ by 16 inches and the perpendicular measurements from the corners of the base to the top are 7¼ inches. The two ends are extended in a point at their tops. The perpendicular measurement from the point of each end to the base is 10½ inches. The cover is composed of two parts, hinged at the sides of the bag, which meet at the top when the bag is closed. The bottom, ends, and sides of the bag are lined with felt cloth one-half inch thick, inside of which is a light metal frame. Within this frame are placed three tight-fitting zinc cases. The two end ones measure 6½ inches in depth, 7¾ inches in length, and 3¼ inches in width. The third case, which is placed between them, is 6½ inches deep, 7¾ inches wide, and 8½ inches long. At the top of each case around the inside is soldered a metal strip making a groove into which the covers fit snugly. The central case is used for the insects and the temperature within it is lowered by packing ice in the two end cases. Small holes are made in the grooves at the top of the end cases, allowing water which splashes to the tops of these cases to run back

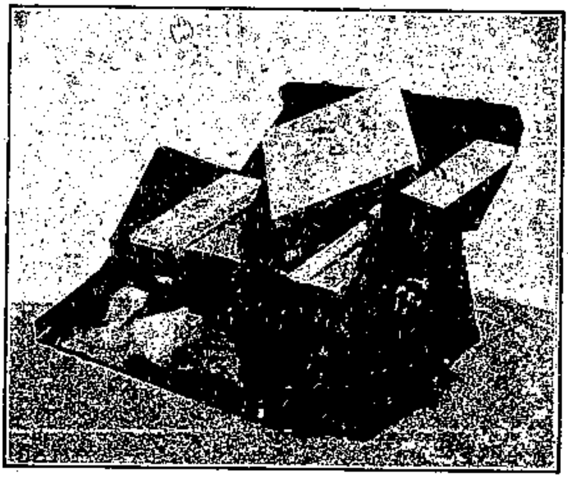


FIG. 43.—Metal refrigerator hand bag used in transporting parasites of the gipsy moth. It contains three separate metal compartments. The two outer ones are for ice and the one in the center for parasite material

into the case and not out into the bag. A piece of heavy felt cloth is placed over the top of the cases. When the two end cases are supplied with ice the temperature of the center case ranges from 36 to 40° F., which will retard insect development.

During the 1923 season 2,486 *A. liparidis* cocoons, obtained from gipsy-moth caterpillars in rearing trays in Hungary, were received. These were packed in small wooden boxes and kept in the cold-storage room of the steamer during the transatlantic trip. Upon arrival in New York they were placed on the first train for Boston, where the train was met by a messenger from the laboratory and the material taken in haste to Melrose Highlands. The cocoons had been from 12 to 15 days on the way. From these 2,486 cocoons 154 adults emerged.

The 70 adults from Japan, together with the 154 from Hungary, were used in reproduction experiments at the laboratory. As a result 26,500 Apanteles were reared. These were placed in several colonies in New Hampshire and Massachusetts as shown in Table 25.

TABLE 25.—*Colonization of Apanteles liparidis in New England*

Year	Towns	Foreign adults	Bred stock		
			Cocoons and adults	Cocoons	Adults
1908	Eastern Massachusetts	46,323			
1909	do	9,600			
1910	do	1,679			
1912	do	19,100			
1922	Bridgewater, N. J.			1,000	
Do	Bourne, Mass.			1,000	
Do	Griswold, Conn.			1,200	
Do	Lunenburg, Mass.			1,200	
Do	Marion, Mass.			1,000	
Do	Plymouth, Mass.			1,500	
Do	Stonington, Conn.		2,500		
Do	Foxboro, Mass.				340
Do	Hanover, Mass.				150
Do	Melrose, Mass.				605
Do	Saugus, Mass.				375
1923	Yarmouth, Mass.			4,000	
Do	Falmouth, Mass.			1,000	3,500
Do	Ashburnham, Mass.				1,000
Do	Rochester, Mass.				2,000
Do	Temple, N. H.				10,000
Do	Weare, N. H.				5,000
Total		76,702	2,500	11,900	22,970

Grand total 114,072.

During the period from 1908 to 1912 *A. liparidis* was very abundant in several European countries and could be imported in such large numbers as to make possible the liberation of foreign adults in New England. Such conditions have not prevailed in these countries during the period from 1922 to 1927, excepting in a location in Poland discovered late in the summer of 1926. With the possible exception of this place and Japan this parasite has been scarce and not at all an important factor in the control of the gipsy moth. This made it necessary to increase, by reproduction work at the laboratory, all of the material that was liberated in 1922 and 1923.

No colonizations of this species have been made since 1923, as several of the colonies which have been liberated appeared to be satisfactory, and it was considered that from them the species would become established if establishment is possible.

Recovery and Dispersion

As has previously been stated, this parasite has never been recovered from the field in this country except during the season of its liberation. When colonized under satisfactory conditions it reproduces and increases rapidly. In 1909, when the parasite was liberated in a territory where first-instar caterpillars were present, the parasite passed through two complete generations on the gipsy moth, and again in 1910 it succeeded in passing one generation in the field.

An interesting record of the dispersion of this parasite was obtained in 1909 when (*14, p. 196*) "a bona fide example of the parasite" was recovered "upwards of a mile away" from the point of liberation in less than one week from the time of colonization. The adults of this Apanteles are rather delicate and not long-lived, and a record of this kind indicates the rapidity of dispersal of even these small insects. The fact that this species has several generations annually would increase its dispersal each year very considerably.

VALUE OF APANTELES LIPARIDIS

As an enemy of the gipsy moth in New England this parasite can not, at this time, be given any rating. So far as is known the species is not established, and the work which has been done indicates that it can not be established in New England at the present time. However, in connection with efforts to establish this species much information in regard to it has been obtained, most of which will be of considerable value in attempting the establishment of other beneficial insects.

It is probable that its hibernating host would survive in New England should it get an opportunity to do so. Many precautions are taken by the Federal Government and by some of the States to prevent the further introduction of foreign insects into this country, and although these precautions undoubtedly prevent and retard the establishment of foreign insects, occasionally a new one is discovered well established here. Should the hibernating host of this parasite ever become established in the area infested by the gipsy moth, it is probable that the parasite could then be established. Again, should the gipsy moth ever become established in some other part of the United States, this important parasite might find in such a location a suitable hibernating host so that it could be introduced and established.

METEORUS JAPONICUS Ashmead

The gipsy-moth parasite *Meteorus japonicus* Ashmead was recovered in small numbers in 1908 and 1909 from gipsy-moth caterpillars from Japan. In the winter of 1909–10 a few specimens were received from S. I. Kuwana, who reported that it had been a common gipsy-moth parasite at Nagaoka in 1908 "but not in Tokyo" (*14, p. 191*). This is another illustration of the prominence of a certain parasite in one section and its relative absence in another.

In 1923 a few cocoons were obtained from Japanese gipsy-moth caterpillars. From several females which were received there were reared five unfertilized ones which were used in a reproduction experiment. They bred, parthenogenetically, a generation of 400 females, and these were liberated. The species has not been recovered.

METEORUS PULCHRICORNIS Wesmael

The species *Meteorus pulchricornis* Wesmael was received from Italy and southern France during the early gipsy-moth importation work in numbers too few for colonization, and it was not considered an important gipsy-moth parasite.

The recent foreign rearing work does not indicate that this species is of much value as an enemy of the gipsy moth. In most cases, however, large gipsy-moth caterpillars have been collected to obtain tachinids. It is probable that should large collections of the smaller gipsy-moth caterpillars be made, a greater variety of the parasites of these instars would result, and some of those which are now received in small numbers might be obtained in considerably larger quantities. In 1922, from a collection of small gipsy-moth caterpillars sent from southern France, two males and two females of this species were obtained; these were used in a small reproduction experiment, resulting in the colonization of 122 adults. No recovery of the species has been made, and it seems doubtful whether it became established from such an unsatisfactory liberation.

HYPOSOTER SPP.

There are two distinct species of Hyposoter in addition to *Hyposoter disparis*, which are occasionally reared from gipsy-moth caterpillars in Europe. In contrast to *H. disparis*, which has a single generation and hibernates in its cocoon, the adults of these species issued from their cocoons during the same season that they were formed. During 1924 and 1925 some 220 cocoons were received from Spain and 57 from Czechoslovakia. The adults which emerged were used in life-history studies, but considerable difficulty was encountered in inducing them to mate and oviposit, and it seemed that they might hibernate. They were finally placed in several types of containers for hibernation, but the last one died after living 92 days. In the summer of 1927 a few adults were obtained from cocoons collected in Hungary and in Yugoslavia.

CAMPOPLEX SP.

A species of Campoplex was reared in 1922 in very limited numbers from a few small gipsy-moth caterpillars sent to the laboratory from Hyeres, France, and 25 cocoons were obtained in 1925 from the rearing work carried on in Czechoslovakia.

PHOROCERA AGILIS Robineau-Desvoidy

A tachinid parasite of the gipsy moth, *Phorocera agilis* Robineau-Desvoidy (*Parasetigena segregata* of authors, not Rondani), was received and colonized to some extent between 1908 and 1910. During that period it was not considered of particular value as a gipsy-moth parasite, but rather as a parasite of the nun moth, *Lymantria monacha* L. In the recent European parasite work, this species has been in most cases the predominating tachinid parasite of the gipsy moth, and has been received at the gipsy-moth laboratory at Melrose Highlands in large numbers. The winter is passed in the pupal stage within the puparium in the earth. This species has several hosts and a single generation each year.

Foreign Distribution and Abundance

In the early work *P. agilis* was received at Melrose Highlands from France, Belgium, Russia, and many parts of Germany. During the foreign work of the last six summers it has been received at the laboratory from Hungary, Czechoslovakia, Yugoslavia, Poland, Bulgaria, and Spain. It is interesting to note the different sections of Europe from which this parasite was recovered during the two periods of foreign work. The same countries do not appear in both lists. The principal cause for this was the scarcity of the gipsy moth in France, Belgium, and Germany during the latter period. Infestations have been reported from Russia during this period, but they have not been investigated. In all of these countries except at Moscencia, Yugoslavia, this species has been the predominating tachinid parasite of the gipsy-moth caterpillars. It has been especially abundant in Hungary, Czechoslovakia, and Bulgaria. In some cases where several gipsy-moth infestations have been nearly wiped out this parasite has been largely responsible, although several other enemies of the gipsy moth had a part in this control, especially *A. porthetriae* and *S. scutellata*.

LIFE HISTORY AND HABITS

The life history and habits of this tachinid have been thoroughly investigated by Heinrich Prell (*22*), of Tharandt, Germany, and T. H. Jones, of the gipsy-moth laboratory, has also made studies of the biology of the species. The notes of Mr. Jones and the paper by Doctor Prell have been freely consulted in the following treatment of the life history of this parasite.

It is a parasite of the gipsy-moth caterpillars, has a single generation each year, and passes the winter in its puparium in the ground. The adult flies issue during the month of May, the males being the first

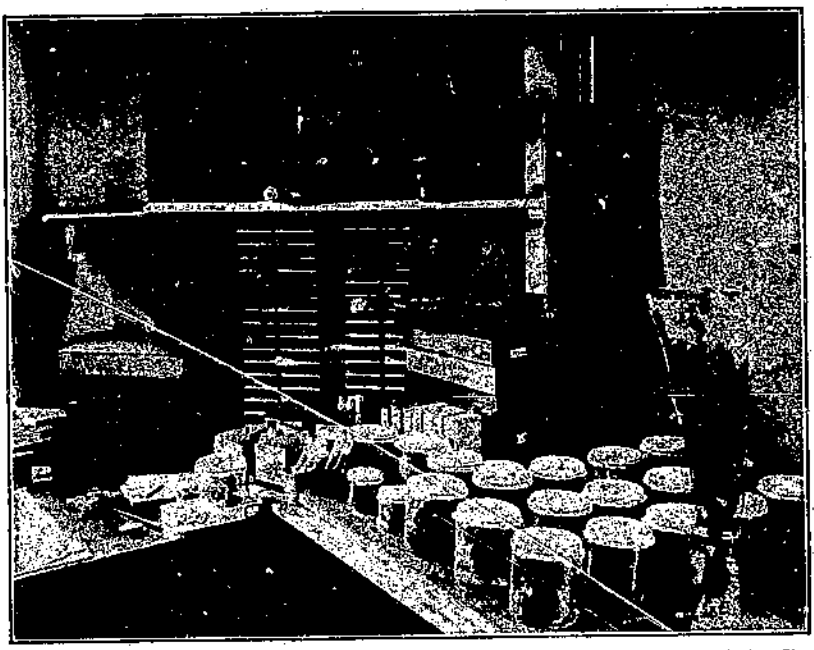


FIG. 44.—Glass cylinders used in rearing tachinids and wire-screen receptacles for inclosing flies with caterpillars on foliage. (Townsend)

to emerge; but the females begin to issue before the issuance of the males has been completed.

In the German experiments (*22*) the flies were fed sugar water which they took eagerly, but as they died relatively quickly, pieces of dry loaf sugar were put in the cages and water was supplied on sponges. This method of feeding was more satisfactory. In some cases flowers of Umbelliferae were placed in the cages, and although the flies seemed to feed on the pollen, the length of life was not prolonged. At the gipsy-moth laboratory in the life-history studies, a mixture of 1 part of honey and 2 parts of water, put on pieces of blotting paper or sponges, has been used for food for adult tachinids. In the larger mating and liberating cages the method of feeding dry loaf sugar and water was used and is discussed in more detail under the topic "Receiving and handling of foreign material at the gipsy-moth laboratory" (p. 19).

In the German experiments glass jars or wire cylinders of about 1 or 2 quarts capacity, similar to the ones used by Townsend (fig. 44), were found satisfactory as small cages for the life-history work. At the gipsy-moth laboratory each fertilized female was placed in a glass tube, 2 by 8 inches, with food and a crumpled piece of crêpe paper. These tubes were kept in darkened trays in an outdoor insectary while the females were not being observed. In order to obtain oviposition the tubes were placed in the light and a gipsy-moth caterpillar was inserted into the glass tube with the tachinid. After oviposition had taken place the caterpillar was removed and another one inserted. The parasitized caterpillars were kept in small individual cans (fig. 16, E), or in trays (fig. 17), where they were fed until the issuance of the parasite larva.

There seems to be considerable variation in the time of emergence of the adults in the spring. In some hibernation experiments which have been carried on in the yard of the laboratory the first males were noted in 1925 on May 29. Up to this date the hibernating cage had not been disturbed. When these adults were observed the cage was removed and females issued up to June 8. The same year, in another experiment, a cage containing 25 puparia was removed from the soil on May 29, and 8 males were found to have issued, 3 of which were still alive; the others appeared to have died recently. The remaining puparia were placed in moist sand and 13 females issued from May 30 to June 3.

The emergence records of adults from the large supply of puparia of *P. agilis* do not add much to this information, for they are disturbed in the spring, which may hasten or retard this emergence. They are placed in hibernation during the summer and are removed in the spring to recover the adults. In 1925 the first hibernating cages were removed from the soil to the rearing room on April 20, and the flies began issuing April 25 and continued doing so until May 30, the heaviest issuance occurring between May 2 and May 21. The next year the cages were not removed from hibernation until May 10 and the first flies were obtained May 11. They continued to issue until June 12, the bulk of the emergence taking place between May 18 and May 30. In 1927 issuance was at its height from May 20 to June 4.

There is undoubtedly considerable variation in the emergence of the flies in the spring, even under natural conditions. It is probable that those flies which have hibernated in warm, protected places issue in the spring before those which are in cold situations.

The flies are rather large, quiet insects. In the experiments, both here and in Germany (*22*), they have lived from a few days to six or more weeks. Two specimens lived 46 days and one 51 days at Melrose Highlands. The average length of life at the laboratory was 23 days.

In experiments carried on at the gipsy-moth laboratory with 41 mated females, one of them began oviposition 5 days, another 6 days, and two 7 days after issuing and mating. The oviposition of the others continued for another two weeks. When the female is ready to oviposit the act is nearly instantaneous. She appears merely to strike the caterpillar with the end of her abdomen. With each stroke an egg is usually but not always deposited. In captivity the adults copulate readily soon after issuing. Copulation may occupy from half a minute to one-half or three-quarters of an hour. Freshly emerged females mate more readily when confined with males which are

2 or 3 days old. It is not unusual for the males to mate often during their life, and the females may mate several times. Doctor Prell (*22*) considers that the longer copulations are necessary in order to fertilize the female entirely, and that fertilization is necessary for the development of the eggs.

The gestation period varies according to temperature and other factors, one of which probably is the food of the parasite during this period. In experiments carried on at the gipsy-moth laboratory the period ranged from five days to two weeks or more. According to the German experiments, the period of gestation of some flies held in a room temperature of 61° to 68° F. was about 12 days. A few fertilized females held in a temperature of 54° to 55° F. for about three weeks did not deposit eggs at the end of that period.

In an experiment at the gipsy-moth laboratory in which 41 flies were used an average of 36 eggs were laid, with records of 103, 118, and 131 for three individuals. In Germany (*22, p. 77, 78*) records were obtained of one female laying 158 eggs and of another laying 166 eggs. Doctor Prell states that in nature the species has a capacity of over 200 eggs.

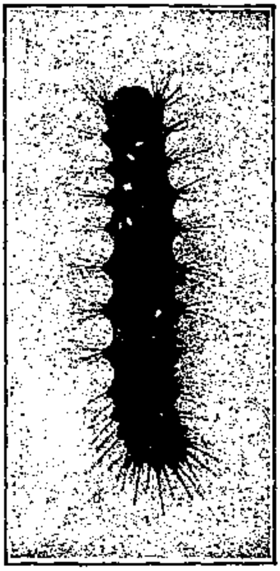


FIG. 45.—Eggs of *Phorocera agilis* on gipsy-moth caterpillar. ×1½

During the warm days of May and June the parasite oviposits readily on the caterpillars. The eggs are usually placed dorsally (fig. 45), and on the anterior part of the host. The greatest number of eggs deposited in the German experiments in a single day was 28, with an average of 4.6 eggs per day. In good weather many flies probably deposit between 10 and 20 eggs a day during their period of maximum oviposition.

There is a great waste of eggs by this tachinid, as several are often placed on the same host, although rarely does more than one parasite maggot mature from a single caterpillar. In Hungary, in 1923 and 1924, Mr. Webber and the junior author noted many second-instar gipsy-moth caterpillars bearing several eggs of this tachinid. The result was that in most cases the small caterpillars died before any of the parasite maggots could develop. Furthermore, several eggs were observed in many cases on caterpillars from which *Apanteles porthetriae* had issued and which were already destroyed. In one case at least, Mr. Webber saw a fly oviposit on a gipsy-moth caterpillar to which was attached a cocoon which had been constructed by an Apanteles larva after issuing from the caterpillar.

The elongate-ovoid eggs vary somewhat in size and form, but most of them are rather large, white, and conspicuous, measuring, according to Prell (*22, p. 70*) from 0.7 to 0.85 millimeter in length and from 0.37 to 0.43 millimeter in width. Dorsally they are strongly convex, and ventrally rather flat. The chorion is thick dorsally but the underside is thin. The whole egg is covered with a fine network of delicate lines forming polygonal areas. The period spent in the egg varies considerably, depending largely upon the temperature. On warm days, according to Prell (*22*), toward the end of May, when the average temperature was 68° F., three days were required for the hatching of most of the eggs. Further investigations indicated that the maximum hatching occurred on the second day after deposition, although a few hatched the first day and some not till several days afterwards.

Upon hatching, in the majority of cases, the tiny maggot enters the body of the caterpillar close by the egg. The actual entering of the host may be accomplished in a few minutes, but usually from a quarter to half an hour is required. The development of the tachinid maggot within its host has been very carefully described by Prell, and it is merely outlined here. Within its host it passes through three larval instars. It is attached by the posterior end to the caterpillar at the point of entrance. The larval instars are passed within a chitinous funnel and delicate sac surrounded with a thick layer of blood cells. In the experimental studies at Melrose great variation was found in the length of time spent in the different larval instars as shown by the following data: One lot consisting of 173 gipsy-moth caterpillars were parasitized June 4. On June 20 third-instar maggots began to issue and on June 23 an apparently healthy caterpillar of this lot was dissected and found to contain a first-instar maggot.

The period required for the entire development, from the time the egg is deposited to the issuance of the maggot from its host, varies considerably, ranging from 16 to 35 days in observations at the gipsy-moth laboratory. In the majority of cases the third-instar maggots issue from the large gipsy-moth caterpillars, although occasionally they issue from the pupae. Upon issuing the maggots enter the soil and here pupation takes place. The winter is passed within the puparium in the pupal stage.

In Europe this tachinid is one of the principal parasites of the nun moth, *Lymantria monacha* L., as well as of the gipsy moth. At the Melrose Highlands laboratory it has been reared in experimental work from the satin moth, *Stilpnotia salicis* L., and from the tent caterpillar, *Malacosoma americana* Fab.

Introduction and Liberation

The first *P. agilis* which were noted at the gipsy-moth laboratory issued in the spring of 1908 from hibernated puparia which were mixed with puparia of *Sturmia scutellata*. There were only a few of them and they were used in biological studies. A few puparia were obtained during the summer of 1908, but there were not enough flies in the spring of 1909 to make a colony. In the summer of 1909 several thousand puparia were received from Europe. The number is not known, for they were mixed with puparia of Sturmia and two species of summer-issuing tachinids. The adults of the two multibrooded tachinids issued during the summer, leaving an apparently healthy lot of puparia of *P. agilis* and *S. scutellata*. Later during the summer several hundred *P. agilis* puparia were received which had been reared in Europe from caterpillars of the nun moth. These puparia were added to those received earlier in the season and all placed in hibernation at the laboratory. In the spring of 1910 the adults which emerged were liberated.

There were no more introductions of this species until 1923. That year, and each succeeding year, large numbers of puparia were received at the gipsy-moth laboratory as a result of the rearing work which has been carried on in Europe during the last few years. Table 26 gives the numbers of *P. agilis* puparia which have been placed in hibernation at the Melrose laboratory.

TABLE 26—*Numbers of foreign Phorocera agilis puparia hibernated at Melrose, Mass., 1923 to 1927*

Year	Source						Total
	Hungary	Czechoslovakia	Yugoslavia	Poland	Bulgaria	Spain	
1923	26,311						26,311
1924	26,998		12,517	408	9,154	6	49,083
1925	22,081	6,332				635	29,048
1926	76,447						76,447
1927	25,616		823	23,758			50,197
Total	177,453	6,332	13,340	24,166	9,154	641	231,086

These figures do not represent the total puparia of *P. agilis* which have been introduced, for some damaged ones were discarded when the material was sorted for hibernation.

Reference to Table 27, which gives the yearly colonization of this species, shows a heavy mortality within the puparia. A great deal of this mortality occurs before the puparia are placed in hibernation, although it does not show until the following spring when the surviving adults issue. When these puparia are being sorted for hibernation many dead ones are included and placed in hibernation with the living ones, as it is difficult to distinguish between them.

The mortality is due to many factors. The material has to be handled several times and many of the puparia, although only slightly injured, are damaged enough to prevent the adults from emerging. When the maggots are removed from the trays in Europe they are placed in damp sawdust, and here the puparia are formed. Very often the puparia are formed in the bottoms of the trays, which is unnatural but unavoidable. During the height of the issuance of the maggots the puparia are formed quickly, and even when the trays are picked over several times a day about as many puparia as maggots are found. The puparia are placed in a box with the tachinid maggots in damp sawdust. Shortly afterwards they must be removed and packed in small boxes in damp sawdust for shipment to the United States. There is more or less jarring of the material during transit in the mails, some of which results in damage to the insects. The moisture conditions of the sawdust in which they are transported is considered the greatest cause for the large mortality. Records indicate that a considerable degree of moisture is necessary for the well-being of the insect within its puparium. Perfect moisture conditions are hard to secure, and more difficult to maintain, in the packages which usually are in transit for two weeks, and occasionally for longer periods.

COLONIZATION

Under the preceding topic, "Introduction and Liberation," have been mentioned the foreign puparia of *P. agilis* which were carried through the winter at the gipsy moth laboratory and from which adults were obtained for liberation. Table 27 shows the total colonizations of this species.

TABLE 27.—*Total colonization in New England of Phorocera agilis*

Year	Town	Liberated	
		Females [1]	Males
1910	Andover, Mass.	542	641
1924	Rochester, Mass.	850	200
	Ashburnham, Mass.	450	0
	Peterboro, N. H.	350	0
1925	Barnstable, Mass.	1,065	925
	Falmouth, Mass.	2,000	300
	Taunton, Mass.	2,265	
	Meredith, N. H.	1,000	
	Rochester, N. H.	1,030	
1926	Barnstable, Mass.	415	462
	Brewster, Mass.	1,030	205
1927 [2]	Boxford, Mass.	2,665	2,080
Total		13,632	4,813

Grand total, 18,445.

[1] Most of the females were mated with males before liberation.
[2] In addition to the number of adult parasites liberated, 2,278 parasitized caterpillars were colonized.

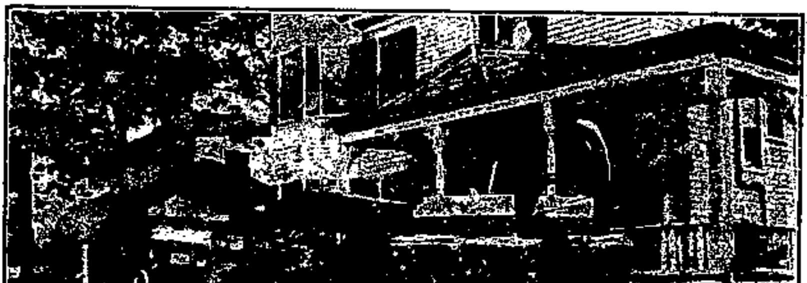


FIG. 46.—Six colonization cages leaving the laboratory at Melrose Highlands, with colonies of adult tachinid parasites for liberation. Note that each cage is wrapped with black paper to keep the cages dark.

After the females have been fertilized and placed in a colonization cage (fig. 9), they are taken by automobile (fig. 46) to a place suitable for liberation. Just before the cages leave the laboratory they are wrapped in black paper to keep them dark and the flies quiet. A large variety of locations with different degrees of gipsy-moth infestation have been chosen as liberating sites for the parasites. The cages containing the adult parasites are constructed so that a portion of one side can be easily removed to allow the flies to escape. The location of each colony is marked on a blue-print map of the town for the laboratory files, and on a tree in the field with white paint.

Recovery and Value of Phorocera agilis

Although many collections of gipsy-moth caterpillars have been made each year near the colony sites of this parasite, no positive evidence has been obtained to show that it has successfully lived through a winter season. This does not prove that the species is not already established, and no reason is known why it should not become established in this country. Its European range is large and varied, including areas where the climate is similar to that in parts of New England. The fact that it has only a single generation and apparently needs no other host than the gipsy-moth leads to the belief that this species should become established here. As has been shown, it is a valuable parasite in Europe and should prove to be a fine addition to the parasites of the gipsy moth that have already been established in this country.

TACHINA LARVARUM Linnaeus

The multibrooded tachinid *Tachina larvarum* Linnaeus is a parasite of both the brown-tail moth and the gipsy moth in Europe, apparently being of more importance as an enemy of the latter. It was one of the first parasites to be received from Europe, and although it has been colonized several times no positive recovery of it has been made.

Foreign Distribution and Abundance

It is widely distributed throughout Europe, and has its counterpart in Japan. This species has been reared at Melrose Highlands from gipsy-moth caterpillars collected in Spain, France, Belgium, the Netherlands, Germany, Austria, Hungary, Switzerland, Italy, and Russia. In Europe it has been reared during the recent foreign investigations in Hungary, Czechoslovakia, Poland, Portugal, Bulgaria, and Yugoslavia.

In some of the early importation work this species was recovered in numbers which suggested that it was one of the most important enemies of the gipsy moth. It was not only recovered from many separate collections, but one lot of caterpillars from the Netherlands produced more puparia than there were hosts in the package, and a similar condition was found in a box of caterpillars from Italy.

During the foreign investigations of the last few years in central and southeastern Europe this species has been the next in importance to *P. agilis* and *Sturmia scutellata* as a tachinid parasite of the gipsy moth, but in Hungary in 1927 it was next to *P. agilis* in abundance, while in Yugoslavia it was second only to Compsilura.

Life History and Habits

The life history of this tachinid has not been studied in detail at the gipsy-moth laboratory. It has several generations annually and appears to need an alternate host. It deposits its rather large, conspicuous eggs on the caterpillars, and the maggots upon issuing immediately enter the host. The mature maggots usually leave the caterpillars before they pupate, although occasionally they issue from gipsy-moth pupae. Some of the earlier work with this species indicated that it occasionally pupated within the body of the caterpillar or pupa, but recent experiments carried on at the gipsy-moth laboratory show that it always issues from its host before pupating. In this respect it differs from *Tachina mella* Walk., which pupates within the body of the caterpillar or pupa. These two closely allied species have been studied at the gipsy-moth laboratory by T. H. Jones and W. F. Sellers, who have noted characteristic differences in the mouth hooks of the first larval instars.

Introduction and Colonization

A few adults were liberated in 1906, 1907, and 1908, but in rather small, unsatisfactory colonies. More satisfactory numbers were liberated in 1909, 1910, and 1911. Up to this time 3,363 were recorded as having been liberated. There were no more liberations until 1925.

More puparia of this tachinid have been sent to Melrose Highlands from Europe during the last three years than of any of the other multibrooded species. These came as puparia packed in small boxes with damp sawdust. They were reared from gipsy-moth caterpillar collections at the temporary stations at Hungary, Czechoslovakia, Yugoslavia, Poland, and Portugal. In 1925 the puparia were removed from the trays each day and sent to the United States every two or three days as they accumulated. In 1926 European rearing work was carried on only in Hungary, where there were two temporary stations. This year the puparia were not only removed from the trays each day, but during the height of the tachinid issuance they were shipped daily to Melrose Highlands, as has been explained in the discussion of the recent foreign work. The results obtained by shipping material every day are very gratifying and are indicated by the liberations made. In 1925, 3,001 *T. larvarum* were colonized in New England, and in 1926, 16,749 adults were liberated. In 1927, 19,039 more were colonized. When these were received they were placed in the emergence and mating cages (fig. 8, B, C, D) and liberated after mating.

The total colonizations of *T. larvarum* in New England between 1906 and 1912 amounted to 3,363; and from 1925 to 1927, inclusive, 38,789 or a grand total of 42,152.

Value of Tachina larvarum

The species has not been positively recovered. During the summers of 1926 and 1927 it was colonized much more satisfactorily than at any previous time, and may now be established, although proof of this may not be obtained for several years. It is one of the most important enemies of the gipsy moth in central and southern Europe, and its establishment here, if that is possible, should assist considerably in the biological control of the gipsy moth and the brown-tail moth.

LYDELLA NIGRIPES Fallen

The tachinid *Lydella nigripes* Fallen was received and liberated in small numbers in 1906, 1907, and 1911, and in satisfactory numbers in 1909. In 1925, 214 adults were liberated; in 1926, 2,198; and in 1927, 3,068 more. These were obtained from gipsy-moth caterpillar collections made in Hungary, Yugoslavia, and Poland during these years.

The earlier work with this species showed it to be a very important parasite of the brown-tail moth in Europe, and it was reared in this country from shipments of large caterpillars of this insect which were collected in Spain, France, Belgium, the Netherlands, Germany, Czechoslovakia, Austria, Hungary, Switzerland, Italy, and Russia. During the last few years it has been encountered as a gipsy-moth caterpillar parasite in the tray work at Debrecen, Baja, Galgamacsa, Simontornya, Olaszliszka, and Doboz, Hungary; Rembertow, Poland; and Moscenica, Yugoslavia; and a record was obtained of its being reared from the brown-tail moth in Yugoslavia.

This species is very similar in appearance and habits to *Compsilura concinnata,* being a larvipositing species. It has several generations annually and has been recorded as a parasite of a large number of hosts.

A total of 10,692 adults have been liberated in New England. Those which were put out in 1926 and 1927 had been mated and they may have become established, although no positive recovery of the species has yet been made. The later colonizations may prove successful, but there will be little opportunity to establish this fact for a year or possibly several years. The fact that Compsilura, which has such similar habits, is well established would indicate that this species, if liberated in sufficient numbers and under favorable conditions, should also become established.

STURMIA INCONSPICUA Meigen

Sturmia inconspicua Meigen, called *S. gilva* Hartig in earlier American literature, is another one of the multibrooded tachinids which has often been encountered during the recent parasite investigations in Europe. It has several generations, and has been recorded from a number of hosts. Between 1906 and 1911 it was reared at the gipsy-moth laboratory from gipsy-moth caterpillars which were sent from France, Italy, Russia, and Germany. During the last few years it has been bred from gipsy-moth caterpillars in rearing trays at Bochnia and Rembertow, Poland; Beli Manastir and Moscenica, Yugoslavia; Debrecen, Baja, Simontornya, Olaszliszka, Doboz, and Galgamacsa, Hungary; and Belki, Czechoslovakia. It was one of the principal parasites of the gipsy moth at Rembertow, Poland in 1927 and appears to be more plentiful in the north.

It was doubtfully colonized in 1906, larger numbers were liberated in 1909, and a few more were colonized in 1911. In 1925 about 1,150 adults were liberated. These were obtained by rearing them from one of its hibernating hosts, *Lophyrus pini* L., collected near Bochnia, Poland. The details of this work have been given under the discussion of the foreign work for 1925. When these puparia arrived at Melrose Highlands they were put into the tachinid rearing cages where adults could emerge and become fertilized. They did not mate readily and were rather inactive, but were kept at the laboratory for a number of days so that a large number of the females could be fertilized before liberation. The puparia came packed in damp sawdust and were kept in cold storage during the ocean voyage. Subjection to the cold for some 8 or 10 days may have been the cause of the inactivity of the adults. Over 15,000 puparia were received from Europe in 1927, resulting in the liberation of 4,698 adults. Most of the puparia were reared from gipsy-moth caterpillars in Poland.

A total of 13,364 adults have been liberated. The species has not been recovered and whether it became established as a result of the colonizations of 1925 and 1927 is not known.

TRICHOLYGA SEGREGATA Rondani

The tachinid *Tricholyga segregata* Rondani, referred to as *T. grandis* Zetterstedt in earlier American literature, is a parasite of the caterpillars of the brown-tail moth and more commonly of the gipsy moth, and also of several other insects. It is very similar to *Tachina larvarum* and *T. mella*, but in contrast to *T. larvarum* it usually pupates within the host caterpillar or pupa.

It was reared from collections of gipsy-moth caterpillars and pupae from southern France, Belgium, the Netherlands, Germany, Czechoslovakia, and Italy during the years between 1906 and 1911. The most recent European work has shown it to be present in Spain, Portugal, northern Africa, and, sparingly, in Bulgaria.

During the early colonization work it was confused with Tachina, and the two species were mixed in the liberations so that the exact number which were colonized is not known. A few were liberated in 1906 and 1907, a rather large colony was liberated in 1909, and in 1911 a few. The total liberations for the early work amounted to 8,766. In 1924 72 adults, in 1925 145 adults, and in 1927 340 more, which came from Spain, Portugal, and Algeria, were colonized, making the total liberations of *T. segregata* 9,323.

This species was doubtfully recovered in 1909, at the site of the summer colony, but it has not been recovered since.

CARCELIA SEPARATA Rondani

Carcelia separata Rondani, referred to as *C. gnava* Meigen in previous literature, is another gipsy-moth parasite which has several generations each year and a variety of hosts. It was doubtfully colonized in 1906 and a few were liberated in 1907 and 1908. In 1909 it was received in gipsy-moth caterpillar collections in large numbers from southern France, and in smaller numbers from Germany, Czechoslovakia, Austria, Hungary, and Italy. In 1910 a few were colonized, and in 1911 a small number which came from Italy were liberated. No more were colonized until 1925, when 167 adults were liberated.

This parasite was reared in 1927 from the gipsy moth in several countries in Europe, but most of the 1,106 adults liberated in New England that year were obtained in Hungary from collections of larvae of the satin moth, *Stilpnotia salicis*.

This species seems to be rather local, and has never been received in large numbers except during the shipments of 1909. It has not been noted as an important parasite of the gipsy-moth caterpillars during the last few years' investigations in Europe, but has been recovered from Spain, France, Czechoslovakia, Bulgaria, Yugoslavia, and Hungary.

A total of 17,061 adults have been liberated, most of which were colonized in 1909 when the species was received in large numbers from gipsy-moth caterpillar collections from southern France. The species has not been recovered.

According to Muesebeck *C. separata* Rondani and *C. gnava* Meigen have been confused and the tachinids which were reared from *Stilpnotia salicis* and liberated in 1927 were *C. gnava*.

ZENILLIA LIBATRIX Panzer

The tachinid *Zenillia libatrix* Panzer appears to be more a parasite of the brown-tail moth caterpillar than a parasite of the gipsy moth. It has been recorded as a parasite of several other insects. It is one of the species which has the habit of depositing its eggs on the foliage to be eaten by the caterpillars. Only limited studies of its life history have been made at the gipsy-moth laboratory. A few have been reared from gipsy-moth caterpillars in the recent foreign work, and these have been used at the gipsy-moth laboratory in experimental work until 1927, when 327 adults were colonized. This species has been liberated in small numbers (only 504 individuals altogether). From 1906 to 1910 only 177 adults were liberated. They were obtained from brown-tail-moth caterpillars which came from France, Germany, Austria, Hungary, Italy, and Russia. In 1927 a few were reared from gipsy-moth caterpillars in Hungary, but most of them came from Yugoslavia.

CROSSOCOSMIA SERICARIAE Coronalia

The tachinid parasite, *Crossocosmia sericariae* Coronalia, of the silkworm in Japan was reared in considerable numbers from gipsy-moth pupae by J. N. Summers while he was studying the parasitism of the gipsy moth in that country during 1922 and 1923. In its habits and life history it is so similar to *Sturmia scutellata*, which is now well established in this country, that no serious attempt has been made to introduce the species. During both years it was an important gipsy-moth pupal parasite, and in some collections nearly all of the pupae were killed by it. Doctor Summers states that it plays in Japan about the same rôle of importance that *S. scutellata* does in this country.

It was first received at Melrose Highlands in 1908, when a few puparia were found in shipments of Japanese gipsy-moth pupae. The following spring no adults emerged, owing to the poor condition of the puparia when they were received. In 1909 more puparia were recovered from gipsy-moth pupae sent from Japan, and from these a few adults were reared the following spring. These were colonized in New England with a few adults of a species of Crossocosmia sent from France which were apparently identical in structure with the Japanese form. A total of 700 adults of Crossocosmia were liberated during 1910. It has not been liberated since, and has never been positively recovered.

PUPAL PARASITES

BRACHYMERIA INTERMEDIA (Nees)

The species *Brachymeria intermedia* (Nees) has been described at some length by Howard and Fiske (*14*) under the name of *Chalcis flavipes* Panzer. More recent investigation shows that this was a misidentification, and that *Brachymeria intermedia* (fig. 47) was the one they discussed. The life-history studies, however, which were made at that time to prove that it was a primary parasite of the gipsy-moth pupae (fig. 48) seem to have been substantiated by recent studies.

During the early investigation eight different species of Chalcis were encountered in the gipsy-moth work and as some of them were positively injurious the good and bad were destroyed together. In 1908 and 1909, after there seemed to be little or no doubt as to the relation of *B. intermedia* to the gipsy moth, a few were colonized. This species was recovered from gipsy-moth pupae received in 1911 from Hyeres and Charroux, France, and in large numbers from Sora, Orsomarso, and Caltagirone, Italy. It was a very important gipsy-moth enemy that year in Sicily, and from about 16,500 gipsy-moth pupae which were sent to the laboratory at Melrose Highlands 15,567 adult parasites were obtained and colonized.

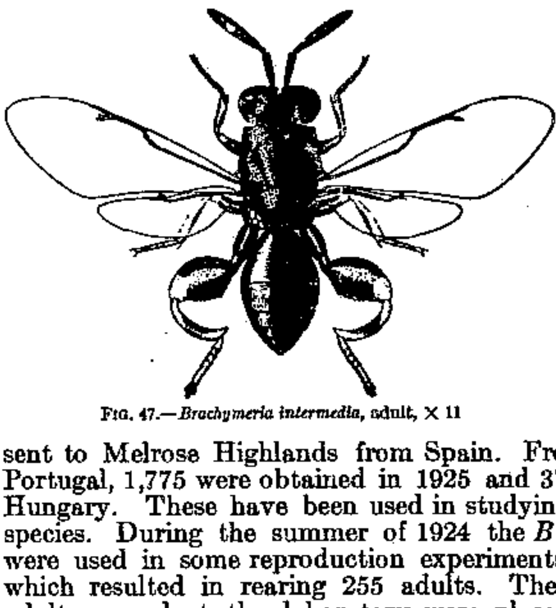


FIG. 47.—*Brachymeria intermedia*, adult, × 11

In 1924, 307, and in 1925, 956 *B. intermedia* were recovered from gipsy-moth pupal collections which were sent to Melrose Highlands from Spain. From collections made in Portugal, 1,775 were obtained in 1925 and 37 specimens came from Hungary. These have been used in studying the life history of this species. During the summer of 1924 the *B. intermedia* from Spain were used in some reproduction experiments on gipsy-moth pupae, which resulted in rearing 255 adults. The foreign stock and the adults reared at the laboratory were placed in different types of cages for hibernation. A few females of both the imported stock and the bred stock lived through the winter and were used in further reproduction studies.

Again in 1925 the foreign *B. intermedia* were used in investigating the habits of this species and over 2,000 were hibernated at the laboratory. Of these only 198 females lived through the winter. These were used during 1926 in reproduction experiments.

Usually only one adult issues from a host. The females are ready for oviposition shortly after emergence. The period from the time of oviposition to the adult stage ranges from 20 to 40 days, according to Muesebeck. There are annually one complete generation and a partial second one, and females of both generations live through the winter.

Many reproduction experiments have been tried during the last few years by Mr. Muesebeck and Mr. Dowden in investigations to determine whether this species ever acts as a secondary parasite. In all cases the evidence is in favor of the parasite. It has been bred freely on gipsy-moth pupae which were reared in an insectary from the eggs and were positively free of any other parasite. It has also been reared as a primary parasite from pupae of the tussock moth, *Hemerocampa leucostigma*. Attempts have been made to have it parasitize brown-tail-moth pupae, but these have given negative results.

Brachymeria intermedia has been induced in experiments to attack puparia of *Sturmia scutellata*. This always appears to be done reluctantly. Several experiments of this sort have given no reproduction by *Brachymeria intermedia* and dissections have shown perfectly

FIG. 48.—Gipsy-moth pupae showing exit holes of *Brachymeria intermedia*, × 1¾

formed nymphs of *Sturmia scutellata*. In one experiment 19 *S. scutellata* puparia were apparently attacked. Later these were dissected and 1 of them showed no parasitism, 11 of them were perfect nymphs, and 7 contained Brachymeria larvae. These Sturmia puparia had been collected in the field and although it seems likely that these larvae were *Brachymeria intermedia*, they may have been *Brachymeria compsilurae*, which is an important native parasite of *Sturmia scutellata*.

In experiments in which this parasite had a choice of parasite-free gipsy-moth pupae and gipsy-moth pupae which contained Sturmia maggots, the parasite invariably chose the parasite-free pupae for oviposition. Records have been obtained of *Brachymeria intermedia* attacking gipsy-moth pupae which contained maggots of

Sturmia scutellata, but in no case has *Brachymeria intermedia* reproduced under such circumstances.

The data which have been obtained, only a part of which are given here, indicate that *B. intermedia* is a primary parasite of the gipsy moth, and that there is no danger involved in liberating it in this country.

There have been 20,798 adults of this species liberated, most of which were colonized in 1911, but 644 of them were colonized in 1927. The species evidently did not become established from the early colonizations, but this fact does not prove that it can not be established. The liberations were made late in the season in a rather limited area near Boston. It seems likely that this species might survive in the southern part of Massachusetts, where the conditions are more like those in the countries from which this parasite has been obtained in greatest abundance.

BRACHYMERIA OBSCURATA (Walker)

Brachymeria obscurata (Walker) is a Japanese gipsy-moth pupal parasite very similar in habits to the European Brachymeria previously discussed, and much of that which has been said of it applies equally well to *B. obscurata.* This species has been received in small numbers from gipsy-moth pupal collections from Japan. A few were colonized in 1908 and 1909. During the summer of 1923, J. N. Summers brought several living adults of this species to Melrose Highlands from Japan. An examination of the gipsy-moth pupae from which they developed indicated that they had developed as primary parasites. In a small reproduction experiment carried on at the gipsy-moth laboratory a new generation was developed on gipsy-moth pupae. Unsuccessful attempts were made to have them reproduce on several tachinid puparia.

Some of the adults were placed in hibernating quarters in the laboratory yard while others were kept in the cellar of the laboratory. All of those in the laboratory yard died after being exposed to temperatures below zero. The last of those in the cages kept inside died March 24.

The investigations which have been made of the habits of this species indicate that it is a beneficial one, and although it failed to survive a winter in captivity at Melrose Highlands, it might find conditions more favorable for its establishment in the southern part of the area infested by the gipsy moth.

ENEMIES OF THE CATERPILLARS AND PUPAE

CALOSOMA INQUISITOR Linnaeus

The beneficial beetle *Calosoma inquisitor* Linnaeus was introduced and liberated in small numbers during the early gipsy-moth investigations. It has been observed in Spain, Hungary, and Czechoslovakia in rather limited numbers during the last few years. In a shipment of 741 beetles from Spain in 1924, 599 were alive upon arrival at the laboratory. These were used in life-history studies and 18 larvae which were reared from them at the laboratory were colonized.

This species hibernates in the adult stage. The beetles are good climbers and in Europe are occasionally seen in the trees, even on the foliage, where they feed to some extent on gipsy-moth caterpillars. The larvae do not climb. The larger ones feed on gipsy-moth pupae, but the smaller ones prefer softer pupae than those of the gipsy moth. The studies which have been made do not indicate that this species would ever become an important gipsy-moth enemy in New England, but in some locations in Europe, where the gipsy moth lays practically all of its eggs on the undersides of stones on the ground, it may be one of the important factors in the control of this insect.

XYLODREPA QUADRIPUNCTATA Schreber

The beetle *Xylodrepa quadripunctata* Schreber has attracted considerable attention during the last two or three years in the gipsy-moth investigations. It has been found feeding to a small extent on gipsy-moth caterpillars in Spain, Hungary, and Czechoslovakia. A few adults were received in 1924 from Spain, and in 1925 a few more came from Spain and Czechoslovakia. Of these, 100 adults were liberated, as also were 15 larvae which were obtained from reproduction work at the laboratory. More adults were received from Hungary in 1926. Only 370 living adults have been received at the laboratory. These have been used in reproduction work and for investigating the life history and habits of this species.

In these studies the beetle passed the winter in the adult stage and a complete generation was reared. The adults climb trees and feed on gipsy-moth caterpillars, but seem to prefer soft-bodied insects. The larvae are ground-feeding insects and do not climb. When confined with gipsy-moth pupae they will feed on them. These investigations of the life history and habits of this predator, however, together with the observations which have been made in its native lands, indicate that it is not an important enemy of the gipsy moth.

HABROCARABUS LATUS Dej., var. gougeleti Reiche

In Spain during March and April of 1924, adults of the beetle *Habrocarabus latus* Dej., var. *gougeleti* Reiche, were found commonly under stones where they had passed the winter. It was reported to be an important enemy of the gipsy moth and 1,039 adults were collected and sent to Melrose Highlands. Of this number 719 were living upon arrival. They were used for life-history studies. It is a terrestrial form, and the limited studies which have been made of it do not indicate that it is an important gipsy-moth enemy. No liberations of it have been made in this country.

FOREIGN ENEMIES OF THE BROWN-TAIL MOTH POSITIVELY ESTABLISHED

LARVAL PARASITES

APANTELES LACTEICOLOR Viereck

Apanteles lacteicolor (fig. 49) was first discovered as a parasite of the small brown-tail-moth caterpillars at the gipsy-moth laboratory in the summer of 1906. It has proved to be one of the principal enemies of the hibernating brown-tail-moth caterpillars. In addition to being a parasite of this insect it passes a generation on the small gipsy-moth caterpillars and on several native insects.

Foreign Distribution and Abundance

This parasite is widely dispersed in Europe and has been recovered at the gipsy-moth laboratory from small brown-tail moth caterpillars which have issued from hibernating webs collected in the following European countries: France, the Netherlands, Germany, Austria, Czechoslovakia, Hungary, Switzerland, Italy, and Poland, and from Kiev and Simferopol, Russia. Later distribution records have been obtained of its presence in Spain, Portugal, Yugoslavia, Bulgaria, and Rumania, by investigators of the Bureau of Entomology studying the parasitism of the gipsy moth in Europe.

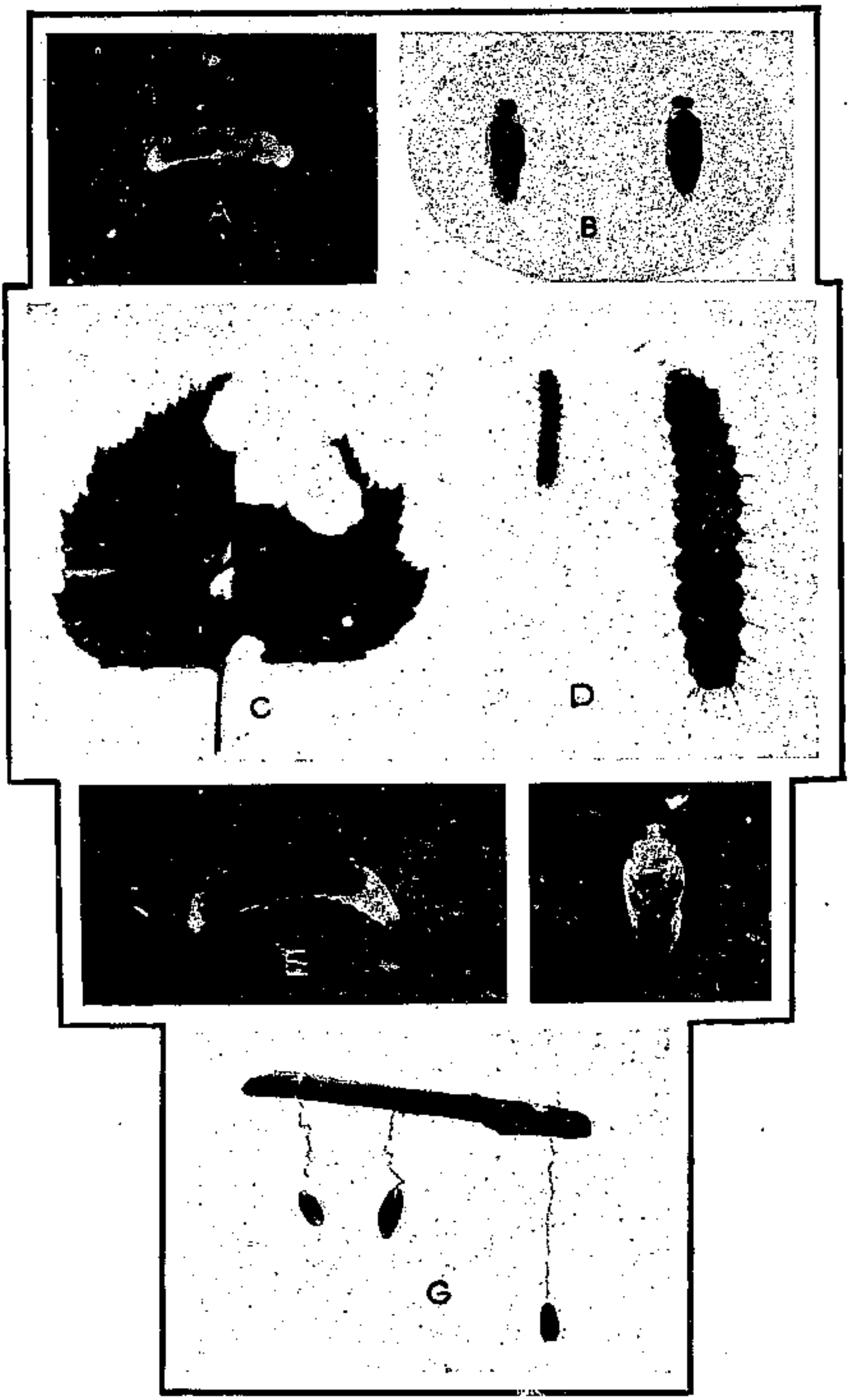
The fact that it is abundant in Europe has been well established by the numbers which have been reared at the gipsy-moth laboratory from European brown-tail-moth caterpillars.

Life History and Habits

The adult parasite is delicate and rather short lived. In August the females may be found parasitizing the first-instar and second-instar brown-tail-moth caterpillars. The recently hatched caterpillars are preferred (*19*), and usually only a single egg is inserted with each oviposition. In experiments carried on by C. F. W. Muesebeck at the gipsy-moth laboratory a single female oviposited in 320 caterpillars, placing two and three eggs in some of them.

The parasite eggs hatch within the brown-tail moth caterpillars a few days after oviposition, and the small larvae pass the winter in their first instar. When the brown-tail-moth caterpillars leave their webs in the early spring and begin to feed, the parasite larvae develop rapidly, passing through the second instar and into the third instar within a few days. The brown-tail-moth caterpillars which are parasitized by *A. lacteicolor* live from a week to 12 days after they commence feeding in the spring. Soon after the death of the parasitized caterpillars the Apanteles larvae issue and spin their cocoons. Many species of Apanteles do not kill their hosts before issuing, but leave them to die several days later.

The cocoons (pl. 6, C) which are constructed by the larvae of *A. lacteicolor* are pure white and measure from 4 to 5 millimeters in length. Most of the cocoons of the first generation are found on or in the brown-tail-moth webs, but the cocoons of the later generations are often placed on the foliage and on the tree trunks. The adult Apanteles issue from these cocoons in about one week and are present in the field during the last week of May and the first two weeks in June.



APANTELES LACTEICOLOR AND METEORUS VERSICOLOR

A, Third-stage larva of Apanteles, anal vesicle still present, × 5; B, Apanteles pupa, × 5; C, third-stage gipsy-moth caterpillar with Apanteles cocoon, natural size; D, two larvae of an undetermined arctiid from the same egg mass, above parasitized by *A. lacteicolor*, below unparasitized, × 2; E, third-stage larva of Meteorus, × 5; F, Meteorus pupa, × 5; G, Meteorus cocoons, natural size. (Muesebeck.)

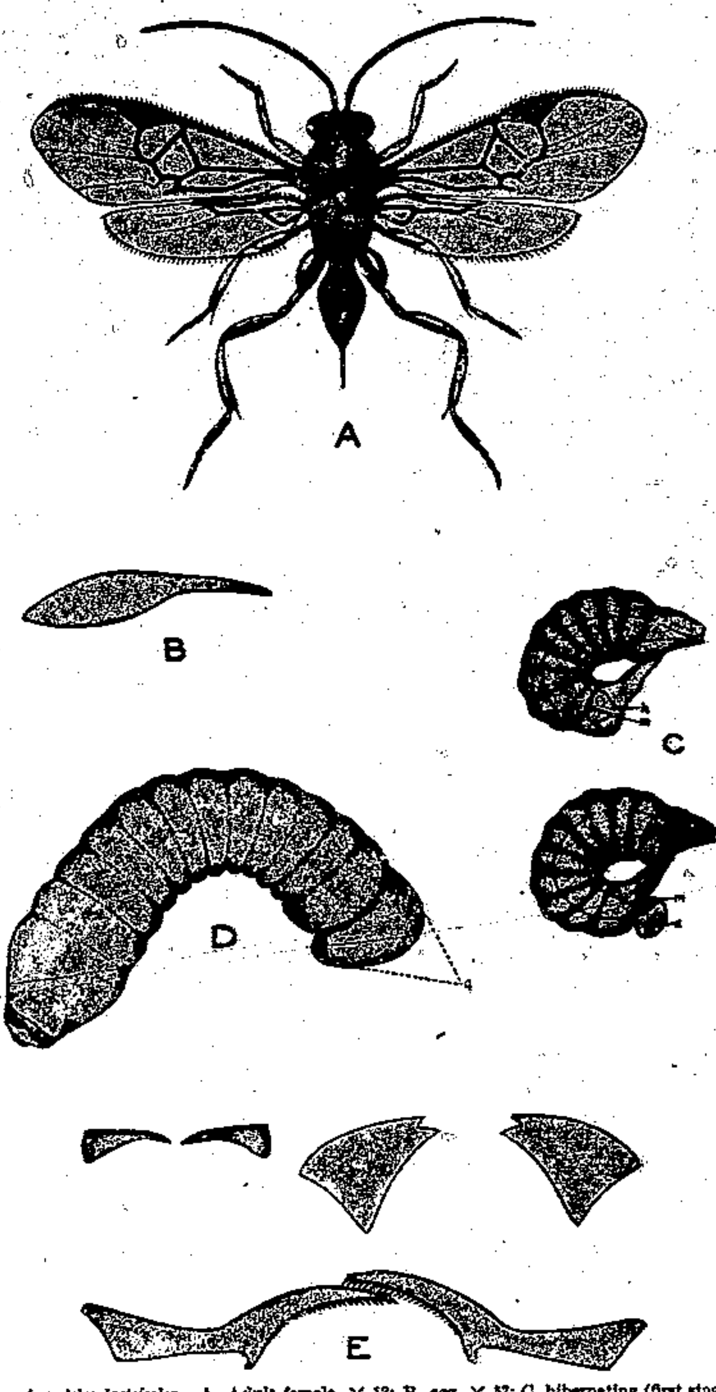


FIG. 49.—*Apanteles lacteicolor.* A, Adult female, × 13; B, egg, × 57; C, hibernating (first stage) larva, × 60, before (above) and after (below) evagination of hind intestine; *h*, hind intestine, showing *m*, place of attachment of midintestine to hind intestine, and *a*, anal vesicle, much enlarged; D, dorsal view of first-stage larva after feeding in spring, ready to pass into second stage, × 60, showing *a*, anal vesicle, much enlarged; E, larval mandibles, showing first stage (upper left), second stage (upper right), and third stage (below). The mandibles of first and third stages are chitinized, those of the second stage not chitinized. Much enlarged. (Muesebeck)

The adults of this generation attack first-instar and second-instar gipsy-moth caterpillars, but only occasionally. There probably is another generation during the summer, with native lepidopterous caterpillars serving as the host. In laboratory experiments this Apanteles readily attacked first-instar caterpillars of *Apatela hasta* Guenée, *Schizura unicornis* S. and A., and an arctiid, and was reared successfully from them and from *Hemerocampa leucostigma* S. and A. It has also been recovered from field-collected caterpillars of *A. hasta, Datana ministra* Drury, and *Hyphantria cunea* Drury.

Importation

The first brown-tail webs were received at the gipsy-moth laboratory from Europe in the winter of 1905–6. The method used in handling them and the difficulties encountered have been explained in great detail by Howard and Fiske (*14*). Only a brief account of this work is necessary here. In the first years the webs were put into large wooden boxes called tube boxes. (Fig. 19, A.) Soon afterwards parasites, caterpillars, and hyperparasites began to issue and enter the tubes. A few of the caterpillars were removed, placed in trays, and fed, and two braconid parasites issued. The first to issue proved to be a new species which was later named *Apanteles lacteicolor* by Viereck. The other parasite was determined as *Meteorus versicolor* Wesm. The discovery of these parasites issuing from small brown-tail-moth caterpillars was a surprise, and plans were made to rear large numbers of them during the following year.

The large wooden tube cages were entirely unsatisfactory for rearing the brown-tail-moth caterpillars, and in 1907 another type of cage similar to a Riley cage was used, but this also did not prove practical. When the shipments of brown-tail-moth webs began to arrive during the following winter a new type of receptacle in which to feed the caterpillars was developed. This was made in the form of a tray constructed with an open top, allowing the operators easy access to its contents, and at the same time preventing the caterpillars from escaping. This tray proved to be more satisfactory than any previous type that had been tried, and it was later known as the Fiske tray. (Fig. 19, B.) The bottom of the tray is covered with white cotton cloth. Around the top is a strip of ½-inch wood, 4 inches wide, projecting inward horizontally from the ends and sides of the tray. On the underside of this strip is spread sticky tree-banding material to prevent the caterpillars from escaping. A strip of wood one-half inch by 1 inch is attached to the inner edge of the horizontal piece at right angles to it, to act as a guard in keeping the operators' fingers from getting into the tree-banding material.

The brown-tail webs are laid on the cloth bottom of the tray. When the caterpillars begin to issue, a double thickness of cloth mosquito netting is placed over the webs. The food for the caterpillars is then laid on top of the netting, and the small caterpillars go from the webs to the foliage on the netting. While the caterpillars are feeding the webs are easily removed by raising the mosquito netting. Before new foliage is put in the trays, another strip of mosquito netting is laid over the caterpillars and the new foliage is placed on this. Most of the caterpillars leave the old foliage for the new, and by raising the second piece of netting with the caterpillars on it the older material beneath is examined for the cocoons of the parasite and later removed. (Fig. 50.)

During the winters of 1906–7, 1907–8, and 1908–9 hundreds of thousands of brown-tail moth webs were received, but it was not until the summer of 1908 that a suitable method was devised to rear the braconids which the small caterpillars contained. The rearing work was more successful in 1908 and still better in 1909. Fewer webs were received during the winter of 1909–10 than during the previous years. These were handled during the summer of 1910 as during the previous summer, and a good supply of *Apanteles lacteicolor* was obtained. After this season only a few brown-tail-moth webs were imported, as all of the parasites which could be obtained in this manner were established.

COLONIZATION

When the species had become established and more colonization of it seemed desirable, similar methods were used to obtain Apanteles.

FIG. 50.—Examining trays containing brown-tail-moth larvae, at the gipsy-moth laboratory to obtain *Apanteles lacteicolor* and *Meteorus versicolor* for colonization

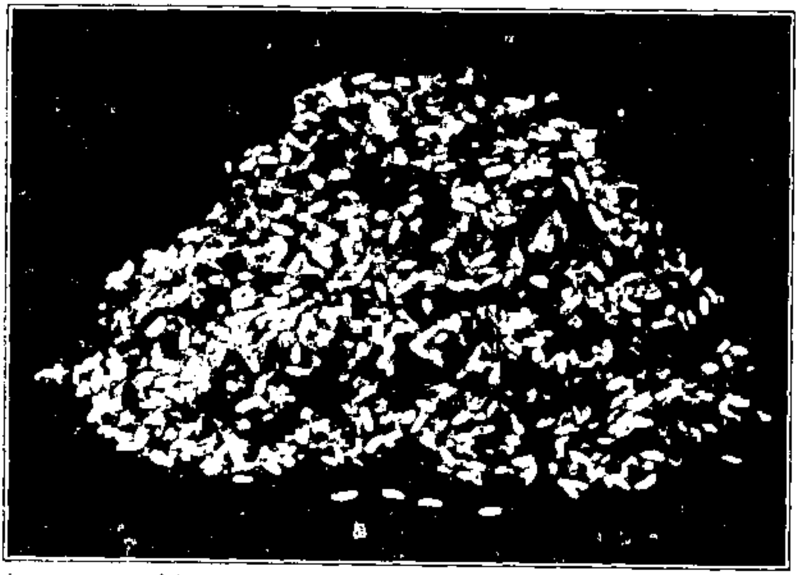
Large collections of brown-tail-moth webs were made during the early winter from various locations in New England. Samples of the different collections were examined to determine the amount of parasitism of the caterpillars. Thus were ascertained the areas where Apanteles was most abundant, and the webs from such locations were used in the spring rearing work. The early liberations of Apanteles are given in Table 28.

During the early colonization work adult Apanteles were liberated, but later when the work developed to a much larger scale the parasite was colonized while still in the cocoon. This method required less handling, and the cocoons (fig. 51) were removed daily from trays and divided into colonies containing 500 each. These were kept in a cool place until several lots were on hand, whereupon they were taken to the field and left in tin cans, nailed to trees, as was done with *A. melanoscelus* (p. 42).

TABLE 28.—[illegible]

Year	New England	Canada	Year	New England	Canada[2]
[illegible]	[illegible]		[illegible]	28,677	17,791
[illegible]	[illegible]		[illegible]	43,834	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	8,452	[illegible]
[illegible]	[illegible]				[illegible]
[illegible]	[illegible]		Total	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	Grand total		[illegible]
[illegible]	[illegible]	[illegible]			

[illegible] of the gipsy-moth [illegible] for liberation [illegible]
[illegible] were [illegible] The re- [illegible] were obtained by rearing them from brown-tail-moth [illegible] in New England.



[illegible] brown-tail-moth [illegible] of the gipsy- [illegible] for colonization

PARASITISM OF BROWN-TAIL-MOTH CATERPILLARS BY APANTELES

In general, two methods have been used to determine the extent of parasitism of the hibernating brown-tail-moth caterpillars. For several years collections of the webs were made in various towns to determine the amount of parasitism of the hibernating caterpillars and the dispersion of this species. Whenever possible, 105 webs were collected in each town. These were kept in cold storage until the early spring. They were then brought to the laboratory where 100 webs from each collection were placed in a large Fiske tray, a separate tray being used for each town. The remaining 5 webs from each town were placed in individual trays. Apanteles for colonization were obtained from the large trays, and the records which were kept of the parasites removed gave an indication of the abundance of the parasite in the area where the webs had been collected. More accurate data were obtained from the small trays, each of which contained a single web. In these trays the caterpillars were counted and a record was made of the parasites reared.

Since the summer of 1918, no further colonization being necessary, the tray-rearing work to determine the amount of parasitism of the hibernating brown-tail-moth caterpillars has been discontinued, as the desired information is better obtained by dissecting the caterpillars. This method is quicker, cleaner, and much more accurate and it can be done during the winter months. Ten webs have been used from each location and approximately 10 living and 10 dead caterpillars from each of these webs have been dissected.

The results obtained by the dissections of the hibernating brown-tail-moth caterpillars in any one year will serve to show the area involved and the amount of parasitism caused by the different species. In Table 29 are given the data obtained during the winter of 1925–26. In this work an attempt is made to dissect caterpillars from the same towns or bordering ones each year. The area involved in these annual dissections is represented in the first 17 towns listed in the table. Usually brown-tail moth webs are collected in from 10 to 15 other towns scattered over the infested area. Some of them come from towns near the border of the infested territory. The data obtained from the dissections made of caterpillars from these miscellaneous collections are shown in connection with the last 11 towns listed in the table. For these dissections no attempt is made to gather webs in the same towns each year.

TABLE 29.—*Results of dissecting hibernating brown-tail-moth caterpillars to determine the degree of parasitism during the winter of 1925–26*

Town	Number of webs	Living caterpillars							Dead caterpillars						
		Number of larvae	Number dissected	Percentage of parasitism					Number of larvae	Number dissected	Percentage of parasitism				
				Apanteles lacteicolor	Meteorus versicolor	Sturmia nidicola	Compsilura concinnata	Total parasitism			Apanteles lacteicolor	Meteorus versicolor	Sturmia nidicola	Compsilura concinnata	Total parasitism
Melrose, Mass.	3	448	35	5.7	0.0	11.4	0	17.1	34	25	8.0	0.0	0.0	0.0	8.0
Beverly, Mass.	10	2,404	106	10.3	.9	18.8	0	30.0	219	94	6.3	6.3	21.3	.0	33.9
Lynn, Mass.	10	2,314	100	2.0	.0	14.0	0	16.0	471	100	8.0	.0	10.0	.0	18.0
Sudbury, Mass.	10	1,844	118	5.1	.0	25.4	0	30.5	283	82	2.4	.0	24.4	.0	26.8
Dover, Mass.	4	814	45	13.3	.0	26.6	0	39.9	53	35	2.8	.0	37.1	.0	39.9
Dracut, Mass.	10	1,967	114	7.0	1.7	18.4	0	27.1	116	86	5.8	9.2	12.8	.0	27.8
Falmouth, Mass.	10	1,223	112	2.6	.8	30.3	0	33.7	120	85	2.3	.0	34.1	.0	36.4
Shrewsbury, Mass.	10	2,601	100	14.0	.0	18.0	0	32.0	181	100	15.0	.0	31.0	.0	46.0
Fitchburg, Mass.	10	2,546	106	10.3	.0	30.1	0	40.4	152	94	10.6	.0	35.1	2.1	47.8
Plymouth, Mass.	10	2,105	100	6.0	.0	30.0	0	36.0	137	100	1.0	.0	47.0	1.0	49.0
Hampton, N. H.	10	3,160	100	11.0	7.0	11.0	0	29.0	195	100	7.0	10.0	23.0	1.0	41.0
Lakeville, Mass.	10	1,861	110	18.1	.0	22.7	0	40.8	127	90	7.7	.0	24.4	.0	32.1
Waterboro, Me.	3	469	30	3.3	.0	3.3	0	6.6	74	30	10.0	.0	13.3	.0	23.3
Manchester, N. H.	10	5,160	100	2.0	.0	12.0	0	14.0	1,373	100	5.0	.0	19.0	.0	24.0
Brockton, Mass.	10	1,686	122	4.1	.0	14.0	0	18.1	103	78	2.5	.0	28.2	1.2	31.9
Concord, N. H.	10	2,680	100	6.0	.0	8.0	0	14.0	232	100	4.0	.0	5.0	.0	9.0
Portland, Me.	5	556	56	16.1	.0	5.3	0	21.4	89	44	9.1	.0	4.5	2.3	15.9
Chatham, Mass.	10	2,159	178	0.0	.0	30.3	0	36.3	24	24	.0	.0	37.5	4.1	41.6
Wellfleet, Mass.	10	5,919	105	0.0	.0	11.4	0	11.4	182	96	1.0	11.5	.0	.0	12.5
Rochester, N. H.	10	2,692	104	4.8	.9	.0	0	6.6	159	96	13.5	1.0	18.7	.0	33.2
Meredith, N. H.	7	1,208	70	7.1	.0	.0	0	7.1	178	70	14.2	.0	2.8	2.8	19.8
Milford, N. H.	10	5,702	122	9.8	1.6	16.4	0	27.8	127	78	10.2	6.4	21.8	.0	38.4
Bath, Me.	10	2,537	100	3.0	.0	8.0	0	11.0	218	100	3.0	.0	14.0	.0	17.0
Freeport, Me.	8	1,740	84	9.5	2.4	13.1	0	25.0	130	78	3.7	3.7	14.1	2.5	24.0
Brewer, Me.	1	116	10	0.0	.0	20.0	0	20.0	32	10	.0	.0	20.0	.0	20.0
Waldoboro, Me.	5	1,959	53	5.6	.0	24.5	0	30.1	227	47	8.5	.0	29.8	.0	38.3
Bar Harbor, Me.	3	278	30	0.0	.0	6.6	0	6.6	92	30	.0	.0	13.3	.0	13.3
Winthrop, Me.	7	2,583	70	5.7	1.4	7.1	0	14.2	138	70	5.7	2.8	15.7	.0	24.2
Total	226	60,800	2,478						5,551	2,041					
Average [1]				6.7	.7	17.2	0	24.6			6.2	1.7	20.3	.5	28.7

[1] The average percentages were obtained by dividing the total number of parasites found by the gross number of larvae concerned in each case.

The parasitism of the hibernating caterpillars shown in Table 29 is typical. It varies from year to year, sometimes being higher than shown in this table, and sometimes not so high. The different parasites also vary in abundance. Some years Apanteles is the leading one in certain sections and an important factor in the control of the brown-tail moth, but during the last few years *Sturmia nidicola* has parasitized the highest percentage of the caterpillars.

An abridged summary of the results of the annual dissections of hibernating brown-tail-moth caterpillars is given in the discussion of *Compsilura concinnata*, in Table 30. This table shows under the parasitism caused by *A. lacteicolor* that practically every year there are sections where this parasite is an important enemy of the brown-tail moth caterpillars, although the average percentage of parasitism credited to Apanteles for the entire area is not very large.

Recovery and Dispersion

When the first liberations of this parasite were made in 1907, the supply was small and the colonies liberated were unsatisfactory. Later in the season and during the following year a search at the sites of these colonies failed to show any trace of this species. In 1908 both large and small colonies of Apanteles were liberated under varying conditions. The first large colony of adults was liberated early in the spring just in time to attack the small brown-tail-moth caterpillars as they were issuing from the webs. A generation in the field was developed in this manner. Under natural conditions, however, adults of *Apanteles lacteicolor* are not found in the field at this time, and it was not surprising that later observations indicated that this colony was not successful. Later in the season two small colonies and a second large one were liberated at about the time when adult Apanteles would naturally be present. No recoveries of this parasite from the small colonies were made. In 1909, however, it was recovered at the site of the second large colony which had been liberated in 1908. The species was also recovered in 1909 at another location, where a very few adult Apanteles had been liberated the previous year just as the small brown-tail-moth caterpillars were feeding and beginning the construction of their winter webs.

In 1910 this species was again recovered and from points several miles distant from where it had been liberated in 1908, showing a rapid spread. By the end of 1910 Apanteles had increased to such an extent that over 4,000 cocoons were obtained in the rearing work of the spring of 1911. From this time the species spread rapidly, and by 1918 had dispersed, aided by the colonization work, over the entire area infested by the brown-tail moth. (Fig. 3.)

Value of Apanteles lacteicolor

This parasite is one of the important enemies of the hibernating brown-tail-moth caterpillars. Records have often been obtained of the parasitism of from 20 to 30 per cent of the caterpillars in individual webs. The species increased and dispersed rapidly, and when the brown-tail-moth infestation was severe over a large part of the infested area this parasite was abundant. During the last few years, since the brown-tail moth has been relatively scarce over most of the territory, this parasite also has become less abundant.

The life-history studies of *Apanteles lacteicolor* revealed that it has several generations annually and attacks small gipsy-moth caterpillars and several native insects. It seems to be dependent upon the brown-tail moth for its hibernating host but needs an alternate summer host. Its present state of relative scarcity over much of the territory is partially explained by the fact that its hibernating host is scarce. This is not the case in southeastern New Hampshire and southwestern Maine, where there has been a rather persistent, heavy brown-tail-moth infestation for several years. In this area the scarcity of *lacteicolor* may be due to the fact that the gipsy moth for a number of years has been relatively scarce there, and possibly some of the native insects which act as alternate summer hosts for *A. lacteicolor* may also have been scarce during this period. During the summers of 1926 and 1927 the gipsy moth increased in abundance, and should this increase continue it will be interesting to see what effect it will have upon the abundance of *A. lacteicolor*. An increase in the abundance of some native insect may at any time provide a summer host for this parasite, and for a time at least help to bring it back to its previous abundance in the area heavily infested by the brown-tail moth.

In addition to the difficulty of finding a suitable host to carry it through the year, *A. lacteicolor* must contend with several species of hyperparasites. The generation which issues from hibernating brown-tail-moth caterpillars usually escapes any heavy attack of hyperparasites, for many of the cocoons are protected within the brown-tail moth webs. In the later generations, however, the cocoons are often exposed, though not for a long time. They become parasitized to a considerable extent, but not so much as *A. melanoscelus*.

In spite of the obstacles confronted by *A. lacteicolor* it is still rated as an important parasite of the brown-tail moth. It has been one of the important factors in causing the decrease of this insect and will undoubtedly become abundant again as is usual with entomophagous as well as phytophagous insects.

METEORUS VERSICOLOR Wesmael

The life history and habits of *Meteorus versicolor* Wesmael (fig. 52) are so similar to those of *Apanteles lacteicolor* that much of the work which has been carried on with hibernating brown-tail-moth caterpillars to obtain data pertaining to Apanteles has served equally well for Meteorus. It passes the winter as a first-stage larva within the body of a hibernating brown-tail-moth caterpillar. The adults are larger and more robust than adult Apanteles, and often live for several weeks and occasionally even for two or three months. There are several generations each year, two of them being on the brown-tail moth.

FOREIGN DISTRIBUTION AND ABUNDANCE

This parasite has about the same distribution in Europe as *Apanteles lacteicolor*. Only rarely has Meteorus been recovered as abundantly as *A. lacteicolor* in the rearing work at the gipsy-moth laboratory with foreign brown-tail-moth caterpillars. It makes up for this deficiency to some extent by attacking medium-size brown-tail-moth caterpillars during the summer. The junior author found this species in hibernating brown-tail-moth caterpillars at Hyeres, France, but in small numbers. At Vetren, Bulgaria, during the summer of 1924, he saw a plum tree with 20 or 30 brown-tail-moth webs on it which

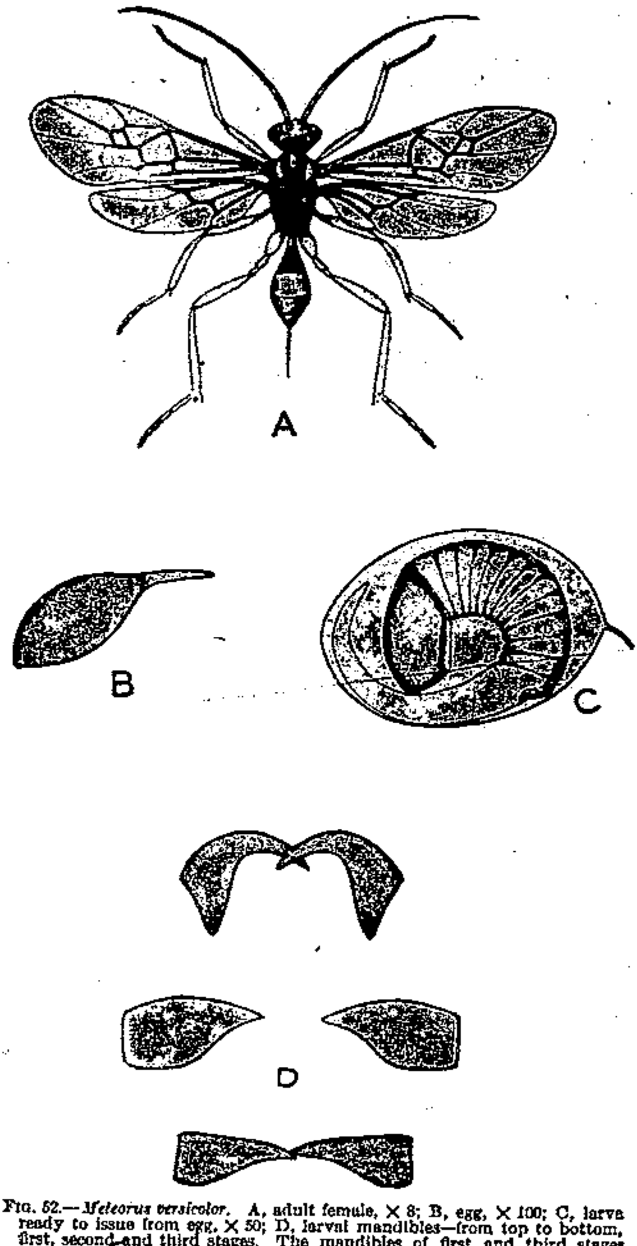


FIG. 52.—*Meteorus versicolor.* A, adult female, × 8; B, egg, × 100; C, larva ready to issue from egg, × 50; D, larval mandibles—from top to bottom, first, second and third stages. The mandibles of first and third stages are chitinized; those of the second stage not chitinized, much enlarged. (Muesebeck)

showed heavy feeding by the caterpillars, but only a few caterpillars survived to pupate. On this tree were several thousand second-generation cocoons of Meteorus. An examination of many of them showed that nearly half of the cocoons had produced adults, and the remainder contained hyperparasites or had given issuance to them. This was the only tree in the immediate vicinity which was observed to have a brown-tail-moth infestation on it. Evidently a few adult Meteorus had parasitized the small brown-tail-moth caterpillars in the fall, and the adults of the spring generation had remained in the tree where there were ample hosts in which to oviposit.

During the same summer Meteorus cocoons were seen commonly, but not in great abundance, on fruit trees which carried a few brown-tail-moth webs and caterpillars, in the back yards of residences in the suburbs of Belgrade, Yugoslavia. In 1925 S. M. Dohanian of the Bureau of Entomology reported Meteorus frequently attacking brown-tail-moth caterpillars at Pancas, Portugal, and it was recovered from a small village not far from Madrid, Spain.

In Europe *M. versicolor* has been recorded as a parasite of a number of lepidopterous caterpillars, but no information is at hand as to what extent it parasitizes the various species.

Life History and Habits

The female parasite oviposits in the small brown-tail-moth caterpillars during August and September. When attacking brown-tail-moth caterpillars a single egg is usually deposited with each insertion of the ovipositor. Muesebeck (*19*) found in laboratory experiments that the females attacked readily quite a variety of other hosts, but often no egg was deposited during the insertion of the ovipositor. This habit is found in other parasites, particularly among the Chalcididae and Pteromalidae. Within the brown-tail-moth caterpillar the parasite egg hatches in a few days, and the winter is passed as a first-instar larva. This larva has a heavily chitinized head and the caudal end of the abdomen is elongated.

In the spring when the brown-tail-moth caterpillars begin feeding Meteorus becomes active and the larvae pass through two spring instars. The development is not quite so rapid as it is with *A. lacteicolor*, but in from 10 days to two weeks the third-instar Meteorus larva issues from its host. The parasitized caterpillar usually molts once in the spring and does not die until after the parasite has issued from it. An interesting comparison between *Meteorus versicolor* and *A. lacteicolor* is that the brown-tail-moth caterpillars parasitized by the latter do not molt in the spring, and are killed before the Apanteles larva issues.

The cocoons (pl. 6, G) are golden brown. They are suspended by a strong thread attached to a branch or twig of the tree on which they have developed. The adult appears in from one week to 9 or 10 days after the completion of the cocoon.

The adults of the first generation are present in the field during the middle of June. They oviposit most readily in the last two caterpillar instars of the brown-tail moth. The caterpillars of *Hemerocampa leucostigma* and *Notolophus antiqua* are eagerly attacked by this species and records have been obtained of *Hyphantria cunea* also serving as a host. Some of the adults of this generation, together with adults of a partial third generation, attack the small brown-tail-moth caterpillars in the fall and hibernate within them.

1781°—29——9

Introduction and Colonization

The information given as to the introduction of *Apanteles lacteicolor* serves for Meteorus, as they came from the same material. Meteorus was first received in 1906 and again in 1907, from hibernating brown-tail-moth caterpillars. There were less than 100 and these were used in reproduction work, but their progeny consisted entirely of males. A few more were obtained from hibernating caterpillars and these were colonized with some others which came in shipments of full-grown and pupating brown-tail-moth caterpillars.

The results obtained the following summer were somewhat better, and 1,000 adults were liberated in a single colony. Later in the season approximately 300 brown-tail-moth caterpillars were collected at the colony site and from them 76 Meteorus cocoons were recovered.

Early in 1909 this parasite was reared from brown-tail-moth caterpillars which issued from webs collected during the winter at the colony site, and the first positive record of its passing the winter in New England was obtained. About 2,000 adults were liberated during 1909. Most of these were obtained from hibernating brown-tail-moth caterpillars received from Europe, although a few came in collections of large caterpillars and pupae. In 1910 and 1911 Meteorus was reared from foreign stock, but only in limited numbers. The few which were obtained, together with a few more reared from New England stock, were liberated. In this manner by the end of 1913 approximately 4,000 Meteorus had been liberated.

During the following years a few more Meteorus were reared from the hibernating brown-tail-moth caterpillars which had been fed in trays at the laboratory to rear *A. lacteicolor* for colonization. In this way 2,900 and 4,145 cocoons of Meteorus were recovered and colonized in 1915 and 1916, respectively. Each year the rearing work was conducted a few Meteorus were obtained, but often in numbers too few to liberate as colonies. They were added to the Apanteles colonies and liberated in the hope that they might become established.

Approximately 11,000 *Meteorus versicolor* have been reared and colonized from the laboratory. Somewhat less than 4,000 of these were of foreign origin. These are not all of the Meteorus which have been introduced from Europe, however, for many foreign brown-tail moth webs were placed in the open in sections in this country infested by the brown-tail moth in an endeavor to establish *Sturmia nidicola*. In most cases the hibernating caterpillars issued in large numbers from these webs and lived long enough in the spring to allow the braconids which they contained to develop. No record is available of the many thousands of Meteorus and Apanteles which developed and gained their freedom in this manner.

Parasitism of Brown-Tail-Moth Caterpillars Caused by Meteorus versicolor

The data which have been gathered on the efficiency of this parasite as an enemy of the brown-tail-moth caterpillars are presented in Tables 29 to 32. Only occasionally do the dissections of its hosts show any appreciable amount of parasitism. In Tables 31 and 32 are given the data obtained from the collections of brown-tail-moth caterpillars. These tables show the parasitism by the second generation of Meteorus on this host, but do not indicate that this parasite has as yet been of prime importance as an enemy of the brown-tail moth here.

Recovery and Dispersion

Recovery of this species was made in the summer of 1907, after a few adults had been liberated. During the fall of the following year it was recovered in very promising numbers from the site of a colony which had been liberated during the spring. Proof of its ability to survive a New England winter was obtained in the spring of 1909 when it was reared from hibernating brown-tail-moth caterpillars which had passed the winter in their webs under natural conditions. The following spring it was reared again under similar conditions, and later in the summer the second generation was recovered from large brown-tail-moth caterpillars in numbers sufficient to indicate that it was increasing rapidly.

Its dispersion during the succeeding years, as determined by rearing it or by dissections of its hibernating host, has been remarkably rapid. This is especially notable because there has never been any large-scale colonization of this species. As early as 1918 it had dispersed over the entire area infested by the brown-tail moth. (Fig. 3.)

Value of Meteorus versicolor

Although this parasite is well spread over the territory infested by the brown-tail moth the records do not indicate that it has been of prime importance as an enemy of this insect. Occasionally in heavy brown-tail-moth infestations its cocoons are found quite abundantly and hang from the twigs of the trees. It has several generations annually, two of them being on the brown-tail moth. Several native caterpillars are also attacked by *M. versicolor*. It is always the loser when in competition with *Apanteles lacteicolor* in hibernating brown-tail-moth caterpillars, and is also seriously reduced by a large number of hyperparasites.

STURMIA NIDICOLA Townsend

The tachinid (fig. 53), formerly referred to as *Zygobothria nidicola* Townsend in American literature, has a single generation each year, passing the winter within the hibernating brown-tail-moth caterpillars, its only known host in this country. It has developed into one of the most important parasites of this insect. Great difficulty was experienced in obtaining this tachinid for colonization, and although at first only a few were liberated they were sufficient for the establishment of the species.

Foreign Distribution and Abundance

S. nidicola appears to be well spread over Europe. It has been recovered at the gipsy-moth laboratory by rearing it from European brown-tail-moth caterpillars, and records of its dispersion show it to have been obtained from France, Spain, Belgium, Germany, Czechoslovakia, Austria, Hungary, and Italy and from Simferopol and Kiev, Russia. Whenever dissections have been made of foreign brown-tail-moth caterpillars this parasite has usually been encountered, and often as high as from 20 to 30 per cent of parasitism, and occasionally considerably higher, has been recorded.

Introduction and Colonization

This species was first discovered to be a parasite of the brown-tail moth at the gipsy-moth laboratory in 1906. Hundreds of thousands of brown-tail-moth webs were imported during the winters from 1905 to 1911, as has already been stated under the discussion of *A. lacteicolor*. Dissections of the hibernating caterpillars which these webs contained showed that many of them harbored the small first-instar maggots of Sturmia. In order to obtain the mature parasites for colonization these caterpillars had to be reared through their feeding period. This proved to be very difficult. Many different ways were tried to rear these caterpillars up to the pupal stage. The small caterpillars invariably would leave their hibernating webs and feed during the early summer through two or three instars, apparently in fine

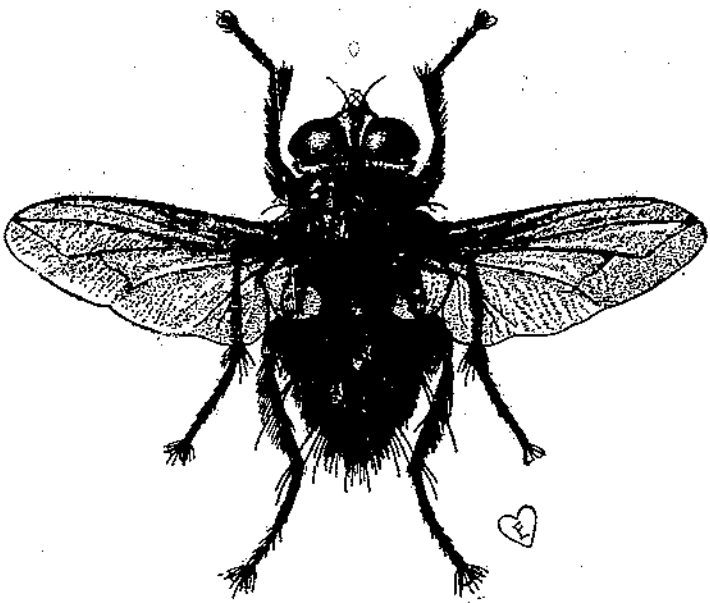


FIG. 53.—*Sturmia nidicola.* Adult male, × 48. (Muesebeck)

condition; but in every experiment for several years, although they were given the most careful attention, practically the entire lot would die just previous to the last larval instars.

In 1908 several Sturmia were reared under these trying conditions. In 1909 the results were similar, and only a very few adults were finally obtained. During the early spring of 1910 the dissections of hibernating caterpillars from Italy and France showed a "very large percentage of caterpillars bearing the larvae of Zygobothria" (*14, p. 291*). The material was divided into two lots. The caterpillars of one lot were placed in trays to rear as usual at the proper time; the other lot of caterpillars was placed in the open on small oak trees. Even under such natural conditions practically all of the thousands of caterpillars which were liberated died before becoming large enough to allow the Sturmia within them to mature. The tray work also resulted as previously and all of the caterpillars died.

During the summers of 1906, 1907, and 1909 about 200 Sturmia were reared from European shipments of full-fed and pupating caterpillars, and in 1911 approximately 3,300 more were reared from shipments. All were colonized.

Parasitism of Brown-Tail-Moth Caterpillars by Sturmia

Two methods are used to determine the amount of parasitism of brown-tail-moth caterpillars by this tachinid. These have already been described under the discussion of *Apanteles lacteicolor*, so it will be necessary here only to refer to the tables presented to ascertain the value of this parasite.

In Table 29 are shown the data obtained in 1925–26 by the dissection of hibernating brown-tail-moth caterpillars from 28 towns scattered over the area infested by this moth. It will be seen that Sturmia was the principal parasite of the hibernating brown-tail-moth caterpillars during that year, when an average of 17.2 per cent of the living caterpillars dissected were parasitized by it. In many places it parasitized over 20 per cent, and in several towns over 30 per cent of the caterpillars showed parasitism by Sturmia.

Under the discussion of Compsilura, in Table 30, is given a summary of each year's dissections of hibernating brown-tail-moth caterpillars from 1916 to 1927. The data in this table show that nearly every year Sturmia has been the leading parasite of the hibernating brown-tail-moth caterpillars, the parasitism frequently averaging 17 per cent and in many cases running over 40 per cent. More data are given in Tables 31 and 32.

Dispersion and Recovery

The first recoveries of this species were in 1910 from field-collected cocoons of the brown-tail moth. The nature of the recoveries showed positively that the species had become established from liberations made previous to that year. These recoveries seemed remarkable, for only 200 specimens had been liberated and these in small lots during 1906, 1907, and 1909. From the time of the first liberations many attempts were made annually to recover the species, but only negative results had been obtained.

During the succeeding years it has been recovered in gradually increasing numbers and over a greater territory. The dissections of hibernating brown-tail-moth caterpillars of 1916–17 showed that this tachinid had spread over practically the entire area infested by its host. Considering the few Sturmia which have been liberated and the limited area in which they were placed, such a rapid dispersion seems rather extraordinary, and particularly so since the species has only one generation annually and depends upon the brown-tail moth for its hibernating host.

Value of Sturmia nidicola

This parasite has been shown to be one of the most important enemies of the brown-tail moth that has been established. It is second only to Compsilura and this only in areas where Compsilura is plentiful. It is often present in areas where Compsilura is absent or very scarce.

Early in the investigations of this species data were secured which indicated that Sturmia would be more efficient in the mild section of New England. Since then it has been proved that this species can survive and parasitize as high a percentage of its host in the colder areas as in the milder part of the area infested by the brown-tail moth.

Much benefit has already been derived from the introduction of *S. nidicola*. Its establishment from such small liberations shows the possibilities in introducing beneficial insects even when they can be obtained only in very small numbers.

COMPSILURA CONCINNATA Meigen

Compsilura concinnata Meigen is an important parasite of the brown-tail moth as well as of the gipsy moth. It has been treated in detail under the parasites of the gipsy moth. The percentage of parasitism of the brown-tail-moth caterpillars caused by Compsilura will be found in Tables 29, 30, 31, and 32.

TABLE 30.—*Summary of annual dissections of hibernating brown-tail-moth caterpillars, winters of 1916–17 to 1926–27, inclusive, to ascertain percentages of parasitism by various species*

Winter of—	Number of towns represented	Number of brown-tail webs examined	Number of larvae dissected [1]	Percentage of parasitism of brown-tail-moth hibernating larvae by— Compsilura concinnata			Apanteles lacteicolor			Meteorus versicolor			Sturmia nidicola			Eupteromalus recovered	Monodontomerus recovered	Percentage of total parasitism
				Lowest	Highest	Average	Lowest	Highest	Average	Lowest	Highest	Average	Lowest	Highest	Average			
1916–17	31	139	7,021	0	3	1	3	28	14	0	20	3	0	23	8	37	0	24
1917–18	42	283	6,651	0	13	1	0	12	4	0	2	1	0	41	16	----	----	20
1918–19	99	818	19,777	0	0	0	0	13	3	0	5	1	0	36	15	50	107	18
1919–20	53	477	L10,102	0	5	1	0	8	2	0	3	1	0	17	9	5	2	12
1920–21	21	199	L3,100	0	3	1	0	14	4	0	5	1	0	30	12	0	17	19
	21	199	D1,161	0	48	14	0	11	5	0	8	2	0	33	11	----	----	31
1921–22	16	123	L1,389	0	1	1	0	15	6	0	4	1	0	28	11	0	0	18
	16	123	D1,066	0	67	11	0	43	9	0	11	2	0	44	17	----	----	30
1922–23	15	133	L1,345	0	2	1	0	14	6	0	6	2	0	39	11	0	0	19
	15	133	D1,315	0	10	2	0	18	7	0	10	3	0	38	12	----	----	24
1923–24	13	110	L1,199	0	3	1	0	13	7	0	0	0	0	35	7	0	0	13
	13	110	D1,191	0	25	5	0	16	9	0	7	1	0	40	9	----	----	23
1924–25	26	215	L2,113	0	2	1	0	66	5	0	3	1	0	47	16	3	13	21
	26	215	D2,187	0	50	4	0	23	4	0	2	1	0	68	17	----	----	26
1925–26	29	233	L2,578	0	0	0	0	18	7	0	7	1	0	58	17	1	3	25
	29	233	D2,141	0	4	1	0	15	6	0	10	2	0	47	20	----	----	29
1926–27	28	247	L2,690	0	6	0.1	1	32	12	0	6	1	0	20	12	92	21	26
	28	247	D2,250	0	4	0.1	0	47	14	0	6	1	0	37	18	----	----	34

[1] L, living caterpillars dissected; D, dead caterpillars dissected.

The results shown in Table 30 are referred to under discussions of the parasites involved. The table is inserted at this point to show the amount of parasitism of the hibernating brown-tail-moth caterpillars caused by Compsilura. This habit is a peculiar one, for, although the host is killed, the parasite also succumbs. Many attempts have been made at the laboratory to rear this parasite from hibernating brown-tail-moth caterpillars but always without success.

In the spring Compsilura attacks the brown-tail-moth caterpillars readily and successfully, often to an important extent, as is shown in Table 31. The caterpillars are collected at about the time they stop feeding and prepare to pupate.

TABLE 31.—*Collections of large brown-tail-moth caterpillars to determine the amount of summer parasitism for 1923*

	Number of larvae collected	Percentage of parasitism caused by—				Total percentage of parasitism
		Compsilura concinnata	Sturmia nidicola	Carcelia laxifrons	Meteorus versicolor	
York, Me.	100	0	1	3	0	4
East Kingston, N. H.	66	45	9	0	0	54
Stratham, N. H.	23	13	0	0	4	17
Kingston, Mass.	15	0	13	0	0	13
Brewster, Mass.	100	3	27	7	0	37
Burlington, Mass.	100	77	10	0	0	87
Hampton, N. H.	100	1	6	5	0	12
Newbury, Mass.	100	53	1	3	1	58
Andover, Mass.	100	63	2	0	0	65
Weston, Mass.	25	20	0	0	0	20
Rowley, Mass.	100	28	8	4	0	40
Scituate, Mass.	100	1	19	0	0	20
Sandwich, Mass.	11	0	18	0	0	18
Bourne, Mass.	100	5	29	22	0	56
Sherborn, Mass.	100	66	1	1	0	68
Salisbury, Mass.	100	2	3	2	0	7
Dedham, Mass.	100	16	19	0	0	35
Total or average [1]	1,340	26	10	4	[2] 1	40

[1] Average percentages derived from original figures, not from the percentages given.
[2] The actual parasitism caused by Meteorus was less than 1 per cent, but wherever a trace of the parasite was found it has been credited with 1 per cent.

The term summer parasitism is used in the heading of Table 31 to denote that the host is attacked in the spring, and that the parasite develops and issues during the same season. It is used in contrast to the parasitism which takes place in the fall, shown in Table 30, of the caterpillars which are to hibernate. The average parasitism by Compsilura for all of the towns was only 26 per cent, but there are several locations represented where the parasitism was considerably higher. The data shown in the table are typical of those which are gathered each year from a similar list of towns.

A summary of the data which have been obtained from similar collections made each year from 1916 to 1927 is given in Table 32.

TABLE 32.—*Summary of data obtained from collections of large brown-tail-moth larvae, 1916–1927, inclusive*

Year	Number of towns	Number of larvae collected	Average percentage of parasitism caused by—			
			Compsilura concinnata	Sturmia nidicola	Carcelia laxifrons	Meteorus versicolor
1916	9	1,629	16	1	23	4
1918	2	1,730	1	4	----	----
1919	11	1,069	7	7	5	3
1920	16	1,887	2	7	4	3
1921	17	2,322	11	7	3	1
1922	15	1,402	1	14	4	----
1923	17	1,340	26	10	4	1
1924	3	917	56	2	1	6
1924	16	[1] 1,427	17	11	1	----
1924	9	[1] 881	18	3	----	----
1925	13	617	35	16	1	1
1925	13	[1] 506	15	11	----	----
1925	6	[1] 250	11	4	----	2
1926	10	525	6	18	.5	2
1926	8	[1] 433	1	12	.4	1
1927	13	486	34	9	.2	2

[1] Brown-tail-moth caterpillars were dissected to determine the degree of parasitism. The other data were secured by rearing the parasite.

Most of the collections have been kept in trays (fig. 19, C), to recover the parasite, but during the last few years a part of many of the collections have been dissected. The latter method is more desirable, for the caterpillars are put in a preservative as soon as they are received at the laboratory and require no further attention until they are dissected. The dissection of the caterpillars can be done after the rush of the summer's work is over, and under such conditions more accurate results are obtained. Also, the handling of large numbers of brown-tail-moth caterpillars or pupae is avoided, whenever possible, because of the extreme irritation caused by their hairs to the operators.

CARCELIA LAXIFRONS Villeneuve

The tachinid *Carcelia laxifrons* Villeneuve has been referred to in previous literature in this country as a brown-tail-moth parasite under the name of *Parexorista cheloniae* Rond. In 1923 R. T. Webber, while consulting with J. Villeneuve at his residence in a suburb of Paris, was told by the eminent dipterist that the brown-tail-moth parasite which was imported as *P. cheloniae* Rond. was not that species but an allied one known as *Carcelia laxifrons* Vill. A few weeks later the junior author and Mr. Webber were privileged to see the Rondani collection of Diptera at Florence, Italy. Here was found the type of (*Exorista*) *Parexorista cheloniae* Rond. Mr. Webber's examination of it proved without doubt that it is not the brown-tail-moth parasite which had been introduced into this country.

Carcelia laxifrons has a single generation annually on the brown-tail-moth caterpillars, and is not dependent on any other host. It appears to be established in this country but has not been one of the important parasites of the brown-tail moth here.

Foreign Distribution and Abundance

This species was often reared from collections containing full-fed caterpillars and pupae of the brown-tail moth from France, Germany, Czechoslovakia, Austria, Hungary, Switzerland, Italy, and Russia. The records obtained at the gipsy-moth laboratory from the foreign material indicate that this parasite is one of the most abundant of the brown-tail moth parasites in Europe.

Life History and Habits

Carcelia laxifrons has its counterpart in this country in what Aldrich and Webber (*1, p. 31, 32*) have designated as *Zenillia cheloniae* Rond., a common parasite of *Malacosoma americana* Fab. and *M. disstria* Hübn. The two flies can not be distinguished but have different biological habits. Thompson (*14, p. 299*) was able to mate males of the foreign race with American females. These females did not attack the brown-tail-moth caterpillars readily and when they did there was usually no reproduction. In 1924 a few puparia were obtained from American tent caterpillars, and a few from brown-tail-moth caterpillars. These were carried through the winter at the laboratory, and during the early summer of 1925, when the flies emerged, they were induced to attack both hosts; reproduction, however, occurred only in their natural host. A more extensive outline of investigation was planned for 1926, but because of the scarcity of the parasite on the brown-tail moth during 1925 a very limited number of Carcelia were obtained, and during the spring of 1926 no fertilized females of the brown-tail moth parasite were secured. A large number of the American tent-caterpillar parasites were obtained, and in the experiments which were carried on with them the same fertilized female attacked both brown-tail moth and American tent caterpillars. Reproduction was secured from the native caterpillars but not from the brown-tail moth. An infertile female parasite obtained from the brown-tail moth deposited 502 eggs on brown-tail moth caterpillars, but there was no reproduction.

The life history of this tachinid has been studied by Townsend (*25*). The female deposits its thin-shelled, pediceled eggs on the brown-tail-moth caterpillars soon after they issue from their hibernating webs. The tiny maggots upon hatching enter the caterpillars, where they pass through four instars, the fourth issuing from large caterpillars. Upon issuing the maggots drop to the ground, where they pass the winter in their puparia. W. F. Sellers, of the gipsy-moth laboratory, has observed that the Carcelia which issue from the brown-tail moth emerge in the spring about a week earlier than do the parasites of the American tent caterpillar. He also obtained a record of *Carcelia laxifrons* and *Compsilura concinnata* maturing within the same host.

Introduction and Colonization

This species is relatively easy to introduce, and the many difficulties encountered in hibernating *S. scutellata* and *P. agilis* have not been experienced with Carcelia. The maggots within the puparia withstand dry conditions in trays or boxes which would cause a heavy mortality to either of the other species. It has been received for colonization by collecting full-fed and pupating brown-tail-moth caterpillars in European countries. These were packed with foliage in small wooden boxes about 8 by 4 by 3 inches, and sent here by mail or express. It was first received in 1906 and colonized in unsatisfactory numbers the same year. In 1907 it was colonized more satisfactorily, and in 1908 more flies were liberated, many of which had been mated previous to liberation. Only a few were liberated in 1909, but in 1910 several thousand adults were liberated. A total of 9,742 *Carcelia laxifrons* have been liberated in New England.

Recovery and Dispersion of Carcelia laxifrons

After the liberations of mated adults in 1908 this species was recovered in a number of collections of brown-tail-moth caterpillars and cocoons which were made at the site of the colonies liberated earlier the same season. In 1909 it was recovered again in rather large numbers, showing a considerable increase and a rapid rate of dispersion. In 1910 and 1911 it was not recovered and was considered lost. For the next few years it was recovered very sparingly, but by 1916 it had spread over practically the entire area infested by the brown-tail moth.

In Tables 31 and 32, under the discussion of brown-tail-moth parasitism by Compsilura, are given the data which have been obtained in regard to the abundance of this species. In Table 31 are shown the data gathered in 1923, and Table 32 shows a summary of them from 1916 to 1927. These records show that the species has not been a large factor in the parasitism of the brown-tail moth in New England except in 1916, when an average of 23 per cent of the caterpillars collected in nine different towns were parasitized by it. Another good record was obtained in 1923 when 22 out of 100 caterpillars collected at Bourne, Mass., showed parasitism by this tachinid.

Value of Carcelia laxifrons

Up to the present time this parasite can not be rated among the leading ones as an enemy of the brown-tail moth here. Its dispersion has been very rapid and it has been present for several years over the territory infested by the brown-tail moth. Occasionally a collection of brown-tail-moth caterpillars shows quite an appreciable amount

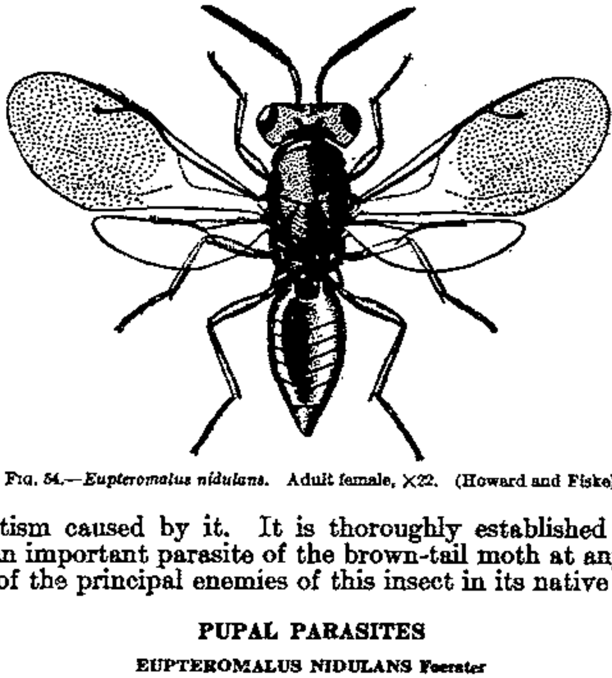


Fig. 54.—*Eupteromalus nidulans*. Adult female, ×22. (Howard and Fiske)

of parasitism caused by it. It is thoroughly established and may become an important parasite of the brown-tail moth at any time, as it is one of the principal enemies of this insect in its native home.

PUPAL PARASITES

EUPTEROMALUS NIDULANS Foerster

Eupteromalus nidulans Foerster is the species described in the earlier publications of the gipsy-moth laboratory as *Pteromalus egregius* Foerst. (*21, p. 28*). It has several generations each year and in New England is of doubtful value as a parasite of gipsy-moth or brown-tail-moth pupae. At times during its history in the United States it has been found abundant in the hibernating webs of the brown-tail moth, where it feeds externally on the small caterpillars. In the spring of 1926 it was discovered by the junior author feeding on the hibernating caterpillars of the satin moth (7). Unfortunately, besides these beneficial habits it is often found acting as a parasite of several braconids, particularly *A. lacteicolor*.

Foreign Distribution and Abundance

Eupteromalus nidulans (fig. 54) is found over much of Europe, and has been reared at the gipsy-moth laboratory from brown-tail-moth webs collected in the Netherlands, Switzerland, Russia, and Japan, and from many parts of France, Germany, Czechoslovakia, Austria, and Hungary. Adults were recovered from many places in quantities which suggested great abundance of the species at these locations in Europe.

Life History and Habits

Eupteromalus passes the winter as a mature larva in the hibernating webs of the brown-tail moth in the pockets with the caterpillars. (Fig. 55.) It also passes the winter as a mature larva within the cocoons of some of the Braconidae. The adults issue in May. They are sturdy little parasites and will live several weeks in confinement if supplied with a small quantity of moisture. There are several generations during the summer, each one requiring from two to three weeks. The adults oviposit freely in a large variety of soft-bodied insects and especially in the cocoons of Apanteles.

Fig. 55.—Portions of brown-tail-moth nests, showing caterpillars attacked by larvae of *Eupteromalus nidulans*, × 3. (Howard and Fiske)

In the fall the adults often enter browntail-moth webs and oviposit on the caterpillars. Before depositing its egg on a caterpillar the female usually pierces the caterpillar with its ovipositor, rendering it quiescent, and sometimes fatally injuring it. The larvae feed externally on the small caterpillars within the webs and there pass the winter as full-grown larvae. In the spring, within two weeks after the caterpillars begin feeding, the parasites have become matured and the adults leave the webs.

Species of Apanteles seem to be favored as summer hosts and those with delicate cocoons suffer more than the species which have tough ones. *A. melanoscelus* is only rarely attacked, whereas *A. lacteicolor* and several native species suffer to a considerable extent. It does not attack the puparia of tachinids to any appreciable degree.

Introduction and Colonization

From the hundreds of thousands of brown-tail-moth webs sent to this country from Europe this species was reared in great numbers. The webs were merely placed in large boxes 30 by 24 by 24 inches, called tube boxes (fig. 19, A), which were made so that nothing could escape except into the numerous glass tubes inserted in the upper third of the boxes. The adult parasites issued from the brown-tail-moth webs and entered these tubes, from which they were removed.

From about 100,000 webs received during the winter of 1905–6, approximately 40,000 Eupteromalus were reared. These were liberated in several colonies where the brown-tail moth was very abundant. During the winter of 1906–7 another 100,000 brown-tail-moth webs were received from various European countries, from which were colonized about 40,000 more adults of this species. The large foreign web collections were continued during the winter of 1907–8, but as the species had not been recovered from the previous liberations it was decided to handle part of the material in a different manner. The first webs to be received during the winter were placed in the laboratory to induce the Eupteromalus to issue early. The adults obtained in this manner were supplied with freshly collected brown-tail-moth webs. The parasites entered them immediately and within three or four weeks a new generation was developed. The rearing work continued throughout the winter. Early in March, 1908, the progeny of 100,000 Eupteromalus in American webs were ready for liberation. These webs were divided into four equal lots and placed in large perforated boxes which were then set out in four widely separated localities, and the parasites were allowed to escape as they issued. It was estimated that 200,000 were liberated in this manner.

Other American brown-tail-moth webs which had been parasitized in the same manner were placed in cold storage together with some of the foreign webs. These were removed to the field in the early fall of 1908 when the new webs were being constructed. It was estimated that about 50,000 Eupteromalus issued at this time.

During the winter of 1908–9 another large lot of Eupteromalus were bred in American webs. They were held in cold storage during the early summer of 1909 and liberated in the fall in one large colony estimated to contain 200,000 individuals. The following summary shows the number of this species which have been colonized in New England: In 1906, 40,000; in 1907, 40,000; in 1908, 250,000; and in 1909, 200,000; making a total of 530,000 individuals.

Collections of Brown-Tail-Moth Webs to Determine the Status of this Species

During the years when this species was being liberated, and for a number of succeeding years, large collections of brown-tail-moth webs were made each year at the colony sites and at various distances from them to determine the effectiveness of the colonizations and the dispersion of Eupteromalus. During the later years of the parasite investigations webs have been collected each year from many locations in connection with the studies of the several parasites which the hibernating caterpillars contain.

No trace of Eupteromalus was found in 1906 or 1907, but in 1908 it was found abundant during the summer, at the places where it had been liberated earlier the same season. In the early part of the winter of 1908 it was found as a mature larva in the webs, proving that it had at least passed through the summer successfully. In the fall of 1909 many Eupteromalus larvae were found in the webs collected from the site of the large summer liberation of approximately 200,000 parasites. The web collections made in the fall of 1909 from the sites of the 1906, 1907, and 1908 colonies failed to produce the parasite during the winter of 1909–10. During the summer of 1910 it was not recovered and appeared to be lost, but it appeared again in December, 1910, and in the first part of the winter of 1911 in brown-tail-moth webs collected from numerous places. For several years it continued to be found in the webs. It has never been very abundant but its dispersion was very rapid. As early as 1916 it had spread over practically the entire area infested by the brown-tail moth.

Table 33 shows the status of Eupteromalus from 1908 to 1915.

TABLE 33.—*Increase of Eupteromalus nidulans in New England, 1908–1915, inclusive*

Place of collection and year	Brown-tail-moth webs collected	Monodontomerus recovered	Eupteromalus recovered
Concord, Mass.:			
1906	22	9	5
1909	158	28	0
1910	100	39	6
1911	100	78	0
1912	100	7	19
1913	100	88	4
1914	100	8	4
1915	100	4	14
Peabody, Mass.:			
1909	325	55	0
1910	100	14	3
1911	100	121	0
1912	100	13	1
1913	100	48	4
1914	100	8	17
1915	100	3	0
Portland, Me.:			
1910	100	65	0
1911	300	93	6
1912	100	12	0
1913	100	38	0
1914	168	91	7
1915	100	118	11
Rochester, N. H.:			
1910	100	37	0
1911	200	90	2
1912	100	90	0
1915	100	1	0

Place of collection and year	Brown-tail-moth webs collected	Monodontomerus recovered	Eupteromalus recovered
Andover, Mass.:			
1909	100	2	0
1910	100	19	97
1911	100	48	0
1912	100	7	5
1913	100	13	11
1914	100	0	18
1915	100	0	18
Pembroke, Mass.:			
1910	125	1	0
1911	100	27	4
1912	100	10	19
1913	100	1	0
1914	100	11	6
1915	100	0	36
Vassalboro, Me.:			
1910	68	1	0
1911	100	1	6
1912	100	3	0
1913	100	72	10
1915	100	0	5
Nashua, N. H.:			
1910	100	19	7
1911	200	45	2
1912	100	6	0
1915	100	6	4

These data are only a few of the typical ones which have been obtained in regard to the abundance of this parasite. After 1916 it gradually became less abundant in the hibernating webs and during the last few years usually less than 10 specimens have been obtained from all of the brown-tail-moth webs examined. There was a slight increase in the abundance of Eupteromalus in the webs examined during the winter of 1926–27 as shown in Table 30. It is probable that it is already established well beyond the brown-tail-moth dispersion line for it is not dependent on this host. No attempts to recover it beyond this line have been made. Although its dispersion has continued to increase, its abundance has materially decreased during the last 10 years, except for a slight increase in 1927.

VALUE OF EUPTEROMALUS NIDULANS

There is not a great deal to be said in favor of this parasite. Even in the years when it was recovered in some abundance the percentage of hibernating caterpillars which were destroyed by it was not large. It seems able to work only in the most easily entered pockets of the webs, and in such places it often deposits so many eggs that the resulting parasite larvae quickly consume all of the caterpillars in the pocket and most of them die of starvation or cannibalism, or mature to small, weak adults. In addition to the ineffectiveness of the species as a brown-tail-moth parasite its apparent preference for braconid cocoons is to its discredit. The recent discovery of its feeding on hibernating satin-moth caterpillars offers, for the present at least, a hope that it will find this species more to its liking.

TOTAL COLONIZATION OF GIPSY AND BROWN-TAIL MOTH PARASITES AND PREDATORS

The colonization of the different introduced parasites and predators of the gipsy moth and the brown-tail moth are summarized in Table 34.

TABLE 34.—*Foreign enemies of Porthetria dispar and Nygmia phaeorrhoea liberated in North America*

Species	Number of individuals of foreign stock liberated	Number subsequently liberated			Total numbers of enemies liberated
		By reproduction from foreign stock	By reproduction from established stock	From New England field collections	
Anastatus disparis Ruschka	138,680			65,505,513	65,644,193
Apanteles lacteicolor Vier	55,000			255,245	310,245
Apanteles liparidis Bouché	76,702	[1] 37,370			114,072
Apanteles melanoscelus Ratz	23,476		132,177		155,653
Apanteles solitarius Ratz	[2] 22,546				22,546
Apanteles porthetriae Muesebeck	12,065	22,522			34,587
Brachymeria intermedia (Nees)	20,798				20,798
Brachymeria obscurata (Walk.) (?)	394				394
Carabus arvensis Fab	108				108
Carabus auratus L	478				478
Carabus glabratus Payk Carabus violaceus L	63				63
Carabus nemoralis L	136				136
Carcelia laxifrons Vill	9,742				9,742
Carcelia separata Rond	[3] 17,061				17,061
Calosoma chinense Kirby	140	128			268
Calosoma inquisitor L	259	27			286
Calosoma reticulatum Fab	83	27			110
Calosoma sycophanta L	2,711			[4] 63,870	66,581
Compsilura concinnata Meig	25,134			122,625	147,759
Crossocosmia flavoscutellata Schiner (?) *Crossocosmia sericariae Corn*	700				700
Ephialtes (Ephialtes) examinator Fab Ephialtes (Ephialtes) instigator Fab	402				402
Eudoromyia magnicornis Zett	4,568				4,568
Eupteromalus nidulans Foerst		[5] 530,000			530,000
Hyposoter disparis (Vier.)	12,543				12,543
Lydella nigripes Fall	10,692				10,692
Masicera sylvatica Fall	23				23
Meteorus japonicus Ashm	5	395			400
Meteorus pulchricornis Wesm	4	118			122
Meteorus versicolor Wesm	3,113			7,887	11,000
Monodontomerus aereus Walk	15,541				15,541
Pales pavida Meig	582				582
Phorocera agilis R. D	18,445	2,278			20,723
Procrustes coriaceus L	75				75
Schedius kuvanae How	1,703		[6] 25,675,884		25,677,587
Sturmia inconspicua Meig	13,364				13,364
Sturmia nidicola Towns	3,500				3,500
Sturmia scutellata R. D	11,097			73,546	84,643
Tachina japonica Towns	471				471
Tachina larvarum L	42,152				42,152
Tachinids unclassified	[7] 9,420				9,420
Tachinids unclassified	[8] 10,499				10,499
Telenomus phalaenarum Nees		[9] 4,650			4,650
Trichogramma spp		[9] 76,000			76,000
Tricholyga segregata Rond	9,323				9,323
Xylodrepa quadripunctata Schr	100	15			115
Zenillia libatrix Panz	504				504
Total	574,402	673,530	25,808,061	66,028,686	93,084,679

Species names set in bold-face type are positively established. Species names set in italics have been received and liberated during the recent foreign investigations.

[1] From a beginning of 288 individuals.
[2] Some doubt as to this species.
[3] Some of these *Carcelia gnava* Meigen.
[4] Some of this number were obtained by reproduction work with foreign and established stock.
[5] Number of foreign stock received not known, but it was very many less than the number given.
[6] Some reproduction from foreign stock but mostly from established stock.
[7] Includes some of multibrooded tachinids liberated from 1906 to 1907.
[8] Mostly *Tachina larvarum* in 1926.
[9] Number of foreign stock received not known.

Table 34 shows a total of 93,084,679 enemies of these insects liberated in this country. Of this number 91,321,780 are parasites of the gipsy-moth eggs. As these species are very slow in spreading, extensive colonization has been necessary in order to establish them more quickly over a large area, and their life histories and habits have made it possible to handle them in large numbers. The other species spread more rapidly, and it has not been necessary to colonize them so extensively. Many of the species have been increased from relatively few individuals. Of the 47 species liberated only 15 are known to be positively established, and of these only 9 or 10 appear to be of importance in New England as enemies of these pests. The list contains many species that are apparently of great importance in their native countries but are not yet established here. A few of them probably never can be, but there is still hope that some of the species recently colonized will become established.

NATURAL MORTALITY OF THE GIPSY MOTH AND BROWN-TAIL MOTH IN NEW ENGLAND DUE TO CAUSES OTHER THAN THE IMPORTED INSECT ENEMIES

None of the native parasites have so far attacked either of these introduced insects to any considerable degree, and they are of slight importance in controlling them. The following native tachinids have been reared in limited numbers from both the gipsy moth and the brown-tail moth: *Tachina mella* Walk., *Achaetoneura frenchii* Will., *Phorocera claripennis* Macq., and *Zenillia blanda* O. S. *Gonia capitata* De Geer, *Phorocera pachypyga* Aldrich and Webber, and *Phorocera saundersii* Will. have been reared from the brown-tail moth only. Native Hymenoptera are reared from these two insects in New England about as frequently as the native tachinids. Some of these hymenopterous parasites are of doubtful value, as they frequently interfere with the efficiency of the imported species. *Trichogramma minutum* Riley is often recovered in small numbers as an egg parasite of the brown-tail moth.

Among the predacious enemies of these insects Kirkland (*in 13, p. 393*) found that the Heteroptera were of some importance. The senior author (*2*) recorded several Carabidae feeding on the gipsy moth, and in 1898 (*3*) reported one of the dermestid beetles destroying a few egg clusters of the gipsy moth. Although dermestids are occasionally observed in gipsy-moth egg clusters in this country they have not been so important here as they sometimes are in Europe.

During the summer of 1925 *Dermestes lardarius* L., a cosmopolitan species, was found in considerable abundance at Belki, Czechoslovakia. P. B. Dowden and A. Ogloblin, who assisted him in conducting the gipsy-moth rearing work there, found the grubs of this insect feeding freely in a great number of freshly laid gipsy-moth egg clusters. It was estimated that at least 50 per cent of the egg clusters in some parts of the infestation contained the grubs of this beetle, and that they were actually eating the eggs was determined by careful examination. A few feeding experiments were conducted which verified these observations. The abundance of the insect is illustrated by the fact that 1,000 specimens were collected in a single day although usually only one grub was found in each egg cluster.

The junior author and R. T. Webber on several occasions have reported seeing gipsy-moth infestations where practically all of the egg clusters had been destroyed and only the hairs which outlined them remained on the tree trunks. Such conditions were seen in Yugoslavia, Rumania, and Hungary. In the light of Dowden's observations it seems probable that these infestations had been cleaned up by dermestids. C. F. W. Muesebeck is making further investigations of the life history and habits of dermestid enemies of the gipsy moth in Europe.

Occasionally spiders destroy the caterpillars of the gipsy moth and the brown-tail moth. Nematodes are reared sometimes from the caterpillars of the gipsy moth and mites have been recorded as destroying their eggs. Forty-six species of birds have been recorded (*16*) as feeding on the gipsy-moth caterpillars and 31 on those of the brown-tail moth but only a few of these can be considered important.

During severe outbreaks of these insects many die from starvation. When conditions are suitable the wilt disease of the gipsy moth and the fungus disease *Entomophthora aulicae* Reiche of the brown-tail moth occasionally become epidemic, and enormous numbers of the caterpillars and pupae are destroyed.

Many caterpillars fail to develop during seasons of unfavorable climatic conditions and severe winter temperatures often kill large numbers of unprotected gipsy-moth eggs and hibernating brown-tail-moth caterpillars.

Notwithstanding the natural mortality of the gipsy moth and the brown-tail moth caused by native parasites and predators, unfavorable climatic conditions, and disease, these pests continued to increase and cause enormous damage to tree growth, and the only relief that has been obtained has been due to the importation of the natural enemies from abroad and the vigorous use of hand measures such as cutting and destroying brown-tail-moth webs, spraying the trees with poisons, and destroying the egg masses by the use of creosote.

CONCLUSION

The foregoing information concerning the imported natural enemies of the gipsy moth and the brown-tail moth reviews briefly their status in America. Although intensive work has been carried on for many years there are still numerous problems connected with the utilization of beneficial insects that require investigation and intensive study. Work of this kind in this country must be correlated with corresponding investigations abroad. A good start has been made with the latter project, facts having been obtained which will make the natural control work more certain of permanent results and perfect the methods used.

The results thus far accomplished by utilizing parasites against the gipsy-moth have been extremely beneficial and have saved the forests of New England from destruction. From 1905 to 1916 the severity of forest defoliation showed no decrease in intensity. In many areas the greater part of the trees most subject to gipsy-moth attack were in a dying condition or had been salvaged by cutting. Foreign natural enemies were being introduced and liberated in substantial numbers, and field recoveries showed that many of the species were becoming established and increasing. From 1920 to 1924 the acreage defoliated gradually decreased until during the latter year few completely defoliated areas could be found. The combined percentage of parasitism by all species increased and in 1923 the maximum was reached, but the following year a decrease occurred. After 1924 the gipsy moth increased rapidly in eastern Massachusetts, and defoliation has reached its former severity over a large part of the older infested area. The deposit of gipsy-moth egg clusters was greater in the fall of 1926 and 1927 over the entire area than for many years, the greater density being noted in the region south of Boston, but severe infestations are present in New Hampshire and Maine. The parasite population was at a low ebb in 1925. There was a slight improvement in 1926 and a noticeable increase of several species in 1927. It is impossible to forecast what conditions will prevail during the next few years. Unless the parasites increase rapidly and do efficient work in the worst-infested areas the chances of preventing the westward spread of this insect will be greatly reduced.

In order to keep the barrier zone in western New England and eastern New York free from infestation the contiguous territory eastward must be kept in good condition.

Artificial methods of control can be employed satisfactorily in cities and towns, and although the expense of operation is rather high, they serve a useful purpose and assist in bringing about the control of the insect. In large forest areas, however, natural control by parasites and the elimination of favored food plants by thinning are the only methods that can be used without undue expense. It will be seen that the success of the parasite work is one of the essential factors in preventing the spread of this pest.

The brown-tail moth is destructive, at the present time, only in the eastern part of the infested territory, and has been more susceptible to the attacks of parasites than the gipsy moth. In some parts of the infested area the increase of the species has been hindered by unfavorable winter conditions. Cutting and destroying the winter webs by hand is an effective remedy.

The result of 24 years of work has demonstrated the great value of this experiment in parasite introduction—the most intensive and extensive that has ever been tried.

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