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PARASITES OF THE BIRCH LEAF-MINING SAWFLY (PHYLLOTOMA NEMORATA)
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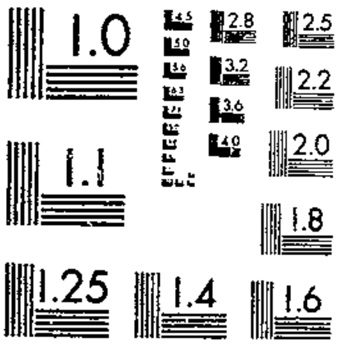

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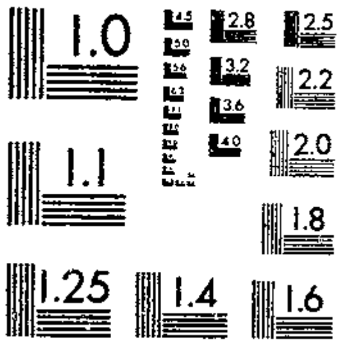

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Parasites of the Birch Leaf-Mining Sawfly (*Phyllotoma nemorata*)[1] [2]

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CONTENTS

INTRODUCTION

The birch leaf-mining sawfly (*Phyllotoma nemorata* (Fall.)) (fig. 1) is a European species. It was present in Nova Scotia as early as 1905, and it appeared abundantly in Maine in 1926. From 1927 to 1933 it caused severe browning of foliage in many sections as far west as the Adirondacks, and it is still abundant in certain areas in Maine. Although the species was recorded in Europe from Scotland, Sweden, and Ostmark, Germany (Austria), no outbreak had ever been reported; it was hoped, therefore, that beneficial

[1] Received for publication May 1, 1940.

[2] This study was conducted under the direction of C. W. Collins at Melrose Highlands, Mass., in 1932, 1933, and 1934, and under the direction of R. C. Brown at Melrose Highlands, Mass., and New Haven, Conn., in 1935, 1936, and 1937. All the foreign work from 1931 to 1934, inclusive, was directed by W. F. Sellers, in charge of the Budapest substation, with the able assistance of W. E. Ripper and G. Bergold, of Vienna. The information on foreign investigations has been compiled by the writer from the annual reports on foreign parasite work submitted by Mr. Sellers. The writer is also indebted to C. F. W. Muesebeck and D. E. Parker for observations on parasites received from Europe in 1930, to H. A. Bess for laboratory assistance in 1935, and to Mary F. Benson and H. B. Bradford for the drawings of the adult insects.

parasites responsible for holding the insect in check might be found there. Requests for parasite material were sent from the Bureau of Entomology laboratory at Melrose Highlands, Mass., to its European substation at Budapest, Hungary, in 1929, but owing to the scarcity of the insect in Europe an infestation was not located until 1930. Small shipments were made from Ostmark that year, and from 1931 through 1934 very satisfactory collections were made from the same general region.

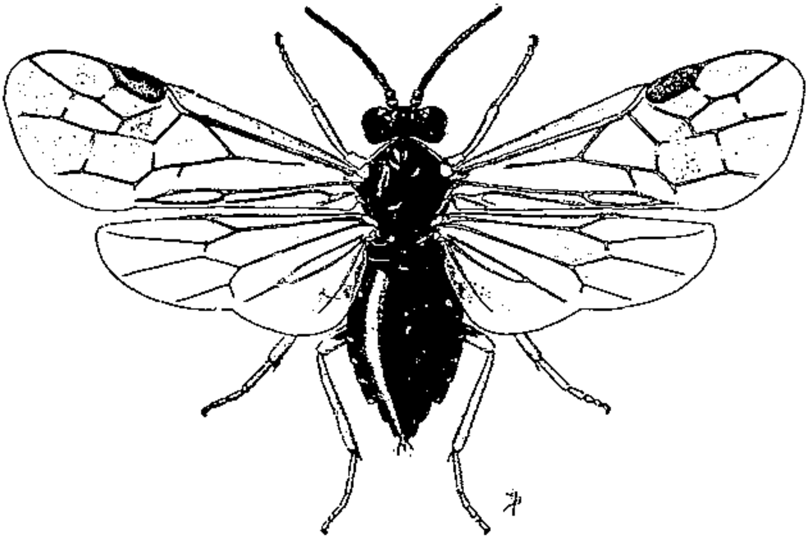

FIGURE 1.—*Phyllotoma nemorata.* Adult female, × 8.

This bulletin is a report of the work done in Europe and of the parasites liberated in the United States, together with biological and morphological notes on the various parasitic species that were reared.

GENERAL LIFE HISTORY OF HOST

The biology of *Phyllotoma nemorata* has been thoroughly studied by Peirson and Brower (*17*),[3] and the following remarks are taken largely from their bulletin.

The insect has but 1 generation a year. The winter is spent as a prepupa within a lens-shaped hibernaculum formed between the upper and lower leaf surfaces. At Bar Harbor, Maine, pupation takes place in June and July, and the adults issue about 9 days later, the height of emergence occurring in the last 10 days of June. The insect appears to be completely parthenogenetic, for no males have been discovered. Egg laying takes place soon after adult emergence and lasts about a week. The eggs are inserted in the leaf tissue between the upper and lower surfaces of the leaf tooth. They hatch in about 19 days. The larva feeds slowly, forming a conspicuous blotch mine (fig. 2, *A*) that remains quite free of excrement. The infested leaf usually hangs downward, and the small pellets of frass

[3] Italic numbers in parentheses refer to Literature Cited, p. 54.

drop through the opening made during oviposition. Feeding is completed in from 5 to 10 weeks. The hibernaculum (fig. 2, *B*) is formed by the prepupa. It is a tough, parchmentlike cell, roughly circular in outline, formed from secretions of the silk gland. Hibernacula are formed from the last of August to the early part of October.

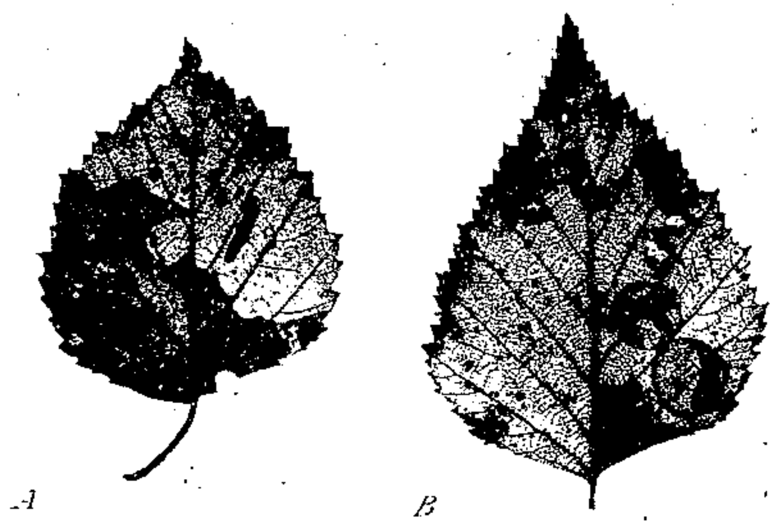

FIGURE 2. *Phyllotoma nemorata*: *A*, Leaf of *Betula pubescens* showing larva in mine. *B*, Hibernacula. Both slightly enlarged. Photos by Ripper (*20*).

NATURAL CONTROL OF PHYLLOTOMA IN THE UNITED STATES

Peirson and Brower (*17*) have also studied the factors of natural control affecting *Phyllotoma* in Maine, and the following notes are a brief summary of their observations.

Weather conditions apparently have little effect on the waterproof *Phyllotoma* hibernacula, but drought may destroy up to 50 percent of the eggs and young larvae.

Birds are the most important predators. Many species have been observed feeding on larvae and tearing open hibernacula to obtain the prepupae. During 1932 and 1933 the estimated destruction by birds was 20 percent of the larvae and 50 percent of the prepupae. Ants destroy large numbers of larvae found in leaves on trees in the vicinity of their nests. A number of miscellaneous predators are of minor importance.

At times *Phyllotoma* suffers severely from competitors. The birch skeletonizer (*Bucculatrix canadensisella* Chamb.) has occurred in destructive numbers in large areas in Maine during the last few years. Where the infestation is heavy a high percentage of the sawfly larvae are unable to mature, for *Bucculatrix* larvae develop more rapidly. The *Phyllotoma* that do complete development are usually small and have a very low reproductive capacity.

Several native species of parasites were reared. *Trichogramma minutum* Riley was the most important egg parasite; and *Gelis urbanus* (Brues), *Agrothereutes slossonae* Cush., *Epiurus indagator* (Cress.), and *Alophosternum foliicola* Cush. were the species most commonly reared from hibernacula and larvae. The extent of parasitization varied greatly, and in many collections it was negligible. The highest egg parasitization recorded was at Bar Harbor and Great Pond, Maine, where it ranged from 21 to 25 percent. The parasitization of larvae and prepupae was also highest at Bar Harbor, ranging from 5.5 to 27.9 percent. Collections made throughout the year indicate that parasitization of the prepupae in the spring by *Gelis* and *Agrothereutes* constitutes the most important parasitic check on the sawfly in Maine.

INVESTIGATIONS IN EUROPE

Areas of Infestation

In 1930 Ripper (*20*) located an infestation of *Phyllotoma nemorata* in the Waldviertel area of Ostmark (Upper and Lower Austria), about 50 km. northeast of Linz in the vicinity of Freistadt. He had no reports of the insect's occurrence there, but visited the area because he believed it might occur in that ecological zone. His belief was justified, and most of the parasite material obtained during the next 4 years was collected in this area. Scouting in 1931 and 1932 showed a general infestation covering about 1,000 sq. km. Birches infested with *P. nemorata* were found commonly between Freistadt (Upper Austria) in the south, Langschlag (Lower Austria) in the east, Kaplitz (southern Bohemia) in the north, and Untermoldau (southern Bohemia) in the west. This part of Ostmark and Bohemia (Czechoslovakia) is very hilly, with many large areas of swampy terrain at an elevation of 630 to 1,000 m. These swamps support a flora characteristic of a considerably more northern latitude, and many species of birch are present, although the tree growth is mostly spruce and pine. Many stands of birch are mixed with spruce on the swamps and swampy meadows, and infestations often occur in mixed growth. Although the insect was distributed throughout the entire district, heavy infestations were scarce, and usually occurred in isolated stands. As a rule an infestation was restricted to 3 or 4 of the older trees in a stand, the remaining birches in the group and the underbrush being uninfested. *Betula alba* L. was the most commonly infested birch, but *B. verrucosa* Ehrh. was also attacked. Collections were made at 45 points, 40 in Ostmark and 5 in southern Bohemia.

Small collections were also made in a second locality about 100 km. directly south of Vienna, near Monichkirchen, Ostmark, in 1931 and 1932. This is a very hilly country, having many wet meadows and a great deal of birch growth, in both mixed and pure stands. *Betula verrucosa* is the only species of birch represented. About 300 sq. km. were scouted, and *Phyllotoma* was found over the entire area, but the infestations were nowhere severe. Elevations scouted ranged from about 600 to 1,200 m., but *P. nemorata* was not found below 850 m. Collections were made at three points in the vicinity of the village.

Bergold noted the presence of *Phyllotoma* at Aich-Assach, about 40 km. south of Ischl, in 1932. The infestation was light, occurring at an elevation of 720 m.

In 1933 *Phyllotoma* was found in another Ostmark area 75 km. south of Linz, near the villages of Poltersluke and Hinterstoder. There was an appreciable infestation at both places, but it was not extensive and no collections were made. The physiography is typical of the area around Monichkirchen.

In the spring of 1930 R. C. Brown, of the Budapest substation, visited Denmark and Sweden in an effort to locate *Phyllotoma* in that part of Europe. Specimens of adult *P. nemorata* taken from all parts of Sweden were present in the museum collections, but there were no known areas where extensive collections could be made. During the summer O. Lundblad, of the Experimentalfaltet, a few miles from Stockholm, inspected the birch forests in the vicinity of Stockholm, and he and Ivan Traghard, of the same institution, sent out circular letters to the forest offices of Sweden requesting information. N. A. Kemner, of the University of Lund (Sweden), and M. Thomsen, of the University of Copenhagen (Denmark), also made special efforts to obtain information and locate infestations, but without success.

Natural Control at the Collecting Points

The *Phyllotoma* investigations constituted only one phase of the program of the Budapest substation. It was therefore impossible to make complete observations throughout the year on the natural control factors affecting this insect. The work was confined to obtaining parasites, and general observations were limited to the period of parasite collections, that is, during August, September, and October.

During the course of this work no *Phyllotoma* infestations were observed in which the insect was seriously damaging the trees. From 10 to 20 infested leaves per tree was considered a fair collection, while occasional trees had 100 to 200 mined leaves. At one point in 1931, 2,000 mines were collected on three trees about 30 feet tall, and in 1934 one large tree was found with 3,500 and another with 6,000 infested leaves. Generally, though, even the most heavily infested trees did not have more than 25 percent of the leaves affected. The fluctuations in infestations that were observed could not be attributed definitely to any particular factors, but it seems almost certain that parasites of the small larvae had an important effect on the host population.

Detailed observations were not made on climatic factors affecting *Phyllotoma*, but when the infested leaves were collected and classified it was found that a considerable number of the mines (8 to 40 percent) were empty or contained small dried-out larvae. The dead larvae in many of them may have been killed by desiccation or frost, for frosts occur at the collecting points early in July and again late in August, and brief experiments conducted by Dr. Ripper indicated that second- and third-stage larvae may be killed by short exposures to a temperature of 25° F.

Birds were important predaceous enemies of *Phyllotoma* larvae and prepupae at both collection areas in Ostmark, and as the season advanced their work was more and more in evidence. The titmouse

Parus major L. was the most important predator, but considerable feeding was also noted by several other species of titmouse and by buntings, finches, and goldhammers. In 1934 the larvae or prepupae in at least 30,000 mined leaves that the collectors had planned on obtaining were destroyed by birds. The infested leaves on 2 trees were removed and classified. One had 134 infested leaves and the other 287, and 69 and 67 percent of these leaves, respectively, had been opened by birds. Throughout 4 seasons counts of infested leaves that had been torn open indicated that from 20 to 50 percent of the late-collected *Phyllotoma* larvae were destroyed by birds.

Ants were important predators of *Phyllotoma* larvae where infested trees occurred in the vicinity of anthills. Often all the mines on trees visited by ants were empty.

Fungi apparently were unimportant in the control of *Phyllotoma*, for less than 1 percent of the mined leaves collected contained infected larvae. Whether the fungi on these specimens were primary or secondary was not determined.

Parasites were important enemies of small *Phyllotoma* larvae, killing large numbers that had mined only a small portion of the leaf. Parasites of large larvae and prepupae were very scarce. Although complete records of infested leaves were kept for each collection point, it is extremely difficult to evaluate the degree of parasitization, for a number of reasons. In the first place, the collectors frequently attempted to obtain parasitized material, and the collections represent partially selected material. In the second place, some of the parasites attacking small larvae have more than 1 generation a year, and many mines were brought in from which the parasite had already issued. Finally, since many of the parasites overwinter as larvae, there was some winter mortality, and the number of adult parasites obtained did not represent the actual number of larvae collected. Nevertheless, some striking instances of parasitization of the small larvae were encountered, and almost everywhere considerable numbers of parasitized small larvae could be collected. At Monichkirchen in 1932 an attempt was made to collect all the *Phyllotoma* mines on a small group of 10 to 12 birches 2 m. high. These birches were in a particularly sunny exposure on the side of a hill. Although it is reasonably certain that all the large mines were collected, some of the small ones may have been overlooked. Of the 397 mines collected, 279 had either chalcidoids or their emergence holes. This represents a parasitization of 70.3 percent, and it is believed that the parasitization of the small larvae explains why large larvae were so hard to collect in that area later in the season. In the Waldviertel area it was estimated that roughly 30 percent of the small larvae were parasitized in 1932.

Collections for the Recovery of Parasites

Collections for each year have been summarized in table 1. In 1931 it was found that a number of chalcidoid parasites attacked the small *Phyllotoma* larvae; therefore, from 1932 through 1934 special collections of small *Phyllotoma* mines were made in August. Collections of large *Phyllotoma* mines to obtain late-issuing parasites, full-grown host larvae, and hibernacula were made in September and early in October. Most of the late material was collected when the larvae were almost full grown and the leaves were still on the trees. Under natural conditions infested leaves drop when larval feeding is practically completed, and hibernacula are rarely formed while the leaves are still on the tree. Early frosts and storms cause the weakened and infested leaves to fall earlier than healthy ones, but larval feeding is successfully completed as the leaves lie on the ground. It is very difficult, however, to find and collect infested leaves after they have fallen, and after the healthy leaves have fallen infested ones are even harder to see. Collections were made, therefore, just before the infested leaves would have dropped. Local labor was hired to collect the infested leaves, which were sorted and counted daily. The discrepancy between the number of large host mines and hibernacula collected and the number of hibernacula sent to America, shown in table 1, is due to mortality of larvae after collection.

TABLE 1.—*Summary of Phyllotoma nemorata collections in Europe, 1930–34*

Place of collection and year	Material collected		Material shipped to the United States			
	Small host mines	Large host mines and hibernacula	Chalcidoid pupae and larvae	Braconid cocoons (*Phanomeris*)	Ichneumonid cocoons (*Epiurus*)	*Phyllotoma* hibernacula
	Number	*Number*	*Number*	*Number*	*Number*	*Number*
Waldviertel area:						
1930		[1] 3,000	132	162		1,866
1931		29,458	21	174		21,538
1932	17,368	43,237	9,170	1,393	54	28,950
1933	16,653	31,981	10,513	854	40	16,253
1934	21,273	151,500	13,863	2,937	597	31,855
Monichkirchen:						
1931		2,157	10	20		1,483
1932		3,511	432			714

[1] Approximate.

Although the early collections of small larvae were made particularly to obtain chalcidoid parasites, large numbers of these parasites were also obtained in the late collections. In 1932, 4,347 were obtained from the small mines and 4,823 from the large mines, in 1933 there were 8,123 from the small mines and 2,390 from the large mines, and in 1934 the small mines produced 2,557 and the large mines 11,306.

In 1933 some of the late-collected material was transferred to Mariabrunn, a suburb of Vienna, the home of Dr. Ripper. The move was made in the interests of economy but proved rather unsuccessful, for there was a heavy larval mortality.

PARASITES REARED FROM EUROPEAN MATERIAL

All the parasites reared from *Phyllotoma nemorata* larvae and hibernacula collected in Europe were sent to the Melrose Highlands laboratory for adult emergence. Some of the chalcidoid parasites of the small larvae issued in the fall, but the bulk of the material hibernated and issued the following spring. Surprisingly few parasites were reared from the large numbers of hibernacula collected, but a considerable number of chalcidoid parasites, representing several species, were obtained from the larval collections, and the braconid and ichneumonid cocoons gave a good adult emergence. Some of the chalcidoids proved to be primary parasites, some secondary parasites, and many of them acted in both capacities. Table 2 gives the number of parasites recovered during the course of the work. The habits of each species will be treated under the discussion of the individual species.

TABLE 2.—*Parasite emergence from Phyllotoma nemorata material received from Europe, 1930–34*

Parasite species emerging from—	Parasites emerging during—										
	1930–31 [1]	1931–32 [1]	1932–33			1933–34			1934–35		
			Fall	Spring	Total	Fall	Spring	Total	Fall	Spring	Total
Large *Phyllotoma* larvae:	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*
Phanomeris phyllotomae [2]	115	155	-----	1,016	1,016	-----	642	642	-----	1,957	1,957
Epiurus foliae	1	1	10	41	51	-----	18	18	231	164	395
Epiurus spp. [2] [3]	-----	-----	-----	2	2	-----	2	2	5	5	10
Agrothereutes pygoleucus	14	-----	-----	53	53	-----	-----	-----	-----	-----	-----
Tranosema pedella	48	44	-----	50	50	-----	28	28	-----	75	75
Mesoleius phyllotomae	26	6	-----	-----	-----	-----	2	2	-----	-----	-----
Hemiptarsenus anementus	-----	-----	-----	-----	-----	-----	-----	-----	-----	124	124
Chrysocharis sp.	-----	15	33	566	599	-----	-----	-----	6	191	197
Small *Phyllotoma* larvae:											
Chrysocharis laricinellae	80	29	179	3,138	3,317	472	266	738	823	4,411	5,234
Sympiesis sp.	4	-----	5	349	354	-----	6	6	18	305	323
Pnigalio cruciatus	-----	-----	33	33	66	1	10	11	9	118	127
Tetrastichus xanthops	-----	-----	92	26	118	110	-----	110	125	59	184
Cirrospilus pictus	2	-----	88	72	160	303	2	305	184	288	472
Cirrospilus vittatus	6	-----	54	27	81	95	-----	95	661	248	909
Closteracerus ?sesquifasciatus	13	-----	8	16	24	7	-----	7	14	43	57
Undetermined chalcidoids	-----	2	-----	3	3	32	-----	32	1	7	8

[1] From the material received in 1930 and 1931 all the parasites emerged the following spring.
[2] *Phanomeris* forms a distinct cocoon in the host mine and *Epiurus* forms a distinct cell.
[3] *Epiurus brevicornis* (Grav.) and ? *E. buolianae* (Hartig); these species could not be separated satisfactorily.

A comparison of the adult parasite emergence (table 2) with the yearly shipments (table 1) shows that, although several species were represented, parasitization of full-grown larvae or prepupae was negligible. The only species recovered in any appreciable numbers was *Phanomeris phyllotomae*, a parasite that forms a distinct cocoon, making it easily separated from the bulk of the material. Peirson and Brower (*17*) found that in Maine there was a much higher parasitization in prepupae (hibernacula) overwintering in the field and not collected until late in the spring than in prepupae collected in the fall. This might well prove to be true in Ostmark also. If importations were resumed, it might be worth attempting, except that the infested area is so swampy that it probably would not be practical.

There was a good emergence of chalcidoid adults each year except from material collected in 1933. That year the local laborers did not distinguish parasitized material well, and a large percentage of the mines shipped to America did not contain parasites. On April 1, 1934, before spring emergence started, a random sample of 400 mines was examined. Of these 225 had dead host larvae, 69 had parasite-emergence holes, 78 had dead parasite larvae, and 28 had living parasites. This condition was remedied the next year. In a random sample of 700 mines examined on April 1, 1935, 48 had dead host larvae, 75 contained dead parasite larvae or had parasite-emergence holes, and all the rest contained living parasites.

In 1932, 682 chalcidoid pupae formed in the mines of an allied tenthredinid birch leaf miner, *Scolioneura betulae* (Zadd.), were sent to America. Emergence from this material was as follows: 499 *Sympiesis* sp. (same as from *Phyllotoma*), 34 *Chrysocharis laricinellae*, 15 *Pnigalio cruciatus*, 3 *Closterocerus* sp., 1 *Cirrospilus pictus*, 1 *C. vittatus*, 1 *Tetrastichus xanthops*, and 1 undetermined eulophid. Since it was not considered advisable to liberate *Sympiesis* sp. in America because of the probability of its acting as a hyperparasite, collections from *Scolioneura* were not repeated.

PARASITES LIBERATED IN THE UNITED STATES

Only five species of parasites reared from *Phyllotoma nemorata* collected in Europe have been liberated in the United States—*Chrysocharis laricinellae*, *Chrysocharis* sp., *Phanomeris phyllotomae*, *Epiurus foliae*, and *Tranosema pedella*. One other species, *Mesoleius phyllotomae*, is undoubtedly a strictly primary parasite, but only a few individuals were obtained, and they all died within a few days after emerging. All the other species recovered have more or less uncertain habits. Most of them are external feeders and may act as either primary or secondary parasites, and it was therefore considered inadvisable to liberate them. A record of liberations is given in table 3.

TABLE 3.—*Liberations of parasites of Phyllotoma nemorata in the United States*

Species	Year	Locality	Living parasites liberated
Chrysocharis laricinellae	1931	Strong, Maine	15 males and 48 females.
	1933	Bar Harbor, Maine	603 males and 742 females.
	1933	Bethel, Maine	600 males and 750 females.
	1934	Bolton, Vt	300 males and 150 females.
	1935	Eustis, Maine	500 males and 1,440 females.
	1935	Stark, N. H.	500 males and 1,200 females.
	1935	North Andover, Mass	130 males and 200 females.
Chrysocharis sp.	1933	Bar Harbor, Maine	70 males and 325 females.
	1935	Eustis, Maine	25 males and 100 females.
Phanomeris phyllotomae	1931	North Conway, N. H.	60 males and 28 females.
	1932	do	28 mated females.
	1933	Bar Harbor, Maine	273 mated females.
	1933	Bethel, Maine	200 mated females.
	1934	Keene, N. Y.	110 males and 100 females.
	1935	Eustis, Maine	488 males and 628 females.
Epiurus foliae	1935	do	50 mated females.
Tranosema pedella	1931	North Conway, N. H.	12 mated females.

PARASITES RECOVERED IN THE UNITED STATES

Two of the five species of parasites liberated against *Phyllotoma* in the United States have been recovered, and these two species, *Chrysocharis laricinellae* and *Phanomeris phyllotomae*, represent a high percentage of the total number of parasites reared from European material. Throughout the 5-year period that parasites were reared a total of 18,523 parasites emerged and 9, 398 of them were *Chrysocharis* while 3,885 were *Phanomeris*. Two other species, *Cirrospilus pictus* and *Tetrastichus xanthops*, which were not liberated but are present in the United States, made up 1,351 of the total number of European parasites reared.

Chrysocharis laricinellae has been recovered from *Phyllotoma* in small numbers at three liberation points—Eustis and Bethel, Maine, and Stark, N. H. It was also introduced from Europe as a parasite of *Coleophora laricella* Hbn., and has been recovered from this host species at several points—namely, Sidney, Maine, Berlin, N. H., Sharon, Vt., and Saranac, N. Y.

Phanomeris phyllotomae was first recovered in this country by A. E. Brower at the Bar Harbor liberation point. In 1937 about 2,000 infested leaves were collected at liberation points in Bar Harbor, Bethel, and Eustis, Maine. In the spring of 1938, 9 *Phanomeris* adults were reared from the Bar Harbor collection and 42 from the Eustis collection.

Experimentation has indicated that it is probably impractical to rear either *Chrysocharis* or *Phanomeris* on *Phyllotoma nemorata* for further colonization. However, field collections for recovery and recolonization may be feasible if these parasites increase somewhat in abundance.

PARASITES OF FENUSA ULMI SUND. IN THE UNITED STATES

During the course of these investigations larvae of the elm leaf miner *Fenusa ulmi* Sund. were collected in Wakefield, Woburn, and Easton, Mass., and in Salisbury and Bellows Falls, Vt. *F. ulmi* is a European species introduced into the United States. Needham, Frost, and Tothill (*14, p. 219*) record it as plentiful in the vicinity of Albany, N. Y., as early as 1895, and note that in America it particularly attacks its chief European host plants, the English and Scotch elms. No detailed study of the parasites of *F. ulmi* was made, but 2 species reared from *Phyllotoma* in Europe were reared from *F. ulmi* in this country. *Chrysocharis laricinellae* was reared from each of the 5 collecting points, and *Tetrastichus xanthops* was reared from the 3 collection points in Massachusetts. It seems quite probable that these species may have been introduced into this country with *F. ulmi*, and may have been here for a number of years. Whether they ever would have spread naturally from infestations of *F. ulmi* to infestations of *Phyllotoma* is problematical.

DISCUSSION OF INDIVIDUAL SPECIES OF PARASITES

From the *Phyllotoma* material collected in Europe about 20 species of parasites were reared. When this material was first obtained, very little was known about any of the species, and so it was necessary to test them in the laboratory to determine their suitability for liberation in the United States. As perhaps could be expected in a leaf-mining host, the majority of the parasites were found to be ectoparasitic; i. e., they fed externally upon the host larva or prepupa within the mine or hibernaculum. These species had to be classed as possibly hyperparasitic, for in general external feeders are polyphagous. They sometimes develop on primary parasites encountered in a mine instead of on the host larva. Only 4 species are internal parasites, and all of these except *Chrysocharis laricinellae* were obtained in very small numbers. As the various species were tried out in the laboratory, considerable information was obtained regarding their biologies. Some species could be studied rather thoroughly. Others were obtained for only 1 year or in such small numbers that only fragmentary notes could be made. Where possible, data on life history, habits, and morphology were obtained, and this information is noted under each species. It was found that larvae of many of the species are so closely related morphologically that considerable repetition could be avoided by referring from one to the other. The following list will indicate the relationship of the 12 species studied, and each species will be discussed as it appears in the list. This arrangement is followed simply for convenience in description, and does not indicate the importance of the various species.

A LIST OF PHYLLOTOMA NEMORATA PARASITES SHOWING THEIR RELATIONSHIP

[The braces indicate a close morphological relationship between immature stages.]

Ichneumonoidea
- Braconidae: External parasite
  - *Phanomeris phyllotomae* Mues.
- Ichneumonidae
  - Ichneumoninae: External parasite
    - *Epiurus foliae* Cush.
  - Cryptinae: External parasite
    - *Agrothereutes pygoleucus* (Grav.)
  - Ophioninae: Internal parasite
    - *Tranosema pedella* (Hlmgr.)

Chalcidoidea
- Eulophidae: External parasites
  - *Sympiesis* sp.
  - *Pnigalio cruciatus* (Ratz.)
  - *Tetrastichus xanthops* (Ratz.)
  - *Hemiptarsenus anementus* (Walk.)
  - *Cirrospilus pictus* (Nees.)
  - *Cirrospilus vittatus* (Walk.)
- Eulophidae: Internal parasites
  - *Chrysocharis laricinellae* (Ratz.)
  - *Chrysocharis* sp.

PHANOMERIS PHYLLOTOMAE Mues.

Phanomeris phyllotomae (fig. 3) is a braconid parasite of the subfamily Exothecinae. It was originally described by Muesebeck (*12*) in 1932 from specimens reared from *Phyllotoma nemorata* collected in Ostmark. The genus *Phanomeris* is a small one. The species with known habits are parasites of leaf-mining sawflies, but almost nothing has been written regarding the biology of any of them.

A total of 5,540 *Phanomeris phyllotomae* cocoons were collected in Europe during the 5 years that work on *Phyllotoma* was conducted there. *Phanomeris* was second in importance to *Chrysocharis laricinellae* as a strictly primary parasite of *Phyllotoma*, but when the large amount of host material collected is taken into account, *Phanomeris* must be considered relatively unimportant as a control factor over the whole area. It attained its greatest importance at Passberg (Waldviertel area) in 1932 and 1933, where 884 out of 4,137 and 166 out of 913 large mines collected produced this species. These figures represent parasitizations of 21 and 18 percent, respectively. At a few other points parasitization reached 5 or 6 percent, but at most places it was negligible. It seems, therefore, as if the species becomes important only under certain conditions. Several good colonies of *Phanomeris* were liberated in New England, and it has been recovered at Bar Harbor and Eustis, Maine.

Phanomeris phyllotomae completes only 1 generation a year. The winter is spent as a full-grown larva within a tough, cigar-shaped cocoon spun in the host larval mine. Pupation takes place in the spring, and the adults emerge by cutting a roughly circular hole through the cocoon and leaf surface. They are delicate insects, rather inactive under laboratory conditions. The majority of males issue before the females. The sex ratio for 3,660 adults was approximately 3 males to 2 females. Emergence extends from about

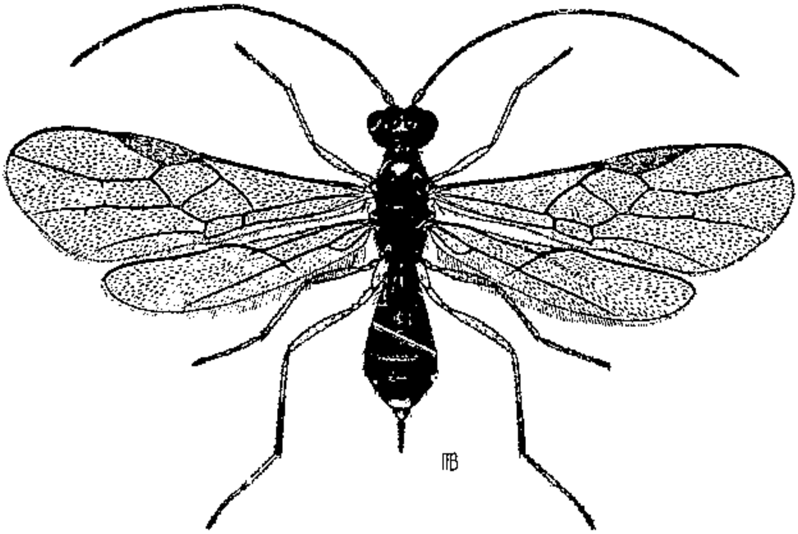

FIGURE 3.—*Phanomeris phyllotomae*. Adult female, × 11.

May 20 to July 10 under laboratory conditions, but it may be later in the field, for *Phyllotoma* larvae are not large enough to be successfully attacked until considerably later in the season. The females, however, are very long-lived. In 1933 a few specimens lived through the summer and oviposited readily late in September. In 1932, 20 females lived an average of 48 days, with a minimum of 32 and a maximum of 61. Mating takes place readily in the laboratory. Coitus averaged 19 seconds. Eggs are deposited in the host larva's mine. Most of them were found near the inner margin of the mine and a few in the immediate vicinity of the host larva. Although eggs were obtained, no very satisfactory observations were made on oviposition. The females were watched for hours, as they sluggishly prodded at the mines with their short ovipositors. Occasionally a host larva was hit, but actual oviposition was not observed. The *Phyllotoma* larvae in cells containing eggs almost invariably had the appearance of being partially paralyzed. Their alimentary tracts were empty, and they lay motionless, making no attempt to feed. If touched, though, they moved actively. The egg hatches in from 36 to 48 hours, and the young parasite larva crawls to its host, where it feeds externally. During the last half of July, 8 to 10 days were spent completing development from egg to cocoon. The cocoon is spun as soon as the larva is full-fed.

It is believed that the tendency to deposit the eggs at some distance from the host larva may result in considerable parasite mortality.

The young larvae can crawl around readily, but apparently many of them die before finding their food supply. In at least 50 percent of the mines observed to contain eggs the parasite larva failed to reach its victim.

Phanomeris material arriving from Europe was almost free from secondary parasites, but the species probably has a number of natural enemies, for it spends a large part of each year in an exposed cocoon. A few adults of *Cirrospilus vittatus* and *Sympiesis* sp. have been definitely reared from the cocoons, and small numbers of *Pnigalio cruciatus*, *Tetrastichus xanthops*, and *Cirrospilus pictus* have been so closely associated with them as to make it seem almost certain that they act as secondaries.

The egg (fig. 4, *A*) averages 0.66 mm. in length and 0.17 mm. in width. The chorion is smooth and hyaline.

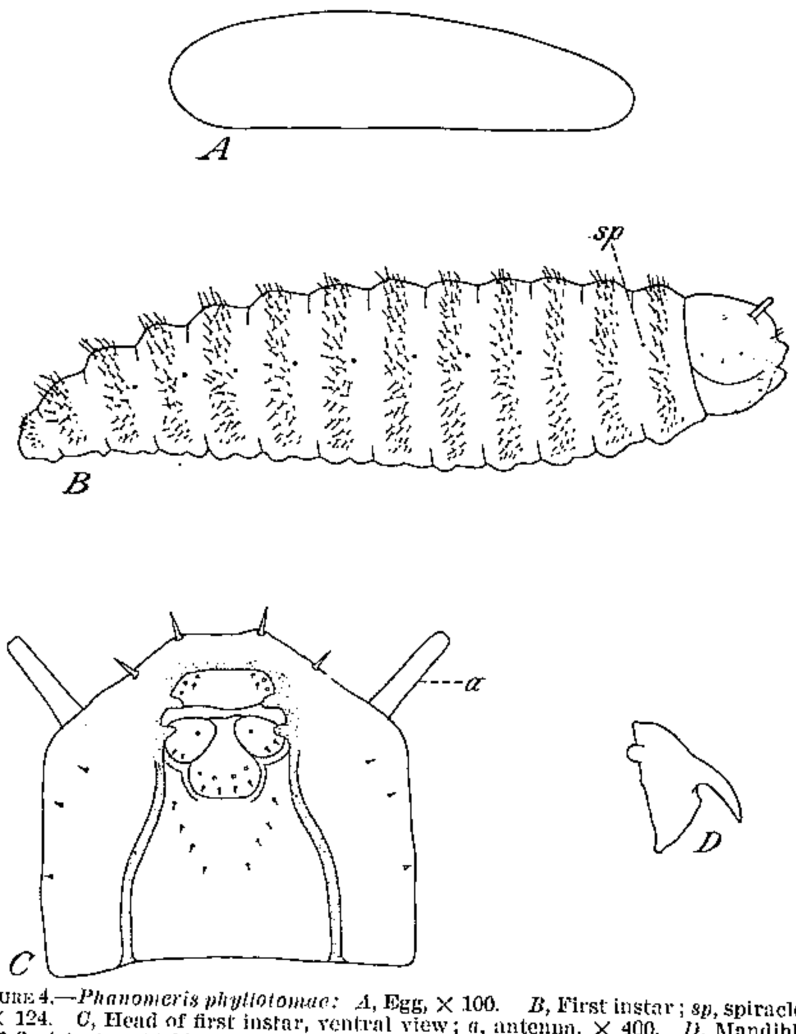

FIGURE 4.—*Phanomeris phyllotomae*: *A*, Egg, × 100. *B*, First instar; *sp*, spiracle, × 124. *C*, Head of first instar, ventral view; *a*, antenna, × 400. *D*, Mandible of first instar, × 780.

There are 5 larval instars. The first instar (fig. 4, *B*) ranges from 0.67 mm. long and 0.17 mm. wide to 0.83 mm. long and 0.21 mm. wide. It has a well-defined head and 13 body segments about equal in length. Each segment bears several transverse rows of long, heavy spines, although on the thirteenth segment the spines are considerably shorter than the others. A narrow area on the venter of each segment is bare. No sensory setae were distinguished on the body segments. There are 9 pairs of minute, open spiracles, 1 near the posterior border of the first thoracic segment and 1 near the anterior border of each of the first 8 abdominal segments. The prothoracic spiracle measures only 0.0025 mm. in diameter. The head (fig. 4, *C*) presents well-defined characters as indicated. The antennae are very long. The hypostoma[4] is particularly heavy. The mandibles (fig. 4, *D*) are sharply pointed and well sclerotized at their tips. They are 0.023 mm. long.

The second instar resembles the first instar, but the cuticular armature is very much reduced. The spines are short and inconspicuous. Five or six rows are present on the dorsum of each segment, but toward the venter the number diminishes rapidly and the lower half of the larva is bare. The posterior segments bear fewer dorsal spines than the anterior segments. Sensory spines are present in this instar in apparently the same number and arrangement as in the full-grown larva, but they are exceedingly difficult to distinguish. The prothoracic spiracles are 0.01 mm. in diameter. The head structures are less heavily sclerotized than in the first instar, but they are clearly defined. The antennae are short. The mandibles closely resemble those of the full-grown larva, although measuring only 0.03 mm. in length. A number of conspicuous urate cells may be distinguished through the body integument.

The third and fourth instars differ little except in size from the second instar.

Fifth instars, or full-grown larvae, (fig. 5, *A*) range in size from about 3.6 mm. long and 1.0 mm. wide to 5.3 mm. long and 2.0 mm. wide. The shape of the body is similar to that of the preceding instars. The most conspicuous change takes place in the color, which becomes bright bluish green as the larva completes feeding. Younger larvae are the usual yellowish white. The bluish-green pigment is apparently contained in the cells of the fat body. These cells are well developed and rather evenly distributed just beneath the body wall. Scattered through the fat body, particularly in the abdominal segments, are many very large, irregularly shaped, yellowish-white urate cells that present a striking color contrast. The cuticle of the body segments is almost covered with short, closely set spines, and a few rows are also present on the posterior ventral portion of the head. A narrow area at the intersegmental sutures is bare, and the thirteenth segment is almost bare. The first 6 abdominal segments have narrow anterior folds or humps on the dorsum, and the sutures setting these areas off are also bare. Each segment bears numerous sensory hairs, but they are so similar to the cuticular spines that they have not been indicated on the drawing except on the thirteenth segment. The prothoracic and first 8 abdominal segments bear 6 pairs; the mesothoracic, metathoracic,

[4] The terminology of the head structures is that of Vance and Smith (25).

and last segment 7 pairs; and the twelfth segment 5 pairs of these sensory hairs. On each segment except the last the hairs are about equidistant from one another in a transverse row around the middle of the segment. On the thirteenth segment there are 4 pairs on the dorsal and 3 pairs on the ventral aspect.

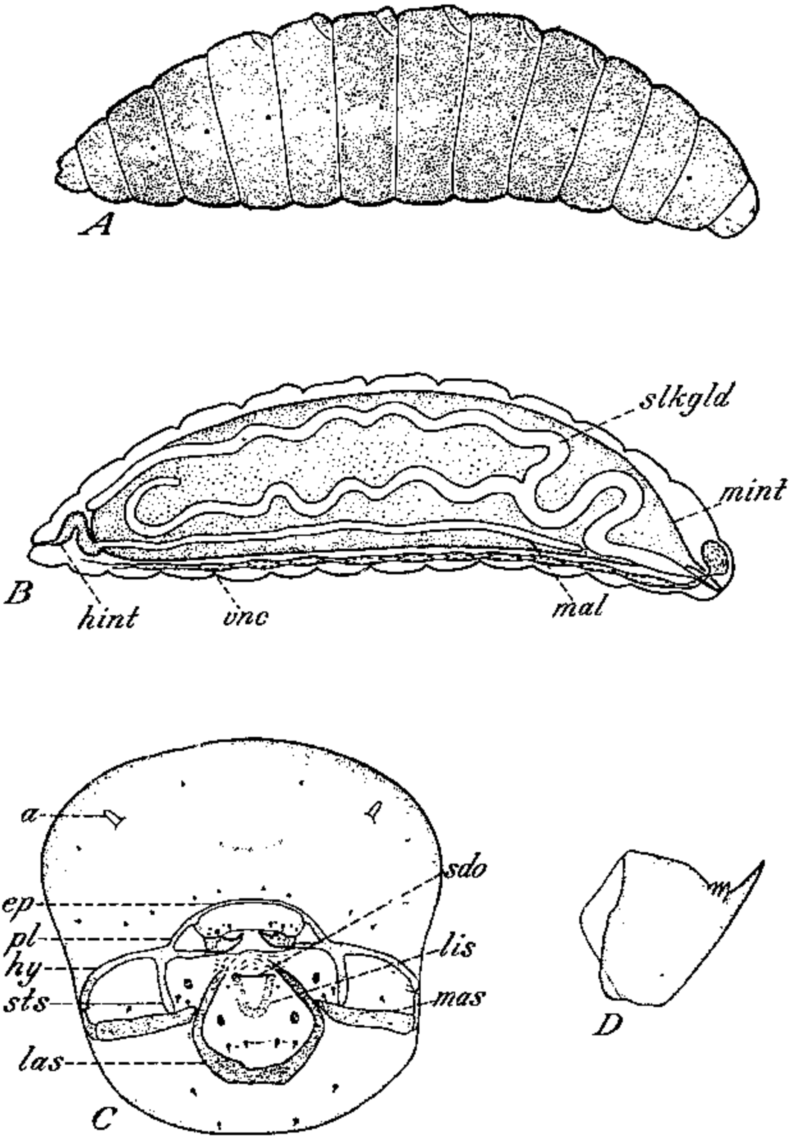

FIGURE 5.—*Phanomeris phyllotomae*: *A*, Full-grown larva, × 26. *B*, Full-grown larva, internal anatomy: *slkgld*, silk gland; *mint*, midintestine; *mal*, Malpighian tube; *vnc*, ventral nerve cord; *hint*, hind-intestine, × 26. *C*, Head of full-grown larva, front view: *a*, antenna; *ep*, epistoma; *pl*, pleurostoma; *sdo*, orifice of silk duct; *lis*, ligular sclerome; *hy*, hypostoma; *sts*, stipital sclerome; *mas*, maxillary sclerome; *las*, labial sclerome; × 144. *D*, Mandible of full-grown larva, × 460.

The head (fig. 5, *C*) presents well-defined external characters which are comparable to those of typical parasitic Hymenoptera as figured by Vance and Smith (*25*). The mandibles (fig. 5, *D*) measure 0.05 mm. in length. The respiratory system presents no differences from the usual braconid type as figured by De Leon (*7*) for *Coeloides dendroctoni* Cush. The prothoracic spiracle measures 0.02 mm. in diameter. The digestive and nervous systems are indicated in figure 5, *B*.

The cocoon is readily seen when a mined leaf is held toward the light. It varies from 4 to 6 mm. in length and from 1.25 to 2 mm. in width, and is noticeably longer than the larva, which can be seen inside. The pupa is enclosed in a thin, closely fitting, transparent skin, through which the adult characters can be plainly seen. The thorax and abdomen are filled with the bright bluish-green body contents of the last larval instar. As the adult characters become plainer, this color is restricted to the abdomen, but even after the adult emerges the abdomen appears bluish green for a number of days.

EPIURUS FOLIAE Cush.

Epiurus foliae (fig. 6) is an ichneumonid belonging to the subfamily Ichneumoninae (Pimplinae). It was originally described by Cush-

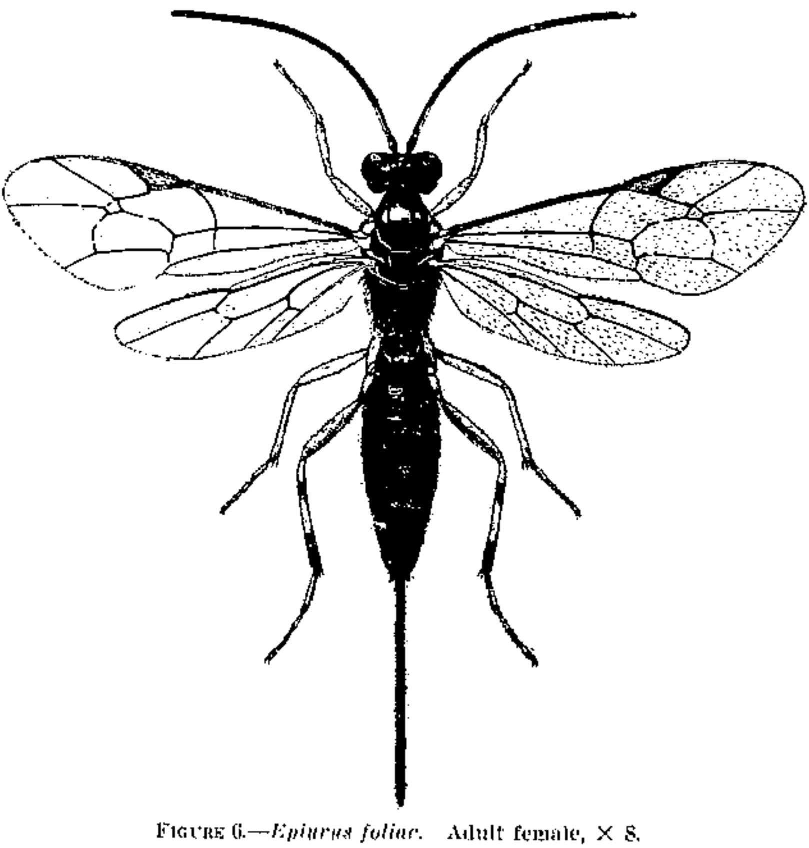

FIGURE 6.—*Epiurus foliae*. Adult female, × 8.

man (*4*) in 1938 from specimens reared from *Phyllotoma nemorata* collected in Ostmark. The writer has not seen very complete notes on the biology of any species of *Epiurus*, but many closely related ichneumonines have been thoroughly treated. Salt (*21, p. 519*) has given an excellent account of *Pimpla detrita* Hlmgr. The species of the genus *Epiurus* whose habits are known attack a wide variety of hosts, most of which are enclosed in leaves, stems, or other protective covering.

A total of 691 *Epiurus* cocoons, almost all of which were *E. foliae*, were obtained from *Phyllotoma* material collected in Europe. Of these 597 were obtained in 1934, but owing to the large amount of material handled that year the species was of minor importance. It was present at almost all the collecting points, but the highest parasitization obtained at any one point was only 2 percent.

Epiurus foliae hibernates as a prepupa, but considerable difficulty was experienced in overwintering the larvae received in the United States. Many larvae pupated and adults issued late in the fall. So few emerged normally in the spring that only 1 colony of 50 mated females was liberated. These were colonized at Eustis, Maine, in June 1935, but the species has not been recovered.

Epiurus foliae probably has more than 1 generation a year under field conditions, for alternate host species may be attacked. In the laboratory 1 summer generation was reared on retarded *Phyllotoma* prepupae within their hibernacula. Sometimes, though, female *Epiurus* may emerge early in the summer and live long enough to attack *Phyllotoma* in hibernacula formed in the fall. Of 9 females mated on May 23 and held in a cool, darkened place in the laboratory, all but 1 had died by the end of July, but this female lived until November 20, or 181 days. The winter is spent as a prepupa within a thin cocoon or cell. Pupation takes place early in the summer, and adults issue 4 or 5 days later. Material that hibernated at the laboratory produced adults between May 17 and June 7. Total issuance from material collected in 1934 was 264 males and 94 females, or about 2.8 males to 1 female, but 18 reared larvae produced 7 males and 11 females. The species mates readily in glass-covered wooden boxes at room temperature. An average of 1 minute and 10 seconds is spent in coitu. *Epiurus* females oviposit readily in *P. nemorata* hibernacula. The host larva is first paralyzed. The ovipositor is then removed, and the egg is laid on or near the victim. The operation requires from 1 to 3½ minutes, with an average of 2½. Very often the parasite feeds upon the host larva either before or after oviposition, completely consuming it. The parasite bites through the *Phyllotoma* hibernaculum, and feeds directly upon the soft larva. Perhaps under natural conditions the female flies away after oviposition, and there is less tendency to feed, but in confinement every one of the host larvae left in a cage will be consumed if not removed in a short time. When a host larva has been fed upon, even slightly, a parasite is unable to develop on it, for the food supply quickly dries up. Of course this results in the loss of many eggs. Oviposition notes were kept on only 1 female. She laid 167 eggs that were counted, but she also laid a number destroyed by feeding. Hatching takes place in from 36 to 48 hours. The young larva immediately commences feeding, and development is completed as an external feeder. Growth is rapid. The parasite becomes full fed in about 5 days, and the cocoon is spun about 2 days later. Parasites reared during June pupated soon after spinning their cocoons, and adults issued 5 or 6 days later. About 2 weeks, therefore, was required from oviposition to adult emergence. When the parasites were reared late in September or in October, pupation did not take place until the following spring.

Most of the *Epiurus* material collected in Europe had developed on *Phyllotoma* larvae attacked in the mine before the hibernaculum

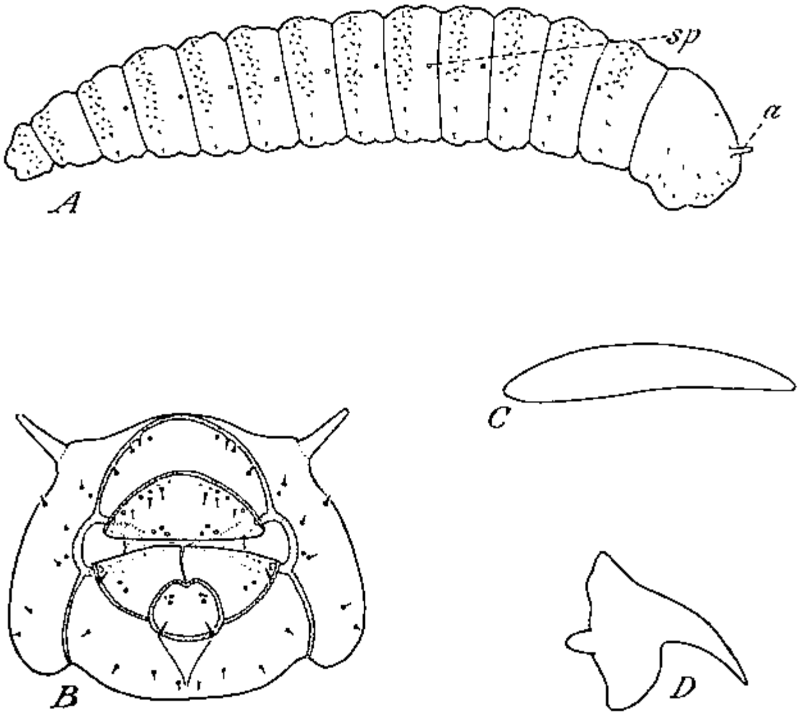

FIGURE 7.—*Epiurus foliae*: *A*, First instar: *a*, antenna; *sp*, spiracle; × 70. *B*, Head of first instar, ventral view, × 200. *C*, Egg, × 25. *D*, Mandible of first instar, × 375.

had been spun. The species probably attacks a variety of enclosed larvae. In the laboratory an undetermined leaf-roller larva was readily attacked, although, unless it was fastened in, the larva often escaped before it was paralyzed. Interest was also shown in larvae of *Rhyacionia buoliana* Schiff., but none were actually parasitized.

A few specimens of *Sympiesis* sp. issued from the leaves that contained *Epiurus* cocoons. Whether they were acting as secondary parasites or not was not determined.

The egg (fig. 7, *C*) is about 1.4 mm. long and 0.2 mm. wide. It is slightly curved, tapering at each end.

There are 5 instars. The first instar (fig. 7, *A*) is 1.4 mm. long and 0.25 mm. wide when first hatched. It has a well-defined head and 13 body segments of about equal length. Each segment bears several rows of tiny, dome-shaped, cuticular protuberances across the dorsum. Some of them may be drawn out to a point at the apex. On the first segment they extend down to about the median lateral line, and on each succeeding segment they extend a little farther, until on the last segment only a narrow ventral area is bare. At the middle of each segment there are also a number of sensory setae arranged in a single transverse row. Six pairs were distinguished on segments 1 and 2, 5 pairs on segments 3 to 11, 3 pairs on segment 12, and 2 pairs on the last segment. There are 9 pairs of minute spiracles, 1 pair near the posterior border of the first thoracic segment and 1 pair near the anterior border of the first 8 abdominal segments. The head presents well-defined characters, as indicated in figure 7, *B*. Practically all the sclerotized facial thickenings and sensory hairs that are distinguished on the full-grown larva may be seen on the head of the first instar. The epistoma forms a complete arch. The mandibles (fig. 7, *D*) are simple, sharply curved hooks measuring 0.065 mm. in length. The digestive and nervous systems are similar to those figured for the last instar.

Second instars differ very little from those of the first instar. They are about 2.00 mm. long. The mandibles in this and the following instars have a row of very fine teeth on both the dorsal and ventral sides of the pointed tip.

Third instars are about 3.00 mm. long. The tiny cuticular processes are thinly scattered on each segment. Many of them are drawn out to a point, thus forming a short, triangular-shaped spine, and on the posterior segments they frequently have a minutely serrated apex. There are several more sensory setae in the transverse row around each segment in this instar, and there are also 3 pairs of tiny sensory setae on the anterior border of each segment. These 6 setae are about equidistant apart. The sclerotized areas on the head are more clearly defined than in the earlier instars. The top of the head is light gray, and this area and the sides of the head bear simple domelike protuberances similar to those on the body segments.

Fourth instars are about 4.00 mm. long. They exhibit almost no differences from third instars except in size and a clearer differentiation of head characters.

Fifth instars, or full-grown larvae (fig. 8, *A*), are 6 to 7.5 mm. long and 1.5 to 2.0 mm. wide. Their shape differs little from that of the preceding instars. Segments 2 to 11 have strong lateral folds. The cuticle is evenly covered with the tiny domelike protuberances found in earlier instars. The transverse row of sensory setae on the middle of each segment is conspicuous. There seem to be 22 of these setae on each of the first 2 segments, from 14 to 18 on each of the next 10, and 22 on the last segment where, instead of being arranged in a row, 5 pairs are distributed over the dorsal half and 6 pairs over the ventral half. Besides these setae there are 3 pairs of smaller setae on the anterior border of each segment except the last. There are 9 pairs of open spiracles situated as in the first instar. The prothoracic spiracle measures 0.03 mm. in diameter. The head presents well-defined external characters, which are indicated in figure 8, *B*. The mandibles, of course, are internal, and the mouth opening has not been shown. The mandibles (fig. 8, *C*) measure 0.11 mm. in length. The digestive and nervous systems are shown in figure 8, *A*.

A number of conspicuous white urate cells are present in the first 9 abdominal segments.

The cocoon is usually spun in the host larva's mine. It is similar to the *Phyllotoma* hibernaculum, but is much lighter in texture, somewhat smaller, and irregular in shape. It was not noted whether a cocoon was spun when an *Epiurus* larva completed development inside a *Phyllotoma* hibernaculum.

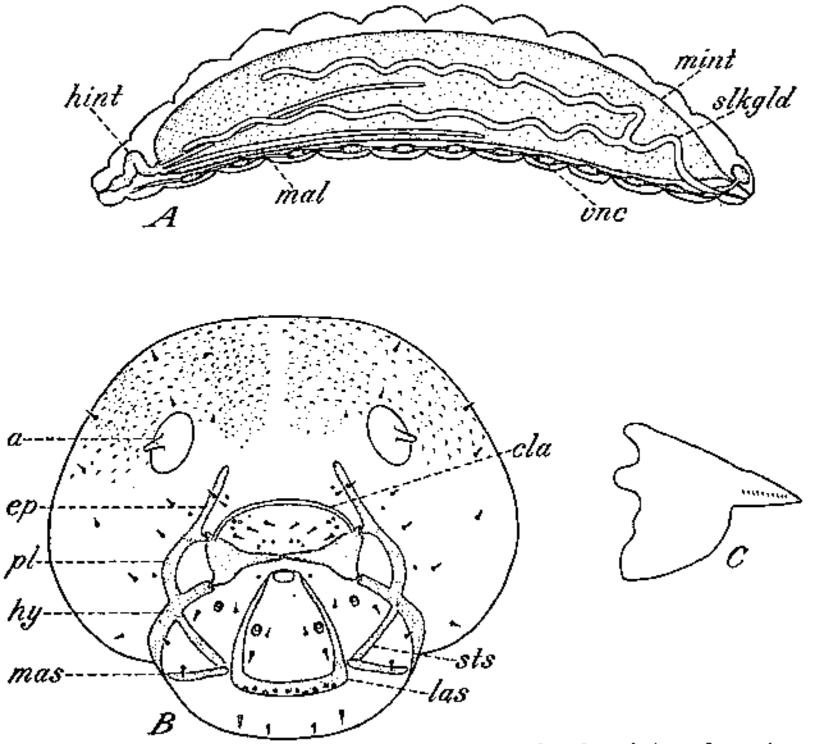

FIGURE 8.—*Epiurus foliae*: *A*, Full-grown larva, showing internal anatomy: *hint*, hind-intestine; *mint*, midintestine; *slkgld*, silk gland; *vnc*, ventral nerve cord: *mal*, Malpighian tube; × 12. *B*, Head of full-grown larva, front view: *a*, antenna; *ep*, epistoma; *pl*. pleurostoma; *hy*, hypostoma; *mas*, maxillary sclerome; *cla*, clypeal arch; *sts*, stipital sclerome; *las*, labial sclerome; × 100. *C*, Mandible of full-grown larva, lateral view, × 227.

AGROTHEREUTES PYGOLEUCUS (Grav.)

Agrothereutes pygoleucus is an ichneumonid parasite belonging to the subfamily Cryptinae. It was originally described in the genus *Cryptus* by Gravenhorst (*9, p. 702*) in 1829. The following hosts are listed by Dalla Torre (*5, p. 606*): *Eupoecilia ambiguana* (Fletcher), *Gastropacha neustria*, *Harpyia bifida*, *Psyche* sp., and *Lophyrus pini* (L.). Cushman (*2*) states that the genus *Agrothereutes* is probably not generically distinct from *Spilocryptus*, of which it is sometimes treated as a subgenus. He uses it in its original restricted sense as including subapterous forms of the tribe Cryptini related to *Spilocryptus*. No detailed notes on the biology of a species of *Agrothereutes* have been seen by the writer, but references to species of *Spilocryptus* are rather numerous. Morris, Cameron, and Jepson (*11*) have given an account of *Spilocryptus abbreviator* (F.) in a paper on parasites of the European spruce sawfly (*Diprion polytomum* (Htg.)), in which several species of Cryptini are treated.

Only a few *Agrothereutes* adults were reared from *Phyllotoma* material collected in Europe. Fourteen issued in the spring of 1931 from hibernacula collected in 1930, and 53 issued in 1933 from hibernacula collected in 1932. The species was not encountered in other years.

It was soon determined that *Agrothereutes pygoleucus* might act as a primary or as a secondary parasite of *Phyllotoma*, and therefore was not suitable for liberation in this country. Notes were made regarding its life history, but only very brief observations were made on its immature stages.

Agrothereutes females show striking characteristics: they have only vestigial wings, and they are negatively phototropic. The winter is spent as a full-grown larva within a thin cocoon spun inside the *Phyllotoma* hibernaculum. Under insectary conditions adults emerge from April 27 to June 2. At least a partial second generation is probably completed each year in the field. During the first week in June a number of *Phyllotoma* hibernacula were attacked in the laboratory. Twenty-eight *Agrothereutes* completed development and issued as adults while three larvae hibernated. Some females issuing in the spring may live long enough to attack *Phyllotoma* hibernacula formed the next fall. Two females lived from May until October in the insectary, but by the end of that time were apparently too weak to oviposit freely, for only one egg was laid, although the last female did not die until October 20. Mating occurs very readily under caged conditions. Coitus lasts on an average 40 seconds. Oviposition also takes place readily. The host larva within the hibernaculum is first paralyzed, and the egg is then laid on or near it. The process of paralyzing a host larva is frequently rather lengthy. The female inserts her ovipositor, prods it around in all directions, withdraws it, and then hurriedly applies her mouth parts to the opening. She may repeat this process many times, but the parasite was never seen tearing open the hibernaculum to feed directly upon the host. Possibly the egg is laid before feeding is begun. Eggs removed and placed on *Phyllotoma* larvae in depressed slides hatched in 36 to 48 hours. The larva feeds externally, completing growth in about 5 days. Another day is spent spinning a thin cocoon, and during June adults issue in from 10 to 12 days. The complete life cycle is from 18 days to 3 weeks during the summer months.

It seems probable that *Agrothereutes* females will attack a variety of hosts that form cocoons similar to those of *Phyllotoma*. In the laboratory they readily oviposited in cocoons of *Spilocryptus extrematis* (Cress.), a primary parasite of *Telea polyphemus* (Cram.).

Agrothereutes pygoleucus is similar to the native species *A. slossonae*, which Peirson and Brower (*17*) list as the commonest ichneumonid reared from *Phyllotoma* larvae in this country. Males of *A. pygoleucus* mated readily with females of *A. slossonae*, but no observations were made regarding the fertility of this cross.

The egg is glistening white with a smooth chorion. It is about 1.28 mm. long and 0.32 mm. wide. The anterior end is bluntly rounded, and the posterior end tapers slightly.

There are 5 instars, but because of the small amount of material available only the first instar was studied. The first instar is about 1.34 mm. long and 0.34 mm. wide. It is similar to the first instar of *Epiurus foliae* (fig. 7, *A*). Instead of tiny, domelike, cuticular protuberances sparsely arranged on the dorsum of each segment; *Agrothereutes* larvae have tiny, broad-based spinules set close together. The arrangement of the sensory setae seems to be the same, and the head characters are very similar in both species. *Agrothereutes* has a rather wide, sclerotized area at the base of the labiostipital sclerome, not present in *Epiurus*, and in general all the sclerotized facial thickenings are more prominent in *Agrothereutes*. The mandibles of both species are similar in size and shape. The digestive system of *Agrothereutes* was not studied, but it was noted that the salivary glands are like those of *Epiurus*, with a pair of long, sinuous tubes on each side of the body.

The cocoon is white, elliptical, and very thin in texture.

TRANOSEMA PEDELLA (Hlmgr.)

Tranosema pedella (fig. 9) is an ichneumonid parasite of the subfamily Campopleginae. It was originally described as *Limneria*

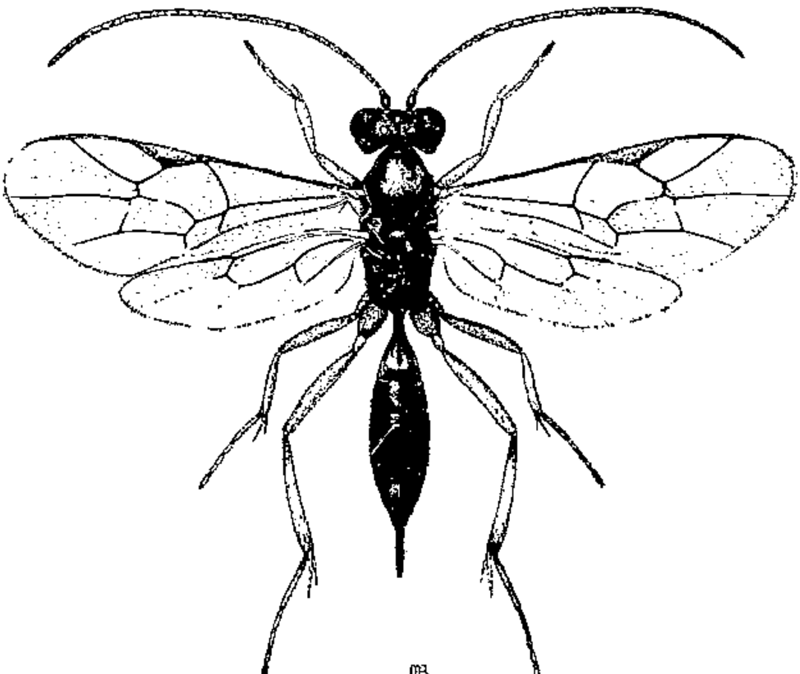

FIGURE 9.—*Tranosema pedella*. Adult female, × 12.

pedella by Holmgren (*10, p. 73*) in 1858. Dalla Torre (*5, p. 107*) lists two hosts, *Fenusa pusilla* (Lep.) (*pumila* Klug) and *Cryptocampus* sp. Cushman (*3*) states that specimens reared from *Phyllotoma nemorata* in Ostmark are not typical *pedella* but agree very closely with Holmgren's var. 1. Only a few species are described in the genus *Tranosema*, and no references to their biology have been seen by the writer. Many closely allied campoplegines, however, are well-known parasites of important insect pests. The species *Eulimneria crassifemur* (Thoms.) has been thoroughly studied by Thompson and Parker (*23*).

Tranosema pedella is a primary internal parasite of *Phyllotoma nemorata*. From the large number of *Phyllotoma* hibernacula collected in Europe from 1931 through 1934, 245 adults were reared. One colony, consisting of 12 mated females, was liberated in the United States. The species has not been recovered. Attempts to rear *Tranosema* under laboratory conditions were unsuccessful. Some notes were made on the life history and habits of the species, and on the first instar, but the later instars were not studied.

Tranosema completes only 1 generation a year. The winter is spent as a first instar within the hibernating prepupa. Development is completed in the spring, and pupation takes place inside the host hibernaculum. Adults issued in the insectary from May 26 to June 30. The sex ratio is about 1:1. The adults are very active and do not live well in confinement. No records were kept on the longevity of individuals, but females used in reproduction work died early and none were alive after July 8. Mating was difficult to obtain under laboratory conditions, the best results being obtained in the morning when cages were held out of doors. Coitus lasts about 2 minutes. Both mated and unmated *Tranosema* females oviposit readily in small *Phyllotoma* larvae, but they have considerable difficulty in attacking larger larvae in more extensive mines. Host larvae from 1.5 to 2.00 mm. long in mines about 6.00 by 3.00 mm. seem to be about the best size for successful attack. Before ovipositing the female parasite runs over a leaf, tapping it with her antennae. As soon as she locates a *Phyllotoma* mine she jabs her ovipositor into it, twisting around in all directions. She may insert the ovipositor several times before striking the host larva, but the parasite usually stays at the same mine until this is accomplished. The egg is laid at almost the moment the host larva is hit. As she removes the ovipositor, the parasite sharply turns her body about halfway around. The *Phyllotoma* larva is not paralyzed and almost immediately after attack it resumes feeding. *Tranosema* eggs do not hatch until 2 or 3 weeks after oviposition. The young parasite develops very little during the summer, and spends the winter as a first instar. Further development takes place late in the spring. One first instar was dissected out as late as April 7. The species was not successfully reared beyond this point.

Although *Tranosema* attacks *Phyllotoma* larvae readily, two factors noted during this work indicate that its effectiveness as a *Phyllotoma* parasite is probably limited. In the first place, more than half of all the *Phyllotoma* larvae attacked by *Tranosema* died without developing much further. The larvae were very small; possibly they were injured by the act of oviposition. In the second place, nearly all the parasite larvae dissected out were found enclosed by phagocytes. Of 17 *Tranosema* eggs or first instars dissected out in 1935, none of the eggs and only 2 of the larvae were clean and apparently healthy. Six larvae still moved feebly in spite of a heavy layer of phagocytes surrounding most of their bodies except the tail. The remaining specimens were heavily encapsulated and dead.

The egg (fig. 10, *C*) is about 0.31 mm. long and 0.09 mm. wide when first deposited. It is slightly curved, and the ends are rounded. The chorion is clear and hyaline except for a slightly roughened area at the anterior end.

The first instar (fig. 10, *A*) is a typical campoplegine. It is composed of a well-defined head and 13 body segments. The first 12 segments are about equal in length, and the last segment is prolonged into a pointed tail about half as long as the rest of the body. The cuticle bears no spines or tubercles, and no sensorial organs were dis-

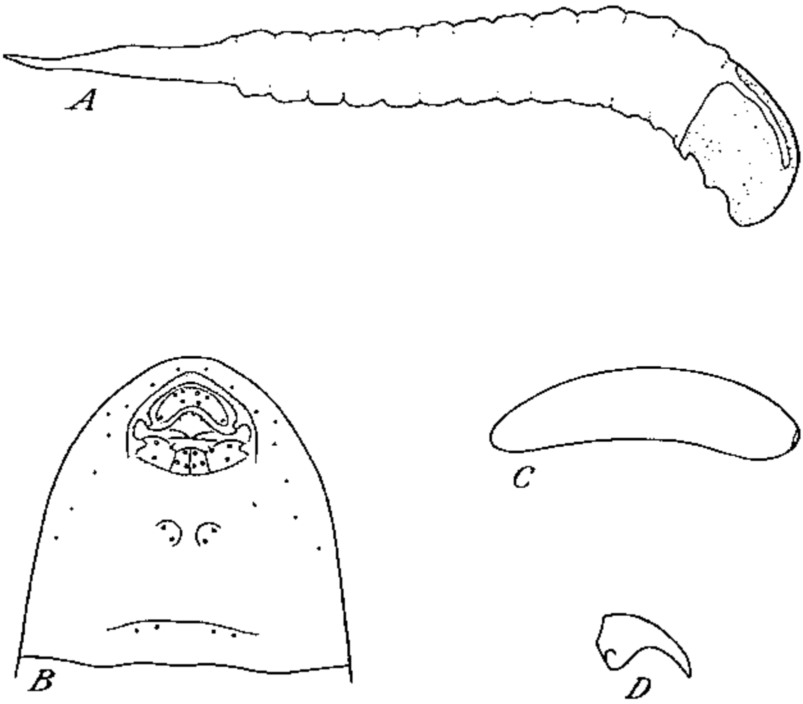

FIGURE 10.—*Tranosema pedella*: *A*, First instar, × 130. *B*, First-instar head, ventral view, × 285. *C*, Egg, × 130. *D*, First-instar mandible, × 370.

tinguished. The head capsule is lightly sclerotized and yellowish. On each side of the head, dorsally, there is a narrow, very lightly sclerotized groove extending from the posterior margin forward for about three-fourths the length of the head. Ventrally there are 2 pairs of raised protuberances. From the ventral aspect of the head the mouth parts may be distinguished, as shown in figure 10, *B*. The mandibles (fig. 10, *D*) are simple, well-sclerotized hooks 0.035 mm. long. A pair of tiny sensory hairs may be distinguished on each of the ventral protuberances, and a number of tiny sensory hairs are present on the sides of the head. The latter, however, are so tiny that their exact number could not be determined with the small amount of material available.

The tracheal system is similar to that described for *Eulimneria crassifemur* by Thompson and Parker (*23*). There are the usual main lateral trunks, giving off branches in each segment, and a secondary thoracic trunk. In *Tranosema pedella* the commissure uniting the main trunks posteriorly is found in the tail, and a number of small tracheal branches are also present in the tail. There are no open spiracles.

The digestive system was not studied.

Sympiesis sp.

Sympiesis sp. (fig. 11) and all the remaining *Phyllotoma* parasites discussed in this paper are chalcidoid parasites belonging to the fam-

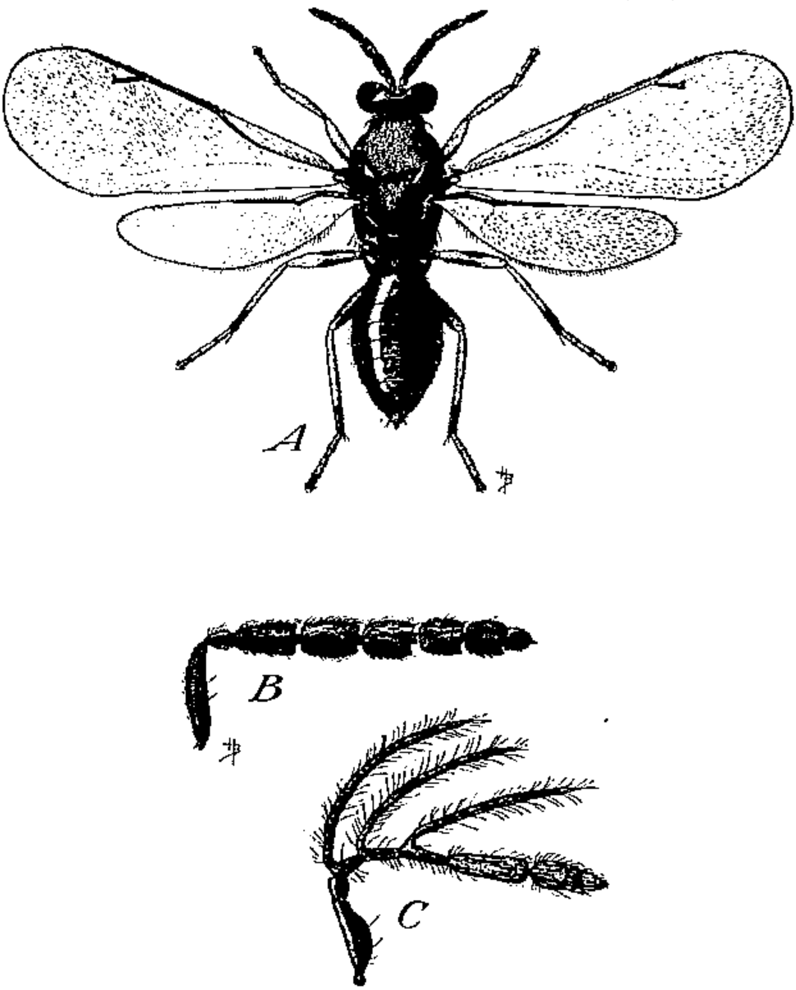

FIGURE 11.—*Sympiesis* sp.: *A*, Adult female, × 14; *B*, female antenna; *C*, male antenna.

ily Eulophidae. The genus *Sympiesis* is a large one, and the species are typically parasitic on insects that mine in leaves. Leaf miners of several orders are attacked, and there are occasional records of *Sympiesis* spp. attacking other insects that live under similar conditions.

Muesebeck and Dohanian (*13*) record *Sympiesis massasoit* Crawford as a parasite of *Apanteles melanoscelus* (Ratz.), and Cushman (*1*) records rearing *Sympiesis* sp. as an external parasite of the eggs of *Cimbex americana* Leach. During the course of this work *Sympiesis* sp. was commonly reared from the leaf-mining sawfly larvae *Phyllotoma nemorata* and *Scolioneura betulae*. It was also occasionally reared as a hyperparasite of *Phanomeris phyllotomae*, and for this reason was not liberated in the United States. Graf (*8*) has given a good short account of *Sympiesis stigmatipennis* Gir., parasite of the potato tuber moth.

A total of 687 *Sympiesis* sp. issued from the *Phyllotoma* material collected in Europe, and all but 10 of them issued from collections made in 1932 and 1934. In 1932 a collection of 682 *Scolioneura betulae* cells that contained chalcidoid parasites was also sent to the United States, and 304 *Sympiesis* sp. adults issued from them. Probably *Sympiesis* sp. usually acts as a primary parasite. Under laboratory conditions it was reared as a primary parasite of *Fenusa ulmi*, but it also oviposited in *Phanomeris* cocoons.

Sympiesis sp. overwinters as a naked pupa within the host larva's mine. Adult emergence took place in the insectary from May 1 to 27, with the majority issuing during the first 2 weeks of May. The sex ratio was about even (140 males and 165 females) for adults issuing from *Scolioneura* material. The adults are active insects that live well in confinement. Fifty adults that issued May 18 lived on an average 42 days, and 2 adults that issued May 20 lived 72 days. Probably there is no more than a partial second generation each year. A few adults issued from pupae formed in June and July, but the majority of the pupae did not produce adults until the next spring. Out of 687 adults obtained from Europe only 23 issued during the fall. One instance of mating was observed. During copulation the female's abdomen was raised to almost a right angle with her thorax. Coitus lasted 37 seconds. Oviposition was readily obtained in mines containing *Fenusa ulmi* larvae. Often the host larva is paralyzed, but paralysis is not necessary for the parasite's development. When the female is ovipositing, the ovipositor is slowly inserted its full length into the mine and held there about a minute until the egg is laid. When the female is attempting to paralyze a larva, she inserts the ovipositor quickly and jabs it around until she strikes the larva. Eggs are sometimes laid in mines where larvae have been paralyzed, but usually paralyzed larvae are fed upon. The egg is apparently laid anywhere in the mine, but often it adheres to a host larva that happens to touch it when moving about. The young larva makes its way to the host and feeds externally. Development is rather variable, but is usually rapid. During June and July many *Sympiesis* larvae become full-fed 6 or 7 days after the eggs are laid. Another day is spent as a prepupa. As a rule all the larvae have pupated 10 days after egg deposition. In the few instances where adults issued the same season, from 7 to 8 days was spent as a pupa, or from 15 to 17 days was required for the complete life cycle.

The egg (fig. 12, *B*) averages 0.52 mm. in length and 0.18 mm. in width. It is a little wider at the anterior than at the posterior end, and both ends are bluntly rounded. The chorion is covered with minute spines.

There are at least 4 and probably 5 instars. Mandibular measurements indicate the presence of 5, but all the molt skins were not isolated for any 1 larva.

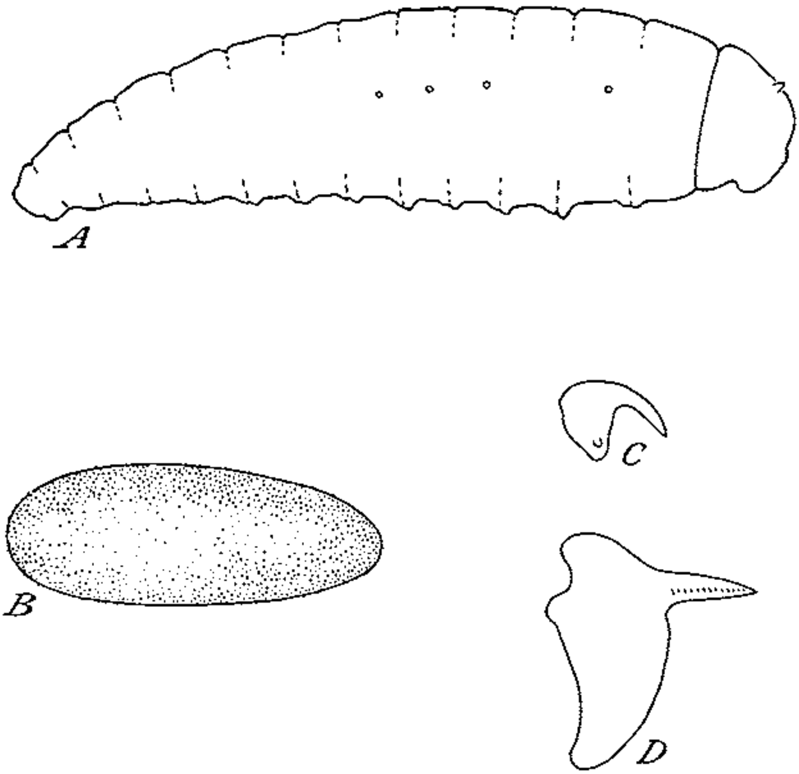

FIGURE 12.—*Sympiesis* sp.: *A*, First instar, × 175. *B*, Egg, × 100. *C*, First-instar mandible, × 650. *D*, Mandible of full-grown larva, × 650.

FIRST INSTAR

The first instar (fig. 12, *A*) is of the usual ectoparasitic chalcidoid type. It averages 0.60 mm. in length and 0.16 mm. in width. There is a well-defined head and there are 13 body segments of about equal length tapering slightly posteriorly. There is no cuticular armature, but a few tiny sensory setae are present. It is believed that they are arranged as in the last instar, but they are so minute that their number and arrangement were not determined. The head is similar to that of the full-grown larva. It bears a pair of tiny colorless antennae, each of which has 2 minute circular sensoria. The facial thickenings (hypostoma, pleurostoma, and epistoma) are well defined, and the tentorium is well developed. The inferior pleurostomal rami unite to form a single cross bar. Below the labial and maxillary regions and between the hypostomae there is a distinct concave fold in the cuticle. Practically all the minute circular sensoria and sensory setae shown in the figure of the full-grown larval head (fig. 13, *B*) may be distinguished in the first instar. The mandibles (fig. 12, *C*) are simple, sickle-shaped hooks 0.02 mm. in length.

The tracheal system consists of a pair of lateral trunks united anteriorly in the first thoracic and posteriorly in the ninth abdominal segment. There are 4 pairs of open spiracles, a pair on the second thoracic and on each of the first 3 abdominal segments. These are joined to the main lateral trunks by short spiracular branches. The mesothoracic spiracles measure 0.003 mm. in diameter. Rudimentary spiracular branches are present in the third thoracic and the fourth to eighth abdominal segments, although there are no open spiracles on these segments. Three or four dorsal and the same number of ventral tracheae arise from the main lateral trunk in each segment. In the first segment these branches are continued into the head, and the ninth and tenth abdominal segments receive tracheae from the lateral trunks of the eighth segment. Occasionally a dorsal trachea arises from the spiracular branch.

The digestive and nervous systems were not studied in this instar.

SECOND INSTAR

Second instars are about 0.90 mm. long and 0.30 mm. wide. They are similar to the first instars except that the mandibles have a broader base and tiny teeth on the inside of the tip, as in the last instar. The mandibles measure 0.025 mm. in length. The mesothoracic spiracle measures 0.01 mm. in diameter.

THIRD INSTAR

Third instars are about 1.10 mm. long and 0.35 mm. wide. They are easily distinguished from the first 2 instars, for they have 9 pairs of open spiracles, a pair each on the mesothoracic and metathoracic segments and on each of the first 7 abdominal segments. The mesothoracic spiracle measures 0.013 mm. in diameter. The mandibles are like those of the second instar, but are 0.033 mm. long.

FOURTH INSTAR

Fourth instars are about 1.55 mm. long and 0.60 mm. wide. They are practically identical with the third instars. The mandibles measure 0.042 mm. in length, and the mesothoracic spiracle measures 0.015 mm. in diameter.

LAST INSTAR

The full-grown larvae vary considerably in size. Ten large individuals averaged 3.0 mm. in length and 0.82 mm. in width when full grown. The outline of the full-grown larva is shown in figure 13, *A*. It has approximately the same shape as the first instar, but is characterized by a row of well-developed intersegmental protuberances, functioning as pseudopodia, on the dorsum and a shorter similar row on the venter. Dorsally the intersegmental protuberances occur from segments 1 and 2 to segments 10 and 11; ventrally they occur from segments 4 and 5 to segments 8 and 9. The pseudopodia undoubtedly aid the larva in moving about inside the mine, and are similar to those described by Taylor (*22*) on larvae of *Elasmus* *hispidarum* Ferr., *Dimmockia javana* Ferr., and *Achrysocharella orientalis* Ferr. These 3 species are parasites of the leaf-mining hispid *Promecotheca reichei* Baly, and the pseudopodia are a distinct aid in the locomotion of these species. The cuticle is unarmed, although tiny sensory setae are present. They are similar in arrangement to those shown in figure 20, *A*, for *Cirrospilus pictus*. There are 4 pairs on each of the thoracic segments. Each of the first 9 abdominal segments has a pair near the median dorsal line. Each of abdominal segments 2, 4, 6, 8, and 9 has an additional pair near

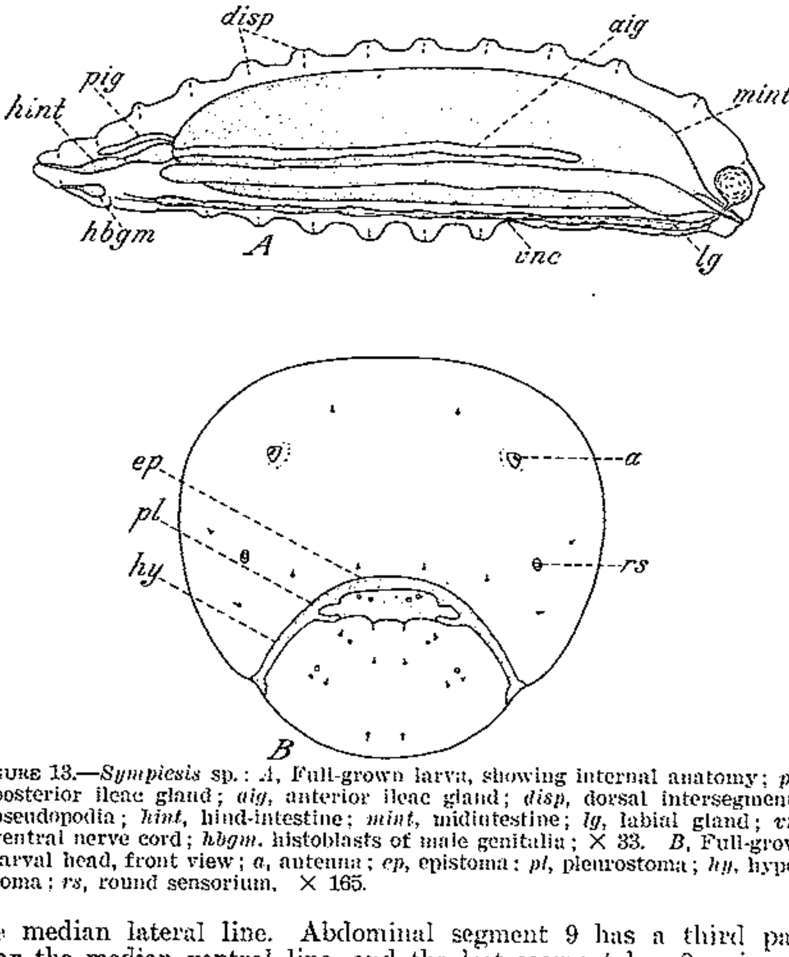

FIGURE 13.—*Sympiesis* sp.: *A*, Full-grown larva, showing internal anatomy; *pig*, posterior ileac gland; *aig*, anterior ileac gland; *disp*, dorsal intersegmental pseudopodia; *hint*, hind-intestine; *mint*, midintestine; *lg*, labial gland; *vnc*, ventral nerve cord; *hbgm*, histoblasts of male genitalia; × 33. *B*, Full-grown larval head, front view; *a*, antenna; *ep*, epistoma; *pl*, pleurostoma; *hy*, hypostoma; *rs*, round sensorium. × 165.

the median lateral line. Abdominal segment 9 has a third pair near the median ventral line, and the last segment has 2 pairs on its dorsal and 1 pair on its ventral aspect.

The head, seen from the front, is shown in figure 13, *B*. The facial thickenings, although almost colorless, are well defined. The lateral epicranial angles are heavy, and the transverse tentorial bar is well developed. The mandibles (fig. 12, *D*) are sharply pointed processes with well-sclerotized yellow tips. They are 0.043 mm. long. Inside the tips there is a row of 10 or 12 extremely minute spines. The antennae are conical, sclerotized yellow protuberances. They bear 2 minute circular sensoria. A number of sensory setae and circular sensoria are present, and their position is indicated in the figure. The circular sensorium found about halfway between the antenna and the lateral epicranial angle on each side of the head is considerably larger and more prominent than any of the others.

The respiratory system is practically the same as in the first instar, except that the tracheae are larger and have many more branches. There are, of course, 9 open pairs of spiracles as in the third instar. The mesothoracic spiracle measures 0.02 mm. in diameter.

The main features of the digestive and nervous systems are indicated in figure 13, *A*. As the larva becomes full-fed, the white and semiopaque histoblasts of the legs, wings, and genitalia are easily distinguished, for they lie just beneath the skin. The fat body also becomes prominent as the larva finishes feeding. It consists of large cells forming an almost complete layer just below the body wall, although narrow areas along the middorsal, midventral, and midlateral lines are bare. Below the midlateral line the cells are arranged in diagonal rows several cells wide that follow the large oblique muscles, while above this line they have no definite arrangement.

No cocoon is spun. Pupation takes place in the host larva's mine, and the pupa changes rapidly from white to glistening, shiny black.

PNIGALIO CRUCIATUS (Ratz.)

Pnigalio cruciatus is closely related to *Sympiesis* sp. It was originally described as *Pteromalus cruciatus* by Ratzeburg (*19, p. 205*) in 1848. His specimens were reared from "*Curculio fagi*." There are few references to *Pnigalio* in the literature. Oldham (*16*) reared *P. cruciatus* with several other species of parasites from the leaf-mining coleopteron *Rhynchaenus* (*Orchestes*) *alni* L. in England, but the status of *Pnigalio* was not determined.

Small numbers of *Pnigalio* adults were recovered from *Phyllotoma* shipments made in 1932, 1933, and 1934. The largest number, 127, issued from the 1934 shipments. At times the species definitely acts as a primary parasite, but since it also issued from the collections of *Phanomeris* cocoons, it may act as a hyperparasite.

Pnigalio cruciatus is multibrooded. The winter is spent as a pupa in the host larva's mine. At Melrose Highlands, Mass., adults issued in the spring between May 2 and 12. This is considerably earlier than the time *Phyllotoma* larvae are available, but the parasite was reared at the laboratory on larvae of *Fenusa ulmi*. The adults are active insects, living well in confinement. The proportion of the sexes is apparently about equal, although too few adults have been recovered to provide definite information on this point. Mating was not observed. Oviposition was readily obtained on larvae of *F. ulmi*. The female parasite walks over a mined leaf, lightly tapping it with her antennae. Upon locating a host larva, she thrusts at it with her ovipositor. If the attack is successful, the ovipositor remains inserted for a brief period, and the victim becomes temporarily paralyzed. The egg is then laid externally either on or close to the paralyzed larva. If the parasite fails to strike its host after several attempts, it frequently lays an egg somewhere in the mine without paying any further attention to the host larva. The egg is evidently covered with a rather sticky fluid, for it will adhere to a larva that touches it. Some eggs were artificially placed in mines of unexposed larvae to see if preliminary paralysis was necessary for successful attack. In almost every case a parasite hatched and completed development normally.

Pnigalio eggs hatch in 42 to 60 hours. The tiny parasite larva attaches itself to its host and feeds externally. Larval development proceeds very rapidly, full-grown larvae appearing in 7 to 12 days after the egg is laid. One day is spent as a prepupa and 7 to 12 days as a pupa before the adult emerges. Seventeen male adults were reared in the laboratory. Their development required on an average 18 days, 2 days as an egg, 6 days as a larva, 1 day as a prepupa, and 9 days as a pupa. Ovipositing females were apparently unmated, as no females were reared.

The egg (fig. 14, *A*) averages 0.40 mm. in length and 0.14 mm. in width. It tapers slightly from the anterior to the posterior end, both ends being bluntly rounded. The chorion is smooth and hyaline, but it seems to be covered with a sticky fluid, as previously noted.

The larvae are so similar in all respects to those of *Sympiesis* sp. that the description for that species applies almost equally well to *Pnigalio*, and only minor differences are noted. Three larval instars were distinguished, and several factors indicate that there are at least four, although only a limited supply of material was available for study. The first, penultimate, and last instars were isolated.

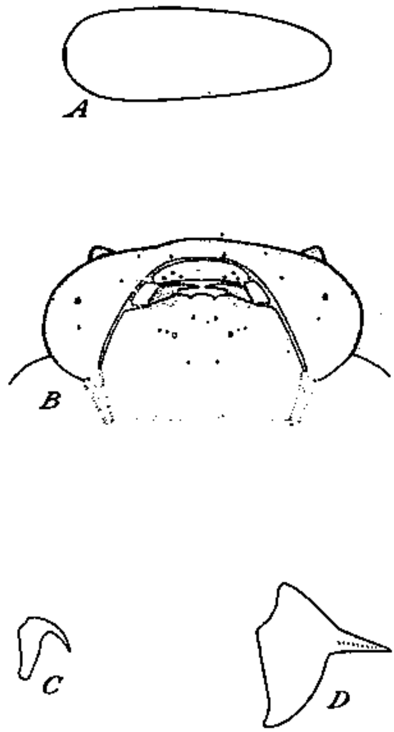

FIGURE 14.—*Pnigalio cruciatus*: *A*, Egg, × 90. *B*, Head of full-grown larva, × 191. *C*, First-instar mandible, × 800. *D*, Mandible of full-grown larva, × 545.

FIRST INSTAR

First instars range from 0.50 mm. long and 0.13 mm. wide to 0.57 mm. long and 0.15 mm. wide. There are 4 pairs of open spiracles, and those on the mesothorax measure about 0.003 mm. in diameter. The mandibles (fig. 14, *C*) are tiny, sharply curved hooks that are only 0.01 mm. long.

PENULTIMATE INSTAR

The penultimate instars are about 1.18 mm. long and 0.34 mm. wide. They differ only slightly from the full-grown larvae. The distinguishing characters, particularly the lateral epicranial angles of the head and the sensory hairs of the body segments, however, are much less clearly defined. The mandibles measure 0.026 mm. long and the mesothoracic spiracle 0.013 mm. in diameter.

LAST INSTAR

The full-grown larvae range from 1.76 mm. long and 0.44 mm. wide to 2.62 mm. long and 0.73 mm. wide. In body form they differ slightly from *Sympiesis* sp. The intersegmental protuberances are present, but they are not so well developed in *Pnigalio* as in *Sympiesis*, and the last 3 abdominal segments taper more sharply; so the last segment protrudes as in a short, fingerlike projection. The head is shown from the venter in figure 14, *B*, and it seems almost identical to that of *Sympiesis*. The mandibles (fig. 14, *D*) measure 0.036 mm. in length. On the inner side of their tips there is a row of 10 or 12 extremely minute spines. The mesothoracic spiracles measure 0.017 mm. in diameter.

No cocoon is spun. Pupation takes place in the host larva's mine. At first the pupa is cream colored, but as development proceeds pigmentation takes place rapidly and it becomes shiny black.

TETRASTICHUS XANTHOPS (Ratz.)

Tetrastichus xanthops (fig. 15) was originally described as *Eulophus xanthops* by Ratzeburg (*18, p. 170*) in 1844. Dalla Torre

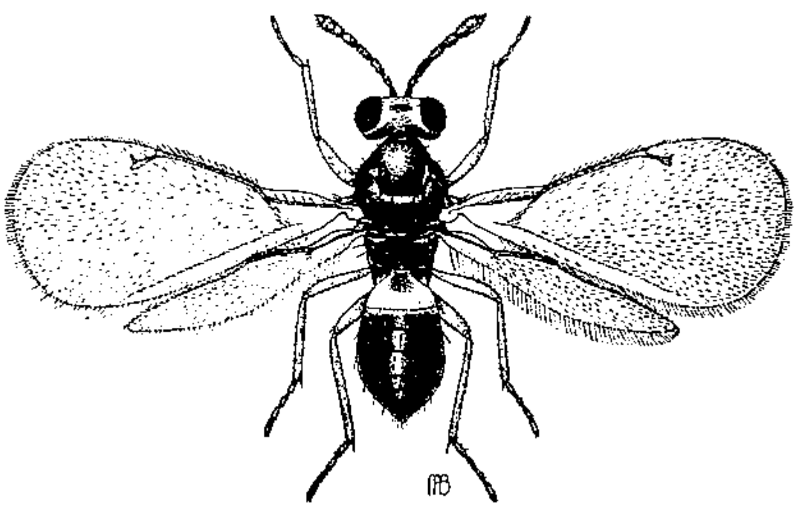

FIGURE 15.—*Tetrastichus xanthops*. Adult female, × 31.

(*6, p. 25*) noted rearing records from "*Cecidomyia fagi*," "*Orchestes fagi*," and "*Lithocolletes* sp." The genus *Tetrastichus* includes a large number of species showing great diversity of habit. Many are true parasites, whereas many others are hyperparasites. A number of species are of considerable economic importance, and the biology of several has been carefully worked out. No references to the biology of *T. xanthops* have been noted in the literature.

A total of 412 *Tetrastichus xanthops* adults issued from *Phyllotoma* material collected in Europe in 1932, 1933, and 1934. Two or three adults may develop from a single host larva. During this study it was reared as a primary parasite of *Fenusa ulmi* larvae and as a hyperparasite on *Phanomeris phyllotomae* and *Chrysocharis* sp. *T. xanthops* is already present in the United States. It was reared from mines of *F. ulmi* collected at Woburn, Wakefield, and Easton, Mass.

Tetrastichus xanthops is multibrooded. It overwinters as a full-grown larva in the host larva's mine, pupating in the spring. Adults issued in May at Melrose Highlands, Mass. *Phyllotoma* larvae were not available until much later in the season, but *Tetrastichus* was successfully reared in the laboratory on larvae of *Fenusa ulmi*. Mating was not observed, but oviposition proceeded readily. *Tetrastichus* females walk over the mined leaf, tapping it with their antennae, but apparently pay no attention to the host larva, for they usually select a spot at the extremity of the mine and slowly insert the ovipositor at a sharp angle. The egg is laid free in the mine, the entire process of oviposition occupying 1 or 2 minutes. Frequently an egg is laid in a mine from which the host larva has been removed. The egg hatches in about 48 hours. The young larva crawls to its host, undoubtedly aided considerably by well-developed pseudopodia protruding between the segments along the median dorsal line. The larvae travel rapidly, and when disturbed they move forward or backward equally well. Upon finding a host larva, the young parasite feeds externally, completing its larval development in about 10 days. One day is spent as a prepupa and about 7 days as a pupa. Development from egg to adult takes about 20 days in midsummer.

The egg (fig. 16, *B*) is of the type commonly laid by externally ovipositing chalcidoids. The chorion is smooth and hyaline. It is about 0.35 mm. long and 0.08 mm. wide.

A very limited amount of larval material was available, and only the first and last instars were studied.

The first instar (fig. 16, *A*) is about 0.38 mm. long and 0.10 mm. wide when first hatched. It has a well-defined head and 13 body segments of about equal length. Between the body segments along the middorsal line are well-developed intersegmental protuberances, which function as pseudopodia. These protuberances are similar to those described for the last instar of *Sympiesis* sp. and those described by Taylor (*22*) for several parasites of *Promecotheca reichei* Baly. They are rather short and narrow, but are easily discernible with a binocular microscope as a living larva moves about, and apparently they are a considerable aid in locomotion, for the larvae move rapidly in contrast to the slow movement of many externally feeding chalcidoids. There are no ventral pseudopodia; so the larva crawls about on its back. The cuticle is covered with tiny spines except in the intersegmental areas. In addition it bears a number of longer sensory spines or hairs, some of which are very long; their relative length and position have been indicated in the figure of the larva. There are 3 pairs of these spines on each of the thoracic segments; 2 pairs each on abdominal segments 2, 4, and 6; 1 pair each on abdominal segments 1, 3, 5, 8, 9, and 10; and apparently none on abdominal segment 7. There is a well-defined tracheal system similar to that described for *Sympiesis* sp., although the posterior commissure is found in the eighth instead of the ninth abdominal segment. There are 4 pairs of open spiracles, 1 pair on the mesothoracic segment and 1 pair on each of the first 3 abdominal segments. The mesothoracic spiracle measures 0.003 mm. in diameter.

The head (fig. 16, *C*) is pale yellow and lightly sclerotized. The mouth opening is circular in outline with a prominent margin. Extending across the head just posterior to the mouth opening is a stout sclerotized cross bar upon which the mandibles articulate, but otherwise there seem to be no sclerotized bars or cuticular thickenings. Two pairs of round sensoria are present on the labrum, and one pair

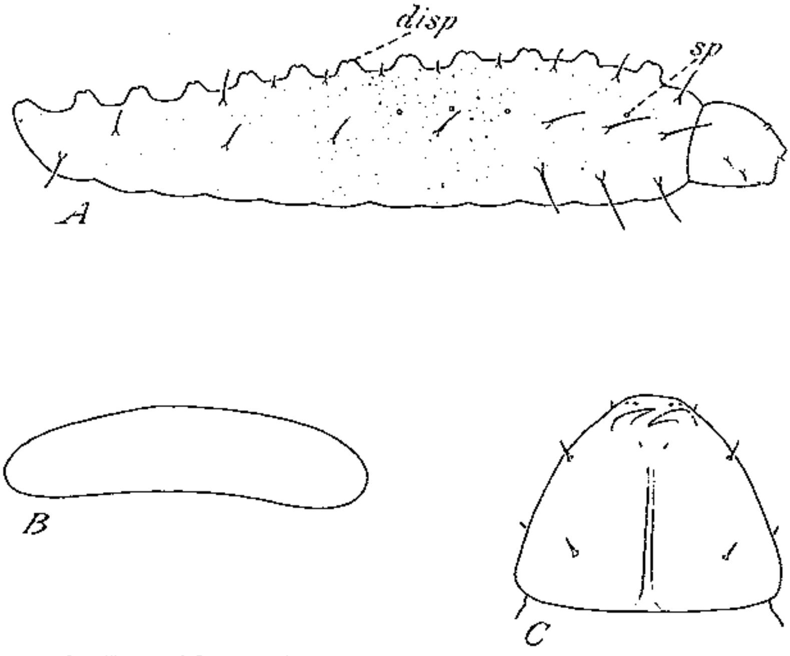

FIGURE 16.—*Tetrastichus xanthops*: *A*, First instar; *sp*, spiracle; *disp*, dorsal intersegmental pseudopodia; × 200. *B*, Egg, × 136. *C*, Head of first instar, ventral view, × 555.

of sensory spines was distinguished on the labium. Four more pairs of well-developed sensory spines are present, as indicated in figure 16, *C*. On the ventral side of the head is a narrow unsclerotized area, which runs from the mouth opening to the base of the head. The antennae are tiny raised tubercles each bearing 2 round sensoria. The mandibles are simple sickle-shaped hooks measuring only 0.01 mm. in length.

Full-grown larvae are about 2.0 mm. long and 0.05 mm. wide. The general form of the body is similar to that of the first instar. The pseudopodia are still prominent, but they appear relatively shorter, for the body of the larva is much thicker. When the larva completes feeding, it appears light green, apparently from the pigmentation contained in the fat body, but the contents of the midgut remain dark brown and may be seen through the skin. The cuticle is unarmed except for short but prominent sensory setae. These are arranged as are the sensory setae figured in the first instar, but with, in addition, 1 pair just above the line of spiracles on the first 3 segments, 1 pair near the median lateral line of segments 11 and 12, and 2 pairs on segment 13.

The head does not differ greatly from that of the first instar. The epistoma is weakly defined, the superior pleurostomal rami are prominent, and the cross bar extending between the inferior pleurostomal rami is well developed, but otherwise no sclerotized skeletal bars or thickenings were distinguished. The sensory setae are arranged as in the first instar, but they are relatively shorter. Two pairs of round sensoria are present on both labrum and labium. The antennae are prominent, sclerotized, cylindrical structures about twice as long as wide. They are truncate and bear a tiny nipplelike process at the apex. The mandibles are simple, sharply pointed hooks 0.04 mm. long. They are shaped like those of *Sympiesis* sp., but they do not bear a row of minute teeth on their inner margins.

The tracheal system is well developed. There are 8 pairs of open spiracles, 1 pair on the second and third thoracic segments and 1 each on abdominal segments 2 to 7. The mesothoracic spiracles measure 0.016 mm. in diameter. The digestive and nervous systems are similar to those shown for *Sympiesis sp.*, although in the specimens studied the ventral nerve cord terminated at about the fifth abdominal segment, where 3 pairs of very long nerve fibers were given off that extended to almost the last segment. The histoblasts of the legs, wings, and genitalia are very conspicuous in full-fed larvae.

No cocoon is spun. Pupation takes place in the host larva's mine.

HEMIPTARSENUS ANEMENTUS (Walk.)

Hemiptarsenus anementus (fig. 17) was originally described as *Eulophus anementus* by Walker (*27, p. 191*) in 1839. No references regarding the biology of a species of *Hemiptarsenus* have been seen by the writer.

Hemiptarsenus anementus is a gregarious parasite of *Phyllotoma* hibernacula. It was recovered in only 1 year from the European collections of *Phyllotoma* material. A total of 124 adults, 107 males and 17 females, issued in the early summer of 1935 from hibernacula that had been collected the previous fall. These 17 females, however, must have laid a large number of eggs before they were removed from the rearing cages, for in August a number of adults were also obtained from the same material. Since the species is an external parasite, it was planned to experiment considerably with it before deciding whether it was suitable for liberation in the United States, but it was not successfully carried through the next winter, and all the stock on hand died. Under laboratory conditions *Hemiptarsenus* appears to be well adapted for development and increase upon *Phyllotoma* hibernacula, but in view of the large number of hibernacula collected in Europe, the species was, of course, insignificant as a control factor during the 5 years that collections were made.

Hemiptarsenus anementus probably passes the winter as a full-grown larva or pupa within the *Phyllotoma* hibernaculum. In laboratory rearing, however, hibernation was not induced. Several hundred adult parasites issued from 80 hibernacula attacked between September 19 and October 4 and held continuously in an outside insectary. The adults issued until the last part of December. They were supplied with food, but all of them died before spring. Emergence from imported material took place between June 24 and 27. The last of these adults died about 46 days later, on August 12. There are probably 2 or more generations each year. Second-generation adults issued from August 7 until September 5, and the first of the third-generation adults issued on August 27. No entirely satisfactory data were obtained on the proportion of sexes, because of the great excess of

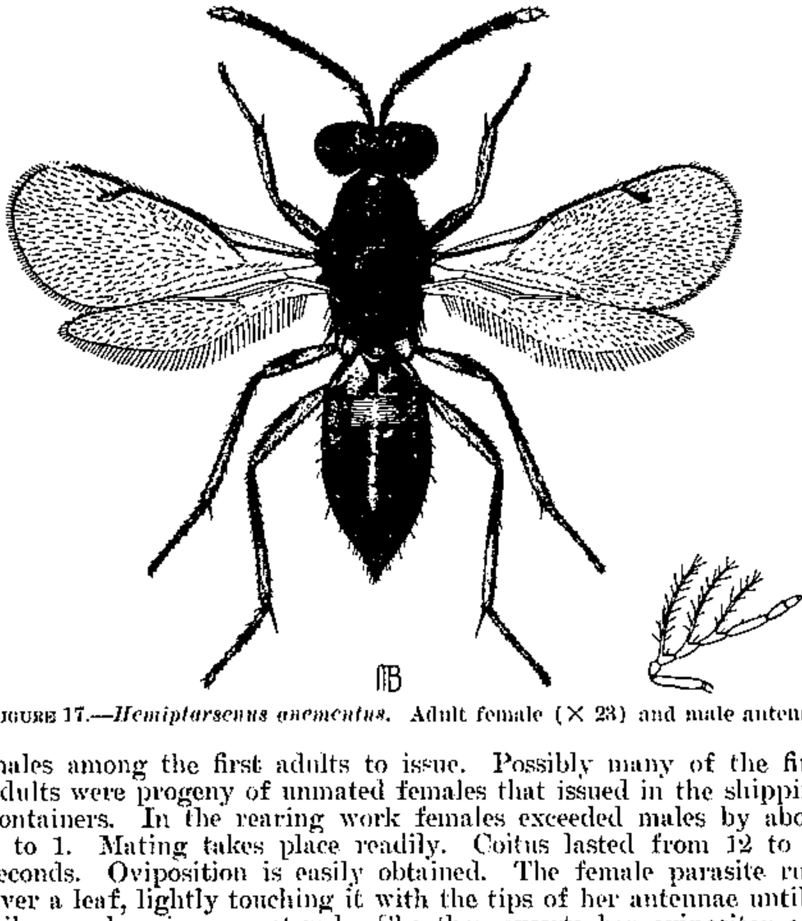

FIGURE 17.—*Hemiptarsenus anementus.* Adult female (× 23) and male antenna.

males among the first adults to issue. Possibly many of the first adults were progeny of unmated females that issued in the shipping containers. In the rearing work females exceeded males by about 3 to 1. Mating takes place readily. Coitus lasted from 12 to 16 seconds. Oviposition is easily obtained. The female parasite runs over a leaf, lightly touching it with the tips of her antennae until a hibernaculum is encountered. She then exserts her ovipositor and after some difficulty pushes it through the surface of the hibernaculum. This action is often repeated many times before the larva inside is struck, but when this is accomplished the ovipositor is tenaciously held in place and the larva soon becomes paralyzed. The ovipositor is then inserted its full length into the cell, and egg deposition takes about a minute. One egg is laid at a time, but several eggs are usually laid in one hibernaculum. As many as 33 *Hemiptarsenus* adults were reared from a single *Phyllotoma* that was exposed to a number of females, but the parasites were abnormally small. Probably from 2 to 10 is the usual number that develop on 1 host larva. No records were kept of reproductive capacity, but 1 female laid 20 eggs in 4 days, with a maximum of 8 during 1 of the days. The eggs hatch in about 48 hours, and the parasite larvae feed externally upon the host. Larvae become full-fed rapidly, and pupae are formed about 10 days after egg deposition. Adults begin to emerge about a week later. Development from egg to adult requires from 17 to 20 days late in the summer.

The egg is 0.47 mm. long and 0.16 mm. wide. Its shape is similar to that of *Sympiesis* sp. (fig. 12, *B*), and the chorion is also covered with minute spines.

There are 5 instars. This fact could be definitely checked, for the skins of previous molts were found adhering to full-grown larvae.

The larvae resemble those of *Sympiesis* sp. and *Cirrospilus pictus* so closely that special descriptions or drawings are unnecessary. The descriptions of the immature larvae of *Sympiesis* apply equally well to *Hemiptarsenus*, although larvae of the latter are a little smaller, and mandibular measurements are also just a little smaller. The full-grown larva differs from *Sympiesis* in one important respect—there are no intersegmental protuberances. It is nearly identical in shape to *C. pictus* (fig. 20, *A*). A minor difference that seems to be constant is that the full-grown larval antennae of *Hemiptarsenus* lack the yellow color noted in *Sympiesis* and they also seem more dome-shaped. In all other respects—respiratory, digestive, and nervous systems, development of fat body and histoblasts, and number and arrangement of sensory setae—the larvae of *Hemiptarsenus* and *Sympiesis* are nearly identical.

CIRROSPILUS PICTUS (Nees)

Cirrospilus pictus (fig. 18) was originally described under *Eulophus* by Nees von Esenbeck (*15, p. 165*) in 1834. Dalla Torre (*6, p. 83*) lists the following hosts: *Nematus salicis* (L.); *Aulax rhoeadis* Gir., and *Coleophora* sp. Thorpe (*24*) reared it in small numbers from *Coleophora laricella* Hbn. collected in England and France. It was commonly reared from the same host species collected in Ostmark by workers from the Bureau of Entomology and Plant Quarantine, and sent to the United States from 1932–35. About 3,500 adult *C. pictus*, representing approximately 20 percent of the parasites recovered, issued from several hundred thousand *Coleophora* cases.

Cirrospilus is a large genus, and many species are known as parasites of leaf-mining and case-bearing insects. Muesebeck and Dohanian (*13*) list several species of *Cirrospilus* as occasional parasites of *Apanteles melanoscelus* (Ratz.). Brief accounts of the life histories of a number of species of *Cirrospilus* have been recorded.

During the 5-year period in which *Phyllotoma* parasites were imported, a total of 939 *Cirrospilus pictus* adults were reared from the small mines. This is far less than the almost 10,000 *Chrysocharis laricinellae* adults reared from the same material, but it is an appreciable number. *C. pictus* is already present in North America.

It was reared by L. Daviault from *Fenusa pusilla* (Lep.) at Berthiersville, Quebec, in 1930 and by the writer from *Phyllotoma nemorata* collected at Eustis and Bar Harbor, Maine, in 1937. *C. pictus* acts either as a primary or as a secondary parasite, and because of this was not liberated in this country. In the laboratory it was reared as a primary parasite of *F. ulmi*, and it oviposited readily on an undetermined sawfly larva in anemone. It was also reared as a secondary parasite on *Apanteles euchaetis* Ashm. Apparently it usually develops as a primary parasite of *Phyllotoma* and *Coleophora* in the field, but it was reared from a cocoon of *Rogas unicolor*

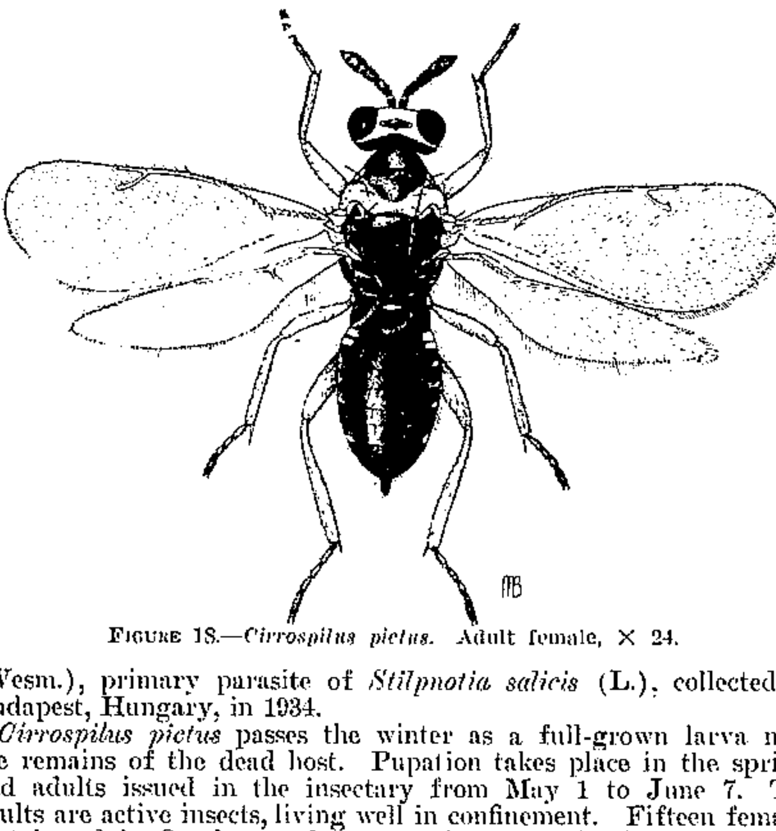

FIGURE 18.—*Cirrospilus pictus*. Adult female, × 24.

(Wesm.), primary parasite of *Stilpnotia salicis* (L.), collected at Budapest, Hungary, in 1934.

Cirrospilus pictus passes the winter as a full-grown larva near the remains of the dead host. Pupation takes place in the spring, and adults issued in the insectary from May 1 to June 7. The adults are active insects, living well in confinement. Fifteen females that issued in October, and were used in reproduction work, lived on an average 33 days, with a minimum of 9 and a maximum of 53. Probably at least 2 generations develop each year. A large percentage of the *C. pictus* adults that issued from *Phyllotoma* material emerged in the fall. Mating was not observed. Oviposition on *Fenusa ulmi* took place after the host larva had been paralyzed. The eggs were then laid on or near the larva. Usually the parasite inserted her ovipositor into the mine a number of times before the larva was hit and paralyzed. In ovipositing upon *Apanteles euchaetis* about 2 minutes was required to bore through the cocoon. The *Apanteles* larva was then vigorously prodded for several seconds, the ovipositor was removed, and sometimes another hole was bored and the prodding repeated. In each case observed the parasite returned to the first entrance hole to oviposit. The egg hatches in from 24 to 36 hours, and the young larva feeds externally upon its host. During June, 15 days were required from oviposition to adult emergence. The egg and larval stages are completed in about 8 days, and about 7 days are spent as a pupa. Three *C. pictus* larvae completed development on one *F. ulmi* larva. The sex ratio in 148 observed individuals showed about 2 males to 3 females.

The egg (fig. 19, *C*) is 0.35 mm. long and 0.13 mm. wide. It is a little wider at the anterior than at the posterior end. Both ends are

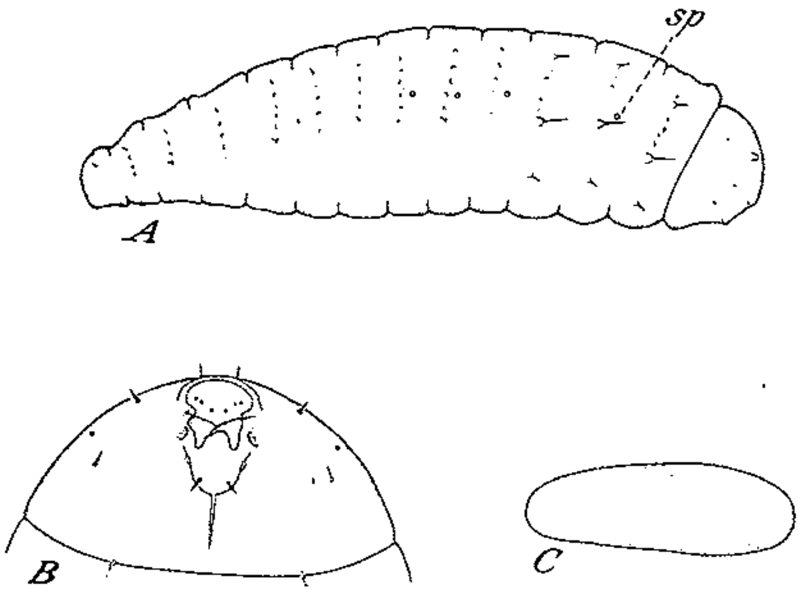

FIGURE 19.—*Cirrospilus pictus*: *A*, First instar; *sp*, spiracle; × 200. *B*, Head of first instar, ventral view, × 400. *C*, Egg, × 100.

bluntly rounded, and the chorion is completely covered with minute papillae. The embryo appears yellowish gray.

Careful observations based on mandibular measurements and observed molt skins have convinced the writer that there are only 4 instars. Full-grown larvae were repeatedly found with 3 old molt skins adhering to their skin.

The first instar (fig. 19, *A*) is of the usual ectoparasitic chalcidoid type. It is 0.44 mm. long and 0.13 mm. wide. It has a well-defined head and 13 body segments of about equal width that taper slightly posteriorly. Each segment has a broken transverse row of minute cuticular papillae across the dorsum. The area near the median dorsal line is bare. The papillae extend downward on each side to about the median lateral line. On the thoracic segments 3 pairs of prominent sensory setae may be distinguished. These 6 setae are about equidistant from one another. The pair on the median lateral line is the longest and most conspicuous. One small sensory seta was observed on each side of the larva near the median lateral line of abdominal segments 2, 4, 6, and 8, and a small seta was also observed on each side of the larva just below the median dorsal line on the last 6 abdominal segments. These setae are so minute, however, that their number and arrangement could not be positively determined. Four pairs of spiracles are present, 1 pair on the mesothoracic and 1 pair on each of the first 3 abdominal segments. The mesothoracic spiracle measures only 0.003 mm. in diameter. The head, viewed from the venter, is shown in figure 19, *B*. The mouth opening is not indicated, and the mandibles (fig. 20, *C*) are flattened out by the cover glass, but

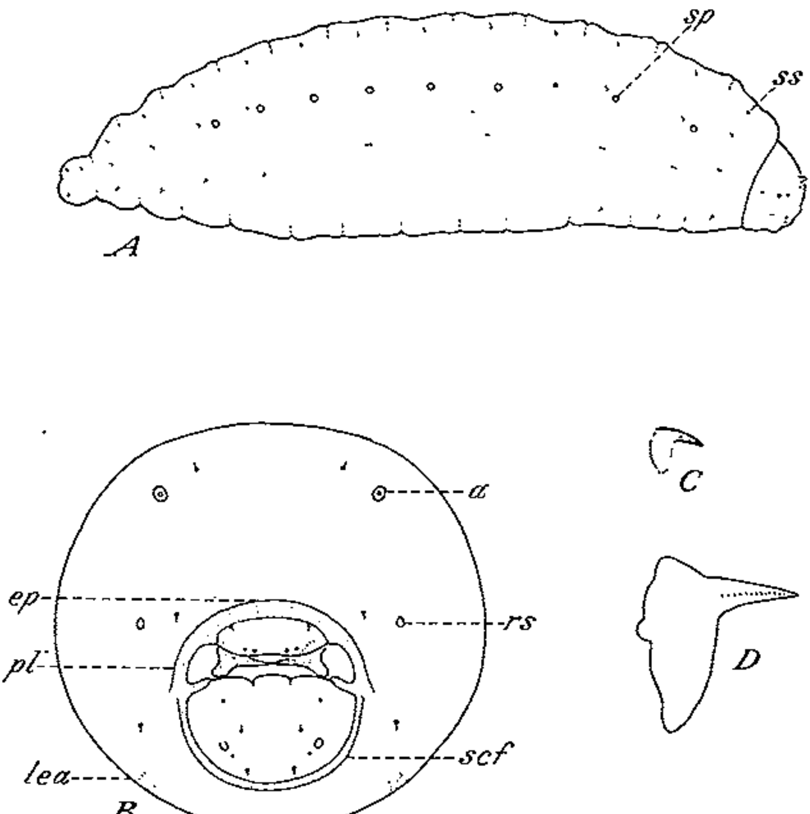

FIGURE 20.—*Cirrospilus pictus*: *A*, Full-grown larva: *sp*, spiracle; *ss*, sensory seta; × 49. *B*, Full-grown larval head, front view; *a*, antenna; *rs*, round sensorium; *scf*, semicircular cuticular fold; *ep*, epistoma; *pl*, pleurostoma; *lea*, lateral epicranial angle; × 250. *C*, Mandible of first instar, × 538. *D*, Mandible of full-grown larva, × 611.

most of the essential characters are shown. The antennae, which are on the dorsal side of the head, are not shown. They are tiny raised areas in the center of which are 2 minute papillae. The mandibles are simple curved hooks measuring 0.013 mm. in length.

The second instar has the same shape as the first instar. The mandibles and antennae are more clearly defined. The mandibles measure 0.02 mm. long. They have a broad base and tiny teeth along the inner margin of the tip similar to those of the last instar. The mesothoracic spiracle measures 0.01 mm. in diameter. The cuticular papillae are absent, and the thoracic sensory setae are not pronounced as in the first instar.

The third instar differs from the second in having spiracles on the last 2 thoracic and the first 7 abdominal segments. The mesothoracic spiracle measures 0.012 mm. in diameter, and the mandibles measure 0.026 mm. in length.

The fourth, or last, instar (fig. 20, *A*) is 2.1 mm. long and 0.65 mm. wide. It has the same general shape as the first instar, although the head is proportionately smaller. The cuticle is unarmed except for the tiny sensory setae shown in figure 20, *A*. In arrangement they are similar to those distinguished in the first instar, but 1 or 2 additional pairs were found on almost all the segments. The head seen from the front is shown in figure 20, *B*. The facial thickenings indicated are almost colorless bands. The lateral epicranial angles are well-defined. The hypostoma seems to be lacking, but there is a well-defined semicircular fold or band beneath the oral cavity. The mandibles (fig. 20, *D*) are pointed processes measuring 0.036 mm. in length. Along the inner edge of their tips there is a row of 10 or 12 extremely minute spines. The antennal organs are circular, truncated swellings.

The tracheal system is well developed. Spiracles are present on the last 2 thoracic and the first 7 abdominal segments, although the pair on the first abdominal segment is only about one-half as wide as the others. The mesothoracic spiracles measure 0.02 mm. in diameter.

The digestive and nervous systems are essentially the same as those shown in figure 13, *A*, for *Sympiesis* sp., but the hind-gut occupies a position in the dorsal part of abdominal segments 8, 9, and 10, and no posterior ileac gland was distinguished. A comparatively small amount of material was available for dissection, and possibly the posterior ileac gland is actually present.

No cocoon is spun, and pupation takes place in the host larva's mine.

CIRROSPILUS VITTATUS (Walk.)

Cirrospilus vittatus (fig. 21) was originally described by Walker (*26, p. 308*) in 1838. Dalla Torre (*6, p. 84*) lists two rearing records, from "*Rhamphus flavicornis*" and *Orchestes fagi L.* Both these hosts are coleopterous leaf miners. It was reared in small numbers from *Coleophora laricella* material sent to this country from Ostmark and England from 1932 through 1936. During the course of this study it was reared from *Phyllotoma nemorata* and *Scolioneura betulae*, and also as a secondary parasite on *Phanomeris phyllotomae* collected in Europe.

About 1,100 *Cirrospilus vittatus* adults issued from the *Phyllotoma* material collected in Europe and sent to the United States, and more than 900 of them were from collections made in 1934. *C. vittatus* acts either as a primary or as a secondary parasite, and therefore was not liberated in this country. It was reared from field-collected *Phanomeris phyllotomae* cocoons, and also from the same species in the laboratory. On the other hand, it was reared under laboratory conditions as a primary parasite of *Fenusa ulmi*, and attacked an undetermined sawfly larva mining in anemone.

Cirrospilus vittatus spends the winter as a full-grown larva near its host's remains. Pupation takes place in the spring, and adults issued in the insectary from May 3 to June 12. The adults live well in confinement. Out of 100 adults issuing October 30, 11 were still alive 50 days later, and 2 that issued in June 1935 lived until August 14. Probably at least 2 generations develop each season. About three-fourths of the adults obtained emerged during the fall (August to November). Mating was not observed. Oviposition was closely observed only on *Phanomeris*. *C. vittatus* females had considerable difficulty in boring through *Phanomeris* cocoons. Often 30 minutes was necessary before entrance was effected, and during this time the parasite wandered around, boring at different places, and then returning to the original

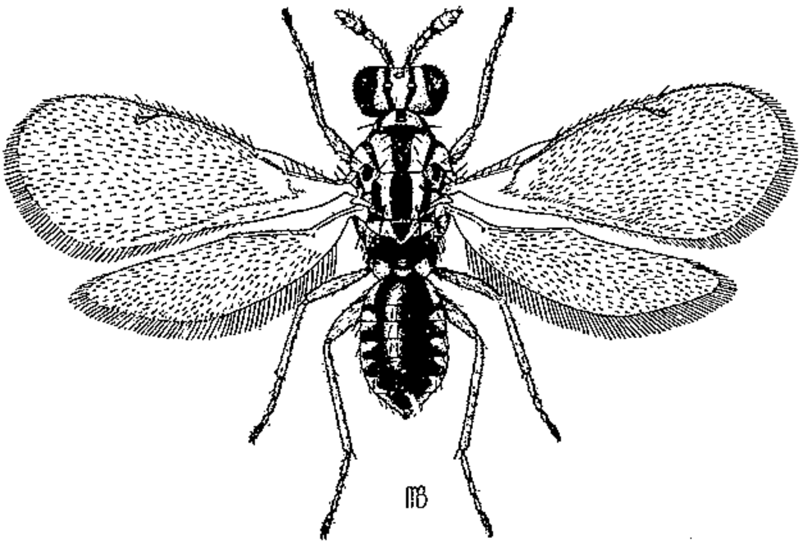

FIGURE 21.—*Cirrospilus vittatus*. Adult female, × 27.

location. The egg is laid externally upon the host. Sometimes oviposition takes place immediately, and the host larva is not punctured. More often it is paralyzed, and frequently a feeding tube is constructed to the outside of the cocoon, at which the adult parasite feeds. Paralysis of a *Phanomeris* larva is unnecessary for the parasite's development. In the limited number of cases observed when oviposition took place on sawfly larvae, the host was paralyzed. The egg hatches in from 36 to 48 hours, and the parasite larva feeds externally. Feeding is completed in about 7 days. The pupa is formed about 2 days later, and the adult issues about 7 days after pupation. The entire life cycle requires about 18 days, but it may be shorter in warm summer temperatures. As many as 3 *C. vittatus* larvae completed development on a single *Phanomeris* larva. The number of *C. vittatus* females greatly exceeded the number of males which issued each year. Complete records on sex ratio were kept only 1 year, when 81 adults issued, and then 1 male emerged to 6 females.

The egg is 0.29 mm. long and 0.085 mm. wide. There is considerable variation in the shape. Some eggs are noticeably curved, and others have almost straight sides. Both ends are bluntly rounded. The chorion is smooth except for a slightly roughened area at the micropyle.

There are 4 instars. Several full-grown larvae have been found with 3 molt skins adhering to them. All the instars resemble those of *Cirrospilus pictus* so closely that special drawings and descriptions have been considered unnecessary.

The first instar is about 0.30 mm. long and 0.085 mm. wide when first hatched. It is similar to the first instar of *C. pictus*, but lacks the cuticular papillae, and also the large sensory setae of the thoracic segments. The only spines distinguished on the body of *C. vittatus* were 3 pairs of extremely minute sensory setae on each of the first 3 segments. The head is also similar to that of *C. pictus*, but the hypostoma can be faintly seen. The mandibles are simple, sickle-shaped hooks that measure 0.01 mm. in length. The mesothoracic spiracle is 0.003 mm. in diameter.

Second instars show only slight changes from the first instar. The mandibles are similar to those of the full-grown larvae, although they are only 0.013 mm. long. The mesothoracic spiracle measures 0.007 mm. across.

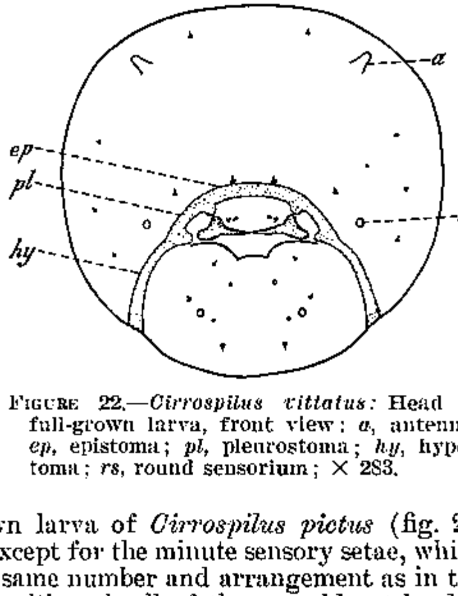

FIGURE 22.—*Cirrospilus vittatus*: Head of full-grown larva, front view; *a*, antenna; *ep*, epistoma; *pl*, pleurostoma; *hy*, hypostoma; *rs*, round sensorium; × 283.

Third instars differ principally from the preceding instars in that they have spiracles on the last 2 thoracic and first 7 abdominal segments. The mandibles measure 0.017 mm. in length and the mesothoracic spiracles 0.01 mm. in diameter.

The fourth instar, or full-grown larva, is 1.96 mm. long and 0.51 mm. wide. The shape is the same as in the preceding instars, being similar to that of the full-grown larva of *Cirrospilus pictus* (fig. 20, *A*). The cuticle is unarmed except for the minute sensory setae, which apparently are present in the same number and arrangement as in the full-grown larva of *C. pictus*, although all of them could not be distinguished on the abdominal segments. The last 2 thoracic and first 7 abdominal segments each bear a pair of spiracles, although the pair on the first abdominal segment is much reduced. The mesothoracic spiracle measures 0.013 mm. in diameter. The head is shown in figure 22. The lower edge of the labrum is not indicated. The head of *C. vittatus* differs from that of *C. pictus* principally in possessing a weakly defined hypostoma and in the absence of a well-defined semicircular facial band beneath the mouth opening. The mandibles are sharply pointed processes that measure 0.023 mm. in length. Along the inner edge of their tips there is a row of 10 or 12 extremely minute spines similar to those observed in *C. pictus*. The internal anatomy shows no readily distinguished differences from that of *C. pictus*. The posterior ileac gland was also not distinguished in *C. vittatus*, although a limited amount of material was available for study.

No cocoon is spun. Pupation takes place in the host larva's mine or case. The pupa is 1.66 mm. long and 0.60 mm. wide. A number of examined specimens appeared shiny black, and the yellow markings of the adult were not visible through the pupal skin.

Chrysocharis laricinellae (Ratz.)

Chrysocharis laricinellae (fig. 23) was originally described by Ratzburg (*19, p. 160*) in 1848 as *Entedon laricinellae*. His speci-

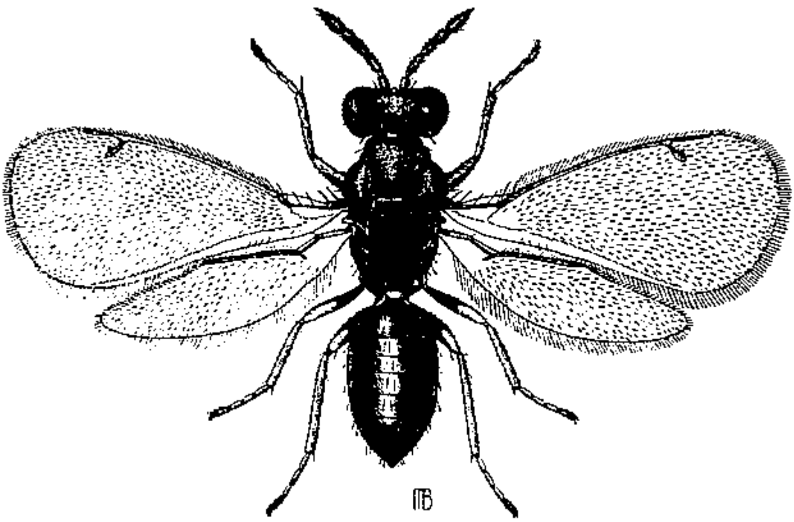

FIGURE 23.—*Chrysocharis laricinellae*. Adult female, × 27.

mens were reared from *Coleophora laricella* Hbn. *Chrysocharis* is a large genus represented by many species in all parts of the world. They all seem to be parasites of leaf miners or casebearers, and larvae of Coleoptera, Diptera, Lepidoptera, and Hymenoptera that mine in leaves or form cases are parasitized. Many species of *Chrysocharis* are polyphagous, and some species attack leaf miners of more than one order. Pests of considerable economic importance are also frequently attacked. *C. livida* Ashm. is one of the most important parasites of the coffee leaf miner (*Leucoptera coffeella* Guer.) in Puerto Rico and Venezuela, *C. gemma* (Walk.) has been imported into British Columbia as a parasite of the holly leaf miner (*Phytomyza ilicis* Curt.), and *C. laricinellae* has been imported into both Canada and the United States for control of the larch casebearer (*Coleophora laricella*). Thorpe (*24*) has given a good account of *C. laricinellae* as a parasite of *Coleophora*. When specimens of *Chrysocharis* were first reared from *Phyllotoma nemorata*, they were referred to as "*Chryscocharis* sp.," for specimens from *Coleophora* showed no apparent interest in *Phyllotoma* larvae. Since then A. B. Gahan, of the Division of Insect Identification, Bureau of Entomology and Plant Quarantine, has definitely determined them as *C. laricinellae.* In the following notes the species is treated almost exclusively as a parasite of *Phyllotoma.*

Chrysocharis laricinellae was easily the most important species of parasite reared from *Phyllotoma* during the 5-year period that collecting work was conducted in Europe. A total of about 10,000 adults issued from material sent to the United States, and more than 5,000 of these were sent in 1 year. The species has the distinct economic value of killing small host larvae when comparatively little of the leaf has been mined, and laboratory rearing indicated that *Chrysocharis* females probably kill, by feeding, a large number of host larvae that they do not parasitize. It is difficult, however, to evaluate properly the importance of *Chrysocharis* from data obtained during this work, for the European collectors frequently attempted to obtain parasitized host material. Furthermore, a rather complex series of adult chalcidoids issued. It is probably sufficient to think of *Chrysocharis* as by far the predominant species of chalcidoid recovered. A number of very good colonies were liberated in New England. The species was recovered from *Phyllotoma nemorata* at Stark, N. H., and Eustis and Bethel, Maine. Of course, it probably was present in this country as a parasite of *Fenusa ulmi* before these liberations were made, and liberations of the species had also been made against *Coleophora laricella.* It is questionable, though, whether it spread from infestations of these hosts or became established from the new liberations. The latter seems probable. During the course of this study it was also reared in the laboratory from *F. pusilla,* and oviposition was obtained in an undetermined sawfly larva mining in anemone.

Chrysocharis laricinellae completes 1 and at least part of a second generation each year. Some laboratory-reared material produced adults the same summer, and a fairly large proportion of the early material collected in the field in Europe produced adults that season. The winter is spent as a full-grown larva in the host larva's mine. Pupation takes place in the spring, and the adults emerge by cutting a roughly circular hole in the epidermis of the leaf. The adults are active, sturdy insects. The males emerge somewhat earlier than the females. The sex ratio for about 8,000 adults that issued in the spring was approximately 3 males to 5 females, and for 757 adults issuing in the fall the ratio was 3 males to 1 female. Under laboratory conditions spring emergence extends from about May 5 until June 23. It is probably somewhat later in the field, for *Phyllotoma nemorata* larvae are too small to be attacked at this time. Field collections indicate, though, that *Chrysocharis* can develop in very tiny larvae. Adults live well for about a month in the laboratory, but mating was only occasionally observed. Coitus lasts about 30 seconds.

The egg is deposited in the body of the host larva. Very poor success was obtained with oviposition, possibly because the oviposition habit is so closely connected with the feeding habit that it was very difficult to separate one from the other. Upon coming in contact with a mined leaf, the female *Chrysocharis* places her antennae close together with the tips lightly touching the leaf and walks slowly over the mine, swaying her body from side to side with a characteristic searching movement. When a host larva is located, the ovipositor is inserted into the mine with a downward thrust. Often the host larva is able to move out of danger in spite of the fact that the parasite moves her abdomen around extending the ovipositor as far as possible in all directions. The parasite usually continues searching, however, until she succeeds in striking a larva. The host larva becomes slightly paralyzed after being struck, and it may be attacked again with less difficulty. One insertion of the ovipositor is frequently sufficient, and the parasite walks away paying no further attention to its victim. The host larva remains semiparalyzed for several hours before resuming feeding, and becomes permanently inactive the second day after oviposition, probably when the parasite egg hatches. In many instances, however, the parasite inserts the ovipositor repeatedly in the same larva, prodding it around in all directions by a sort of seesaw motion of the abdomen, and then withdrawing it to feed at the puncture hole. This procedure is often repeated as many as 50 times. Sometimes an egg is laid in the larva and sometimes

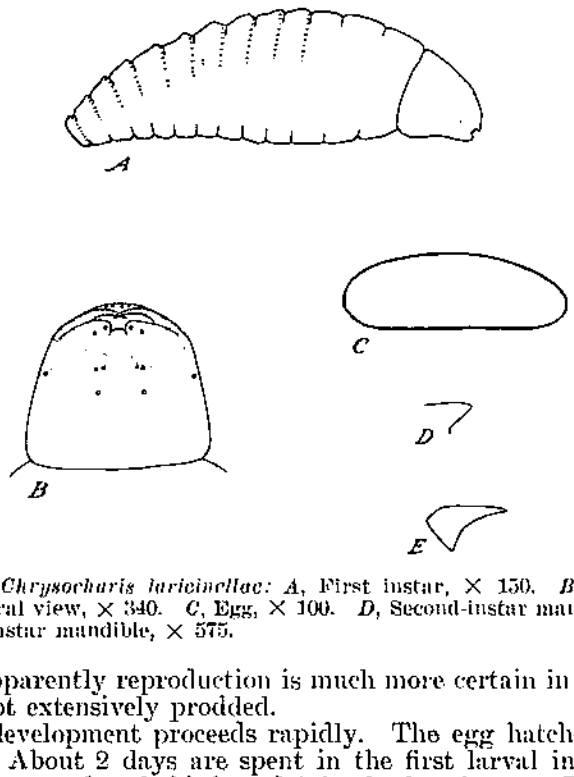

FIGURE 24.—*Chrysocharis laricinellae*: *A*, First instar, × 150. *B*, First-instar head, ventral view, × 340. *C*, Egg, × 100. *D*, Second-instar mandible, × 546. *E*, Third-instar mandible, × 575.

not, but apparently reproduction is much more certain in host larvae that are not extensively prodded.

Larval development proceeds rapidly. The egg hatches in about 48 hours. About 2 days are spent in the first larval instar, 1 day each in the second and third, and 2 in the last instar. By the time the parasite has reached the last instar, it can be plainly seen through the skin of the host. When feeding is completed, the parasite larva pushes itself through the host larval skin and makes its way to the extremity of the mine, where it may rest for 1 or 2 days or hibernate. In the laboratory rearing work (in June) larvae frequently voided their meconium in about 24 hours and transformed to pupae. From 8 to 10 days were spent as a pupa before the adult emerged. Records indicate that a total of 17 to 23 days were required for development from egg to adult, with the highest emergence on the eighteenth day after oviposition.

The hibernation habit of *Chrysocharis* is undoubtedly a factor in the limitation of its increase. Probably hibernating larvae are preyed on by numerous predators, and very likely they are also attacked by secondary parasites. No secondaries have been definitely reared from it in the course of this study, but its close association with *Tetrastichus xanthops* and *Closterocerus ? sesquifasciatus* (Ratz.) makes it seem also certain that they act as hyperparasites. Under natural conditions *Chrysocharis* overwinters on the ground, where it is protected by snow, leaves, etc., but there is probably some mortality due to low temperatures. During the winter of 1933–34, when the temperature went as low as −18° F. at Melrose Highlands, Mass., larvae exposed in an outdoor insectary suffered a mortality of 50 to 70 percent, and the following winter with a minimum temperature of −11° F. there was a mortality of 25 percent.

The egg (fig. 24, *C*) is 0.27 mm. long and 0.09 mm. wide. The chorion is smooth and hyaline.

There are 4 instars. The first instar (fig. 24, *A*) ranges from 0.30 mm. long and 0.10 mm. wide to 0.41 mm. long and 0.12 mm. wide. The head is well defined, and there are 13 body segments. Each of the abdominal segments bears a row of very minute spines on its anterior border. Anteriorly these spines are found only on the dorsal half of the abdominal segments, but posteriorly the rows become somewhat longer, and the last segment is completely encircled. No sensory setae were distinguished on the body segments, and there is no tracheal system. The head (fig. 24, *B*) is very lightly sclerotized. It bears a pair of sharp, strongly curved mandibles that are 0.03 mm. long. There is 1 well-sclerotized cross bar extending across the head, but the usual sclerotized folds are absent or very feebly indicated. A pair of minute antennal organs are situated dorsally near the apex of the head, and a few circular sensoria are present as indicated.

The second instar is similar to the first. The mandibles (fig. 24, *D*) are tiny, blunt, colorless processes very difficult to distinguish, 0.013 mm. in length. There are no open spiracles, but a delicate tracheal system can be distinguished with spiracular branches in the second and fifth to tenth segments, inclusive.

The third instar exhibits almost no changes except in size. The mandibles (fig. 24, *E*) are more clearly defined, are 0.02 mm. long, and the epistoma is faintly indicated.

The fourth instar, or full-grown larva (fig. 25, *A*), ranges from 1.63 mm. long and 0.45 mm. wide to 2.5 mm. long and 1.00 mm. wide. When feeding is completed, the larva spends considerable time squeezed into the narrow space between the upper and lower surfaces of the leaf at the extremity of the host larva's mine. This gives it a very flattened shape dorsoventrally. There are no cuticular spines, but the following sensory hairs were noted: 3 pairs on the first thoracic segment and 4 pairs on the second and third thoracic segments, 1 pair on the first 7 abdominal segments, 2 pairs on the eighth and ninth abdominal segments, and 3 pairs on the last segment. The head, seen from the front (fig. 25, *C*), presents well-defined characters. The maxillary and labial palpi are represented by heavy and conspicuous round sensoria. The epistoma and pleurostoma are strong and clearly defined, although rather lightly sclerotized. The hypostoma, however, fades out so that it is very difficult to distinguish. The inferior pleurostomal rami are prolonged into a strong, well-sclero-

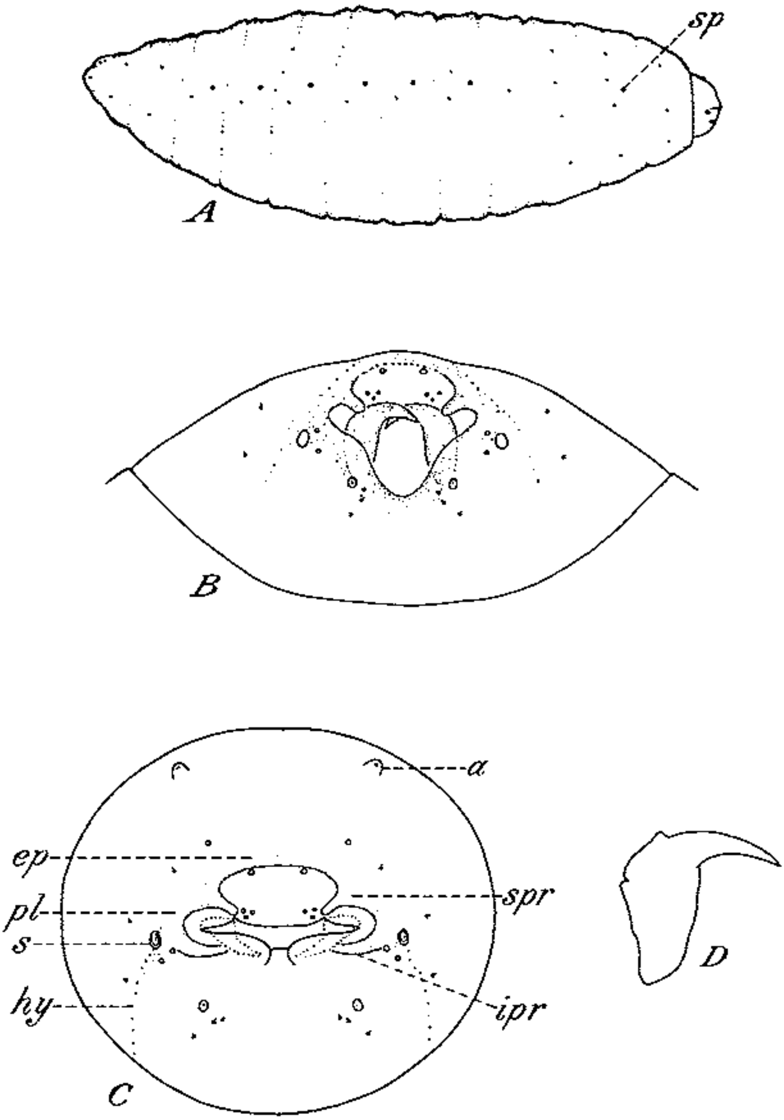

FIGURE 25.—*Chrysocharis laricinellae:* *A*, Full-grown larva; *sp*, spiracle; × 36. *B*, Head of full-grown larva, ventral view, × 254. *C*, Head of full-grown larva, front view: *a*, antenna; *spr*, superior pleurostomal ramus; *ipr*, inferior pleurostomal ramus; *hy*, hypostoma; *ep*, epistoma; *pl*, pleurostoma; *s*, sensorium; × 275. *D*, Mandible of full-grown larva, × 600.

tized cross bar that meets in the middle. Since this cross bar passes under the mandibles, it cannot be seen when the head is viewed from the front. Seen from the venter (fig. 25, *B*), though, it is one of the most prominent head processes. The mandibles (fig. 25, *D*) are simple hooks, heavily sclerotized at their tips. They measure 0.04 mm. in length. The respiratory system is of the usual type.

There are 7 pairs of open spiracles, 1 on the mesothoracic segment and 1 one each on the second to seventh abdominal segments, inclusive. The mesothoracic spiracle measures 0.013 mm. in diameter. The digestive and nervous systems are so similar to that shown in figure 13, *A*, for *Sympiesis* sp. that no special description is necessary, although the anterior ileac glands are relatively wider and extend forward to the first thoracic segment. The fat body lying just beneath the body wall is well developed and dense in the full-grown larva. It is distributed evenly over the body.

Pupation takes place in the host larva's mine shortly after the dark-brown, shapeless meconium is cast. At first the pupa is grayish brown and the adult appendages can be clearly seen through the light, transparent skin. It rapidly darkens, however, until it is entirely jet black. Pupae are about 1.50 mm. long and 0.53 mm. wide.

CHRYSOCHARIS SP.

In 1932 the collectors in Europe found several *Phyllotoma* mines containing large host larvae parasitized internally by a number of small chalcidoids. The contents of the host larvae had been almost completely consumed, and the parasite larvae could be plainly seen inside the host's transparent skin. In the spring the larvae completed their metamorphosis, and the adults issuing proved to be an undetermined species of *Chrysocharis*.

Fifteen adults of this species had issued from material collected in 1931, but they were not associated with the large host larvae. The material collected in 1932 produced 599 adults. Thirty-three issued in the fall, and the rest the next spring. None were received in 1933, but 197 adults were recovered from material shipped in 1934, and only 6 of them issued that fall. Altogether 811 *Chrysocharis* sp. adults were obtained. This is a very small number, when the amount of host material collected is considered, but it is third among the strictly primary parasites recovered. Two fairly good colonies were liberated at different points in Maine. It has not yet been recovered.

Very little was learned regarding the biology and habits of this species. Adults issued the last part of May, before *Phyllotoma* larvae were present in the field. Adults held a considerable time in the laboratory refused to attack small *Phyllotoma* larvae, and they all died before large host larvae were available. All the *Chrysocharis* that were recovered issued from large host larvae, and possibly under field conditions emergence is considerably delayed and large *Phyllotoma* larvae are attacked. Mating is similar to that described for *Chrysocharis laricinellae*. On an average 9 parasites were found in each parasitized *Phyllotoma* larva. They were not tightly packed together as in certain polyembryonic species, but were rather loosely distributed inside the skin. The contents of the host larva had been completely consumed with the exception of the digestive tract, which had been left intact and had turned black, adhering to the transparent skin. Just before pupation most of the larvae cut their way out, and pupated a short distance away. Out of 334 adults issuing in the spring, there were 72 males and 262 females, a ratio of almost 1:4.

Only the overwintering larva was studied. It is similar to the overwintering larva of *Chrysocharis laricinellae* (fig. 25, *A*), measuring 2.41 mm. in length and 0.74 mm. in width. The body form, the number and arrangement of the sensory hairs, and the number and position of spiracles are apparently identical in both species. The mesothoracic spiracle is somewhat smaller, measuring only 0.008 mm. in diameter. The head (figs. 26, *A* and *B*) is also similar to that of *Chrysocharis laricinellae*, but there is sufficient difference to separate

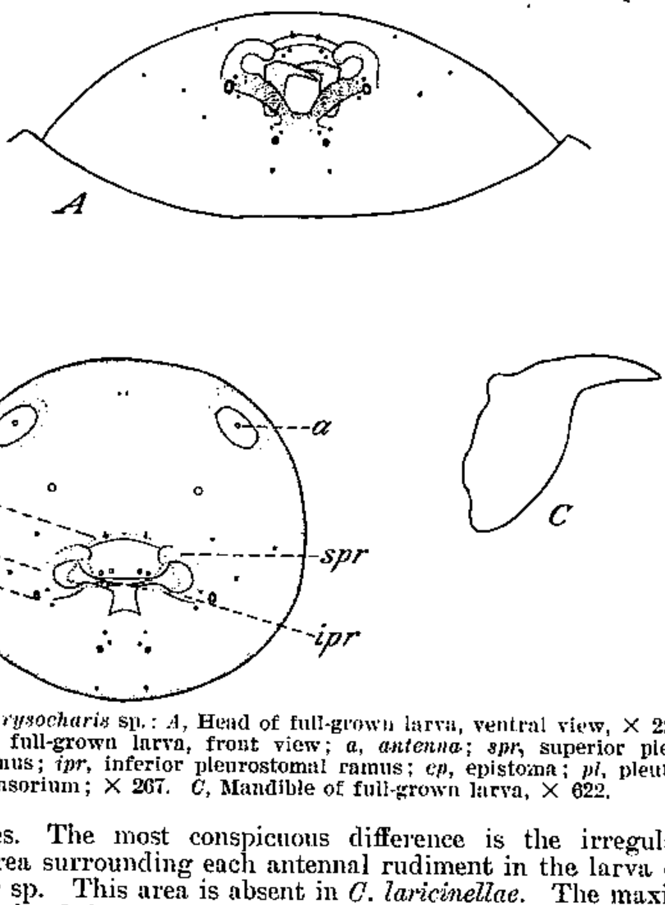

FIGURE 26.—*Chrysocharis* sp.: *A*, Head of full-grown larva, ventral view, × 220. *B*, Head of full-grown larva, front view; *a*, *antenna*; *spr*, superior pleurostomal ramus; *ipr*, inferior pleurostomal ramus; *ep*, epistoma; *pl*, pleurostoma; *s*, sensorium; × 267. *C*, Mandible of full-grown larva, × 622.

the 2 species. The most conspicuous difference is the irregular sclerotized area surrounding each antennal rudiment in the larva of *Chrysocharis* sp. This area is absent in *C. laricinellae*. The maxillary and labial palpi are represented by prominent sensoria, but they are considerably smaller than in *C. laricinellae*. *Chrysocharis* sp. has a heavy, well-defined pleurostoma, but the hypostoma is either lacking or so weakly sclerotized that it could not be distinguished. The mandibles of the 2 species are very much alike. Those of *Chrysocharis* sp. (fig. 26, *C*) measure 0.037 mm. in length.

MISCELLANEOUS SPECIES

A few species of parasites issued from the *Phyllotoma* material in such small numbers that practically no observations could be made regarding their biology. They are recorded, however, and a few notes are given regarding their abundance and what is known about their habits.

MESOLEIUS PHYLLOTOMAE Cush.

Twenty-six *Mesoleius phyllotomae* adults issued from *Phyllotoma* material collected in 1930, six from material collected in 1931, and two from material collected in 1933. The adults all issued in the spring, but they were very feeble. Neither mating nor oviposition was observed.

EPIURUS SPP.

A small percentage of the *Epiurus* adults obtained were *E. brevicornis* (Grav.) and ? *E. buolianae* (Htg.), but owing to the difficulty of separating these species from *E. foliae* the exact number that issued cannot be given.

CLOSTEROCERUS ? SESQUIFASCIATUS (Ratz.)

Although a total of 101 *Closterocerus ? sesquifasciatus* adults were obtained during the 5 years that *Phyllotoma* material was reared, only a small number issued each year, and no observations were made regarding the biology and habits of this species. A few *Closterocerus* adults were obtained from *Phanomeris* material, and at times the species is probably a secondary parasite through *Phanomeris*. The majority of *Closterocerus* adults issued from *Phyllotoma* mines containing chalcidoid pupae or larvae, and its status in this material was not determined.

UNDETERMINED CHALCIDOIDS

Forty-five adult parasites were reared and classified as undetermined chalcidoids. Many of these were very tiny or peculiarly marked adults belonging to one of the determined species. A few specimens were determined as *Sympiesis* sp., *Pnigalio* sp., and *Tetrastichus* sp.

METHODS OF LABORATORY REARING

The rearing of parasites of *Phyllotoma nemorata* larvae presents some rather difficult problems. *Phyllotoma* is a leaf miner, and larvae cannot be successfully transferred from one leaf to another. They must therefore be parasitized in growing leaves or, if the leaves are removed from the trees, they must be kept in good condition long enough for the parasite to complete development.

Two species, *Tranosema pedella* and *Phanomeris phyllotomae*, were successfully reared on host larvae left in growing leaves. For this purpose a number of heavily infested potted birches were used. Parasitization by *Tranosema* was obtained by placing a female parasite in a suitable glass vial and then inserting an infested leaf, still attached to its twig, into the same vial. Actual attack by the parasite could thus be observed and each leaf labeled properly. For rearing *Phanomeris* a potted birch tree was enclosed in a cellophane bag having a gauze top and bottom to provide ventilation. Several *Phanomeris* females were placed in the bag at a time. These parasites are large enough to be seen and removed when desired. The use of small trees was found impractical for minute chalcidoids. These parasites are too small to be observed or removed readily. After considerable experimentation it was found that infested leaves would keep fresh in tin boxes if a thin film of vaseline was put around the edge of the cover. In rearing the various species of chalcidoids, infested leaves were removed from the trees, their stems were placed in very small vials filled with water, and the vials were plugged with absorbent cotton. These leaves were then placed in large glass vials containing female parasites. After oviposition was observed, the leaves were removed from the small vials and placed in the tin boxes.

The rearing of parasites of *Phyllotoma* hibernacula presented no difficulty, for the host larvae or prepupae had completed their feeding. It was possible with these species to transfer eggs and host material to depressed slides for close observation when desired. Many *Phanomeris* larvae were also reared in depressed slides, but this species had to be confined within narrow limits to prevent the parasite larvae from wandering.

The above methods worked well, but a further complication arose due to the very slow development of *Phyllotoma* larvae. Most of the parasites had issued by the middle of June, but *Phyllotoma* adults did not begin ovipositing until about this time. Several weeks elapsed before host larvae were large enough to be parasitized, and under laboratory conditions only a few parasites survived the long period between emergence and oviposition. Fortunately another leaf miner, *Fenusa ulmi*, was obtained during June, and most of the chalcidoids were reared on this species. The parasites that attack hibernacula were reared on retarded material.

SUMMARY

The birch leaf-mining sawfly (*Phyllotoma nemorata* (Fall.)) became abundant in Maine in 1926, and is still plentiful in a number of areas. It has one generation a year. The winter is spent as a prepupa within a lens-shaped hibernaculum spun inside the larval mine. Several native species of parasites attack *Phyllotoma* in Maine, and at times birds act as important predators.

Although *Phyllotoma* is present in many European countries, no severe infestation has ever been reported. From 1930 through 1934 workers in the Bureau of Entomology collected *Phyllotoma* material in Ostmark and southern Bohemia to obtain beneficial parasites for liberation in this country. Parasitization was generally low in 2 general areas at about 48 collecting points. At some localities small *Phyllotoma* larvae were heavily parasitized, but very few parasites were reared from the hibernacula. Birds were the most important control factor at the collection points. About 20 species of parasites were reared, but many of them act as both primary and secondary parasites; consequently only 5 were liberated in the United States. Two species, *Chrysocharis laricinellae* (Ratz.) and *Phanomeris phyllotomae* Mues., have become established, and small numbers have been recovered at several liberation points in Maine. These 2 species were the most important parasites reared in Europe. Together they represented about 72 percent of the parasites reared.

The biology and immature stages of 12 species of *Phyllotoma* parasites were studied in detail.

Phanomeris phyllotomae is a braconid that develops as an external parasite of *Phyllotoma* larvae. It has one generation a year. This species has been recovered at Bar Harbor and Eustis, Maine. *Epiurus foliae* (Cush.) is an ichneumonid parasite of *Phyllotoma* hibernacula. Its larvae feed externally upon host prepupae.

Agrothereutes pygoleucus (Grav.) is a cryptine. The females are subapterous. They attack *Phyllotoma* hibernacula, laying eggs on or near the hibernating prepupae. Since cocoons of primary parasites are sometimes attacked by *Agrothereutes*, the species was not liberated.

Tranosema pedella (Hlmgr.) is a campoplegine parasite that develops as an internal parasite of *Phyllotoma* larvae. Eggs are laid in very small host larvae, but the parasite spends the winter as a first instar, and adults do not issue until the following spring. The species seems poorly adapted to *Phyllotoma*, for many eggs and larvae die without completing development. The remaining 8 species of parasites are chalcidoids of the family Eulophidae.

Chrysocharis laricinellae was the most important parasite of *Phyllotoma* in Europe. It is a solitary internal parasite of small *Phyllotoma* larvae. It has been recovered from *Phyllotoma* at three liberation points—Stark, N. H., and Bethel and Eustis, Maine. *C. laricinellae* has also been successfully introduced as a parasite of *Coleophora laricella* Hbn.

Chrysocharis sp. is a gregarious, internal parasite that completes its development in large *Phyllotoma* larvae.

Hemiptarsenus anementus (Walk.) is a gregarious external parasite of *Phyllotoma* prepupae that have spun their hibernacula. *Sympiesis* sp., *Pnigalio cruciatus* (Ratz.), *Cirrospilus pictus* (Nees), *C. vittatus* (Walk.), and *Tetrastichus xanthops* (Ratz.) are all external parasites of partly grown *Phyllotoma* larvae. Each of them at times develops as a hyperparasite, and for that reason none of them were liberated. *C. pictus* and *T. xanthops*, however, are already present in this country.

Laboratory rearing of *Phyllotoma* parasites was difficult, because the host is a leaf miner which develops very slowly. Various methods of rearing were used, and many of the chalcidoid parasites were reared on another leaf miner, *Fenusa ulmi* Sund., an introduced pest of elms. Two *Phyllotoma* parasites, *Chrysocharis laricinellae* and *Tetrastichus xanthops*, were reared from *F. ulmi* collected in the United States.

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