Bulletin 348 February, 1933

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Fenusa pumila Klug

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CONTENTS

THE BIRCH LEAF-MINING SAWFLY

Fenusa pumila Klug

Roger B. Friend

The birch leaf-mining sawfly *(Fenusa pumila* Klug) was first discovered in this country in Connecticut in 1923 (Britton 1924, 1924a), having been introduced into the northeastern United States at some time prior to this date, probably by accident. The adults were reared at this Station by the writer in 1924 and identified by Mr. S. A. Rohwer, then of the United States National Museum. The insect is of some interest to those concerned with shade and forest trees. It is a European species with a high reproductive potential which is apparently well adapted to natural conditions in New England, New York, and southeastern Canada and has become very abundant and widely spread in this region during the last ten years. There is no reason at present to believe that we have not acquired a permanent resident. In Europe, where this sawfly is native, its geographic and climatic range is extensive. It is the purpose of this bulletin to give the results of the writer's observations on the biology of the insect during the last five years and its relation to white and gray birches, particularly in Connecticut.

The writer expresses his appreciation to Dr. W. E. Britton, Entomologist of this Station, under whose direction the investigations were conducted; to his associates on the Station staff, B. W. McFarland and Neely Turner, for assistance in the field and laboratory, and B. H. Walden, for the photographic work. For aid in obtaining specimens from Europe and information regarding the status of the insect on that continent, thanks are due to R. C. L. Perkins, A. W. Stelfox, I. Trägårdh, Y. Sjöstedt, I. Philipjev, and R. B. Benson. Philip B. Dowden has very kindly aided in identifying the parasites.

HISTORICAL

Fenusa pumila was originally described by Klug in 1814 and placed by him in the genus *Tenthredo,* although apparently known by Fallén in 1808 as *Hylotoma intercus.* Konow (1905), who places the species in the genus *Caliosysphinga* Tischbein along with the species *ulmi* and *dorhnii*, gives the following synonymy:

> "*C. pumila*, Klug (Tenthredo p.), Mag. Ges. Naturf. Berlin, Vol. 8, p. 277 (1814) (Eur. md. et bor.).
> *Hylotoma intercus*, Fallen, Svensk. Vet. Ak. Handl. Vol. 29, p. 46 (1808).
> *Dolerus pusillus*, Lepeletier, Mon. Tenthr. p. 120 (1823).
> *Tenthredo pygmaea*, Zetterstedt, Ins. Lapp. Vol. 1, p. 340 (1838).
> *Aphadnurus tantillus*, O. Costa, Fauna Napoli, Tenthr. p. 41, t. 66, f. 6 (1859).
> *Fenusa fuliginosa*, Healy, Entom. Vol. 4, p. 225 (1869).
> *F. minima*, Brischke, Schrift. Ges. Danzig, N. F. V. Vol. 4, p. 264 (1883)."

Little has been written about the biology of this insect, and apparently the species has been confused with other leaf-mining sawflies that feed on birch. Zetterstedt (1840) simply stated the insect *(T. pygmaea)* to have been found in Lapland, although not common ("Habit. in Lapponia Norvegica, rarius"). Healy (1869*a*) briefly described the life cycle, noting that the insect had two generations a year and was common on *Betula alba* in certain parts of England. He called the species *Fenusa fuliginosa*, and although later authors have been of the opinion that the species concerned was really *Fenusa pumila*, the description of the larva as given by Healy does not agree with that of Enslin (1914), nor with the larvae reared by the writer. Some other sawfly was probably involved. The "Life History of *Fenusa pumila*" by Healy in 1869 refers to still another species. Cameron (1882) seems to have likewise described the larva of some other species in writing about *Fenusa pumila*. He gave the continental distribution of the insect as Sweden, Germany, France, Italy, and Russia. Brischke (1883) stated *Fenusa pumila* to be a leaf miner in *Alnus* in the larval stages, but his description and figures of the larva agree with neither this insect nor *F. dorhnii*, a common leaf miner in *Alnus*. On the other hand, Brischke's description and figures of *F. minima* indicate that this latter species was *F. pumila*, as Konow has indicated in his synonymy. The latter author (1905) gave the geographical distribution as central and northern Europe.

Enslin (1914), whose work was mainly taxonomic, stated that the larvae mined the leaves of *Betula* and there were two generations a year. His larval description, though brief, agrees with the observations of the writer. Hering (1928) briefly described the larval mines in birch. Ripper (1931) found the larvae mining the leaves of *Betula verrucosa* in Central Europe. In his description of the last feeding larval instar, he mentioned the presence of a dark brown thoracic shield, a character never observed by the writer and not mentioned by Enslin. The writer (Friend, 1931) has published a brief description of the life cycle of the species and methods of controlling it by the use of insecticides.

R. B. Benson of the British Museum very kindly examined adult specimens collected in Connecticut by the writer and in correspondence has stated that they appear identical with the European species. Specimens received from R. C. L. Perkins of Newton Abbot, Devon, England, and from Prof. Y. Sjöstedt of Stockholm, Sweden, also appear identical with those collected in Connecticut.

SYSTEMATIC POSITION

Although placed in the genus *Tenthredo* by Klug, the species later was made the genotype of *Fenusa* Leach (Enslin, 1914). Konow (1905) considered *Fenusa* as a genus containing several other species of sawflies and placed the species *pumila* along with *ulmi* and *dorhnii* in the genus *Caliosysphinga* Tischbein. Cameron (1882) believed *Fenusa* and *Caliosysphinga* to be synonymous, and Enslin (1914) took the same view. Both authors placed the species in the former genus. *Pumila* can be readily distinguished from *ulmi* and *dorhnii* by Enslin's key. MacGillivray (1916) placed *dorhnii* in the genus *Fenusa* and *ulmi* in his genus *Kaliofenusa*. Although *pumila* was not known in North America at the time, it fits into MacGillivray's classification in the genus *Fenusa*.

There are other species of sawflies in Europe and North America the larvae of which mine the leaves of birch. However, the species *pumila* may be readily distinguished from these by the characteristic black marks on the ventral side of the body of the larva and by the type of mine.

The position of the species in the Tenthredinidae is indicated below according to Enslin and MacGillivray.

	Enslin	MacGillivray
Family	Tenthredinidae	Tenthredinidae
Subfamily	Tenthredininae	Fenusinae
Tribe	Blennocampini	—
Genus	Fenusa	Fenusa
Species	pumila	(pumila)

Yuasa (1922), in his "Classification of the Larvae of the Tenthredinoidea," follows MacGillivray as far as this particular species is concerned.

GEOGRAPHICAL DISTRIBUTION

Fenusa pumila is a native of Europe, where its host plant is the birch. According to Cameron (1882) it is found on the British Isles and in Sweden, Germany, France, Italy and Russia. From correspondence with European entomologists, it appears to the writer that the insect is not sufficiently abundant to be a serious pest of its host plants. In Ireland it is present but not very common. In England it is common and is probably present wherever birch grows, and it also occurs in Scotland and Wales. In Sweden the insect is found all over the southern and middle parts of the country, but just how far north it occurs is not known, although it has been taken in the northern third. In Russia its abundance is problematical, although it is found here.

In North America the writer has received reports of the insect or specimens of it from northeastern United States and southeastern Canada. It occurs on the native white and gray birches and on the imported European white birch. It has been reported from New Brunswick, Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, and Pennsylvania. It is distributed entirely over New England where the white and gray birches grow.

LIFE HISTORY AND HABITS

The earliest account of the life history of *Fenusa pumila* Klug is that of Healy (1869), who called the insect *Fenusa fuliginosa.* "A Life History of *Fenusa pumila,*" published by Healy the same year, refers to a leaf miner in *Rubus fructicosa* and is another species. Even Healy's *fulignosa* is questionably the true species *pumila.* According to this author, in England the insect is two-brooded, the larvae of the first generation appearing on *Betula alba* about June 12. There are three larval molts, after which the insect enters the ground and forms a small cocoon in which it pupates. The maximum abundance of larvae of this generation occurs about July 4, and few are found ten days later. Adults of the second generation appear about the end of July and the larvae of this generation are abundant during August and the first part of September. This generation hibernates.

Ripper (1931) has published a short paper on the species in which the manner of feeding is briefly described. The writer (Friend, 1931) has given a brief report of the life cycle.

EMERGENCE OF ADULTS FROM HIBERNATION

In Connecticut the first adults of the season appear about May 12 in the vicinity of New Haven. The first leaves of the gray birch are then fairly well developed. Males and females may be easily seen walking over the upper surface of the leaves and hovering in the air above the plants. During warm quiet days they are particularly abundant. It is easier to find females than males, because the former remain on the leaves to oviposit, but the sexes in copula are quite commonly found on the leaves, the female dragging the male after her. In 1928 our insectary records gave the following dates of emergence of adults from hibernating larvae. These larvae had been placed in soil-filled glass jars the preceding year and kept in an out-door cage during the winter.

TABLE 1. EMERGENCE FROM HIBERNATION IN 1928

Larvae entered soil	Adults emerged	Sex and number of individuals		Total number
		Males	Females	
Aug. 10–17, '27	May 11–22, '28	7	15	22
18	11–22	0	1	1
19	11–22	0	2	2
20	11–22	4	10	14
21	11–22	1	0	1
28	11–22	11	7	18
29	11–22	2	6	8
10–17	23–24	2	2	4
19	23–24	0	1	1
20	23–24	0	3	3
28	23–24	1	2	3
29	23–24	1	0	1
10–17	25	0	1	1
20	25	0	1	1
27	25	0	2	2
10–17	26–28	2	6	8
18	26–28	0	2	2
28	26–28	1	1	2
29	26–28	1	0	1
10–17	29–30	1	0	1
18	29–30	2	3	5
19	29–30	0	2	2
28	29–30	1	0	1
Sept. 17	31	0	1	1
Aug. 22	June 4	2	3	5
Aug. 10–Sept. 17, '27	May 11–June 4, '28	39	71	110

The proportion of sexes gives a sex ratio of .65, or almost two females to one male. The 1930 emergence from hibernation is given in Table 2. The larvae were kept in a soil-filled metal container about 7 inches wide and 12 inches deep which was buried in the ground out-doors, so that the top was level with the surface, and allowed to remain during the winter.

The sex ratio in this case is .51 or very nearly an even proportion. Table 2 does not include two males and three females that emerged between October 1 and October 8, inclusive, in 1929. The emergence records of the summer generations, given in Table 15, lead the writer to the belief that the sex ratio of .65 obtained in 1928 more nearly indicates the true situation than that obtained in 1930, for the ratio for all the summer rearings included is .60. It is also true that in the insectary females have produced eggs parthenogenetically from which larvae have hatched.

TABLE 2. EMERGENCE FROM HIBERNATION IN 1930

Larvae entered soil	Adults emerged	Sex and number individuals		Total number
		Males	Females	
Sept. 12–18, '29	May 9, '30	21	24	45
12–18	10	7	8	15
12–18	11	4	3	7
12–18	12	0	1	1
12–18	16	2	0	2
Sept. 12–18, '29	May 9–16, '30	34	36	70

OVIPOSITION

The females lay their eggs inside the leaf tissue, inserting the ovipositor through the upper epidermis. The eggs are usually placed in the central area of the leaf and singly. The length of time taken to lay one egg, from the insertion of the ovipositor in the leaf to its withdrawal, is about 71 seconds. When conditions are favorable a small number of eggs may be deposited in one leaf by one female in a relatively short time. One individual noted deposited seven eggs in one leaf between 3:21 and 3:33 P.M. (temperature 65° F., relative humidity 56 per cent). The time required for each of the seven eggs was 70, 70, 75, 70, 65, 80, and 65 seconds respectively. The remainder of the 12 minutes was spent in wandering over the leaf surface. The female then flew to another leaf. This appears to be the normal procedure. A few eggs are laid in a leaf after the insect has examined its upper surface in a rather hurried, but what appears to be critical manner. The total number of eggs in one leaf varies considerably.

One female does not tend to overcrowd a leaf with eggs, but when the adults are abundant the number of eggs per leaf may be high. After the first two generations have been completed the number of larvae per leaf drops off somewhat except on young sprouts, where an intense infestation usually lasts throughout the summer. As many as 63 eggs and living larvae have been found in a single gray birch leaf on a sprout (this leaf had an area of about 500 square millimeters), but the usual number is much less. Twenty-six gray birch leaves examined in August, 1930, had an average of nine eggs per leaf hatch in a period of eight days. The egg mortality varies up to about 36 per cent, so more than nine eggs per leaf were probably deposited. In August, 1929, an examination of 84 leaves showed an average of seven larvae per leaf, the actual number present being from one to 22 per leaf.

Some larvae had doubtless left the leaves when the count was made. The eggs can be easily seen if a leaf is held to the light.

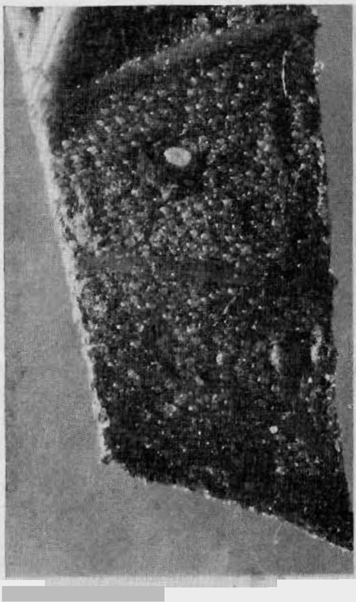
The act of oviposition and the presence of eggs affects the leaf somewhat. A small scar in the upper surface remains where the female ovipositor cuts into the leaf, and after two or three days the position of the egg is indicated by a raised spot on the upper and lower surface. The position of the egg inside the leaf is shown in Plate 1, figure 1, and the more sharply pointed end, which is toward the scar, adheres firmly to the inside of the upper epidermis. In addition to the scar formed over the incision made by the ovipositor the presence of eggs in a leaf is often indicated by a grayish discoloration over a considerable area around the egg itself, particularly on white birches *(B. papyrifera)*. This greyish discoloration is easily seen on well developed leaves and occurs whether or not the eggs hatch. The presence of eggs also appears to cause a slight local arrestation of leaf growth with a consequent slight wrinkling.

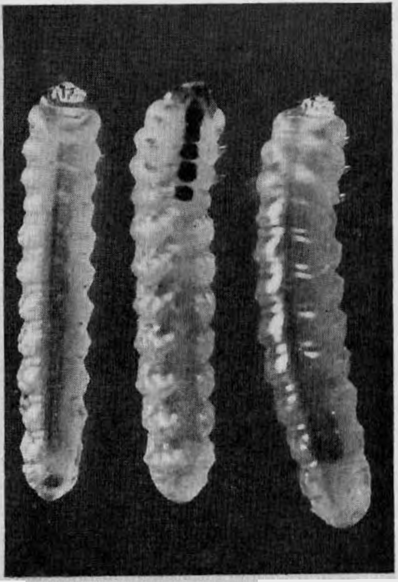
The number of eggs normally laid by one female has not been determined definitely. Three females dissected before they were allowed to oviposit showed respectively 66, 96, and 44 fully developed eggs and 100, 100, and 84 immature eggs in the ovarian filaments. In one day as many as 22 eggs have been secured from a virgin female and 23 eggs from a fertilized female. In captivity most of the females oviposit one day only, and the number of eggs usually secured is much less.

There is at times a considerable mortality of eggs under natural conditions. In one instance out of 55 eggs observed 20, or 36 per cent, failed to hatch. In the laboratory, there was also at times a fairly large mortality of eggs in leaves on twigs cut in the field and placed in jars of water. This varied from 2 to 28 per cent. This mortality of eggs occurred in leaves in good condition for incubation; that is, young growing leaves. If the eggs are deposited in leaves which have almost or entirely completed their growth, no larvae hatch. This occurs at times under natural conditions. In the laboratory females have not oviposited in hardened foliage, nor does this occur normally in the field. Due to the fact that the period of incubation is six to ten days in length, and that females oviposit in young leaves only, the eggs in one leaf hatch during a relatively short period of time and there is little mortality due to injury of eggs by feeding larvae. Since the larval mines are small and immediately around the position of the egg during the first few days of feeding, and the eggs are separated usually by a relatively great distance, the chance of eggs being injured by feeding larvae is further reduced.

The preoviposition period of the females observed in captivity is usually less than 24 hours; that is, females will oviposit the day they emerge from the soil. The duration of adult life in captivity

PLATE I





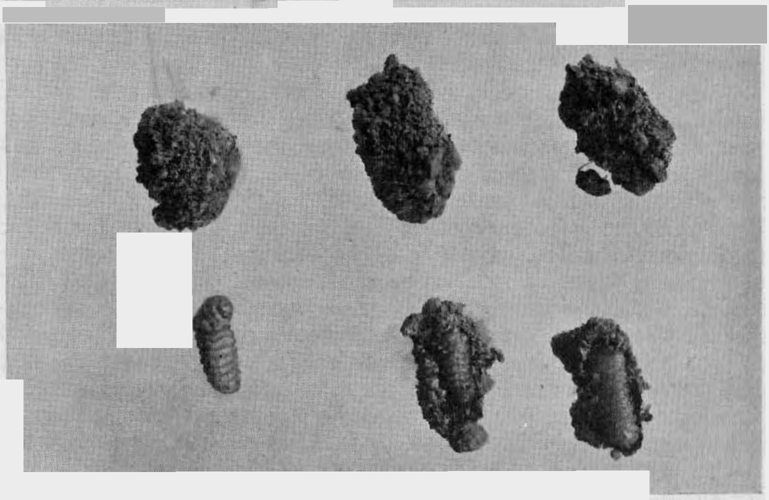


FIGURE 1. Upper left. Egg in leaf showing well-developed embryo. Leaf tissue covering egg removed. X 2.

FIGURE 2. Upper right. Fully grown larvae. Left and right dorsal aspects, center ventral aspect. X 8.

FIGURE 3. Lower. Prepupae and cocoons. X 4. Lower row shows part of cocoon removed in two right figures and prepupa removed from cocoon in left figure. Upper row shows cocoons intact.

is short, rarely exceeding two days, but under natural conditions it is probably longer, for adults captured in the field usually live a day or two in cages. Adults have never been observed to feed under natural conditions or in cages, and they did not appear attracted to honey and water placed in the cages. It has been recorded by Hamilton (1932), however, that adults are attracted to sweet poisoned syrup and are killed by feeding on this material. Whether or not they take food or water under natural conditions is problematical, but certainly neither food nor water are necessary for mating and oviposition.

As previously mentioned, virgin females will lay eggs, and these eggs will produce larvae which feed the normal length of time. Adults have not been secured from such larvae, so the sex of the progeny of these females was not determined. Parthenogensis in sawflies is a common occurrence.

It appears generally true that adults will fly to low growth to oviposit in preference to trees 20 to 30 feet high. It has been observed in several cases that sprouts 4 to 6 feet high growing from the base of a tree were heavily infested, whereas the top of the tree itself, about 20 or 25 feet high, contained neither eggs nor larvae. It is true that the first and second generations of adults will oviposit in the tops of tall gray birches, but as a rule the infestation is not so intense as that which occurs in low sprout growth. This may be due to a disinclination of the insect to fly far above ground or to a preference for leaves of young plants. Air currents may affect this somewhat, for a slight breeze over the top of a birch will clear the air of individuals in flight, and air currents are presumably stronger over the tops of the tall trees than over the tops of shrubs.

The maximum flight distance has not been determined, nor are there any data available on the extent of spread by flight. Since its first appearance about nine years ago this insect has been found all over New England and in southeastern Canada.

EGG STAGE

The duration of the egg stage shows some variation. The following table gives the length of the egg stage during the indicated periods.

The shortest observed egg stage was five and the longest 13 days. Very few eggs had either extreme period, the majority hatching after 6 to 10 days. This variation does not occur among eggs laid by one female at one time, for in almost all cases all the eggs laid on one plant in one cage on the same day hatched on the same day, having the same period of incubation.

The size of the egg increases after it is laid. The average length of an egg when deposited by the female is about 0.38 mm., but after a few days it swells to a length of about 0.47 mm. This increase in the size of sawfly eggs after oviposition has been noted by others in other species.

TABLE 3. DURATION OF EGG STAGE

Date	Number of eggs	Length of stage
May, 1929	9	8 ±.00 days
May, 1930	60	10.6±.14
June, 1928	13	8.4±.10
June, 1930	35	6 ±.00
	5	7 ±.00 Laid the same day
	1	8 ±.00
	9	6 ±.00 Laid the same day
	14	7 ±.00
June–July, 1930	162	6.5±.03
July, 1929	30	6.6±.08
July–Aug., 1930	70	7.3±.08
August, 1929	5	8.0±.00
Aug.-Sept., 1927	44	9.2±.09
Aug.-Sept., 1930	114	6.7±.04
June-Sept., 1927	79	8.4±.20

ACTIVE LARVAL PERIOD

When the larva first hatches from the egg the abdomen is curved back and remains so for a day or two. At the time of hatching the total body length is about 0.7 mm. and the black ventral marks characteristic of later instars are absent. During the first instar, which is from two to three days in length, the larva mines a kidney-shaped area close to the egg, the latter being in the lateral indentation of the mine. During this first instar the body length increases to about 1.4 mm. and the head capsule measures from .273 to .299 mm. in greatest width. During the act of molting the head splits longitudinally on the dorsal side and the cast skin is worked posteriorly off the abdomen. The second instar is two to three days in length and during this time the body reaches a length of from 2.0 to 3.0 millimeters. The head width is about .426 mm., although it varies considerably. The mine is extended and although very frequently the kidney shape is maintained, it often becomes elliptical or roughly circular. The third instar is also two to three days in length and the total body length during this instar increases to from 4.0 to 4.5 mm. The head capsule is about .572 mm. in width, but this varies more than in the preceding instar. The mine is of the blotch type, but varies much in shape. The fourth instar is of about the same duration as the third, and at the end of this instar the larva is fully grown. Its head width varies from .611 to .767 millimeters in width, with a mode at .650 millimeters. The body length at the end of this instar is about 6.0 mm.

Immediately after molting the insect leaves the leaf, drops to the ground, and forms a pupal cell. No feeding occurs in the fifth instar and no increase in size takes place. The body length and head width of the fifth instar are thus practically the same as those of the fourth. The last instar does, however, change in color. The color of the body becomes yellowish white and the ventral black markings are absent. Whether or not the males and females have the same number of instars has not been determined by actual observation on a series of individuals, but the fact that the head widths of all individuals measured show one definite mode in the fifth instar inclines the writer to the belief that there is no sexual difference in this respect.

The duration of larval life in the leaf varies somewhat, as is indicated in Table 4.

TABLE 4. DURATION OF LARVAL LIFE IN THE LEAF

Date	Number of larvae	Mining period
Sept., 1925	17	11.8 ± .41 days
Aug.-Sept., 1927	70	13.0 ± .16
Aug., 1927	14	11.0 ± .0
Sept., 1927	5	14.0 ± .0 (from virgin female)
May–June, 1928	17	14.6 ± .75
July, 1929	25	8.4 ± .09
July, 1929	26	12.2 ± .28
June, 1930	24	10.9 ± .19 (Generation I)
July, 1930	44	9.4 ± .09 (Generation II)
Aug., 1930	57	9.4 ± .13 (Generation III)
Sept., 1930	25	11.0 ± .18

The shortest larval mining period observed was six days, but this was an observation in the field, and there may be some question as to the ultimate fate of the insect. The maximum number of days that a larva was observed to mine was 18. The usual mining period is between 8 and 13 days in length. Aside from inherent variability among different individuals several external factors could presumably cause a variation in the duration of the mining period. The variations in the qualities of the leaves, the position of the leaf as regards shade and sunlight, and the air temperature, would all have their effect. That air conditions outside the leaf are not entirely responsible is easily seen. From five eggs that hatched on May 31, 1930, one larva matured in 11 days, one in 12 days, and one in 13 days. Two eggs hatching July 30, 1930, produced larvae of which one matured in 11 days and one in 14 days. Six eggs hatching July 30, 1930, produced larvae of which one matured in nine days, four in 10 days, and one in 13 days. It is nevertheless generally true that in the majority of cases eggs haching on any one day will produce larvae that attain full growth within a day of each other.

The number of larval instars and the duration of each has been based on the width of head capsules and the assumption that the last instar does not feed and has the same head dimensions as the preceding instar. On this basis there are five instars, during the first four of which the larva feeds and grows. Immediately after the fourth molt the larva breaks through the leaf and drops to the soil, which it enters for the prepupal and pupal periods. The prepupal period is thus the fifth larval instar.

Our observations on the larval instars have not been completed to the extent that the above sequence of events have been determined directly, but the usual process for sawfly larvae indicates that this is true of *Fenusa pumila,* and the width of the head capsules, together with the change in color which takes place immediately prior to the exit of the larva from the leaf, supports the above conclusions. Marlatt (1890) states that sawfly larvae in general go through this process of development. Dyar (1893) records six larval instars for *Fenusa varipes (dorhnii?)* and states that the last instar leaves the leaf immediately after the fifth molt and enters the ground. This instar is pale yellowish white in color, has evacuated the alimentary canal, and has the same width of head as the preceding instar. Taylor (1931) describes the seventh (last) larval instar of *Phyllotoma nemorata* as having the same width of head as the sixth. Middleton (1923) in his description of *Diprion simile,* says the same is true, although in this case the male insect has one less instar than the female. The measurements of the head capsule of *Fenusa pumila* indicate that the two sexes have the same number of larval stages, as there are fairly definite peaks to the curve representing head widths throughout larval life, considering the natural variation among individuals, and the measurements of the prepupal stage show one modal peak in the curve, not two as would be the case were the sizes of the sexes different.

Several mines of *Fenusa pumila* have been opened and a search made for head capsules. In the great majority of cases only three capsules were found, but in several instances four have been found, and the large size of many of these where either three or four were present indicates the occurrence of four feeding instars. The head capsules are always split when shed, and this makes exact measurements difficult.

Measurements have been made of the head widths of 802 larvae extracted from leaves before the prepupal stage was attained. These widths were plotted and showed four distinct peaks, indicating four feeding instars (Figure 89). The first instar varied from .260 to .312 millimeters in width, the second from .351 to .481 millimeters, the third from .494 to .598 millimeters, and the fourth from .611 to .767 millimeters. The first instar is clearly defined, but the others merge into one another as regards size. There were four larvae possessing head widths of .468, one of .481, and seven of .494 millimeters. The line of demarcation between instars two and three was arbitrary, but it should certainly fall between .468 and .494. The finest division of the micrometer measured .013 millimeters at the magnification used, and all heads were measured to the nearest micrometer division. The same condition holds for the separation of the third and fourth instars. There were 21 larvae having head widths of .585 millimeters, seven of .598 millimeters, and three of .611 millimeters. The width of .598 millimeters was set as a limit for the third instar. In measuring the head widths of the prepupae, three were determined at .585 millimeters, two at .598, and 14 at .611. There is thus a definite overlapping between instars three and four, for the fifth or prepupal measures the same as the fourth. The number of larvae measured in each instar was as follows: I, 254; II, 124; III, 125; IV, 299.

The prepupae were all collected under the trees in oilcloth funnels and all had the characteristic pale yellowish color and absence of black ventral marks. The head widths of 415 of these individuals were measured and they varied from .585 to .741 millimeters, being almost identical with the fourth instar.

Figure 89 shows graphically the head widths of the larvae measured. The overlapping of the last four instars and the modes of each are indicated. For the first two instars and the fifth, the modes are distinct at .299, .416, and .650 millimeters respectively, but the third and fourth instars are not clearly unimodal. The mean for each instar is as follows: I, .293 ± .0005 mm.; II, .416 ± .0014; III, .552 ± .0018 mm.; IV, .680 ± .0013 mm.; V, .661 ± .001 mm. In the figure, the number of larvae of each dimension was weighted to a basis of 100 in order to give a true picture, so the figures indicating the number of larvae are in reality the percentages of the total number measured.

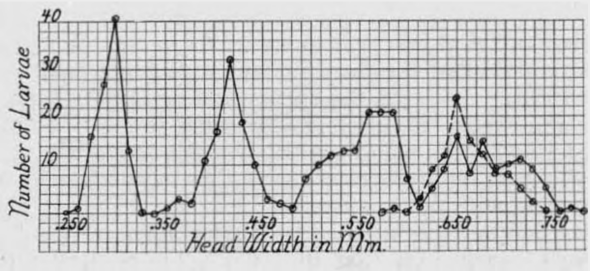


FIGURE 89. Head widths of the larvae of *Fenusa pumila* Klug.

In order to determine the duration of the larval instars, larvae were removed from leaves at certain definite periods after the eggs had hatched, and the head capsules were measured. Each of the first four instars is between two and three days in length on the average, although variations do occur. The duration of the instars is practically the same in both white and gray birch. The prepupal period in the soil is given on page 313. During the summer it is about 12 days in duration, but the prepupa hibernates, and the instar is then several months in length.

The question as to the applicability of Dyar's Rule in determining the instars in leaves naturally arises. It appears that this rule does not apply to the second or third larval instars with this species. It obviously would not apply to the fifth, which has the same head width as the fourth, but the second and third instars have too broad heads to correspond to the theoretical mean which Dyar's Rule would necessitate. In Table 5, the actual and theoretical means are given. The ratio was determined by getting the mean ratio as follows:

$$\frac{\frac{I}{II}+\frac{II}{III}+\frac{III}{IV}}{3} = \frac{\frac{.293}{.416}+\frac{.416}{.552}+\frac{.552}{.780}}{3} = R = .757$$

Table 5. Head Width of Larval Instars

	Number larvae	Actual mean	Theoretical mean
I	254	.293 ± .001	.293
II	124	.416 ± .001	.386
III	130	.552 ± .002	.510
IV	299	.680 ± .001	.674
V	415	.661 ± .001	....

The error in the theoretical mean of the second instar is about 7 per cent and that of the third instar about 8 per cent.

Taylor (1931) discusses the application of Dyar's Rule to sawfly larvae and concludes that it holds within reasonable limits. In the case of *Phyllotoma nemorata* cited by this author the actual and theoretical means approximate each other very closely, more so than is the case with *Fenusa pumila.*

The data in other species cited by Taylor apparently substantiate this author's conclusions that the rule holds as well with Tenthredinid larvae as with Lepidopterous larvae. In the case of *Fenusa pumila* the difference in instars II and III between the theoretical and actual means is too great, for the head width in the great majority of cases falls far above the theoretical means. In any species of insect, the use of Dyar's Rule depends on the amount of growth which occurs in each instar and the relation between this amount and the variation in size occurring among individuals in any one instar.

It should be pointed out here that Dyar's Rule is primarily of use in determining whether or not one or more instars have been *missed* in the observations on the life cycle (Dyar, 1890), and not whether an *average ratio* obtained as Taylor obtained his would give means corresponding approximately to the mean observed. The validity of the rule, then, depends on whether or not one can take a ratio obtained from two successive instars and, granted the head width of the first and last instars are known, determine the number of unobserved instars if any. In extreme cases, the rule might lead to some confusion. In the case of *Fenusa pumila,* the mean of the first instar is .293 and the calculated means for the second and third instar fall at points (.386 and .510 respectively) where very few larvae can be found. Moreover, if the ratio obtained by using the means of the third and fourth instars, .812, be used to determine the existence of other instars, then we get the following results: I, .293; II, .361; III, .445; IV, .548; V, .675. This gives us five feeding instars, and the last two correspond very closely to our actual means of .552 and .680. Yet, if we compare these means with those actually obtained, we find that two of them fall at points where the larvae are more than likely not to be present, that is, at each extreme of the variation in the real second instar. In a field collection of larvae made June 13, 1930, at New Haven, all four feeding instars were found, and their distribution as regards mean head widths is illuminating. Fifteen occurred between .273 and .299, four between .351 and .364, 26 between .390 and .442, 36 between .481 and .585, and 73 between .624 and .728. Basing our conclusion on this collection alone, an assumption of five feeding instars would not be unwarranted. If we take Taylor's figures for *Phyllotoma nemorata,* we find that here again there is some likelihood of confusion. The means actually found by this author for six feeding instars, the variation in each instar, the calculated mean obtained by using a *mean* ratio (.816), and the calculated mean obtained by using the ratio derived from the last two instars (.838) are given in Table 6. In these calculations the measurements for instars I, V, and VI are assumed definitely established and the question arises as to the possible number of instars between the known first and the known *penultimate feeding* instar.

There is, of course, too much difference between the theoretical and actual means of the last two instars when the ratio .838 is used to warrant the assumption that there are seven (instead of six) feeding instars, but the results would lead to confusion due to the fact that the theoretical third and fifth instars in this case could be found in the field and the theoretical fourth instar might be absent.

TABLE 6. PHYLLOTOMA NEMORATA (FROM TAYLOR)

Instar	Actual mean	Variation	Theoretical mean Ratio = .816	Theoretical mean Ratio = .838
I	.385	.384–.430	.385	.385
II	.469	.435–.530	.472	.459
III	.594	.544–.648	.578	.548
				.654
IV	.728	.661–.791	.709	.780
V	.892	.826–.978	.868	.931
VI	1.064	1.000–1.130	1.064	1.111

If we take Middleton's (1923) figures for the head widths of the larvae of *Diprion simile* and attempt to apply Dyar's Rule, the same confusion is evident. The mean ratio for male larvae, which have five feeding instars, is .727, but the four ratios from which this mean is derived are .667, .750, .714, and .778. Applying the mean ratio and comparing the theoretical with the observed widths, the results are fairly good. If, however, we take the ratio for head widths of the fourth and fifth instars and apply it in order to determine the number of instars theoretically intervening between I and IV, we obtain three instead of the two that actually occur, and yet our theoretical results as regards the known instars (I, IV and V) give widths that compare very favorably with the actual means observed for these three stages. If we use the ratio obtained from the widths of instars I and II, and try to estimate the instars intervening II and V, the confusion is just as great. The exact figures are deemed unnecessary here, but the observed widths are recorded in Middleton's paper. This author, however, does not apply Dyar's Rule.

The use of this rule should be confined, as Taylor suggests, to a corroboration of the number of instars observed, but even then the determination of the instars by actual measurements requires such a large number of cases that the application of the rule for corroborative purposes may be superfluous. Where the variation in size within one instar is great and there are several instars, it is essential that each instar be determined by actual observation, a suggestion which the above author also makes. Certainly Dyar's statements (1890) regarding the regularity of the progressive increases in head widths in progressive instars of lepidopterous larvae does not hold for *Fenusa pumila*.

LARVAL MINES IN GRAY BIRCH

The manner in which the mines are formed in the leaves and the extent of the mines are of some interest. Figure 90 is a diagram of mined leaves, with one exception all gray birch, made by pressing the leaves and tracing the outline of both leaves and mined areas. Four of the leaves in the figure show the contours of the mines at two-day intervals. These contours were obtained by outlining the mines with black ink every two days. This diagram is of particular interest in that it shows the direction of larval feeding as growth proceeds. Due to the fact that the eggs are laid and the larvae begin feeding while the leaf is still growing, the growth of the latter is arrested locally by the mining of the larvae and wrinkles more or less. It is thus extremely difficult to determine the mined areas exactly, and the calculated areas are hence subject to some error. Moreover, as the leaf develops its qualities change somewhat, so the relative amount of food consumed during two different periods of larval development may not be determined by the relative size of the mines. The number of larvae that occur in each leaf, the date of the mining period and its length, the total area mined, and the area mined per larva are given in Table 7. The areas were measured with a planimeter. The dots in the diagram indicate the position of the eggs.

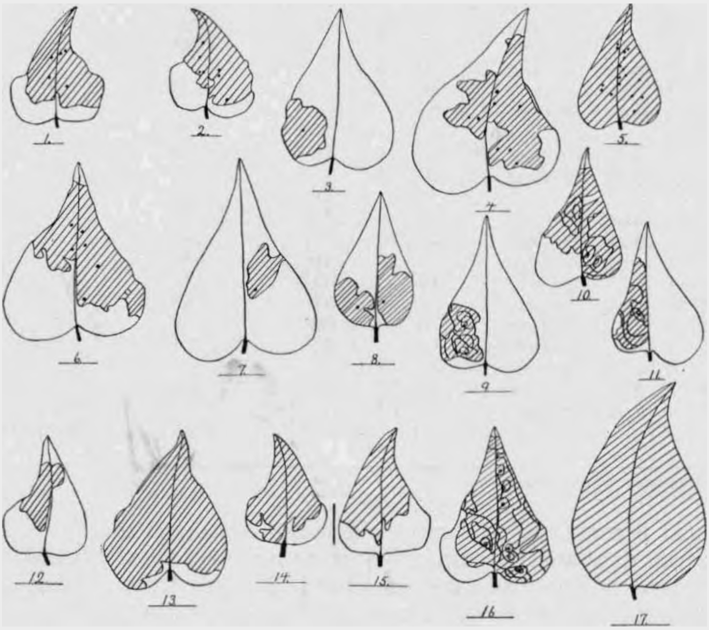


FIGURE 90. Larval mines in birch leaves. X 1/3. For explanation see text.

TABLE 7. EXTENT OF LARVAL MINES

Leaf	Number of Larvae	Date of mine formation	Days in mine	Area mined	Area mined per larva	Host tree
		31–Aug. 31–Aug.		1.024 sq. in.	.205 sq. in.	Gray birch
2	5	July 31–Aug. 9, '30	9		.103	" "
	2	July 31–Aug. 10, '30	10			
3	1	..... –Aug. 14, '30		.474	.474	" "
4	8	..... –Aug. 11, '30		1.525	.191	" "
*5	17	Aug. 29–Sept. 5, '30	7	1.460	.086	" "
*6	4	Aug. 4–Aug. 12, '30	8	1.660	.332	" "
	1	Aug. 4–Aug. 13, '30	9			
	1	Aug. 4–dead Aug. 6				
7	1	....		.262	.262	" "
8	1	July 30–Aug. 10, '30	11	.286	.286	" "
	1	July 30–Aug. 13, '30	14	.456	.456	" "
*9	2	....	..	.446	.223	" "
*10	2	Aug. 28–Sept. 7, '30	10	.640	.320	" "
	1	Aug. 28–Sept. 7, '30	10	.470	.470	" "
11	1	Aug. 28–Sept. 7, '30	10	.450	.450	" "
12	1	.......–July 17, '30	..	.342	.342	" "
*13	13	.......–July 17, '30	..	2.57	.198	" "
14		.......–July 17, '30	..	1.00	.333	" "
15	5	.......–July13-16-30	..	1.02	.204	" "
16	3	Aug. 5–Aug. 15, '30	10	1.96	.280	" "
	3	Aug. 5–Aug. 16, '30	11			
	1	Aug. 5–Aug. 17, '30	12			
*17	33	....		4.45	.135	White birch

*See explanation in text.

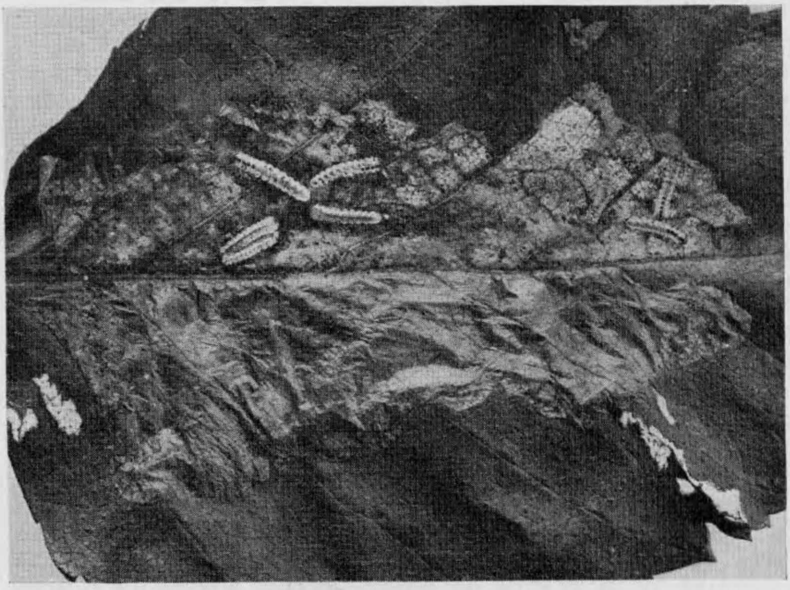
Leaf 5 contained 17 larvae which had consumed the entire leaf in seven days at which time they were removed from the leaf and measured. The head capsules varied in width from .598 mm. to .676 mm., all within the range obtained from measurements of fully grown individuals. These 17 larvae were small, however, the body length varying from 2.2 to 3.0 mm., whereas mature larvae are about 6 millimeters long. They would very doubtfully have been able to pupate and produce adults. Although the head widths are within the range of those of fully grown larvae found in the field, they are at the lower end of this range. Nevertheless they are not relatively as small as the body lengths that are within the range of normal second instar individuals. This is a discrepancy for which no explanation can be offered here. Leaf 6 contained six larvae originally, but one died after two days. However, the area mined in two days is very small, about 6.45 square millimeters, which is within the error of the measurement of the entire mined area, so the area mined per larva and the total area mined are sufficiently accurate for comparative purposes when based on the feeding of five larvae.

In leaf 10 the area to the left of the midrib and at the tip above the oblong unmined area was mined by one larva, and the area to the right of the midrib and below the unmined oblong area near the tip was the result of the work of two larvae. In leaf 13 the 17 larvae all appeared mature at the time they left the leaf. The head widths varied from .585 to .663 mm., which is practically within the limits of the range of mature larvae, and all appeared normal in size and coloration. In leaf 17, that of a young white birch *(B. papyrifera)* 33 larvae were present and emerged, being caught in a glass container placed around the leaf. Of these 33 larvae 11 were mature, having head widths varying from .650 to .702 mm. and normal body size and coloration for mature larvae. Twenty-two others had not become fully developed, which the presence of the black ventral markings clearly indicated, although most of them were in the last feeding instar without doubt. Only two had head widths (.507 mm. and .572 mm.) within the range of the third instar. One had a head-width of .598 mm., and the head capsules of the others ranged from .624 to .715 mm. in width.

The diagrams illustrate to a certain extent the manner and extent of larval feeding. The eggs are laid in the central area of the leaf and the larva mines close to the egg during the first two days, making a small more or less oval mine with the egg on one side. The extent of the mine during these two days is slight, as indicated by the first of the concentric lines around the eggs in leaves 10, 11, and 16. During the third and fourth days the mine is enlarged to about 14 to 20 square millimeters in area and usually maintains its oval or kidney shape with the egg at one side, although frequently the vacated egg becomes entirely surrounded by the mined area. During the fifth and sixth day the mine extends to an area of from about 41 to 112 square millimeters. If the leaf contains many eggs or if the eggs when few in number are close together, the mines tend to coalesce after about the fourth day of larval life. Even if no coalescence of mines occurs these areas become irregular in shape after this time and have no definite geometrical pattern (Plate 2, figure 2).

The total area mined by one larva varies, as would be expected, presumably because of the variable nature of the leaf tissue on which the larvae feed and the inherent variability of the larvae themselves. In Table 8 there are recorded seven individual larval mines which vary in area from approximately 0.262 square inches (170 square millimeters) to approximately .474 square inches (306 square millimeters). If there are enough eggs in the leaf so that the mines coalesce, which almost always happens when more than two eggs are present, the average area mined per larva is usually less than that area mined by isolated larvae. In leaf 9 the two larval mines coalesced after about eight days of feeding, and the area mined was 0.446 square inches (287 square millimeters) giving each larva an average of 0.223 square inches. In leaf 14 the

PLATE 2



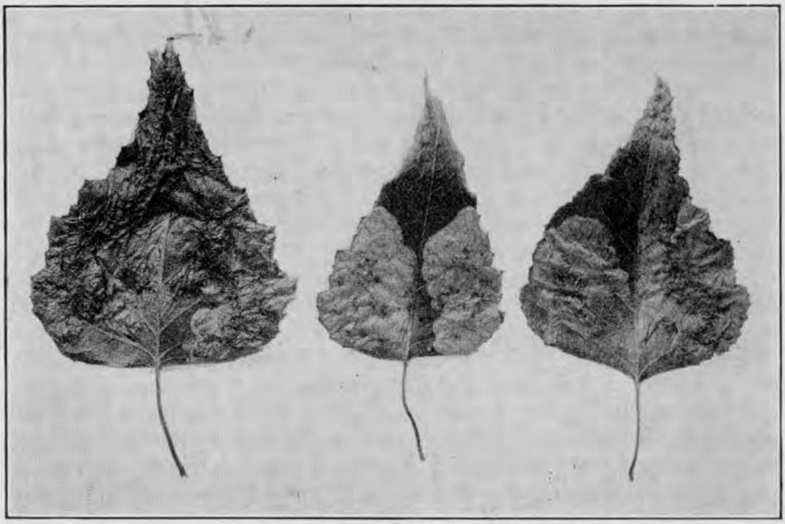


FIGURE 1. Upper. Larvae in mine in gray birch leaf. Upper covering of mine removed on upper side. X 2.

FIGURE 2. Lower. Larval mines in gray birch leaves.

average area mined for each of the three larvae present was 0.333 square inches (214 square millimeters). In leaf 10 one isolated larva mined an area of 0.470 square inches (303 square millimeters) and two larvae whose mines fused after four days of feeding mined a total area of 0.640 square inches, or an average of 0.320 square inches (206 square millimeters) each. These three larvae hatched on the same day and left the leaf the same day. The figures in the table show this tendency toward a decrease in the area mined when more than one larva is present in any one mine. The data are not sufficiently extensive to permit the assumption of any regularly decreasing mined area (up to a definite limit) which might accompany an increasing number of larvae working in one mine, nor to indicate how soon mines must coalesce in order to show this tendency. Nevertheless the tendency is fairly pronounced. Just what causes this decrease in the consumption of leaf tissue is not clear. It has been observed that after the leaf tissue is entirely consumed, if the larvae are not fully grown, their intestines become filled with brownish material which they must obtain from either dead leaf tissue or refuse within the mine. There is, however, no indication that this material is consumed as long as there is healthy leaf tissue available, even though several larvae occupy one mine.

The manner in which the larvae feed is, of course, responsible for the shape of the mine. The larva orients itself with its ventral surface toward the upper surface of the leaf and feeds in such a manner that the upper leaf epidermis is separated from the veins (Plate 2, figure 1). There is a marked tendency for the young larvae to stop at the midrib and work along it rather than through it, as the illustrations of the mines clearly show, but during the latter part of the period of growth the mine is usually extended across this obstacle. The larva holds itself with the posterior part of the body directed toward the center of the mine and feeds along the arc of a small circle peripherally. When many larvae are present they usually remain well separated, but as the available food supply becomes more restricted they naturally feed in closer proximity. The excrement is dispersed indiscriminately in the mine.

PREPUPAL AND PUPAL STAGES

After the larva has become fully grown it ceases feeding, loses its black ventral markings, and becomes light yellow in color. It does not remain in the leaf long after it ceases feeding, never as long as 24 hours according to our observations, but soon makes a hole through the roof of the mine and drops to the ground. In view of the fact that it cannot maintain itself on any smooth surface with an appreciable inclination, once out of the mine it cannot crawl externally on the host plant.

On reaching the ground the larva burrows into the soil an inch or two to make its pupal cell. Under forest conditions where the ground under the trees is covered with litter the larva probably penetrates to the mineral soil, or at least into the humus immediately above it. At Rainbow, Conn., examination of the ground under birches October 1, 1930, revealed the larvae in pupal cells from 1 to 3 inches deep in the mineral soil which was covered with about 4 inches of humus and litter. In the insectary larvae will burrow a maximum of about 7 inches into loose sifted soil in jars, but the majority do not penetrate below the upper 2 inches. In an attempt to determine the depth to which the larvae will penetrate into moist (not wet) soil, larvae which had emerged from gray birch leaves were placed in containers filled with loose sifted sandy loam, and after a suitable interval of time this soil was examined for pupal cells, a layer 1 inch in thickness being taken as a unit of depth. The results are given in Table 8.

TABLE 8. DEPTH OF PUPAL CELLS IN SOIL

Container	Larva entered	Soil examined	Pupal cells found								Total
			1"	2"	3"	4"	5"	6"	7"	8"	
1	Aug. 9, '29	Aug. 19, '29	11	34	8	4	0	0	0	0	57
2	Aug. 10, '29	Aug. 19, '29	34	11	0	0	0	0	—	—	45
3	Sep.9-20, '29	June 3, '30	4	11	3	2	10	1	2	0	33
4	Aug. 21, '30	Sept. 6, '30	19	37	4	0	0	0	0	0	60
5	Aug. 23, '30	Sept. 9, '30	27	5	0	0	0	0	0	0	32
6	Aug. 23, '30	Sept. 9, '30	8	0	0	0	0	0	0	0	8
7	Aug. 25, '30	Sept. 9, '30	10	0	0	0	0	0	0	0	10
8	Aug. 28, '30	Sept. 9, '30	29	1	0	0	0	0	0	0	30
Total			142	99	15	6	10	1	2	0	275

The soil must be slightly moist in the laboratory in order to have the larvae penetrate below the surface. When sifted soil was allowed to become air dry, most of the individuals died on the surface in 24 to 48 hours. Whether or not this would be a factor of importance under natural conditions is doubtful, especially where there is a layer of litter over the surface of the ground, for under these conditions the mineral soil does not tend to dry out rapidly. Moreover, sifted air-dry soil is an obstacle the like of which larvae would rarely, if ever, meet in their normal habitat·

Two types of containers were used in the experiments of which the results are given in the table. The first two consisted of two glass plates separated by about one-twelfth of an inch of soil and placed on edge so that the larvae could penetrate to a considerable depth if they were so inclined. The plates were covered with black paper to exclude light. Container 1 was 3 inches wide and 12 inches deep, container 2 was 2.5 inches wide and 6 inches deep. Containers 3 to 8 inclusive were paraffined cardboard tubes 1 inch in diameter and about 10 inches deep. The results listed under container 3 were obtained from a group of five such tubes kept out-doors buried in the ground and used as hibernation cages. The pupal cells found were empty at the time, the adults having emerged. All the other containers were kept in the insectary and the cells contained larvae or pupae when examined. As mentioned previously, in the insectary the larvae never penetrated beyond a depth of 4 inches, and investigations in the field in October showed the pupal cells in the upper 3 inches of mineral soil, but in the tubes kept out-doors the penetration was much deeper, some cells being found as far as 7 inches below the surface. This may have been due to the looseness and moisture content of the soil. It is the writer's belief that such a deep soil penetration does not occur naturally under the usual conditions.

The pupal cell is formed by the larva within a day of the entrance of the latter into the ground. This cell consists of small particles of soil and debris held together by a lining of a brownish homogeneous material which shows no fibrillar structure under low magnification. It does not appear to contain any silken strands. The shape is oval (Plate 1, figure 3), the length being about 3 millimeters. When the larvae are crowded into containers, clusters containing two or three cells each are quite common, and cells are frequently found on the side of the container, but under natural conditions the cells are single. The larva inside the cell has its head bent under the ventral side of the thorax, giving its anterior end a humped appearance.

Between the cessation of feeding and the last larval molt a prepupal period of varying duration, spent in the pupal cell, intervenes. During the summer months this period is as a rule 9 to 16 days in length, with an average of about 11 days. The available data on the prepupal period are given in Table 9. All records are from insectary cages.

Following the prepupal stage the insect undergoes a pupal stage of about a week. The records obtained for the pupal stage are not numerous, due to the heavy mortality that follows the act of opening pupal cells, but when the total period spent in the soil is considered, the estimate of four to eight days appears correct. The records for the duration of this stage are given in Table 10.

If the length of the pupal period of all individuals that pupated between June 26 and June 30, 1928, which gives data for the same part of the season and the same year, is averaged, the 21 individuals give a mean of six days, a maximum of seven days, and a minimum of four days. The mean period for males and females is the same.

The total number of days in the soil, which is the sum of the

TABLE 9. PREPUPAL PERIOD

Number larvae	Entered soil	Pupated	Period in days
5	Aug. 22, 1927	Sept. 2–4, 1927	11–13
2	Aug. 27, 1927	Sept. 8, 1927	12
7	Aug. 27, 1927	Sept. 5–7, 1927	9–11
28	June 16, 1928	June 26, 1928	10
27	June 16, 1928	June 27, 1928	11
11	June 16, 1928	June 28, 1928	12
5	June 16, 1928	June 29, 1928	13
2	June 16, 1928	June 30, 1928	14 } 109 larvae
2	June 16, 1928	July 2, 1928	16 11.1 ± .8 days
8	June 17, 1928	June 27, 1928	10
20	June 17, 1928	June 28, 1928	11
5	June 17, 1928	June 29, 1928	12
1	June 17, 1928	June 30, 1928	13
131	June 15– July 23, 1928	June 26– Aug. 6, 1928	11.4 ± .1
1	June 15, 1928	June 30, 1928	15 Male
1	June 15, 1928	June 28, 1928	13 Female
2	June 16, 1928	June 30, 1928	14 Female

prepupal and pupal periods, should be about 18 during the summer months, based on the separate calculations of the two stages as given above. As a matter of fact, this varies greatly, in some cases extending to 51 days. In Table 11 the available records are given for the duration of this period, which includes the prepupal and pupal stages. These are insectary records.

TABLE 10. PUPAL PERIOD

Number pupae	Pupated	Adults emerged	Pupal period	Sex
2	Sept. 8, 1927	Sept. 16, 1927	8 days	....
2	June 26, 1928	July 2, 1928	6	Female
1	June 26, 1928	July 2, 1928	6	Male
3	June 26, 1928	July 3, 1928	7	Female
2	June 26, 1928	July 3, 1928	7	Male
1	June 27, 1928	July 3, 1928	6	Female
1	June 27, 1928	July 3, 1928	6	Male
2	June 28, 1928	July 2, 1928	4	Female
2	June 28, 1928	July 3, 1928	5	Female
1	June 28, 1928	July 4, 1928	6	Female
3	June 30, 1928	July 5, 1928	5	Female
1	June 30, 1928	July 5, 1928	5	Male
1	June 30, 1928	July 6, 1928	6	Male
1	June 30, 1928	July 5, 1928	5	Female
4	Aug. 3, 1928	Aug. 11, 1928	8	....
1	Aug. 4, 1928	Aug. 11, 1928	7	....

TABLE 11. PERIOD IN SOIL (INSECTARY RECORDS)

Number insects	Date	Days in Soil			Sex
		Mean	Max.	Min.	
195	August, 1927	18.5 ± .07	26	15	Male
307	August, 1927	18.0 ± .19	31	15	Female
7	Sept., 1927	21.0 ± 0.0	21	21	....
19	June, 1928	16.8 ± .09	18	16	Male
21	June, 1928	16.1 ± .12	18	15	Female
26	June-Aug., 1928	16.8 ± .14	21	16	Male
29	June-Aug., 1928	16.8 ± .14	19	15	Female
2	June, 1929	16.5 ±	18	15	Male
5	June, 1929	16.0 ±	16	16	Female
21	July, 1929	16.5 ± .14	18	15	Male
32	July, 1929	15.9 ± .13	19	14	Female
2	July, 1929	17.5 ±	18	17	....
7	August, 1929	21.9 ± .50	24	18	Male
6	August, 1929	20.2 ± .92	24	16	Female
17	*June 3, 1930	16.1 ± .12	18	15	....
37	*June 14, 1930	15.03 ± .19	21	13	....
7	*June 15-18, 1930	19.1 ± 1.22	28	14	....
85	July-Sept., 1930	21.6 ± .33	43	15	Male
138	July-Sept., 1930	23.1 ± .57	51	14	Female

*Date given is that on which larvae entered soil. The figures given under date of June 15-18, 1930, are for individuals that entered the soil around potted plants.

The data given in the table, with one exception, represent the period in loose sifted sandy loam in jars in the insectary. Under natural conditions this period might be longer or shorter, according to the environment. The high mean period of the individuals recorded under the date of June 15-18, 1930, is due to one individual which spent 28 days in the soil, the average of the other six being 16.5 days. The pot containing these seven individuals was exposed to the sun and watered daily. The duration of the period does not differ greatly from that given for June 3, 1930, or for June, 1929, and cannot be considered significant. In order to form some idea of the variations in the time spent in the soil that might occur under some natural conditions, larvae were placed in soil filled metal cylinders which were buried in the ground where they were exposed to the weather. The results are given in Table 12. These larvae were placed in each container over a period of several days, so the records are not exact, but if compared with the data for August, 1929, in Table 11, it will be seen that no striking difference occurs. It is not to be inferred that the conditions in the metal containers, which were screened with light cloth, simulated those under trees growing naturally, but the data obtained probably closely approximated the duration of the period in the normal habitat of the insect. A further discussion of this habitat appears in the later pages of this bulletin.

TABLE 12. PERIOD IN THE SOIL (OUT-DOOR RECORDS)

Container	Larvae entered soil	Adults emerged	Number	Sex	Days in soil
1	July 29–Aug. 3, 1929	Aug. 21, 1929	1	Female	18–23
		Aug. 26, 1929	2	Male	21–28
		Sept. 3, 1929	1	Female	31–36
2	Aug. 5–Aug. 10, 1929	Aug. 21, 1929	1	Female	11–16
		Aug. 22, 1929	2	Female	12–17
		Aug. 26, 1929	1	Female	16–21
3	Aug. 12–Aug. 17, 1929	Sept. 3, 1929	6	Male	17–22
		Sept. 3, 1929	2	Female	17–22
		Sept. 5, 1929	1	Male	19–24
		Sept. 5, 1929	1	Female	19–24
4	Sept. 12–Sept. 18, 1929	Oct. 1, 1929	1	Female	13–19
		Oct. 7, 1929	1	Female	19–25
		Oct. 7, 1929	1	Male	19–25
		Oct. 8, 1929	1	Male	20–26
		Oct. 8, 1929	1	Female	20–26

As is indicated in Table 11, the males do not differ from the females in regard to the combined prepupal and pupal stages in the soil. The minimum observed period for males and females was 13 days (June 14, 1930) and the maximum period for males was 48 days and for females 51 days. In general the period is about three weeks in the summer. The larvae that entered the soil in the insectary cages in the summer of 1930 showed a peculiar condition. Among those that began the prepupal stage between July 11, 1930, and August 1, 1930, two peaks of emergence occurred, one between 16 and 24 days and one between 43 and 48 days. These insects were all kept under similar conditions, and this variation occurred in many cases in one lot of larvae placed in one container. For example, in the case of the larvae entering the soil in one jar July 11, 1930, six adults emerged in 16 to 23 days and 11 adults emerged in 45 to 48 days. In another jar in which the larvae entered the soil July 13, 1930, nine adults emerged in from 15 to 28 days and five in from 43 to 45 days. The leaves containing the larvae placed in one jar were collected in the same locality. This phenomenon confuses the regular sequence of generations during the summer somewhat.

Another peculiar condition observed was the partial hibernation of larvae of the late summer generations. From May 11, 1928, to June 4, 1928, there emerged from hibernating cages individuals that entered the soil between August 10, 1927 and August 22, 1927. Yet the same year some larvae that entered the soil as late as September 15 emerged October 6, that is, 21 days later. In the case of three lots of larvae which entered the soil between August 13, 1927, and August 17, 1927, 121 adults emerged the same season and 67 larvae were alive November 17, 1927. In 1929 five adults emerged from one hibernating cage between October 1 and October 8 of the same year, and 70 adults emerged between May 9, 1930, and May 10, 1930. The rearing records show that adults will emerge through the month of September, but it is evident that after the first part of August a proportion of the larvae hibernate. The data on this point are not extensive, but in Table 13 are the records obtained from several cages kept in the insectary, in which the larvae entered the soil the first half of the month of August, 1927, and which were examined November 17, 1927 after the possibility of the emergence of adults the same season was no longer present. In the absence of more extensive records no conclusion can be drawn as to the exact proportion of larvae of the late summer generations that hibernate, but this phenomenon may account for the relatively early disappearance of larvae in certain localities and their persistence through the month of September in others. In localities where there is a sprout growth of gray birch the adults emerging late in the season would find newly developing leaves in which to oviposit, a condition not found in stands of mature birch. Yet in these mature birch stands it is evident that the earlier hibernating larvae could cause a reinfestation of the trees the following summer, and thus eliminate the necessity of mature trees becoming reinfested each year by adults flying in from localities containing sprout growth on which the late generations developed the preceding year.

TABLE 13. HIBERNATION OF LARVAE

Larvae entered soil	Adults emerged in 1927	Larvae alive Nov. 17, 1927
August 4, 1927	10	0
August 5, 1927	18	0
August 6, 1927	16	0
August 10, 1927	1	1
August 11, 1927	73	2
August 12, 1927	99	1
August 13, 1927	95	4
August 16, 1927	15	31
August 17, 1927	11	32

In order to obtain some conception of the variability in the prepupal and pupal period in the soil under uniform conditions of temperature, several individuals were kept in an incubator at 24° C. (75° F.) and the length of time taken to complete these periods determined. The results are given in Table 14. These were larvae that developed the last of the season, and other generations might show a difference in the length of this period. The number of days in the soil is less than occurred under normal summer temperatures in the rearing cages and it varies somewhat, that is, from 12 to 17 days. There is little, if any, difference between sexes. The variation exhibited indicates that temperature is not the only factor that might cause some variations in the total length of the pupal and prepupal period, and either period may also vary with different individuals.

TABLE 14. PERIOD IN SOIL AT 24° C.

Number larvae	Entered soil	Pupated	Days prepupa	Adults emerged	Days pupa	Days in soil	Sex
1	Sept. 6	Sept. 14	8	Sept. 18	4	12	Male
5	Sept. 6	Sept. 14	8				
1	Sept. 7	Sept. 14	7	Sept. 19	5	12	Female
1	Sept. 7	Sept. 17	10	Sept. 19	2	12	Female
3	Sept. 10	Sept. 19	9				
2	Sept. 10	Sept. 19	9	Sept. 26	7	16	Female
1	Sept. 10	Sept. 19	9	Sept. 26	7	16	Male
1	Sept. 27			Oct. 9		12	Male
1	Sept. 27			Oct. 9		12	Female
7	Sept. 27			Oct. 10		13	Female
1	Sept. 27			Oct. 10		13	Male
5	Sept. 27			Oct. 11		14	Female
1	Sept. 27			Oct. 11		14	Male
1	Sept. 28			Oct. 11		13	Female
1	Sept. 28			Oct. 15		17	Female
Mean			8.5		5.3	13.6	

NUMBER OF GENERATIONS

Although the number of possible generations of this insect each year in Connecticut may be estimated fairly closely, there is some overlapping and irregularity, due both to the usual variations in the duration of the various stages of the development of individuals and to the less common extreme variations in the period spent in the soil. As a general rule the number of generations that actually occur in any one locality would appear from our observations to be correlated with the type of birch growth. If we take the normal time of adult emergence as about May 15, the time taken to complete one generation as five to six weeks (preoviposition period nil, egg stage one week, larval mining period 11 days, prepupal and pupal periods a total of three weeks), and the disappearance of the last larvae on sprout growth as occurring about the last of September, it is possible to have at least three complete generations in one season and perhaps a partial fourth. However, mature birch trees that cease producing new foliage abundantly in the middle of the summer are not markedly infested with more than the first two generations.

It has been our observation that in the vicinity of New Haven the first generation of adults appears between the 10th and 20th of May. The flight of this generation continues until the first part of June, usually disappearing about the 10th to 15th. The second generation of adults appears about the first week in July or a little earlier. The flight of the second generation continues about two weeks, and the earlier larvae are going into the soil by the middle of the month. The generations after the second are not so clearly defined, but the third generation adults fly during August. In 1928 what appeared to be the third generation of adults in the field was in flight the first three weeks in August. There had been two

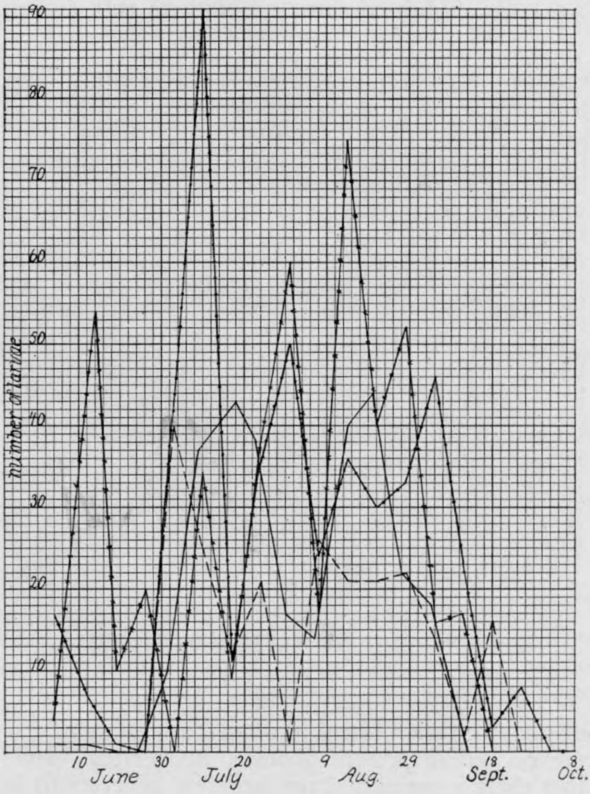


FIGURE 91. Seasonal occurrence of the first larval instar. Hamden ———; Rainbow — — —; Winsted ●—●—●; Hartland x—x—x.

previous peaks of adult abundance that year, one in May and one the first part of July. There were certainly four generations in 1928, the larvae of the fourth being abundant the fourth week in September. In 1930 the adults were flying abundantly near New Haven the first two weeks in August and had almost entirely disappeared by the beginning of the fourth week. The last larvae around New Haven had gone into the ground by the middle of September, which indicated three generations only during 1930 in that locality, and in the central and northern parts of Connecticut there were no larvae present about a week later. It is safe to assume that there were only three complete generations in 1930 in the state.

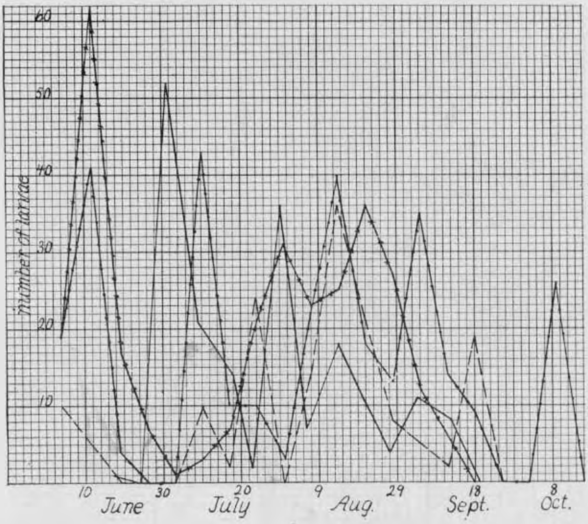


FIGURE 92. Seasonal occurrence of second larval instar. See Figure 91 for explanation.

During 1931 larvae were collected at weekly intervals beginning June 4 at Rainbow, Winsted and East Hartland, and at approximately weekly intervals beginning June 17 at Hamden. In each locality the collections were made from gray birch sprout growth, about 4 to 6 feet in height, from a narrowly restricted area, that is, inside a 30-foot radius. The primary object was to detect, if possible, the variations in the seasonal development of the insect. In collecting the specimens all the infested leaves from a number of tips were taken until the container was filled. At certain periods larvae were rare and it was impossible to collect the desired quantity of leaves. The actual number of larvae collected in any one locality in one day was not great. The method permits a considerable fluctuation in the number of individuals, so only general trends can be ascertained, and even these are sometimes not clear. The determination of the instars was made by measuring the head capsules.

Hamden adjoins New Haven on the north, and the locality in which collections were made is about 8 miles from the coast and has an altitude of about 300 feet above sea level. Rainbow is 50 miles north of New Haven and the altitude of the locality is about 160 feet. It is in the town of Windsor, which borders the Connecticut River. The Winsted locality is approximately 20 miles west of Rainbow and has an altitude of 900 feet. The East Hartland locality is 6 miles north and 8 miles east of Winsted and has an altitude of about 1000 feet. In regard to the effect of altitude and latitude alone, no great seasonal difference between Hamden and Rainbow or between Winsted and East Hartland would be expected, but there might be a difference between the two former and the two latter.

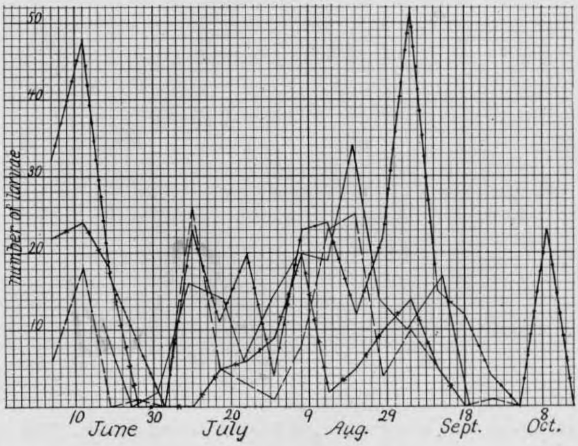


FIGURE 93. Seasonal occurrence of third larval instar. See Figure 91 for explanation.

Figures 91 to 94 show the curves of abundance of the instars at the dates indicated. It appears that in 1931 the seasonal development of the insect began about a week later at Winsted than at Hamden or Rainbow, and slightly later at East Hartland than at Winsted. The sites on which collections were made differed in all these localities particularly in regard to exposure, so that some variation due to this cause might be expected. This may account for some of the difference between Winsted and East Hartland. The first generation was well begun before the collections were started and hence is not fully indicated in the figures. The first generation in each case is very distinct, and the second is fairly clear, but after the middle of the summer the generations are not clearly delimited. It is evident that three full generations occurred at Hamden and Rainbow, with a partial fourth at Rainbow. At Winsted there were four generations, and at East Hartland there were three. The abundance of fourth generation larvae at the Winsted locality, which is on a southern slope beside a fairly large lake, may be due in part to the site, but more probably it is due largely to the condition of the birch sprouts late in the season. The last larvae of the season were found at Hamden September 11, at Rainbow September 25, at Winsted October 8, and at East Hartland September 11.

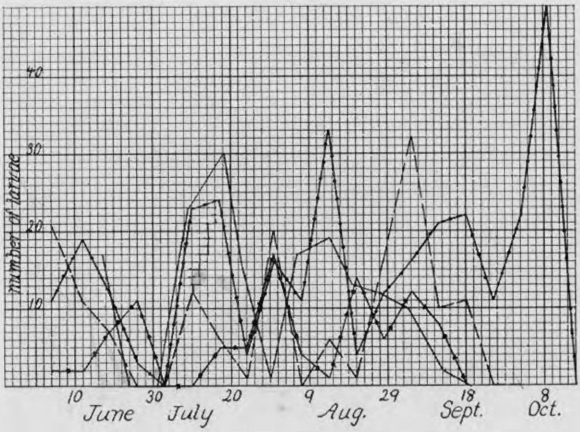


FIGURE 94. Seasonal occurrence of fourth larval instar. See Figure 91 for explanation.

SEX RATIO

It has been previously mentioned that there is a definite preponderance of females in all generations. The sex ratio of all reared adults was .60, or 40 males to 60 females. This phenomenon is very common among sawflies and was not unexpected. Parthenogenetic reproduction is possible and has occurred in the rearing cages, although just how widely this occurs under natural conditions is not known. In Table 15 are the data giving the number of males and females reared from larvae collected in the field. In making field collections of adults the proportion of females cap-

TABLE 15. SEX RATIO

Date	Males	Females	Total
August, 1927	195	307	502
June, July, Aug., 1928	26	29	55
June, 1929	2	5	7
July, 1929	21	32	53
August, 1929	7	6	13
July, Aug., Sept., 1929	23	22	45
July, Aug., Sept., 1930	85	138	223
*May, 1928	39	71	110
*May, 1930	34	36	70
Total	432	646	1,078

*From hibernation cages

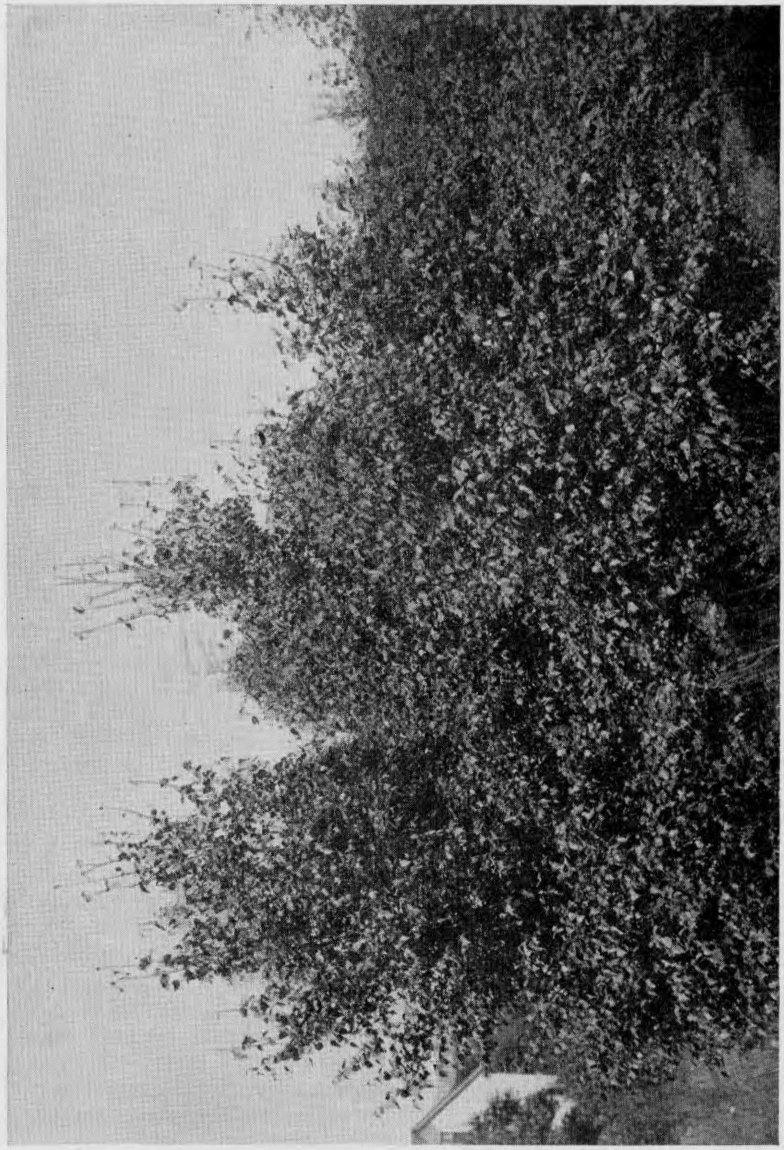
tured is much greater, as the females tend to be more abundant on the leaves and remain on the leaves longer than males. An example of this occurred in the course of some field collecting on sprout growth. This netted eight males and 46 females, which is far from being the true proportion of sexes.

RELATION TO HOST PLANTS

In Connecticut the adult female oviposits in the leaves of gray birch *(Betula populifolia);* white, paper, or canoe birch *(B. papyrifera);* and European white birch *(B. alba),* this last tree not a native. The black birch *(B. lenta)* and the yellow birch *(B. lutea)* have never been observed to be infested. No observations have been made on the red or river birch *(B. nigra),* as this is a very rare tree in the state.

The effect of oviposition on the leaves, in that it causes a slight grayish discoloration and at times a slight local retardation of growth, has been mentioned previously (p. 299), but the most striking feature of the act of oviposition is that it occurs only in leaves that are young. The adult female lays its eggs in young birch leaves as soon as they are opened sufficiently to allow the insect to crawl readily over the surface, and oviposition will continue in those leaves for a few days thereafter. As soon as the leaf ceases growing rapidly and becomes hardened, a rather poorly defined limit, it is no longer attractive to the female. On young sprouts the individual leaves remain attractive over a longer period of time than on well-grown trees or young seedlings, and the infestation in young sprouts is more intense than in other forms of growth. During the late spring when the adults first emerge, all the leaves are attractive to the females and susceptible to attack, but later in the season the tops of the trees produce new foliage in

PLATE 3



Gray birch trees about nine feet tall showing tops defoliated by larvae.

greater abundance and the infestation concentrates there. The result is that the tops of birch trees are more heavily infested during the summer and are frequently completely defoliated while the rest of the tree does not appear badly injured. (Plates 3 and 4.)

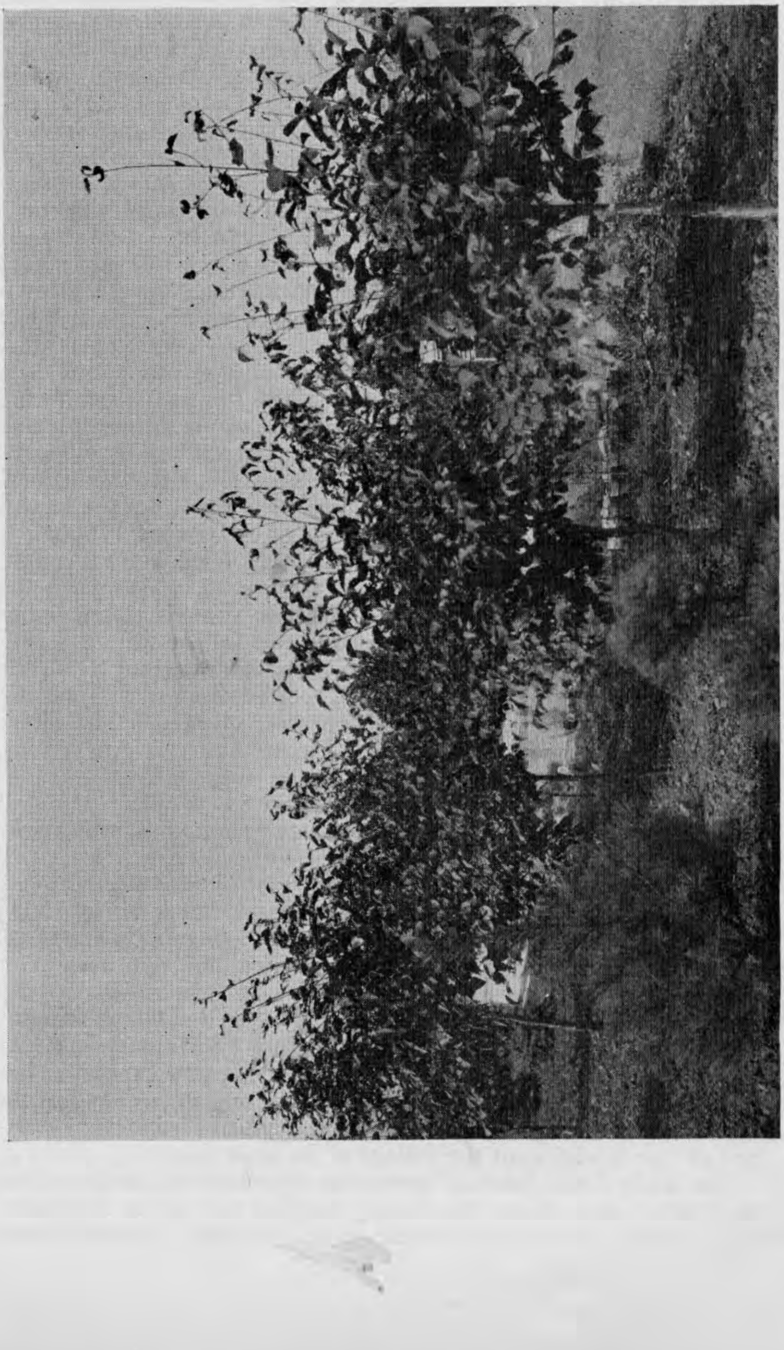
There is thus a distinct relation between the abundance of this insect and the type of birch growth. For example, at Barkhamsted on June 12, 1930, a heavy larval infestation was found in gray birch sprouts about 5 feet tall, but in the tops of the trees from the bases of which these sprouts grew there were no larvae present. This may indicate a preference for sprout growth where both small sprouts and trees are present. On July 21, 1930, the infestation on sprouts 6 feet high at a locality in Hamden was heavy and adults were abundant, but a mile away, where no young sprout growth occurred, there were no adults present around seedling trees, either low or tall growth, the tip leaves of these having begun to harden. The infestation on tall birches by the second generation had been light. About the middle of August, in 1930, a group of small gray birches (about 4 feet high) on the Station farm at Mount Carmel had ceased producing new foliage, and the infestation by ovipositing adults had ceased, yet within a distance of one mile the infestation on young sprouts, which continued to produce foliage late in the season, continued through the middle of September. This tendency, illustrated by the examples given above, is apparent throughout the state and is clearly shown in Figure 95, which gives the results of collections of prepupae in oilcloth funnels placed under seedling trees which produced very little new foliage after the middle of the summer. The number of prepupae emerging from the leaves is indicated for each five-day period beginning June 15. Those emerging before this date were not collected. The figure clearly indicates a heavy infestation for the first two generations, but a very light infestation after the last of July.

It appears that two generations of the insect will develop on all types of gray birch growth, but the later generations are largely confined to young sprouts that continue to produce new leaves all summer. In our insectary at Hamden, just outside New Haven, adults have emerged from cages as late as October 8 (in 1929) from larvae that entered the soil between September 12 and 18. It is true that adults occur locally throughout the state in greater or less abundance during the entire growing season of the gray birch, but new leaves must be present for oviposition by the females.

The extraordinary abundance of this insect in Connecticut may be partly due to the abundance of gray birch sprout growth in this region. In the case of this sawfly we have an insect of which the rate of increase in numbers seems to depend to a considerable extent on the condition of the foliage of its host plants.

The white birch does not sprout as vigorously as the gray, and the infestation on this tree is largely confined to the first two generations of the insect, except where young trees put out new growth

PLATE 4



Young white birch trees about seven feet tall showing tops defoliated by larvae.

late in the season. There seems to be little preference on the part of the insect between the two species of trees. The white birch leaves are larger and may contain more larvae per leaf in the early summer than do leaves of the gray birch. In some cases it has appeared to the writer that growing white birch leaves have remained attractive to the females longer than those of the gray birch. In a mixed stand of gray and white birch both species are often well infested.

In forest growth where the trees are 20 or more feet high, the injury is usually not very severe to either gray or white birch. The tops of the trees in midsummer show some defoliation and bear injured leaves, but not to the extent that commonly occurs on younger trees or on gray birches growing in the open.

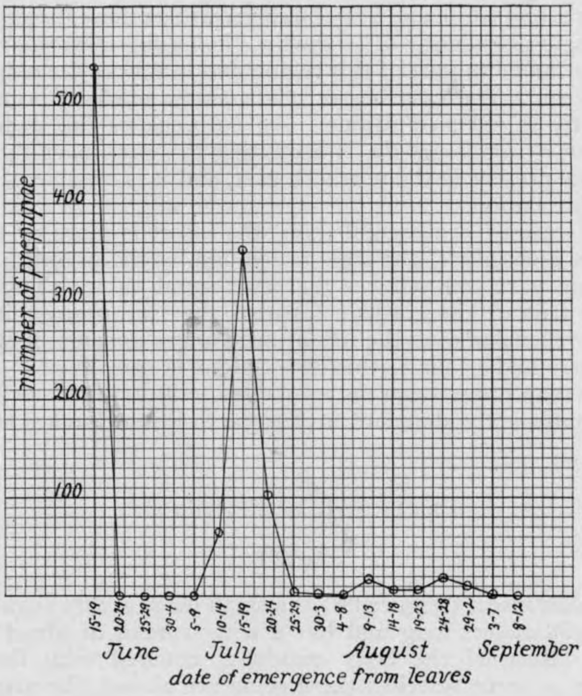


FIGURE 95. Emergence of prepupae from leaves of gray birch in 1931.

The mining of one or two larvae may not kill a leaf, but usually the number of larvae per leaf is greater than this and the affected foliage dies. When the larvae begin their mines, the leaf is usually still growing, and a local retardation of growth caused by the mine results in wrinkling. The effect of a heavy infestation on a birch is to strip the top of the tree of its foliage, not over any great proportion of the branches, but only on the growing tips. This is very clearly shown in the photographs of young birches in Plates 3 and 4. The continuous larval activity during the period when new leaves are produced may keep the tips bare throughout the season.

The writer has not observed any cases where trees or branches died as a result of the feeding activities of the larvae, nor has the effect on height and diameter growth been measured. There are, however, several leaf-eating insects on birch at the present time in parts of northeastern United States, and their combined attack may seriously affect white and gray birch growth as these insects become increasingly abundant. The sawfly *Phyllotoma nemorata* is present in the northern part of this region and it attacks the older leaves of the trees. The case bearer, *Coleophora salmani,* occurs quite abundantly in parts of Maine. An outbreak of the skeletonizer, *Bucculatrix canadensisella,* is beginning to sweep over the region, being now present in the northern part, and it is capable of causing severe defoliation.

In the case of ornamental trees, the insect is more or less of a nuisance, especially if the trees are young, as the presence of dead leaves and bare tips reduces the ornamental value. This is particularly true of the cut-leaf form of the European white birch. Any apprehension over the life of such a tree appears, however, to be unwarranted as far as this insect alone is concerned.

If one may judge from the available literature, this sawfly is not usually sufficiently abundant in Europe to injure birches seriously.

EXTERNAL MORPHOLOGY

ADULT

The adult insect (Figure 96) is a small black sawfly slightly more than 3 millimeters long and has a wing spread of about 7 millimeters. Most of the body cuticle is covered with fine setae, although on some sclerites these setae are absent, the areas being bare. The males are slightly smaller than the females, but specimens of both sexes show some variations in size, so that some males are as large as the average female, and some females are smaller than large males. The following description applies to the male in particular, but where the female shows marked differences these are noted.

Head. The head (Figure 97), viewed from the dorsal side, is somewhat oblong in shape, being much wider than long, and about as wide as the prothorax. On the frontal aspect the capsule is about as wide between the eyes as it is deep from the dorsal surface to the fronto-clypeal suture. The posterior surface is slightly concave. The entire head capsule is covered with fine setae except the posterior surface, which is bare and smooth for the most part, being setiferous around the dorsal and lateral margins only. On the dorsal side there are three ocelli *(oc.)* from each of the lateral two of which a furrow extends forward to the supratentorinae *(s. p.)* and a suture extends back to the occipital foramen *(o. f.)*. There is also a furrow extending between the two lateral ocelli and curving forward to meet the posterior margin of the median ocellus. The furrows leading to the supratentorinae are not true sutures, although they may indicate obsolete sutures, there being no internal ridges to indicate their presence. The sutures extending from the ocelli to the occipital foramen are true sutures and divide the posterior part of the head capsule, separating off the vertex from the remainder of the epicranium. The furrow connecting the ocelli is represented on the ental side of the cuticle by a slight ridge and may be a true suture.

FIGURE 96. Adult male of *Fenusa pumila* Klug. X 15.

On the anterior side of the head capsule the supratentorinae and the pretentorinae *(f. p.)* are distinct, although the former are not as deep as the latter. The supratentorinae are just above the antennal sockets *(a. s.)*, and from each one a furrow extends meso-cephalad and another to the antennal socket just below. Each meso-cephalad furrow extends to a depression in the frontal aspect of the head. No true frons is clearly differentiated by sutures, but the area between the ocelli and the clypeus represents it. The pretentorinae are immediately beneath the antennal sockets. Projecting into each antennal socket from the cephalo-lateral side is a small triangular antacoila *(ac.)* which articulates with an acetabulum, the antartis, on the scape of the antenna.

The fronto-clypeal or epistomal suture is distinct medially but indistinct laterally, although at the dorsal articulation of the mandible a slight sutural spur is evident. From this same point a short sutural spur extends towards the pretentorina on each side. The clypeus *(cl.)*, which projects slightly over the labrum *(l.)*, is approximately trapezoidal in shape and bears scattered setae. The labrum is somewhat more densely setiferous than the clypeus and is triangular in shape. The tormae are narrow and project inward from the inner side of the lateral basal angles of the labrum.

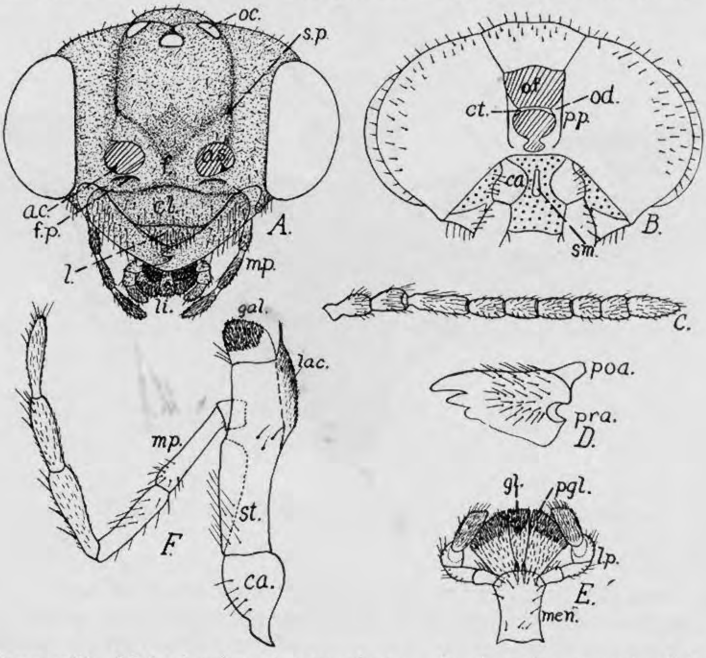


FIGURE 97. Male head and appendages. A: Anterior aspect of head. B: Posterior aspect of head. C: Left antenna, dorsal aspect. D: Right mandible, dorsal aspect. E: Labium, ventral aspect. F: Right maxilla, ventral aspect. *ac.*, antacoila; *a. s.*, antennal socket; *ca.*, cardo of the maxilla; *cl.*, clypeus; *ct.*, base of the tentorium; *f.*, frons; *f. p.*, pretentorinae; *gal.*, galea; *gl.*, glossae; *l.*, labrum; *lac.*, *lacinia; l. p.*, labial palpus; *men.*, mentum; *m. p.*, maxillary palpus; *oc.*, ocellus; *od.*, odontoidea; *o. f.*, occipital foramen; *poa.*, postartis; *p. p.*, metatentorinae; *pra.*, preartis; *sm.*, submentum; *s. p.*, supratentorinae; *st.*, stipes.

On the posterior side of the head the metatentorinae *(p. p.)* are evident on each side of the occipital foramen, and the line of attachment of the posterior tentorial arms is represented by the postoccipital suture which extends parallel to the foramen. This suture is not present on the capsule dorsal to the foramen and hence the postocciput as a distinct area is limited to the sides of this opening. Projecting mesad on each side of the foramen is the articulatory surface on which the head is supported by the anterior projections of the latero-cervicals. These articulatory surfaces are called the odontoidea *(od.)*. If the occiput be considered as the area dorsal to these two articulatory surfaces, then it is divided by the two sutures demarcating the vertex and extending anteriorly from the dorso-lateral angles of the foramen. The lateral areas of the occiput are continuous with the posterior areas of the epicranium and with the genae. The articulatory regions (paracoilae), which support the maxillae, consist of two lateral projections, one on each side, located just inside the ventral border of the capsule and on the post-occipital, or postgenal bridge (genaponta), which borders the lower side of the foramen. The cervical membrane is attached to the margin of the occipital foramen.

Laterally the genae are narrow, and a membranous area separates them on the anterior side from the bases of the mandibles. The posterior articulatory condyle for the mandible is on the gena in the postero-lateral region (the postgena). This articulation is the postcoila.

Inside the head certain sclerotinized structures are well developed. All arms of the tentorium are complete and extend to the ental surface of the head capsule, their attachments being indicated externally by pits, all of which have been mentioned above. The base of the tentorium, or corpotentorium, *(ct.)* is visible through the occipital foramen as a narrow curved bar. On the dorsal side of the pharynx the epigusta is represented by a strap-like sclerite, which possesses four pits laterally on each side arranged in a longitudinal row. Anteriorly the angles of the epigusta flare slightly toward the tormae, and posteriorly the angles also flare slightly laterally. The epipharynx is rather densely setiferous. The hypopharynx is narrow, wedge-shaped, and setiferous, but is not highly developed.

The mandibles (Figure 97, D.) are symmetrically developed and similar in structure. The apex of the mandible bears three teeth, of which the outer is by far the largest. The basal two-thirds of the mandible is setiferous. The dorsal articulatory surface, or preartis *(pra.)*, is an acetabulum, and the ventral articulatory area, or postartis *(poa.)*, is a conspicuous condyle. The coloration of the mandible is blackish brown except the apical region, which is lighter.

The maxillae (Figure 97, F.) articulate as mentioned above on the lateral regions of the genaponta. The cardo of the maxilla is prolonged into a projection (parartis) which abuts on a projection (paracoila) from the head capsule. The general shape of the maxilla is long and slender. The cardo *(ca.)* is distinct and bears a small group of setae on the ventral surface laterally. It is fairly well sclerotinized. The stipes *(st.)* is long and rather narrow, making up most of the appendage. It is sclerotinized on the ventral side, and this sclerotinized region extends laterally and on the dorsal side proximal to the palpus. No distinctly demarcated palpifer is present. There are a few setae on the proximo-lateral region of the stipes and about three near the base of the lacinia. The lacinia *(lac.)* is slender, pointed apically, and covered with a fine pile. The galea *(gal.)* is short, blunt and also densely pilose over the apex with a few large setae basally on the dorsal side. The palpus is six-segmented and longer than the body of the maxilla. The first segment of the palpus is very short, about one-fourth the length of the second, and bare. The segments slightly decrease progressively in length from the second to the sixth, the latter being about four-fifths the length of the former. The second segment bears a few setae distally, and the third bears scattered setae over much of its length, but segments four, five, and six are covered with a dense fine pile among which are a few larger setae.

The labium (Figure 97, E.) is membranous in its basal region except for a small club-shaped sclerite which lies between the cardines of the maxillae. This may represent a reduced submental sclerite *(sm.)*. The mentum *(men.)* is about twice as long as it is broad and bears a few scattered setae, particularly anteriorly. The terminal part of the labium is trilobed, the two outer lobes being paraglossae *(pgl.)* and the inner the fused glossae *(gl.)*. These three lobes are covered with a fine pile which is very dense at the tips. At the inner basal angle of each paraglossa is a small sclerite which projects slightly dorsally over the mentum, and the lateral basal angles of the middle lobe bear similar sclerites. The palpi *(l. p.)* are four-segmented. The first three segments are each of approximately the same length and are each shorter than the fourth. The setae on these segments are indicated in the figure. The fourth segment is flattened on the outer aspect and is densely pilose with a few larger setae.

The eyes show no striking peculiarities and their position on the head is shown in the figures. There is little if any difference in the head width between the eyes in the two sexes.

The antennae (Figure 97, C.) are nine-segmented and similar in the two sexes. It has been stated previously (Cameron 1882) that the male antennae are thicker than those of the female, but the difference is very slight, if any. The terminal segments are slightly thicker than the basal segments. The relative lengths of the segments from base to apex are approximately as follows: 1.2, 1, 1.5, 1, 1, 0.8, 0.7, 0.6, 1.2. The first segment bears an articulatory acetabulum on its basal end on the ventral side. In length the antennae are about equal to the width of the head.

Thorax. The segments of the thorax (Figure 98) are unequally developed, the mesothorax being much larger than either the prothorax or the metathorax, as would be expected. The segments are setiferous in those areas indicated in the figures.

The head is supported on the anterior processes *(o. a.)* of the latero-cervicals. These processes appear to be distinctly demarcated conical bulbs, the cephaligers, each of which bears on its inner side a ventro-posteriorly directed pointed apodeme. The latero-cervical sclerite appears to be fused with the corresponding prothoracic episternum to form one plate *(epi. c.)*. The writer follows Weber (1927) in so designating this sclerite and in considering the suture that extends from the coxal articulation dorso-caudad, as the pleural suture. Snodgrass (1910) has called the sclerite here designated *epi. c.* the episternum, but as Crampton (1926) states, the head of insects is usually borne on the cervical sclerites. Although Weber produces very good evidence for considering the latero-cervical and the episternum to be fused into one sclerite, there is evidence in the structure of the propleuron that Crampton (1926) may have interpreted the structures in this region correctly when he called the sclerite here labeled *epi. c.* the latero-cervical and considered the pleural suture above mentioned to be the suture separating the latero-cervical from the propleuron.

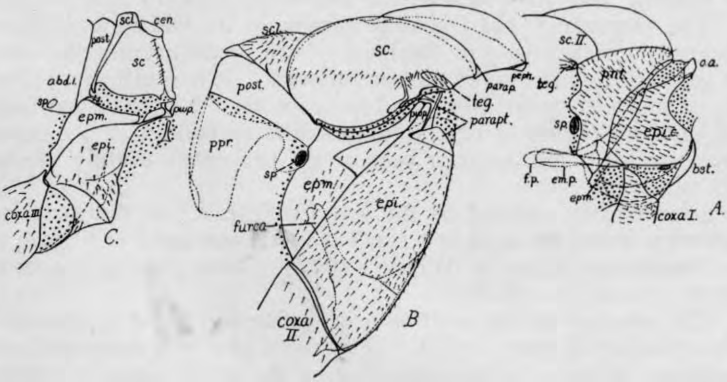


FIGURE 98. Male thorax. A: Prothorax. B: Mesothorax. C: Metathorax. *bst.*, basisternum; *emp.*, pleural ridge; *epi.*, episternum; *epi. c.*, episterno-cervical sclerite; *epm.*, epimeron; *f. p.*, furcal process; *o. a.*, cephaligers; *parap.*, parapsidal suture; *parapt.*, paraptera; *peph.*, prephragma; *pnt.*, pronotum; *post.*, postnotum; *ppr.*, postphragma; *pwp.*, pleural wing process; *sc.*, scutum; *scl.*, scutellum; *sp.*, spiracle.

As is indicated in Figure 98, there are two sutures arising from the coxa-pleural articulation, one running in a dorso-caudad direction and mentioned above as the pleural suture, and one running below it more directly caudad. Both are indicated internally by slight ridges, and the lower of the two continues internally in the body cavity as a flange *(em. p.)* which parallels the posteriorly directed furcal process *(f. p.)* and to which the latter is actually attached. If the process of the furca is attached to the internal side of the exoskeleton at all, it is usually to the pleural ridge, that is, the invagination of the pleural suture. More commonly there is a muscular connection between the two. Bearing in mind that the internal flange *(em. p.)* is a continuation of the lower suture and that the furca is attached to it, the correct interpretation of the pleuron may well be as Crampton indicates, that is, the dorsally directed suture may separate the latero-cervical. sclerite from the pleuron, and the small sclerite posterior to and below it, the epimeron of Weber (1927) and Snodgrass (1910) may be the entire pleuron, although in following Weber it is here designated epimeron *(epm.)*. If it is the entire pleuron, then the caudally directed lower suture is the pleural suture, the small sclerite above it the episternum, and the much reduced narrow sclerite below it the epimeron. All of which would follow Crampton's interpretation.

The pronotum *(pnt.)* is very narrow at its middle and extends laterally on each side to the level of the coxal articulation where it touches the pleuron of the mesothorax. It is much more simple in structure than the meso- and metanotum. A narrow area along its anterior border is separated from the remainder of the sclerite by a suture. The anterior part of the pronotum slightly overlaps the pleuron.

Immediately ventrad of the sclerite *(epi. c.)* in the membrane between it and the coxa is a small sclerite, bearing a few setae, the trochantin according to Weber (1927). This may be a precoxal plate (Snodgrass 1927).

The sternum of the prothorax is similar to that of *Tenthredo* as described by Weber (1927). It consists of a well developed plate between the coxae and approximating the sclerite *(epi. c.)* anteriorly. This plate consists of the fused basisternum *(bst)* and furcasternum. The coxae articulate on the furcasternal region. The entire sternal plate is infolded along the mid-line, and the furcal pits are present in the furcasternum. A median longitudinal suture indicated internally by a ridge is present. The furca is well developed and extends dorsal to a point above the level of the pleural flanges marked *(em. p.)* and thence the furcal processes *(f. p.)* extend posteriorly as long salients. These processes are attached to the pleural apodemes or flanges as mentioned previously.

The postfurcasternum of the prothorax bearing a spina is attached to the presternite of the mesothorax. It is a very narrow sclerotinized strip, reduced almost to a line, bordering the presternite anteriorly. The spina is short but distinct.

The mesothorax (Figure 98, B.) is well developed, and its notum is distinctly divided into an anterior narrow prescutum bearing a small prephragma *(peph.)* a median broad scutum *(sc.)*, a triangular scutellum *(scl.)*, and a broad postnotum *(post.)* bearing a deep conspicuous postphragma *(ppr.)*. The principal sutures of the notum, that is, those separating prescutum, scutum, and scutellum, are indicated on the ental surface by conspicuous apodemes except the prescutal-scutal suture. The prescutum is a very narrow inconspicuously demarcated area at the anterior border of the notum. In Figure 98 it is shown between the prephragma *(peph.)* and the scutum *(sc.)*. The scutum is divided by a median longitudinal suture which also bears a conspicuous apodeme internally. Anteriorly the parapsidal sutures *(parap.)* separate off a triangular area. This area is usually called the prescutum, but really is part of the scutum according to Snodgrass (1927). A tegula *(teg.)* is borne on each anterior lateral angle, and laterally are located the anterior and posterior wing processes. Immediately caudad of the anterior wing process a suture projects medially and is continued by a setiferous ridge which curves posteriorly to the caudo lateral angles of the scutellum. The triangular scutellum is partly divided by anterior and posterior short median longitudinal sutures (Figure 96), there being no suture in the central region. On the caudal margin a slight horizontal suture delimits the posterior region. Laterally the posterior angles extend to the borders of the notum and continue in the axial cords of the wings. The postnotum is a broad band adjoining the epimera laterally. A median longitudinal suture divides it and continues caudad to the posterior limit of the postphragma. This suture is indicated internally by a conspicuous apodeme. The postphragma is deep and medially cleft in the posterior margin. Laterally on each side a posterior salient is present.

The pleuron of the mesothorax is large and presents a large episternum *(epi.)* separated from the much smaller epimeron by an anteriorly inclined pleural suture which terminates in the wing process above and the coxal articulation below. The episternum is fused with the sternum below. Dorsally the episternum bears two paraptera *(parapt.),* the posterior of these being slender and projecting up towards the tegula, the anterior being triangular and broadly joined to the episternum. In the dorsal region of the epimeron there is distinctly demarcated by sutures a triangular area, and the internal ridge of the delimiting suture of the dorsal side of this area extends anteriorly across the dorsal ental margin of the episternum. If this triangular area be considered the anepimeron, the remainder of the sclerite may be designated katepimeron. There is a small basalar sclerite in the pleural membrane just beneath the base of the wing.

The sternum of the mesothorax is here interpreted according to Weber (1927). Anteriorly a triangular presternum is present as a distinct sclerite. The sutures bordering it laterally are conspicuously invaginated to form two internal apodemes which meet posteriorly in the invaginated part of the basisternum, a perpendicular suture marking their posterior limit. The basisternum is laterally fused completely with the episterna and medially it is invaginated deeply. The line of the invagination is indicated externally by a longitudinal suture and internally by a conspicuous apodeme which continues posteriorly in the furca. The furcasternum is completely fused with the basisternum and is likewise reduced. Posteriorly it extends in two small processes on which the coxae are supported. The furca is well developed, its processes extending dorsally into the body cavity from a median ridge-like base. There is no distinct postfurcasternum present, and the spina, which is not visible, may be considered as being fused with the median invagination of the furcasternum. The presternum of the metathorax may have also entered into this structure and be indistinguishably fused with it.

The metathorax (Figure 98) is much reduced compared to the mesothorax. The notum consists of a narrow prescutum, a scutum which is much restricted medially, a rather conspicuous scutellum, and a relatively broad postnotum. What is here called the prescutum is a narrow slightly infolded band extending across the notum anterior to the cenchri. It disappears medially where the scutum is narrowest. The scutum is much restricted medially, but broadens laterally. Anteriorly it bears the cenchri *(cen.)*, one on each side of the mid-line. These membranous lobes are quite conspicuous. Laterally on the scutum are the anterior notal wing processes, shown in Figure 98 as just above the posterior part of the pleural wing process *(pwp.)*. The scutellum is a broad roughly oblong conspicuous sclerite, the posterior lateral angles of which extend out into the axillary cords of the wings. The postnotum is relatively broad and meets the epimera laterally. There are no conspicuous phragmata on the metathorax.

The pleural sclerites of the metathorax are unequal in size, the episternum being much larger than the epimeron. The pleural suture swings in a broad curve from the coxal to the pleural wing process *(pwp.)*. In its general conformation the pleuron resembles that of *Cephus* as pictured by Crampton (1931), and this author has designated the upper narrow somewhat horizontally directed part close to the wing process as anepimeron and anepisternum. In this case the greater part of the pleuron becomes katepimeron and katepisternum. There is, however, a very slightly indicated suture extending ventro-caudad from the anterior margin of the episternum which partly divides this sclerite. At the anterior upper corner of the episternum there is also a short spur-like ridge which extends ventro-caudad on the ental surface of the sclerite. Any true division of the episternum into upper and lower regions is, in this case, difficult to make. Immediately below the pleural wing process and in the pleural membrane is a small triangular sclerite, the nature of which is obscure.

The sternum is fused with the episternum in front of the coxae and the sternal-episternal suture is incomplete, terminating anterior to the coxal process of the pleuron. There is no indication of a presternum, and the basisternum and furcasternum are completely fused. The furcasternum divides posteriorly to form the coxal supports. The anterior margin of the sternum is infolded to form an internal ridge, and between the coxae the sternum is infolded and narrow. The furca projects up into the body cavity from between the coxae and its base extends along the ental surface almost to the anterior margin where the two furcal processes are given off. Each process widens just above the base and then narrows to terminate in a point.

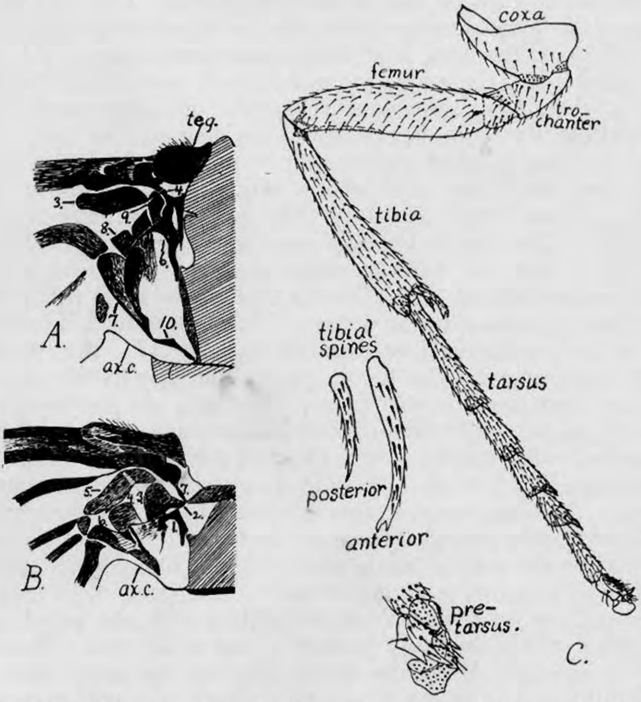


FIGURE 99. Male thorax. A: Mesothoracic axillaries. B: Metathoracic axillaries. C: prothoracic leg. The Arabic numerals indicate the axillaries.

There are two pairs of thoracic spiracles *(sp.)*, one belonging to the mesothorax and one to the metathorax. The mesothoracic spiracle lies in the membrane in a slight emargination of the posterior border of the pronotum, and metathoracic in the membrane in an emargination of the mesothoracic epimeron.

The axillary sclerites (Figure 99) lie in the membranes connecting the thorax with the wings. In the mesothoracic membrane (Figure 99, A.) there are seven of these sclerites. The most conspicuous (3) lies posterior to the base of the radius and is approximately oblong in shape and horizontal in orientation. It touches another smaller longitudinal axillary (9) which in turn articulates with the "principal" axillary (6). This latter sclerite is irregular in shape and articulates anteriorly with the anterior wing process (shown black in the figure) of the scutum and posteriorly it touches the scutum just behind the lateral emargination. There is a minute sclerite (4) at the apex of the anterior wing process. This may be a detached part of the principal axillary (6) or of the base of the radius. Distally an arm of axillary (6) is continued in the edge of a pocket or axillary fold in the membrane. This fold does not appear to be homologous with the marsupium described by Crampton (1927), as the wing base folds at the outer edge of the sclerite on its floor when the wings are moved back over the abdomen. A large sclerite (8), somewhat triangular in shape and with an indented outer margin, lies partly in the floor of this fold. Posteriorly is a large bilobed sclerite (7) to which the edge of the fold is attached anteriorly and which articulates posteriorly with a slender sclerite (10). Axillary (10) extends to the scutal-scutellar angle. The costal-subcostal base articulates on axillary (4) and thence with the anterior wing process. The first anal vein articulates on axillary (7). At the base of the costa there are two small distinct sclerotinized plates. There is a small sclerotinized area in the membrane just distal to axillary (7), the identity of which is uncertain. The tegula covers the base of the costa.

In the metathoracic membrane there are six axillaries. The most conspicuous (5) lies caudad to the base of the radius. It articulates with a large axillary (3) and this in turn touches a narrow sclerite (2). Both (2) and (3) extend to the anterior wing process. A rather conspicuous sclerite (1) also articulates with the anterior wing process (the membrane is stretched in the figure) and touches the scutum again posteriorly. The edge of the axillary fold is attached to its outer end. The outer end of the edge of the axillary fold is attached to axillary (6), the proximal end of which extends close and parallel to the axial cord. Two sclerites (3) and (4), lie partly in the floor of the axial fold. The base of the radius meets the small axillary (7) which may be a detached part of it. The anal veins abut on axillary (6), and (5) touches (6) when the wing is in the normal condition.

The homologies of the axial sclerites in the wings of insects have been studied by Snodgrass (1910 and 1927). In the fore wing of *Fenusa* the axillaries (6), (9), (7) and (10) apparently correspond respectively to the first, second, third and fourth of this author; and in the hind wing (1), (3) and (6) correspond to the first, second and third, the fourth being absent. In the fore wing (3) and (8) and in the hind wing (5) and (4) are the median plates of the above author.

The wings (Figure 100) are slightly tinted with brown and covered with a fine pubescence. The venation is indicated in the figures, and the nomenclature is that of MacGillivray (1906 and

1916). In the anal area of the fore wing the vein called IIIA is very slightly indicated, and the spur which is shown projecting toward the margin of the wing may be simply a thickening due to the folding of the wing at this point. Granting IIIA to be the true third anal vein, the lanceolate cell of older authors becomes contracted. The vein r of the fore wing meets R_3 just distal to the fork of R_3 and R_4, a character distinguishing the genus *Fenusa* from some of the related genera.

In his "Study of the Wings of the Tenthredinoidea" MacGillivray pictures the wing venation of *Fenusa* with the vein r terminating proximal to the base of R_4 and the venation of *Kaliosysphinga* with r terminating distal to the base of R_4. In his "Tenthredinoidea" (**1916**) it is stated that in *Fenusa* the vein r terminates in cell R_3 a considerable distance beyond the free part of R_4, which is correct, although it reverses the previous description. The **1906** description of *Kaliosysphinga* is labeled *dorhnii,* but in **1916** this species is placed in the genus *Fenusa* and the characteristic termination of r is used to distinguish *Kaliofenusa ulmi,* with r terminating before the free part of R_4 from *Fenusa dorhnii* with r terminating beyond the free part of R_4. In the writer's specimens, r terminates before the free part of R_4 in *Kaliofenusa ulmi* and beyond it in *F. dorhnii* and *pumila.* The specimens of *dorhnii* show some variation, since in some cases r terminates at the base of R_4.

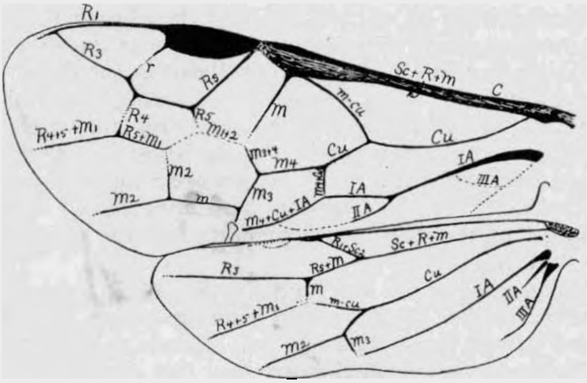


Figure 100. Wings of male. *IA, IIA, IIIA,* anal veins; *C,* Costa; *M,* median, *R,* radius, *Sc.,* subcosta; *r,* radial cross vein; *m-cu,* medio-cubital cross vein; *m,* median cross vein.

On the costal margin of the hind wing, near the center, is a row of about seven strong curved setae, the hamuli, which hook into a fold in the posterior margin of the fore wing. This fold is finely toothed.

There are light streaks running longitudinally through both fore and hind wings, and the veins are broken where these streaks cross them. The brownish coloration characteristic of the wings is absent in the streaks. A peculiar characteristic of these streaks is the nature of the wing pubescence borne along them. The setae found over the wing surface are of two kinds, one very minute, the other larger and quite conspicuous. In the fore wing the minute setae, although found scatteringly all over the wing, are concentrated along the streaks and on the anal folded area posterior to vein IIIA. The same condition of concentrated fine setae on the streaks occurs on the hind wing, although the relative abundance of the setae over the rest of the wing is slightly greater than on the fore wing. There is also an abundance of these minute setae along veins Sc-R-M on the fore wing and in the light area at the lower inner angle of the stigma.

In the fore wing there are two of these streaks. The first extends from cell M_4 parallel to and through vein $M_1 + {}_2$ to bend caudad through vein $M_1 + {}_2 + R_5$ and then break through vein M_2. The second streak extends from the base of the wing anterior to and parallel to vein IA about as far distad as the distal junction of veins IA and IIA. This furrow breaks through vein $M_4 + Cu$. Veins r and R_4 are also broken in the fore wing, and there are two small areas, one (mentioned above) at the lower inner angle of the stigma, and one just distal to M_3 which are similar in appearance to the streaks. There is a hyaline bare club-shaped area on the caudal margin of the wing which projects into the terminations of veins IA and M_3.

In the hind wing there are four streaks, all of them beginning at or near the base of the wing and running distad. The first lies just caudad to vein Sc + R + M and extends to the fork of this vein. The second begins at the proximal end of the first and runs through cell Cu to end near the junction of veins M, M-Cu, and $R_4 + R_5 + M_1$, breaking this junction. The third extends from the base of the wing just anterior to and parallel with IA and breaks through vein M_3, ending just beyond this latter vein. The fourth begins just posterior to the middle of vein IIA and extends out to the margin of the wing.

The legs (Figure 99) are black at the bases and becomes lighter distally. The fore legs have the coxa, trochanter, and basal third of the femur blackish and the rest of the leg light straw to whitish except for tarsal segments four and five which are infuscated. On the mesothoracic legs the blackish region extends through the basal two-thirds of the femur, the coloration being otherwise as on the fore legs. On the hind legs the coxa, trochanter and femur are all entirely black and the tibia and last two tarsal segments are infuscated.

The legs vary in length, the fore legs being shortest and the hind legs longest. Much of the difference in length between the hind legs and the others is due to the much longer hind tibiae. The relative lengths of the segments of the legs, measured on a male of average size, were found to be approximately as follows:

TABLE 16. LENGTH OF LEG SEGMENTS IN MILLIMETERS

Segment	Prothoracic	Mesothoracic	Metathoracic
Coxa	.20	.25	.30
Trochanter	.20	.20	.25
Femur	.40	.50	.60
Tibia	.50	.60	.90
Tarsus	.70	.70	.80

In the prothoracic legs the coxa is much longer on the outer side than on the inner, which makes the segment relatively longer than that of the mesothoracic coxa which is more nearly of equal length on both sides. The coxa of the hind legs is also longer on the outer side than on the inner. The trochanter of the prothoracic leg appears to be composed of two distinct segments, but the second segment is smaller than the first, firmly fused to the femur, and articulated with the first, so it may well be merely a differentiated part of the femur phylogenetically. Snodgrass (1927) states that this so-called second trochanter is really part of the femur. The femur, although not as long as the tibia, is the largest leg segment. The tibia flares slightly at its distal end and bears two spines distally on the inner side. These two spines are of unequal length and of different shape, the posterior being shorter and simple, the anterior being longer and bifurcate at the tip. Both spines bear numerous minute setae, giving them a scaled appearance.

The tarus is five-segmented and the segments are of unequal length. The basal tarsal segment is just equal in length to segments two and three combined. Segment four is slightly shorter than segment three, and segment five (not including the pretarsus) is about equal in length to segment two. Segments one to four, inclusive, flare slightly distally, and segments three and four bear a small scaled spine terminally on the postero-lateral angle. The pretarsus (Snodgrass, 1927) is large and consists of one dorsal and two ventral sclerotinized plates connected terminally and laterally by an expanded membrane, the arolium, and a pair of lateral claws. The dorsal plate is raised medially to form a "hump", and bears a pair of setae. The proximal ventral plate is triangular and finely setose, and the distal ventral plate is trapezoidal, its narrower end adjoining the proximal, and more coarsely setose. On each side just below the claw and supporting it is a small triangular sclerite arising from the distal end of the proximal ventral plate. All of the segments of the leg, including the sclerotinized parts of the pretarsus, are setiferous. On the coxa the setae are mainly on the anterior and outer sides, the posterior and inner sides being bare except for a few setae proximally. Both segments of the trochanter are setiferous on all sides, and the femur is sparsely setiferous on the posterior side. The tibia and the tarsal segments are densely setiferous.

The mesothoracic and metathoracic legs are similar in general form to the prothoracic legs. The coxae vary in shape as mentioned above, and the inner side of this segment is more abundantly setiferous than on the prothoracic leg. The trochanters are similar to those of the fore legs, as is the femur. The tibial spines of both middle and hind legs are simple and approximately equal in length. The tarsi are similar to those of the prothorax.

Abdomen. The abdominal segments of the two sexes are similar in the anterior part of the abdomen, that is, tergites one to seven and sternites two to six. The dorsal part of the first segment is membranous medially as shown in Figure 96. The first sternite is absent in both sexes, unless the membranous area connecting the thorax and abdomen on the ventral side be considered as involving it. On the lateral sides of each of the first eight abdominal segments is a pair of spiracles. These are above the pleural membrane and hence on the tergites. The pleural membrane actually occurs on the ventral side of the abdomen, the tergites extending ventrally at the sides of the body. Practically all the sclerotinized parts of the abdomen, including the genitalia, are setiferous, but the setae are rather minute and never conspicuous.

The terminal part of the abdomen (not included in the genitalia) shows marked differences between the two sexes. In the male the eighth tergite is slightly sinuate on the posterior margin and its lateral regions are not produced far ventrally (Figures 96 and 101). On the female this tergite resembles those immediately preceding in general form and its lateral regions extend ventrally and slightly medially (Figure 102). In the female the eighth sternite is evident only in the genitalia. In the male the seventh sternite (Figure 101) is similar to those immediately anterior to it, but in the female the seventh sternite (Figure 102) projects posteriorly in a bluntly pointed apex. The eighth sternite in the male is divided medially by the ninth, so that it consists of two lateral triangular sclerites connected medially by a narrow membranous strip. The remainder of the posterior part of the abdomen is more or less involved in the genital apparatus and each sex will be discussed separately. The sexes are very easily differentiated by the appearance of the abdominal apex.

Externally the most conspicuous part of the tip of the male abdomen (Figure 101) is the sternite of the ninth segment, the hypandrium of Crampton and sub-genital plate of Boulangé. Anteriorly it terminates in a prominent protuberance, the pregenital apophysis. Except during the act of mating, this plate conceals the genitalia. The ninth tergite, or what is here interpreted as it, consists of a membranous band concealed beneath the posterior part of the eighth. This membrane contains a pair of flask-shaped sclerites, one on each side. At its posterior margin the integument of the ninth sternite is reflexed back anteriorly to meet the anterior margin of the genitalia proper. Much of this reflexed part is occupied by a sclerotinized triangular plate which has its apex directed anteriorly. What is here interpreted as the tenth tergite is normally partly visible beyond the posterior margin of the eighth. It consists of two relatively large sclerotinized plates separated medially and bounded posteriorly by a membrane. At each posterior lateral angle of this tergite a short "cercus" is attached by an articulatory membrane. The tenth sternite is probably represented by the membrane between the genitalia and anus. No eleventh abdominal segment is visible, although the tenth probably represents the combined tenth and eleventh.

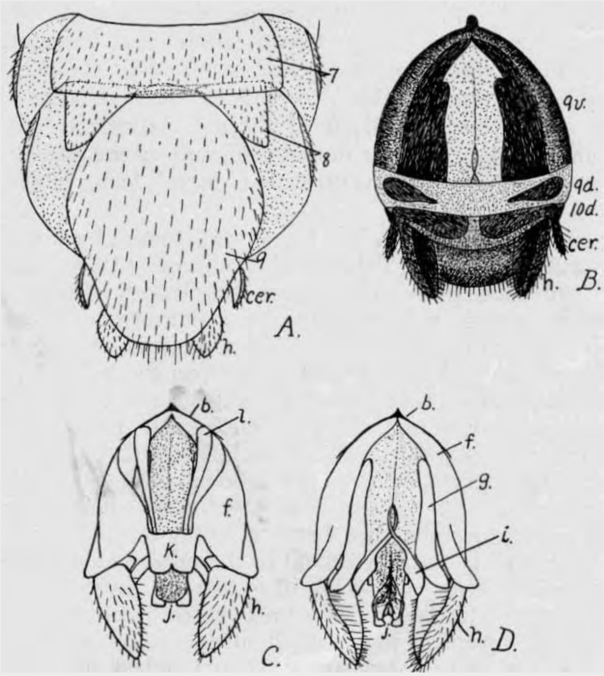


FIGURE 101. A: Tip of the male abdomen, ventral aspect. B: Tip of the male abdomen, dorsal aspect. C: Male genitalia, ventral aspect. D: Male genitalia, dorsal aspect. *b,* basal ring; *cer.,* cercus; *f,* basal part of gonopods; *g,* complementary sclerites or volsellae; *h,* terminal part of gonopods or harpes; *i,* copulatory ossicles or sagittae; *j,* sheath of penis; *k,* parapenes; *l,* penis rods. Arabic numerals refer to abdominal segments. *9v,* 9th sternite, *9d* and *10d,* 9th and 10th tergites.

Middleton (1921) has concluded from a study of certain sawflies that the structures here called "cerci" are not truly such, but originate in the anal uropods (postpedes) of the larva. The fact that the larva of *Fenusa pumila* has no anal uropods would not necessarily mitigate against this view, since the absence of these structures may well be a modification related to the leaf-mining habit. The structures here called cerci, for the sake of convenience, in the female are fused with the ninth abdominal tergite. Snodgrass (1931) states that it is doubtful if true cerci, which he considers appendages of the eleventh abdominal segment, occur in any holometabolous insects except possibly in the females of Mecoptera. Crampton (1929) considers these structures to be true cerci and to be appendages of the tenth segment. Certainly on the female they are on the dorsal side, and on the male they can not be considered any more ventral than dorsal, being at the lateral angle.

The genitalia of male sawflies have been studied by many investigators, and Crampton (1919) and Boulangé (1924) have paid particular attention to the comparative morphology of these organs. Crampton compared the Tenthredinidae with more primitive forms, as the Siricidae, and concluded that at some time during development the genitalia had rotated 180 degrees on the longitudinal axis in the Tenthredinidae, with the result that the true morphologically ventral side became dorsal. This phenomenon does not occur in the more primitive sawflies. Boulangé, after studying the development of certain species, came to the conclusion that this torsion of the genitalia occurs at the time that the imago emerges from the pupal stage. In the following description the term "dorsal" refers to that side which is actually dorsal in the adult insect, although it is morphologically ventral and is still so in adult Siricidae and other primitive forms. Likewise the term "ventral" refers to that side which is actually ventral in the adult insect. The descriptive terminology is that of the above two authors unless otherwise indicated.

Some question has been raised regarding the abdominal segment to which the genital appartus belongs. According to the description given by Boulangé the male genitalia develop in the body of the larva just dorsal to the ninth sternite. Moreover, in the adult the entire appartus is attached between the ninth sternite and the anal region. Inasmuch as the present work is not a treatise on the comparative morphology of sawflies, the question of homologies is outside its scope and in the following description is omitted.

The basal ring (b) is reduced to a crescentic sclerite anteriorly pointed to form a gonocondyle and is fused to the basal part of the gonopods (f). This basal part of the gonopods, the *pièce principale* of Boulangé, although open on the dorsal side, is much extended on the ventral side where the two lateral halves meet and are completely fused to a central quadrilateral plate (k), the parapenes, which probably represents a fusion of two lobes of (f). On the dorsal side and attached to the median edges of the basal part of the gonopods are two slender sclerites (g), the volsellae or complementary sclerites. The posterior ends of these turn ventrally close to the base of the harpes (h). Median to the sclerites (g), and touching their inner posterior margins is a pair of copulatory ossicles *(pièce en trébuchet)*. These have been called sagittae by Crampton and are labeled (i) in Figure **101** of this paper. They taper anteriorly and overlap slightly at the cephalic end. The sheath of the penis (j) extends beyond the parapenes and is supported laterally by a pair of sclerotinized penis valves at the tip. These valves extend anteriorly as a pair of penis rods (l) to the region of the basal ring. The rods, termed *apophyses péniales* by Boulangé, serve for the attachment of muscles. The terminal segments of the gonopods (h), called harpes or *palettes,* are spoon-shaped and setose. The ejaculatory duct extends anteriorly between the cephalic ends of the penis rods.

For the comparative morphology of the male genitalia and the terminology of various authors the works of Crampton and Boulangé should be consulted. According to the latter the terms sagittae and volsellae, employed by Crampton, should not be used in describing the genitalia of chalastogastrous Hymenoptera but should be restriced to certain sclerites found in the higher forms. A study of the musculature of the genitalia of the Hymenoptera leads Boulangé to doubt that the sclerites concerned are morphologically homologous in both divisions of the order, although they may in many cases occupy similar positions with respect to the rest of the genital apparatus.

The tip of the female abdomen (Figure **102**) bears the usual ovipositor, and the terminal segments are modified accordingly. On the dorsal side the last distinct sclerite is the ninth, and this bears terminally a pair of cerciform appendages fused with it. According to Crampton (1929) the cerci are derived from exopodites of the primitive appendages of the tenth segment. Snodgrass (1931) considers true cerci to be appendages of the eleventh segment. The conclusions of Middleton (1921) have been mentioned. The tenth tergite may be fused with the ninth, or the "cerci" may have shifted their position and become attached to the ninth, the entire tenth segment in this latter case becoming membranous. In the pupa the "cerci" are attached to the tenth segment each side of and below the anus. The location of the "cerci" leads the writer to believe that part, at least, of the tenth segment becomes fused with the ninth tergite. Certainly no sclerotinized distinctly demarcated tenth tergite is present. The anal opening is just under the posterior margin of the ninth dorsal sclerite. This sclerite extends laterally and then ventro-mesad on the ventral side.

The ovipositor itself consists of a pair of valvifers (vf), and three pairs of valves, a dorsal, a ventral, and an inner. The valvifers belonging to the ninth sternite are small sclerites on the ventral side and are inset in the basal parts of the dorsal valves. Crampton (1929), whose interpretation of the female genitalia is followed here, states that he provisionally interprets this as the valvifer (of the ninth segment) rather than a basivalvula (belonging to the eighth segment). As stated below, the "saws" appear definitely attached to this sclerite, which indicates that it may well be a basivalvula. The dorsal valves, which belong to the ninth segment, almost completely enclose the ventral and inner valves and consist of an apical part (ds) and a basal part (pv) separated by a membranous region. The basal parts are entirely ventral and extend to the membrane separating them from the seventh sternite. The ventral valves, which constitute the "saws," are derivatives of the appendages of the eight segment. They are blade-like in shape and covered dorsally by the line of junction of the inner valves. Each "saw" bears nine series of teeth (Figure 102, B, C.) on its ventral edge. Anteriorly the heavily sclerotinized "back" of the saw extends around the anterior margin of the basal part of the dorsal valve to attach itself to the anterior margin of the valvifer. The inner valves of the ovipositor (Figure 102, B.), which actually

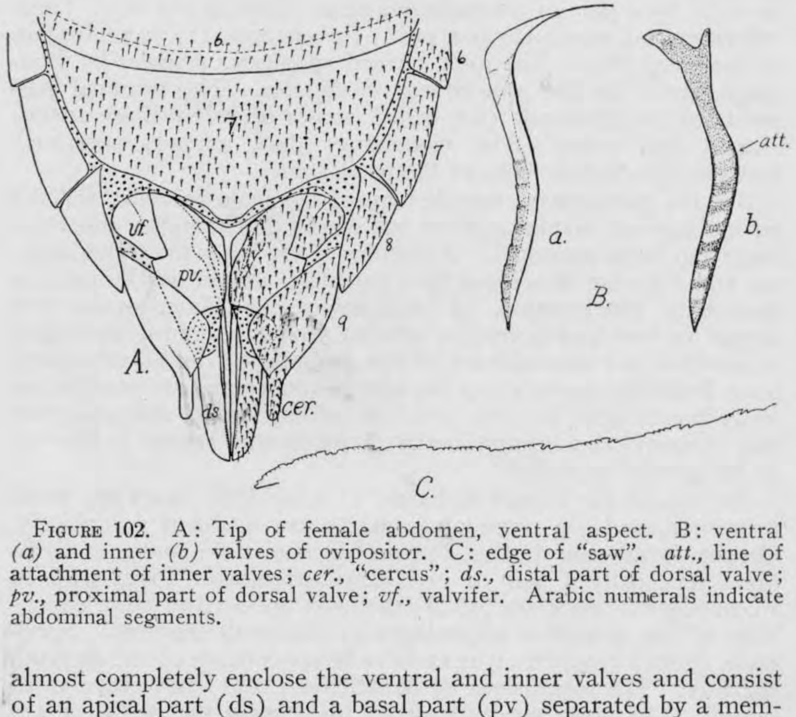


FIGURE 102. A: Tip of female abdomen, ventral aspect. B: ventral *(a)* and inner *(b)* valves of ovipositor. C: edge of "saw". *att.,* line of attachment of inner valves; *cer.,* "cercus"; *ds.,* distal part of dorsal valve; *pv.,* proximal part of dorsal valve; *vf.,* valvifer. Arabic numerals indicate abdominal segments.

enclose the ventral valves on the dorsal and lateral sides, are also blade-like in shape and banded in appearance. This banding is due to the presence of transparent cross bands, the ground color of the blade being brown. Anteriorly these light bands are distinct, but apically they become vaguely outlined. The two inner valves adjoin each other dorsally along the distal half and are actually fused for a short distance just posterior to the point of divergence. Anteriorly they diverge and each expands at the base and adjoins the antero-median angle of the basal part of the corresponding dorsal valve. The inner valves are appendages of the ninth segment.

LARVA

In its gross appearance the larva of *Fenusa pumila* (Figure 103 and Plate I, figure 2.) is distinctly of the leaf-mining type, the color being translucently whitish and the body being slightly compressed dorso-ventrally. The body length varies from about 0.7 mm. in a newly hatched individual to about 6.0 mm. in one that is fully grown. The abdominal segments are divided dorsally into annulets, and the tergum of each of the last two thoracic segments is divided by a median horizontal depression. In the second, third, and fourth instars there is a conspicuous black area on the ventral side of each of the thoracic segments and of the first segment of the abdomen. The terminal abdominal segment bears a characteristic dorsal sclerotinized area which is slightly protuberant near its center. The integument appears smooth to the naked eye, but is seen to be rugose with some spinose areas when sufficiently magnified. Setae are practically absent except on the head. In many instances the writer has been unable to find any setae present where there are circular pore-like pits in the integument. The setae are easily lost in handling and are very minute. In the figures of the head both setae and pits are shown, although the latter may indicate setal attachments. The general distribution of these is shown in the figures for the fourth instar. There are three pairs of thoracic legs and a pair of vestigial prolegs on each of the abdominal segments two to eight inclusive.

The first and fifth instars differ markedly from the three intervening instars in that they lack the black areas on the ventral side of the thorax and abdomen. Moreover, the fifth instar is yellowish in color and has the head more nearly hypognathous than do the earlier stages (Figure 103, D.).

The description of the larva as here given pertains particularly to the fourth instar, but where other instars differ markedly, this will be noted.

Head. In the mining instars the head (Figure 103, A, B, C.) is prognathous in position and is compressed slightly dorso-ventrally, but in the last instar, which does not feed in the leaf, the head is inclined toward a hypognathous position and is somewhat less compressed. The greatest width is slightly anterior to the middle, and the lateral margins taper in each direction. The caudal part of the head is concealed on the dorsal side by a fold of the prothorax. The surface of the head is smooth and the setae present are short.

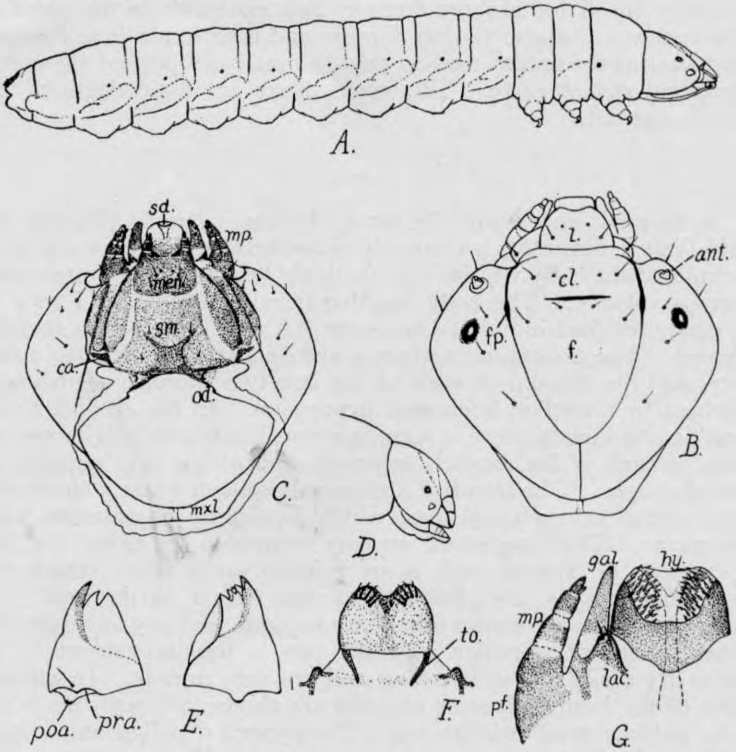


FIGURE 103. A: Fourth instar larva. B: Head of 4th instar larva, dorsal aspect. C: Head of 4th instar larva, ventral aspect. D: Orientation of head of 5th instar larva. E: Left mandible of 4th instar larva, dorsal aspect at left, ventral aspect at right. F: Epipharynx of 4th instar larva. G: Maxilla and hypopharynx of 4th instar larva. *ant.*, antenna; *ca.*, cardo of maxilla; *cl.*, clypeus; *f.*, frons; *fp.*, pretentorinae; *gal.*, galea of maxilla; *hy.*, hypopharynx; *l.*, labrum; *lac.*, lacinia of maxilla; *men.*, mentum; *mp.*, maxillary palpus; *mxl.*, maxillariae; *od.*, odontoidea; *pf.*, palpifer; *poa.*, postartis; *pra.*, preartis; *sd.*, silk duct; *sm.*, submentum; *to.*, torma.

The epicranium is divided on the dorsal side by the Y-shaped epicranial suture. The stem of this suture, the coronal suture so-called, extends from the occiput about one-third the distance to the clypeus, at which point it divides into the frontal arms which extend anteriorly to the frontal pits (pretentorinae) near the caudo-lateral angles of the clypeus. The arms are about twice the length of the stem. The frontal pits indicate the point of attachment of the anterior arms of the tentorium, and the frontal sutures, as well as the sutures bordering the clypeus laterally, are heavier in the region of these pits. According to Yuasa (1922) this thickening along the lateral borders of the clypeus corresponds to the clypealia of the larva of Corydalis.

The vertex extends over the dorsal side of the head and includes all of this region except the frons. It bears the antennae, ocelli, and a few setae. There are no vertical furrows. The lateral borders of the vertex occur, according to Yuasa, at an imaginary line drawn ventrad of each ocellus and parallel to the ventral margin of the head. There are a few relatively prominent setae on each side of the vertex, one anterior to and slightly mesad of the ocellus, one directly posterior to it and posterior to the ocellus, and a third anterior to the origin of the arms of the epicranial suture, about half the distance from this point to the second seta mentioned.

The ocelli (ocellarae) are located laterally on the vertex, slightly anterior to the widest part of the head and midway between the lateral margin and the frontal arm of the epicranial suture. Each ocellus consists of a darkly pigmented area, more or less circular in outline, with a clear spot in the center. There does not appear to be any distinct convex lens present.

The antennae (ant.) are at the antero-lateral angles of the vertex. Each consists of a somewhat conical protuberance of one segment borne on a circular area (antacoria) clearly demarcated from the surrounding vertex. Three lightly sclerotinized areas, presumably sensoria, are found at the tip of the antenna, two visible dorsally as shown in Figure 103, B, and one ventrad and laterad of these.

Attached to the posterior margin of the vertex is a sclerotinized roughly crescentic plate, the so-called maxillariae (mxl.) (Yuasa 1922). It is divided by a narrow, lightly sclerotinized, median strip opposite the posterior end of the epicranial suture.

The frons (f.) is approximately triangular in shape and is bounded on the sides by the arms of the epicranial suture and anteriorly by the fronto-clypeal or epistomial suture which is incomplete at the ends.

The clypeus (cl.) is roughly quadrangular in shape. Anteriorly it is membranous, but for the most part it is sclerotinized. The sutures separating it laterally from the vertex are conspicuous and each curves mesad at the anterior articulation of the mandible (precoila) and terminates as a short spur. That part of the clypeus between these two spurs and the clypeo-labral suture includes the membranous area mentioned above. A horizontal row of setae and pits occurs about midway between the anterior and posterior borders. The division into preclypeus and post clypeus is not distinct, but probably is represented by a line between the lateral suture spurs previously described. The only part of the clypeus lying free of the vertex is that part anterior to the precoilae.

The labrum (l.) is small and attached to the anterior margin of the clypeus. Its lateral margins converge slightly anteriorly and the anterior border is emarginate.

The genae and postgenae, the separation of which from the rest of the epicranium is purely arbitrary due to lack of sutures, extend from the vertex to the lateral borders of the labium and maxillae and the occipital foramen on the ventral side of the head, the postgenae being caudad of the genae. The postgena is usually considered as being bordered mesad by the occipital foramen. The flattening of the head brings about the location of these areas on the ventral side for the most part. The gena bears several setae as indicated in Figure 103. One or two of these on each side are usually concealed by the lateral border of the stipes of the maxilla. There extends from the posterior articulation of the mandible (postcoila), which is an acetabulum, to the postgenal area a straight narrow cuticular thickening. The gular pits (metatentorinae) are concealed beneath the cervical membrane, being located close to the anterior margin of the occipital foramen. This anterior margin is membranous. The paracoila, where the cardo of the maxilla articulates with the head capsule, is laterad of the gular pit and is inconspicuous. The odontoidea (od.), which serve as articulatory supports for the cervical sclerites, are conspicuous projections, one on each side of the occipital foramen near the anterior border and on the mesad projections of the postgenae. The terms "anterior" and "posterior" as used here in reference to the borders of the foramen refer to the morphologically ventral and dorsal margins respectively. The prognathous orientation of the head shifts the true ventral margin anterior to the dorsal.

The epipharyngeal region (Figure 103, F.) bears on each side a curved row of five broad setae of which the tips project slightly beyond the anterior border of the labrum. Each side of the median emargination of the anterior border is a row of short striae which give the edge a somewhat crenulated appearance. This is visible only under high magnification. At the posterior lateral angles of the epipharyngeal region the tormae (to.) project medially. These sclerites are long and slender.

The mandibles (Figure 103, E.) are very nearly if not absolutely symmetrical and articulate dorsally with the epicranium by means of an acetabulum (preartis) which fits over a condyle (precoila) on the head capsule, and ventrally by means of a condyle (postartis) which fits into an acetabulum (postcoila). The median face of the mandible is sharply incised, giving a dorsal cutting edge with three dentes and a ventral cutting edge with four. A single relatively conspicuous seta is borne on the dorso-lateral surface near the base. Between the lateral basal border of the mandible and the head capsule is a large distinct membranous area (mandacoria).

The maxilla (Figure **103**, C and G.) consist of a cardo, stipes, subgalea, palpifer, palpus, galea, and lacinia. The submentum of the labium lies between the bases of the two maxillae. The cardo is subtriangular on its lateral part (alacardo) where it adjoins the stipes and continues narrowly mesad (subcardo) to the tip (parartis) where it articulates with the paracoila. The stipes extends from the cardo to the galea and is separated from a medially lying subgalea by a conspicuous suture. The basal part of the stipes is membranous and projects as the stipal angle. The palpifer (pf.) is borne on the anterior lateral angle of the stipes. It is lightly sclerotinized and bears two rather prominent setae. The palpus consists of four segments, all somewhat sclerotinized, and extends about as far anteriorly as the tip of the labium. There is a conspicuous seta on the ventral side of each of the first three segments and two minute spines at the tip of the fourth segment. At the distal inner margin of the third segment are three broad blunt setae, two visible dorsally and one visible ventrally. The subgalea is long, broad at the base, and tapering to a point distally. It is lightly sclerotinized. The galea (gal.) is long, flat, blunt at the apex, and sclerotinized except for a membranous area at the base. It bears a longitudinal row of three small setae on the ventral side of the distal half, and there are three minute spines at the tip. There are three or four pore-like structures on the ventral side of the distal half. The galea tapers slightly toward the apex, curves slightly mesad, and extends a little beyond the tip of the maxillary palpus. The lacinia (lac.) is a somewhat conical lobe less than one-third the length of the galea and located just dorsal and medial to the base of the latter. It bears two prominent setae on the dorsal side of the apex.

The labium (Figure **103**, C.) consists of a submentum, mentum, palpigers, palpi, and ligula. The submentum (sm.) is flat and trapezoidal in shape, sclerotinized, and separated from the maxillary subgalea on each side by a membranous area. It is continuous with the cervical membrane caudally. The mentum (men.), much smaller than the submentum, is likewise sclerotinized. The caudal margin of the sclerite is indented and the anterior margin merges imperceptibly into the ligula. The palpigers project from the antero-lateral angles of the mentum and are not distinctly demarcated from it at their bases. Each bears a two-segmented palpus the segments of which are sclerotinized. The basal segment of each palpus bears a small seta on the ventral side near the distal end. The palpi lie ventral to the lateral sides of the ligula and extend about two-thirds of its length. The tip of the palpus bears three or four minute pore-like structures. The area between the bases of the palpi has been termed the stipulae by Yuasa (**1922**), but this area is not distinctly separated from the mentum and ligula (totaglossa of Yuasa). The ligula is an approximately quadrangular lobe slightly convex at its terminal end. The opening of the silk duct (sd.) is at the mid-line just ventrad of the tip. The base of the ligula is lightly sclerotinized and at the lateral basal angles the terminations of the heavily sclerotinized band of the hypopharynx are seen.

The hypopharynx (Figure 103, G.) of this larva is divided into two distinct regions, a membranous apical area and a broad basal sclerotinized band extending around each side to terminate at the caudo-lateral angles of the ligula. The membranous apical area bears an abundance of minute spines on each side, leaving the median part glabrous. On the anterior margin of the sclerotinized basal band and close to the middle of the group of spines on each side is a minute seta.

The tentorium (Figure 103, C.) consists of three parts, the posterior arms (metatentorium), the body (corpotentorium), and the anterior arms. The posterior arms extend medially from the gular pits (metatentorinae) to the large body of the tentorium which lies between the ventral nerve cord and the oesophagus. From the anterior lateral angles of the body of the tentorium the slender anterior arms extend to the frontal pits (pretentorinae) on the epicranium at the anterior lateral angles of the frons. There are no dorsal arms.

Cervix (Figure 104, A and B.). The cervix, a membranous connection between thorax and head, possesses a pair of short slender cervical sclerites (cs.) which extend from the odontoidea on the head to the sternal region of the prothorax. These must be lateral cervicals, since they extend to the occipital region of the head to which they give some support. There is no distinct thoracic episternum, but the sternum of the thorax is lightly sclerotinized.

Thorax (Figure 104, A, B, and C.). The thorax is somewhat broader than the abdomen and narrows slightly in the posterior direction. The prothoracic tergum slopes anteriorly and folds over the caudal aspect of the epicranium and the sternum continues into the cervix. There is no distinct prothoracic shield. The terga of the meso- and metathorax are each divided in the middle by a horizontal furrow. The pleural lobes of the prothoracic segments are slight, not nearly so distinct as those of the abdomen. A spiracle is borne on the prothoracic pleural region near the caudal margin. It is larger than the abdominal spiracles. This is the true mesothoracic spiracle which has migrated to its present position. The metathoracic spiracle is absent. There are three pairs of thoracic legs, and each divided into a coxa, femur, tibia, and claw according to Yuasa's (1922) interpretation of the leg segments, tarsus being represented only in the claw. According to Snodgrass (1927) the tibia and tarsus are united in *Pteronidea ribesii* and the terminal segment is a true pretarsus. Figure 104, C of the writer is labeled accordingly. The trochanter is not present, a characteristic of Fenusinae according to Yuasa. The pretarsus is a simple claw. The segments of the leg are lightly sclerotinized and decrease in diameter distally, giving the appendage a conical shape. The prothoracic legs are slightly longer than those of the meso- and metathorax. There is no evidence in this larva of a sclerotinized pleural area.

On the ventral side of the thorax there is a conspicuous black median area on each segment. The shape of these areas, which varies slightly, is shown in Figure **104**, B. They are absent from the first and fifth instars. There are about four pore-like structures on the prothoracic black area, usually on the anterior half. The sternum of each thoracic segment is lightly sclerotinized.

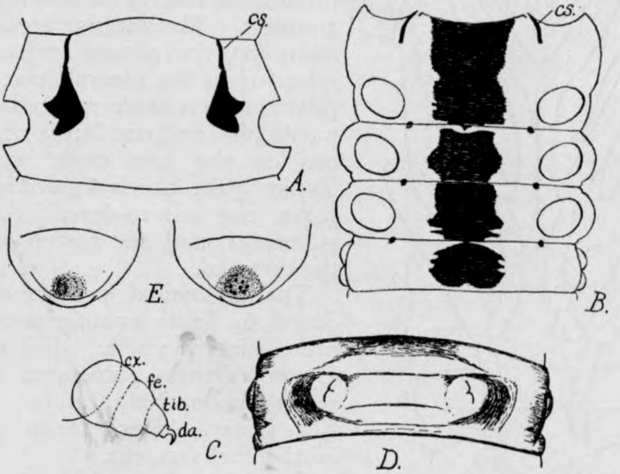


FIGURE **104**. Thoracic and abdominal larval structures. A: Cervix and prothorax of 1st instar larva, ventral aspect. B: Sternum of thoracic and first abdominal segments of 4th instar. C: Prothoracic leg of 4th instar. D: Prolegs of second abdominal segment, 5th instar. E: Suranal plate of larva, 4th instar right, 5th instar left. *cs.,* cervical sclerites; *cx.,* coxa; *da.,* pretarsus; *fe.,* femur; *tib.,* tibia-tarsus.

At the caudal border of each thoracic sternum there is a small internal protuberance on each side, nearer to the base of the leg than to the mid-line. These function for the attachment of muscles which extend to the pleural region. In the middle of the caudal border of the prothoracic sternum is a slight sclerotinized internal process, the profurcellina. This process is much less prominent on the mesothorax and is hardly discernible on the metathorax.

In the first larval instar there is on each side of the prothoracic sternum an irregularly shaped sclerotinized area (Figure **104**, A.) which extends from the cervical sclerite to the region of the coxa. This is shown in black in the figure but is brownish in the living larva. From its position and its relation to the above mentioned lateral cervicals it may belong to this sclerite or be part of a reduced precoxal bridge.

Abdomen. There are ten visible abdominal segments, the second to eighth of which are similar in appearance (Figure 103, A.). The spiracles, which are smaller than the pair on the prothorax, are on segments one to eight inclusive. These are slit-like in appearance with a sclerotinized peritreme. The first abdominal segment is not divided into annulets dorsally, nor are the ninth and tenth, but each of segments two to eight inclusive is divided on the dorsal side into two annulets. The anterior annulet extends on the pleural region, terminating at the pleural lobe. This pleural lobe is much reduced on segments nine and ten, but is conspicuous on the first eight segments. Typically the lobe is divided into two parts, one antero-dorsal, the subspiracular, and one postero-ventral, the surpedal.

The abdominal prolegs are reduced to fleshy protuberances, but are distinctly visible. Figure 104, D shows these structures on the second abdominal segment of the fifth instar. There are no prolegs on the anal segment.

On the tergum of the tenth abdominal segment is a sclerotinized area, the suranal plate (Figure 104, E.). This is slightly convex and in the fourth instar bears five minute papillae. These structures are not present on the suranal plate of the fifth instar.

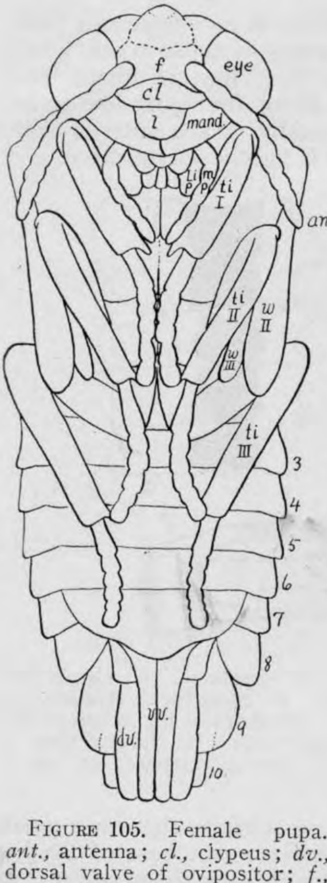


FIGURE 105. Female pupa. *ant.*, antenna; *cl.*, clypeus; *dv.*, dorsal valve of ovipositor; *f.*, frons; *l.*, labrum; *mand.*, mandible; *li. p.*, labial palpus; *m. p.*, maxillary palpus; *ti.*, tibia; *vv.*, ventral valves of ovipositor; *w.*, wing. The Roman numerals refer to thoracic segments and the Arabic to abdominal segments.

PUPA

The pupa (Figure 105) is white in color, of the usual sawfly type, that is, with all the appendages free, and measures about 4 millimeters in length. The integument is free of setae, but is very finely asperate. The segmentation of the body and of the appendages is quite distinct, and the external genitalia are clearly demarcated. The principal external adult structures are all present in the pupa, and the abdomen of each sex possesses ten segments dorsally. The anus in each sex is visible on the dorsal side, and the "cerci" appear attached to the tenth segment each side of and below the anus. The dorsal and ventral valves of the female ovipositor are distinct, and in the male the tips of the gonopods extend slightly beyond the caudal margin of the hypandrium. The pupa possesses no striking characters, and a detailed description of it is deemed unnecessary.

CONTROL

The natural factors affecting the abundance of this insect have not been thoroughly investigated. As has been noted previously, the large amount of young gray birch growth in the state, particularly sprouts, is favorable to the sawfly, but the elimination of this factor is impracticable. Since its first appearance the insect has not been affected by climatic factors to the extent that marked fluctuations in its abundance have occurred.

A few natural insect enemies, both predaceous and parasitic, have been noticed, but the percentage of parasitism is not at present high. Four species of hymenopterous parasites have been reared from the larvae, namely:

Chrysocharis pallipes Gahan
Closterocerus utahensis Cwfd.
Derostenus fullowayi Cwfd.
Derostenus diastatae How.

None of these are abundant. For the identification of the species the writer is indebted to C. F. W. Muesebeck and P. B. Dowden of the United States Bureau of Entomology.

Three species of predaceous Hemiptera have been observed to feed on this sawfly, *Podisus maculiventris* Say, and *P. placidus* Uhler on the larvae, and *Sinea diadema* Fabr. on the adults. The nymphs of the two species of *Podisus* will push their beaks through the surface of the leaf and into larvae in the mine. The wasp, *Polistes pallipes* Lepel., has been observed to cut through the covering of the mine with its mandibles and remove the larvae. Ants of undetermined species frequently capture prepupae as the latter attempt to enter the ground.

The writer (Friend, 1931) has previously published the results of laboratory experiments with insecticides. The larvae are very difficult to kill, being protected by the covering of the mine, but it was found that a high mortality of eggs, 100 per cent in many cases, followed the thorough application of nicotine sulfate (without soap) in water diluted 1-1000. Both sides of the leaves should be well covered with the material.

In 1931 the writer carried out field experiments at Rainbow, Conn., with this material (Friend, 1932) and obtained good results. The birches were sprouts 4 to 8 feet high, and two adjacent blocks, each about 20 feet square, were used, one being sprayed and one serving as a check. Adults of the first generation were abundant during the latter part of May and the first few days in June, and second generation adults were abundant the first two weeks in July. The sprouts were sprayed May 25 and June 5 for the first generation and July 3, July 10, and July 17 for the second generation.

The control of the first generation, although not complete, was appreciable, the sprayed plants being markedly less injured. The survival of some of the eggs may have been due to cool weather at the time of spraying, or to slightly incorrect timing of the applications. The control of the second generation was excellent. On July 24 a count of leaves was made on both plots. Beginning at the first fully opened leaf at the tip, six leaves were examined down the twig. This included all the leaves having any indication of injury, whether or not the larvae were still present. The eggs in the younger leaves in the unsprayed plot were not hatched. In the sprayed plot a few mines, 1/4 to 3/8 inches in diameter, contained dead larvae. These leaves which contained the dead larvae only, and not any uninhabited mines, were considered as showing control of the insect, for this condition did not occur in the unsprayed plot. Even in the sprayed plot such dead larvae were not common. In each plot 50 tips were examined, that is, approximately 10 tips from each of five clumps of sprouts. In the tables leaf No. 1 is the tip leaf, and leaf 6 is the basal leaf. The fact that almost all leaves 1 and 6 were intact and not injured indicates that this range of leaves covered the observable injury. The results are given in Tables 17 and 18.

In the unsprayed plot almost all leaves 1 and 6 were not injured. Only 13 showed larval mines. In the sprayed plot none of these showed larval injury. One hundred and seventeen leaves in 300, or 39 per cent, of the leaves in the check plot were injured by larvae, whereas in the sprayed plot 20 leaves in 300, or 6.7 per cent, were injured. This gives a control of 82.1 per cent. If leaves 1 and 6 in both plots are eliminated from the calculations, the control is 80.8 per cent. This may be a better estimate of the efficiency of the control measures, due to the small number of these leaves injured on the unsprayed plot. The small number of leaves injured in the sprayed plot was negligible as far as the appearance of the trees was concerned.

For the control of this insect on ornamental trees it is recommended that nicotine sulfate, diluted in water at the rate of 1-1000, be used. For the first generation the trees should be sprayed twice, at weekly intervals, beginning about 10 days after the first adults appear. For the second generation the trees should be sprayed three times, at weekly intervals, the first application to be made about six weeks after the first application for the first generation. This holds for southern Connecticut, and in this region the date of first application for the first generation should be about May 25 and for the second generation about July 3.

TABLE 17. *Fenusa pumila* CONTROL, 1931. SPRAYED PLOT—NICOTINE SULFATE 1-1000

Leaves *not* injured by larvae marked "x"

Tip	Leaves						Total not injured	Total injured
	1	2	3	4	5	6		
1	x		x	x	x	x	5	1
2	x	x		x	x	x	5	1
3	x	x	x	x	x	x	6	0
4	x	x	x	x	x	x	6	0
5	x	x	x	x	x	x	6	0
6	x	x		x	x	x	5	1
7	x	x	x		x	x	5	1
8	x	x	x	x	x	x	6	0
9	x	x	x	x	x	x	6	0
10	x	x		x	x	x	5	1
11	x			x	x	x	4	2
12	x	x	x	x	x	x	6	0
13	x	x	x	x	x	x	6	0
14	x	x	x	x	x	x	6	0
15	x	x	x	x	x	x	6	0
16	x	x	x	x	x	x	6	0
17	x	x	x	x	x	x	6	0
18	x	x	x	x	x	x	6	0
19	x	x	x	x		x	5	1
20	x	x	x	x	x	x	6	0
21	x	x	x	x	x	x	6	0
22	x	x	x	x	x	x	6	0
23	x	x	x	x	x	x	6	0
24	x	x	x	x	x	x	6	0
25	x	x	x		x	x	5	1
26	x	x	x	x	x	x	6	0
27	x	x		x	x	x	5	1
28	x	x	x	x	x	x	6	0
29	x	x	x	x	x	x	6	0
30	x		x		x	x	4	2
31	x		x	x	x	x	5	1
32	x	x	x	x	x	x	6	0
33	x	x	x	x	x	x	6	0
34	x	x	x	x	x	x	6	0
35	x	x	x	x	x	x	6	0
36	x	x	x	x	x	x	6	0
37	x	x	x	x		x	5	1
38	x	x		x	x	x	5	1
39	x	x	x	x	x	x	6	0
40	x	x	x	x	x	x	6	0
41	x	x	x	x	x	x	6	0
42	x	x	x	x	x	x	6	0
43	x	x		x	x	x	5	1
44	x	x	x	x	x	x	6	0
45	x	x		x	x	x	5	1
46	x	x		x	x	x	5	1
47	x	x		x	x	x	5	1
48	x	x	x	x	x	x	6	0
49	x	x	x	x	x	x	6	0
50	x	x	x	x		x	5	1
Total							280	20

TABLE 18. *Fenusa pumila* CONTROL—1931. CHECK PLOT—NOT SPRAYED.

Leaves *not* injured by larvae marked "x."

Tip	Leaves						Total not injured	Total injured
	1	2	3	4	5	6		
1	x			x		x	3	3
2	x			x	x	x	4	2
3	x				x	x	3	3
4	x					x	2	4
5	x		x		x		3	3
6	x				x	x	3	3
7	x				x	x	3	3
8	x	x	x	x	x	x	6	0
9	x	x	x	x	x	x	6	0
10	x						1	5
11	x	x		x	x	x	5	1
12	x	x		x	x	x	5	1
13	x	x		x	x	x	5	1
14					x		1	5
15	x	x	x	x		x	5	1
16	x					x	2	4
17				x		x	2	4
18	x	x			x	x	4	2
19	x					x	2	4
20	x					x	2	4
21	x	x			x		3	3
22	x					x	2	4
23	x	x			x	x	4	2
24	x			x	x	x	4	2
25	x	x				x	3	3
26	x				x	x	3	3
27	x			x	x	x	4	2
28	x				x	x	3	3
29	x	x	x		x	x	5	1
30	x	x			x	x	4	2
31	x	x			x	x	4	2
32	x	x		x	x	x	5	1
33	x	x	x			x	4	2
34	x	x		x	x	x	5	1
35	x	x	x	x	x		5	1
36	x	x	x	x	x	x	6	0
37	x	x	x	x	x		5	1
38	x						1	5
39	x					x	2	4
40	x			x	x	x	4	2
41	x		x	x	x	x	5	1
42	x	x				x	3	3
43	x	x		x	x		4	2
44	x	x		x	x	x	5	1
45	x	x	x	x	x	x	6	0
46	x	x			x	x	4	2
47	x				x	x	3	3
48		x	x	x	x	x	5	1
49	x				x	x	3	3
50				x	x		2	4
Total							183	117

SUMMARY

The birch leaf-mining sawfly *(Fenusa pumila* Klug), a native of Europe, was introduced into the northeastern United States sometime before 1923. A brief historical account of the insect is given, together with its systematic position. At the present time it is found throughout northeastern United States, in southeastern Canada, and over much of continental Europe and the British Isles.

There are three, and sometimes a partial fourth, generations in one season in Connecticut. The first adults emerge during the second week in May and the completion of one summer generation requires about six weeks. Eggs are laid in the leaves of gray, white, and European white birches, only the young growing tip leaves being suitable for oviposition. The period of incubation varies from 6 to 13 days, but most of the eggs hatch in 6 to 10 days.

The larva mines in the leaf from 8 to 13 days as a rule and then enters the ground to pupate. There are four feeding larval instars and a fifth instar, the prepupal stage, during which the larva is in the cocoon and does not feed.

It is concluded that "Dyar's Rule" does not hold with this species.

The larval mines in gray birch are described, and measurements of the mined area are given.

Pupation occurs in cocoons made of particles of soil at a depth of from 1 to 2 inches below the surface of the ground. The prepupal period averages about 11 days in length in the summer, and hibernation occurs while the insect is in this stage. The pupal period is about six days in length. In a small proportion of cases the period in the soil (prepupal plus pupal) is prolonged in the summer to about 45 days.

Beginning about the second week in August the insect begins to go into hibernation, and an increasing proportion of prepupae hibernate as the season progresses. The larvae occur in the field until the last of September and the first of October, and a few adults are found as late as the first week in October.

The sex ratio of all adults reared was .60. Virgin females will oviposit in leaves and larvae develop from their eggs.

The relations of the insect to its host plants are discussed. The insect shows a preference for young sprout growth, and where sprouts grow vigorously and produce new foliage throughout the season the maximum number of generations of the insect occur. There are only two generations on trees the foliage of which hardens in midsummer. The habit of ovipositing in newly developing leaves only, restricts severe foliage injury to the tops of the trees. The writer has never observed any trees that were killed by the insect.

The external morphology of the adult, larva, and pupa is described.

Natural parasitic enemies of this sawfly are not very numerous and do not appear to exert any great degree of control over its

abundance, although the influence of natural factors has not been thoroughly investigated. Spraying with nicotine sulfate diluted in water at 1 part in 1000 will kill the eggs if both sides of the leaves are covered with the insecticide. For the first generation in Connecticut, two applications should be made at weekly intervals beginning about May 25, and for the second generation three applications at weekly intervals are necessary, the first to be made about July 3.

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