THE LIFE HISTORY AND MORPHOLOGY
of the
GREEN SPRUCE LOOPER, SEMIOTHISA GRANITATA GN
(LEPIDOPTERA, GEOMETRIDAE).

By

Cecil V. G. Morgan.

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I. INTRODUCTION

Forest entomological control is primarily dependent on a thorough knowledge of the interrelationships of all insects existing in the forest. Some of these insects rise and fall in population and periodically are capable of causing much damage when a high population is attained. To these we devote our greatest attention. Quite often, however, we mistakenly pass over other forest insects which appear to remain at a more or less constant level of population and which give us no economical concern. The biological importance of this latter group is axiomatically almost unknown. We know very little of the part played by such invertebrates in the forest insect community and of their probable importance as reservoirs of parasites and pathogens for other more destructive pests in infestation status.

The green spruce looper, *Semiothisa granitata* Gn. is a forest insect which may be classed in the latter group. Throughout the forests of Canada and the United States it is exceedingly common. For instance, in 1941 the Canadian Forest Insect Survey received more samples and specimens of this looper than any other lepidopterous spruce feeder. Brown (4) has recorded that 1,682 samples containing 5,077 specimens were sent to survey centres in that year. In the British Columbia section of the survey this spruce feeder has played a similar role. Nevertheless, it has never been known to produce infestations or occur in any great numbers. To the writer's knowledge heavy or moderate damage by *S. granitata* is unknown. Therefore, it has been classed by forest entomologists as being unimportant. Though it is unimportant it is still typed as being capable of causing serious damage, probably because it is a vigorous larval feeder. Its feeding habits are comparable to that of other insects of the same group such as the important forest defoliator the hemlock looper (*Lambdina* (=*Ellopia*) *fiscellaria lugubrosa* Hulst.). This perplexing problem--why *granitata* had not increased in the past--was one of the reasons which instigated the writer to undertake a study of this insect as a subject of a thesis.

The life history studies of this geometrid were conducted at the Trinity Valley field station of the Dominion Forest Entomological Laboratory at Vernon, British Columbia. The data were secured mostly from material reared in cages and in vials in an insectary, and from material received through the Dominion Forest Insect Survey. Some observations were made on individual larvae in the field. The absence of infestations or even large numbers under natural conditions very much limited the field studies.

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II. HOST PLANTS AND DISTRIBUTION

Semiothisa granitata is a pest of conifers; it has never been known to occur on other plants. The common name "the green spruce looper" is, in a way, misleading for quite a number of species of trees have been found to serve as breeding hosts besides spruce. Probably spruce is the favorite host but since the inception of the Forest Insect Survey other coniferous hosts have been revealed.

The biological data presented in this report were taken from experiments in which Engelmann spruce (Picea engelmanni Engelm.) was always used as the host. On this tree the looper develops very well. Survey information shows that in addition to its common occurrence on Engelmann spruce, it is frequently found on sitka or tideland spruce (P. sitchensis (Bong.) Carr). These larvae have often been successfully reared to the adult stage. Other British Columbia spruce species on which it may undoubtedly develop, but not officially recorded, are black spruce (P. mariana (Mill.) B.S.P.), white spruce (P. glauca Voss.), and western white spruce (P. glauca Voss. var. albertiana Sarg.). Larvae have never been taken from, or reared on, ornamental spruces, but such trees may possibly serve equally well as hosts.

Larvae collected in the Forest Insect Survey have been taken from a number of other trees. It is doubtful if all of these are specific for Semiothisa granitata. Adults have been recovered from larvae which were collected and reared on the following trees: Douglas fir (Pseudotsuga taxifolia (Lamb.) Brit.), western hemlock (Tsuga heterophylla (Raf.) Sarg.) Alpine fir (Abies lasiocarpa (Hook.) Nutt.), amabilis fir (A. amabilis (Dougl.)

Forbes), western white pine (Pinus monticola Dougl.), lodgepole pine (P. contorta Dougl. var latifolia Engelm.) and western larch (Larix occidentalis Nutt.). Larvae would probably develop also on related British Columbia species of the above trees, such as mountain hemlock (Tsuga mertensiana (Bong.) Sarg.), balsam fir (Abies balsamea (L.) Mill.) and grand fir (Abies grandis Lind.), but no attempt has ever been made to rear the adults on these hosts. Only one instance has been noted of larvae collected on cedars; this was made on western red cedar (Thuga plicata D. Don.), The data supplied with this collection are not considered to be very authentic, and it is doubtful whether larvae will develop on this conifer.

Prior to 1942 a number of larvae collected on western larch (Larix occidentalis Nutt.) and western yellow pine (Pinus ponderosa Dougl.) were thought to have been S. granitata, but it has been shown since that most of these belong to different species. Occasionally granitata is found on western larch but it does not occur on western yellow pine. On larch it may be confused with a commoner species, S. sexmaculata Pack. var. incolorata Dyar.

In British Columbia the range of S. granitata coincides closely with that of its hosts, and is therefore generally distributed throughout the country. It is found from the Pacific Coast to the Rocky Mountains, at least in the southern part of the province. To the north it is known to range as far as Prince George, and undoubtedly occurs some distance beyond that point.

III. SYSTEMATIC POSITION AND SYNONYMY.

The green spruce looper, Semiothisa granitata, is the larva of a geometrid moth taxonomically placed in the subfamily Geometrinae, family Geometridae, superfamily Geometroidea of the order Lepidoptera. The moth was originally described by Achille Guenée. The date of the description is unknown to the writer--Guenée lived between the years 1809 and 1880.

Since the time of the original description much confusion has existed as to the correct specific term for this species. To the writer's knowledge this confusion still exists. This confusion has been due, in part, to the fact that several varieties of this species are said to occur on conifers. It is in the opinion of the writer that some of these so-called varieties which have been given specific rank are one, and that the variations in color pattern of the wings which give rise to the confusion are due to larval feeding on different hosts. The writer has no definite experimental proof of these statements but has observed that line-bred larvae reared on different hosts give rise to moths having different wing patterns. For instance Douglas fir-reared moths are darker in color than those reared on Engelmann spruce. Another factor which adds to the confusion is the different wing patterns of line-bred individuals reared on the same host. Experimental rearings of such specimens have definitely shown that the progeny of two parents may produce moths of totally different wing patterns though the larvae were reared on the same host and under the same environmental conditions. It is considered that experimental rearings of granitata larvae on different hosts would materially help in solving

Lepidoptera of Boreal America placed granitata Gn. (species 4345) in the genus Macaria Curt. No synonyms were listed for Macaria. Synonyms given for granitata were contemptata Gn., haliata Gn., and retractaria Wlk., the latter listed as doubtful. Seven varieties of granitata were listed as follows: irregulata Wlk., quadrisignata Wlk., dispuncta Wlk. (with four synonyms--inordinaria Wlk., subapiciaria Wlk., haliata Wlk., and fissinotata Wlk.), sexmaculata Pack. (with one synonym--labradoriata Moesch.), retinotata Wlk., exnotata Wlk., and submarmorata Wlk.

McDunnough (16) in 1938 published a new and up-to-date "List" of the Lepidoptera of Canada and the United States of America. In this compilation granitata Gn. (species 4680) was placed in the genus Semiothisa Hbn.: Macaria Curt was listed as a synonym. In this work McDunnough listed no true synonyms for granitata. However, haliata Gn. and retractaria Wlk. were given as doubtful synonyms. Only six granitata varieties were mentioned in this work, all of which were given in the check list of 1917. The one omitted was sexmaculata Pack. which was given specific rank. A total of seventy-seven species was listed under the genus Semiothisa Hbn.

The most recent reference is that by W. C. McGuffin (17) in July, 1943, in which the egg and six larval instars are discussed under the title Semiothisa granitata Gn. A footnote to McGuffin's article states that H. G. Dyar in 1904 described the form of this larva found in British Columbia.

IV. LIFE HISTORY.

A. EGG.

Generally the eggs are laid singly, but occasionally they are found in small masses of two or three. Where conditions favour the deposition of large masses they may consist of as many as eight or ten eggs. The masses are always single-layered, the eggs of the mass being closely applied to each other. When laid singly the egg is placed on its side, but when in masses it stands on end.

The female deposits her eggs usually on the leaders and lateral branches of the current year's growth of the host tree. She prefers to place these eggs in the small longitudinal depressions of the stem in the pocket-like area at the base of the needle, or, at least, around the proximity of this attachment, either on the stem or on the base of the needle. The eggs are also often found attached to any area of the needle proper. In all such cases, however, the upper surface of these structures is preferred. They can also be located in the crevices of other areas of the stem and on pieces of foreign material, such as lichen, attached to branches in the vicinity of the terminal growth. The moths will readily deposit their eggs on white paper and on cheesecloth; in such instances they are more often laid in small, single-layered masses.

The number of eggs deposited by a single female may vary considerably between different individuals. This particular point was determined accurately in a few cases, It was found that as many as 180 eggs may be laid by a single female. As shown in the following table the number of eggs laid per moth averages about 120.

TABLE I. NUMBER OF EGGS LAID PER FEMALE

Year	Female	No. of eggs laid per female
1939	1	71
1940	1	64
	2	180
	3	133
1941	1	118
	2	145
Total		711
Average per female		118.5

The duration of the egg-laying period as existing in the field was not determined. Under insectary conditions in the vicinity of Lumby, British Columbia, the eggs are laid during the latter weeks of May and the early part of June. In the field this period would probably be somewhat extended for moths would possibly not come in contact with each other so soon and mate as quickly as was done under an artificial environment.

The incubation period, which was determined in a few instances, varies somewhat depending in part, at least, on weather conditions. It varied between 10 and 21 days (Table II): a period of 19 days appeared to be the most consistent. Dyar (10) said the eggs hatched in six days. In 1939 eggs which were laid on June 7 all hatched on June 28, the incubation period being 21 days, at mean temperatures ranging between 48 and 63.5°F., the latter mean occurring on June 28. Previous to June 28 the highest mean noted was 59.7°F. which was recorded on June 22.

TABLE II. INCUBATION OF EGGS.

Year	First egg laid	Date and Number of Eggs Hatched in June 10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	28	Min. Incubation Period.
1939	June 7																71	21
1940	May 28							12	20	24	1							19
	June 3									128	15	28				5		15
	" 9										73	50	4			4		10
1941	May 22	43	37	12	8	3	3	1										19
	" 23		85	36	12	4	2	2	1									19

In 1940 the first eggs hatched 19, 15, and 10 days in three respective cases after the first eggs were laid, that is on June 16, 18, and 19 respectively. The mean temperatures during these incubation periods ranged between 49.5 and 64.2°F., 49.5 and 65.2°F., and between 49.5 and 67.7°F. respectively. Between June 13 and 16 inclusive, the highest mean recorded was 59.2°F. on the latter date. The mean temperatures of 65.2°F. and 67.7°F. occurred on June 18 and 19 respectively.

In 1941 the incubation period was the same in two cases, 19 days. The mean temperatures here ranged between 50.2 and 60.7°F. in the first, and between 50.2 and 66.2°F. in the second case. On June 1 the mean was 60.7°F., and between the period June 2 and 9 inclusive the mean did not rise above 57.0°F. On June 10 it rose to 60.5°F. from 53.5°F. on June 9. The highest mean of 66.2°F. was noted on June 11.

Throughout the three years there was, as may be seen from the data presented, a fairly consistent (except in one instant) correlation between time of hatching and temperature, the first eggs hatching with a definite rise in mean temperature. This conclusion, which may be the result of coincident factors, cannot as yet be taken for fact until more information is acquired.

The exact period of hatching for a total complement of eggs from an individual moth is not known. In 1940 it consisted of from 4 to 7 days, and in 1941 of only 7 days. These figures do not truly show the variability of the incubation period amongst eggs from the same individual for it was not determined how long egg-laying continued after the first eggs were deposited. It is known nevertheless that the egg-laying period of any moth may be at least two days duration.

The viability of the eggs is constantly quite high. A 97% hatch has been frequently obtained. Seldom does the percentage of hatched eggs drop below 95, and only on one occasion has the percentage been known to reach a low of 89%.

B. LARVA

A number of records were made of the development of the larva from the egg to the pupa. As shown in Table II hatching usually takes place during the last two weeks of June.

1. First Instar

On hatching the first instar larva,if not already on the new foliage, migrates to the current year's growth. During the early larval stage of oclosion from the egg and migration, the small loopers may often be observed dropping by fine threads from the foliage on which the eggs were laid to underlying new foliage. Here they immediately commence to feed on the comparatively succulent new needles. In this stage the feeding habits are very characteristic as compared to that of most other geomtrids. The newly hatched larvae show primitive or ancestral feeding habits which are lost or modified in successive instars. Always, feeding takes the form approaching that exhibited by most needle miners; and in this case, the needle is actually mined. The extent of the mining, however, is comparatively small in relation to the length of the needle.

The majority of the first feeding takes place towards the tip of the needle. Specifically the larva begins to feed at a distance of the length of the body from the apex of the needle. Grasping this point by the prolegs the larva digs a round hole through the epidermis and into the interior of the needle. The hole is just big enough to allow the body to pass within. These holes, which are about the size of the head of a small sewing needle, are rather conspicuous on the foliage of the twig. They occur generally on the upper surface and sides and abnut 2 mm. or so from the distal end of the needle. It is not known if the epidermis of this hole is devoured or cast aside.

Having successfully made an entrace hole, the larva feeds on the mesophyll between the upper and lower epidermis. This mesophyll-feeding extends from the entrance hole towards the stem of the twig, rarely is it made in the distal direction. Eventually the needle in the proximity of the hole is mined of its inner tissues. The mine is seldom longer than the larval body; in fact it is usually only about three-quarters of its length for, during this feeding period, the prolegs are often found attached to the perimeter of the hold while the larva is vigourously digging away in its enclosed habitat.

Two or three days after hatching, the twig will now be found to bear, in some cases, as many as six holes on the upper surface of any one needle. Where the entrance holes have been made mostly on one side, two holes may be found opposite to each other especially at the tip of spruce needles, which are four-sided. All the holes will also be found to be constructed in the same manner as the distal one, but curiously enough, they are on the average about the same distance apart, that is, the length of the larva. Why the holes are only as long as the larval body is a matter of speculation. Attaching the prolegs to the edges of the hole undoubtedly enables the larva to remove itself more easily from the tunnel. The construction of a long tunnel would not be conducive to the development of an insect in which the mining habit was a temporary means to an end. Furthermore, this looper has not attained the backing-up habit as exemplified by most leaf and needle miners.

The mines are also similar to each other in construction but those proximal to the first may be made in either direction from the hole, depending upon how far apart each entrance hole was spaced.

A number of holes on one needle would indicate that they were made by the same larva. This fact is not definitely known but it would appear that more than one tunnel is made by a larva for this feeding habit extends over a period of three to nine days.

Feeding in the first instar is not necessarily confined to the new foliage; although it is not very common, the same type of feeding described above may occur on old foliage.

Dyar (10) in his description of this insect under the genus Sciagraphia states: "Eggs were obtained from Kaslo, British Columbia. The larvae fed on spruce, choosing the needles of the previous year which they closely matched by their dark bluish-green color." In the author's investigations new needles were always preferred by the young larvae. If forced to feed on needles of the previous year, a high mortality resulted. Third, fourth, fifth and sixth stage larvae would feed on old foliage but still preferred new needles.

The injury produced by the mines becomes more evident a day or so after the larva migrates to other feeding grounds. In the area of the mine the epidermis turns a whitish-green as sharply contrasted to the bright dark green of the remainder of the needle. In this stage the pale green bands are quite conspicuous. Several feeding tunnels on one needle produce a multiringed effect. Such foliage soon withers and browns-up as if it had been frost-bitten.

The resting attitude of the first instar larva is also characteristic. In this position the prolegs are attached to the needle and the rest of the body, including the other anterior abdominal segments, is raised into the air at a forty-five degree angle. More often than not, the larva is parallel to the needle with the head pointing towards the stem.

In this stage, the larva spins a very fine and sparse webbing which may be found in the environs of the insect.

The first stadium is at least of three days duration. Probably some larvae may spend as long as 9 or 10 days or more in this stage, depending upon climatic conditions and available food etc. In one experiment of 1940 in which eggs hatched over a three day period commencing on June 18, the first moult apparently did not occur until June 27. All had moulted once by June 30. In 1941 one lot of eggs laid by the same parent began to hatch on June 11 and continued until June 17. Here the second instar was not observed until June 19 and then the numbers in this stage were proportionately few. By June 26 all larvae in this lot had gone beyond the first instar.

2. Second Instar.

The second instar larva continues to feed in the same manner as the first instar, that is, as a needle miner. The entrance holes are proportionately larger in diameter and the mines considerably longer than in the first. Except for these two facts the habits of this stage are identical with the former.

The second stadium probably lasts somewhat longer than the first. In 1940 the second instar was first observed on June 27 and the third not until July 10. In 1941 the corresponding dates were June 19 and June 26. In the latter case the number of specimens still in the second instar was very few.

3. Third Instar.

Beginning with the third instar the needle mining habit possessed by the preceding instars is lost. Now it acquires habits which are commensurate with other needle-eating geometrids.

The feeding habits of this stage although fundamentally the same, are somewhat variable. In all instances the needle is chewed always from the exterior. The variations presented are in the type of this feeding. In some cases, which are probably the most primitive, the needle is chewed through at one point so that the portion beyond falls to the ground. When reared under artificial conditions, these pieces become quite evident on the floor of the cage. Another type is that in which the needle is destroyed only on one side of the midrib throughout its entire length from the apex to the base. The latter type might consist in part, of the first; the needle eaten on one side being consequently cut off. Still a third and final type, which is begun in this stage, is that in which a portion of the entire needle, including the midrib, is eaten.

4. Fourth, Fifth and Sixth Instars.

In the fourth and remaining instars, the larva is a typical coniferous defoliator, eating whole needles. The needles are chewed only to the petiole leaving a twig on which much damage has been done, rather ragged looking.

During these stages the larvae prefer to feed on the current year's growth which at this time of the year (July 31) in British Columbia, is approaching maturity. Nevertheless, some larvae, particularly those in the later instars, will feed anddevelop normally on the preceding year's needles.

Webbing formed after the first and second instars is almost negligible. About the only time it is produced is when the larvae are dislodged from a twig and drop for a foot or so hanging by a fine, silk-like thread. Unless further disturbed an attempt is made to regain the original position by ascending the thread. To accomplish this, the head, in the first operation, is used as a fulcrum and the body is thrown up in a U-shaped curve enabling the larva to grasp the thread by the metathoracic legs. In the second operation, the legs form the fulcrum around which the larva makes a quarter turn thus bringing it to the upright position again. If the first operation was begun on the right side, the third will usually be started on the left and so on up the thread. With each operation, the larva ascends upwards a distance equal to that between the last pair of thoracic legs and the mouth parts. No doubt much energy is expended in climbing the thread particularly in the carrying out of the first operation and the succeeding corresponding ones. It is not surprising therefore, that the larva may rest several times in reaching its objective, and that these rest periods are often quite long.

In 1940 larvae in the third instar were first observed on July 10, though no observations had been made after July 3; they were not taken after the former date. In 1941 larvae were in the third instar first on June 26 and they were never seen after July 3 when only a small number were in this form. The length of the third stadium is, therefore, about six or seven days.

The number of instars existing in this insect after the third is variable.

The number of instars was determined from specimens preserved in Frehling's solution at short intervals throughout the summer months from the time of hatching until pupal formation. The width of the head capsule was later measured in all specimens. These observations were then compared to measurements calculated according to Dyar's rule. As seen in Table III the two measurements, observed and calculated, did not differ by more than .113 mm. in any one case, and in all instances were less than this. It should be noted that any ratio of growth of all the instars of 1940 was, on the average, higher than in 1941.

TABLE III NUMBER OF LARVAL INSTARS.

Year	Instar	Observed width of head capsule	Calculated width of head capsule	Difference	Ratio of Growth
1940	6	2.140 mm.	2.140 mm.	.000	.703
	5	1.505 "	1.435 "	.070	.715
	4	1.076 "	.963 "	.113	.641
	3	.690 "	.646 "	.044	.669
	2	.462 "	.434 "	.028	.628
	1	.290 "	.291 "	.001	....
					Ave. .671
1941	5	2.165 "	2.165 "	.000	.634
	4	1.372 "	1.295 "	.080	.571
	3	.785 "	.774 "	.011	.616
	2	.484 "	.463 "	.021	.572
	1	.277	.276	.001	.....
					Ave. .598

From the table it is seen that results obtained in 1941 were not in agreement with those of 1940: five larval stages were recovered in 1941 and six in 1940. In both years the larvae were reared in the same manner and on the same host. The differences might possibly have been due to climatic conditions during the summer months which varied considerably between the two seasons. It is concluded, however, that the number of instars existing in this insect is variable and that larvae may pupate directly from the fifth instar or from the sixth. In 1943 McGuffin (17) stated: "Sixth Instar: This instar is not always present; most larvae pupate directly from the fifth stage." In the light of these experiments, the author feels justified in modifying this statement and condensing it to just 'larvae may pupate directly from the fifth stage or from the sixth'. It is felt that pupation from the sixth is not an exception for in 1940 all larvae pupated from the sixth stage.

A comparison of the figures for the two years shows that the first three instars are in fair agreement, the width of the head capsule in the third instar of 1941, however, being slightly larger. The next instar (4th in 1940) shows a radical difference. The fifth instar of 1940, although much larger than the fourth of 1941 is apparently equivalent to it. From the above table it can be seen that if an instar had been missed in 1941 it probably would have shown up in the calculated widths of the head capsules; this was not the case.

The stadia of the fourth, fifth, and sixth instars can now be stated in the light of the above. In 1940 the fourth instar was first observed on July 10 and continued until July 18. The fifth stadium was of a similar duration, first being taken on July 18 and not after July 25. The sixth stadium began on July 25 and in some cases lasted until after August 1. In 1941 the fourth instar,first observed on July 3,was not seen after July 10. The fifth and last stadium of the same year began July 10 and continued in some specimens through to and after July 24.

5. Prepupa.

The larva when ready to pupate stops feeding and migrates from the host tree to the ground. The amount of time spent in wandering about is very small compared to other Lepidoptera in this stage. The stage is comparatively sluggish, no haste being made to reach a habitat of pupation.

Throughout the prepupal stage the larval skin loses its lustre and becomes more and more wrinkled. The body shortens and enlarges slightly, particularly in the region of the thoracic segments. This is probably due to secretions of the moulting glands given off into the space between the outer and inner cuticular layers.

Coincident with these changes in shape and size, the larva darkens in color and loses the body markings. Darkening of the body is confined mainly to the area of the dorsum. In this region a red pigmentation takes place which proceeds posteriorly from the first thoracic segment, obliterating the longitudinal stripes. The intensity of this pigmentation is greatest in the thorax and decreases also posteriorly towards the last body segment. Pigmentation is first observed on the mid-dorsal line immediately behind the head. As it proceeds backwards into the abdominal segments it spreadslaterally in the thoracic segments to cover the dorsum and at least the lateral regions above the spiracles. In later stages the entire dorsal and latero-dorsal areas of the body are pigmented in this manner.

The prepupal stage is relatively short. An accurate determination of the period in 1941 revealed that it may be as short as two days under artificial conditions, and as long as six days under field conditions during the summer months. The length of time spent in this stage depends, however, upon climatic conditions and time of year. In 1942 one specimen which began to prepupate on October 12 did not reach its pupal stage until October 26 and even at that time, the pupa had not yet hardened. Similar cases were experienced in September of the same year, one specimen in particular requiring approximately thirteen days to pupate.

C. PUPA.

Under field conditions the pupae are seldom, if at all, formed on the surface of the ground. Nearly always the larvae enter the humus layer of the soil, or debris composed of leaf mold, small rocks, and pieces of wood, to pupate.

They may penetrate loose soil or sand to a depth of one inch or more for the dormant stage. Once a sheltered spot is reached the larva forms a pupal cell the walls of which are lined by a sparse, loose network of fine webbing; in this cell the larva pupates.

Under artificial conditions, the caterpillars will pupate on the surface of glass etc. without any covering, but the survival of pupae from such a state is comparatively low. No pupal cell or webbing is formed under such conditions. Where frass is at hand, the larva will use this as a medium in which to pupate, a cell being formed as in soil etc.

Data from rearing experiments performed under insectary conditions have shown that pupal formation starts in the latter half of July and continues into the third week of August. In 1939 the first pupae were present on August 8; all larvae had pupated by August 21. In 1940 pupae were first observed on July 26 and larvae continued to pupate until August 19. In 1941 larvae pupated as early as July 16, and all had entered the dormant stage by July 28. Larval specimens collected in the field throughout British Columbia and Alberta, and whose development had been completed under insectary conditions have revealed a varying period of pupation extending,in some instances, into the first of November. In 1941 for example, pupae from these field collections first formed on July 25. The last pupation occurred on September 19. Collections in 1942 showed a wide range of pupation. In these the first larvae pupated on July 20, while the last did not mature until November 4, thus extending the pupation period to 107 days. The dormant period was reached by the majority of the specimens in the latter part of August and the first half of September.

D. ADULT.

1. Emergence.

The moths of Semiothisa granitata normally emerge in the spring of the year. This emergence occurs in the months of May and June.

In 1938 a number of pupae were reared under artificial conditions in glass vials and overwintered in a chamber in which the temperature did not fall below 27° F. When field temperatures rose above freezing in the spring of 1939 they were removed to a field insectary. Emergence commenced on May 27, 1939, and continued until June 20. Similar experiments in 1939 produced moths between May 23 and June 4, 1940.

These examples may be contrasted to others of more natural conditions of material subjected to experiment in 1940, when the larvae which were allowed to pupate in soil were overwintered under conditions comparable to those in the field. Adults in this experiment began to emerge on May 11, 1941, and continued to do so until May 21. In addition to this material subjected to more natural conditions, some pupae which had also formed in the soil, were overwintered in a chamber in which only a few degrees of frost were allowed to exist. In the spring of 1941 they were removed to the field insectary where emergence began on June 1 and continued at irregular intervals until June 30, 1941.

Although none of the examples given here truly represent conditions in the field, they do indicate the approximate time of adult field emergence. Here it may be mentioned that very few adults have been taken in the field. It has never been possible therefore, to determine just what is the natural emergence period. Collections of larvae made through the Forest

Insect Survey have indicated that the emergence period in the field might be somewhat later, or at least extended over a longer period than that obtained artificially. For several years larvae obtained in the Survey have been in earlier instars than those being reared in the insectary experiments at the time. Also, larvae have been collected even in the district of the insectary, in the months of September and October, long after insectary material had pupated. There is, on the other hand, the chance that such larvae are the result of early summer emergence of diapause pupae.

Besides the usual spring emergence of moths discussed above, there is also a small summer emergence resulting from pupae formed the same year or from diapause pupae created the previous year. There is every reason to believe that these two summer emergences might coincide and produce a large number of adults. The data of experiments show, however, that the number of moths emerging from any one of these two life cycles is relatively very small. Also, since there seems to be no definite emergence period of these two rhythms, the possibility of having summer adults in large numbers is very remote.

Since the inception of the Forest Insect Survey in British Columbia all overwintering pupae have been incubated early in the year to clear up the work of the previous season. The incubation periods of Semiothisa granitata obtained in this work have given some interesting facts. Every winter the pupae have been placed in an overwintering chamber and removed to a constant temperature cabinet in January or February. Most complete information on hand on this technique was taken in 1942 and 1943. During the season of 1943 the pupae were placed in the overwintering chamber on November 1, Temperatures obtained in this chamber never fell below 25.0°F. while those outside fell to as low as -3.0°F. On January 12, 1944, all pupae were placed in a constant temperature cabinet of approximately 75.0°F. and 90-95% relative humidity. Technique followed in previous years was similar to that of 1943 (Table V).

TABLE V -OVERWINTERING PERIOD AND TEMPERATURES

Year	Min.field temperature °F.	Min.temp. of overwintering chamber °F.	Overwintering incepted	Incubation incepted	Overwintering period in days.
1938-39	-8.5	28.5	Oct.31, 1938	Jan.9,1939	70
				Feb.6,1939	98
1939-40	-5.0	28.0	Oct.27, 1939	Feb.5,1940	101
				Mar.4,1940	129
1940-41	-3.0	25.5	Oct.31, 1940	Feb.21,1941	113
1941-42	-5.0	25.0	Nov. 3, 1941	Jan.31,1942	89
1942-43	-28.0	15.5	Nov. 9, 1942	Jan.13,1943	65
1943-44	-3.0	25.0	Nov. 1, 1943	Jan.12,1944	72

The following tables give the emergence of adults from the constant temperature cabinet for the years 1938-1943 inclusive. The various specimens are given here in the order that they were received as larvae from localities in British Columbia and Alberta. It is important to note that after receipt at the field insectary all material in each year was treated alike as to the method of rearing in the field insectary, overwintering chamber and constant temperature cabinet. Temperature and humidity have been approximately the same each year in the latter environment.

TABLE VI- EMERGENCE OF ADULTS FROM CONSTANT TEMPERATURE CABINET - 1938

No.	Place collected in B. C.	No. of specimens	Pupated 1938	Incubated 1939	Emerged 1939	Sex	
						Male	Female
1	Birch Island	2	Aug.1 Aug.1	Jan. 9	Jan.20 Jan.20		1 1
2	Morrissey	1	Sept.3	"	Jan.19		1
3	Trinity Valley	1	Sept.26	"	Jan.20		1
4	" "	3	Sept.16-22	"	Jan.19 -20		3
5	" "	1	Sept.20	"	Jan.20		1
6	" "	1	Oct. 4	"	Jan.19		1
7	" "	1	Sept.16	"	Jan.20	1	
8	Vennadon	1	Oct. 6	"	Jan.21		1
9	Creston	1	Sept.14	"	Jan.20		1
10	Fernie	1	Sept.26	"	Jan.20		1
11	Ootsa Lake	2	Sept.27	"	Jan.19	1	1
12	Little Fort	1	Sept.20	"	Jan.22	1	
13	Jervis Inlet	1	Sept.30	"	Jan.22	1	
14	Quesnel	1	Sept.14	"	Jan.19		1
15	Valemount	1	Sept.20	Feb. 6	Feb.15		1
16	Capilana	1	Sept.14	"	Feb.16		1
17	Guilford	1	Sept.20	"	Feb.14	?	?
18	Hazelton	1	Sept.20	"	Feb.16	?	?
19	Irvine's Landing	1	Oct.11	"	Feb.16		1

TABLE VI continued --

No.	Place collected In B. C.	No. of specimens	Pupated 1938	Incubated 1939	Emerged 1939	Sex Male	Sex Female
20	Marysville	1	Sept.14	Feb. 6	Feb. 16		1
21	Vancouver	1	Sept.13	"	Feb. 16		1
22	Hazelton	2	Sept.20	"	Feb. 15		1
			Sept.20	"	Feb. 16		1
23	Bear Creek, Chase	1	Sept.20	"	Feb. 16		1
24	Hazelton	1	Sept.26	"	Feb. 16	1	
25	Valemount	1	Sept.30	"	Feb. 15		1
26	W. Vancouver	1	Oct. 18	"	Feb. 17		1

TABLE VII - EMERGENCE OF ADULTS FROM CONSTANT TEMPERATURE CABINET - 1939

No.	Place collected in B. C.	No. of specimens	Pupated 1939	Incubated 1940	Emerged 1940	Sex Male	Sex Female
1	Quesnel	1	Aug. 10	Feb. 5	Feb.15	1	
2	Barriere 5	1	?	"	Feb.14		1
3	Kamloops	1	Aug. 11	"	Feb.15	?	?
4	Prince George	1	Sept.14	"	Feb.13	1	
5	Likely	1	Sept. 14	"	Feb.13	?	?
6	Baynes Lake	1	Sept.14	"	Feb.16	?	?
7	Enderby	1	Sept.14	March 4	Mar.13	1	
8	Barriere	2	Sept.28	"	Mar.12	1	
					Mar.13		1
9	Dixon Creek	3	Sept.13- Oct.18	"	Mar.13	3	
10	Barriere	2	Sept.30- Oct.18	"	Mar.13		1
				"	Mar.14		1
11	Hector	1	Sept.13	"	Mar.12	?	?
12	Newland	1	Oct. 2	"	Mar.11	?	?
13	Hansard	1	Sept.30	"	Mar.12	?	?
14	Hansard	1	Oct. 2	"	Mar.11		1
15	Morrissey	1	Oct. 2	"	Mar.13	1	

TABLE VIII - EMERGENCE OF ADULTS FROM CONSTANT TEMPERATURE CABINET - 1940

No.	Place collected	No. of specimens	Pupated 1940	Incubated 1941	Emerged 1941	Sex	
						Male	Female
1	Michel,B.C.	1	Aug.27	Feb. 21	Mar. 1		1
2	Goat River,B.C.	1	Aug.16	"	Mar.10	1	
3	Lund, B.C.	1	Sept.3	"	Mar. 3	1	
4	Jasper,Alta.	1	Aug.27	"	Mar. 1	1	
5	Barriere, B.C.	2	Sept. 9 Sept.11	" "	Mar. 1 Mar. 3	1	 1
6	Williams Lake, B.C.	1	Sept. 9	"	Mar. 1	1	
7	Cedarvale, B.C.	1	Sept.13	"	Mar. 1	1	
8	New Hazelton, B.C.	1	Sept.23	"	Mar. 1		1
9	Hazelton,B.C.	1	Sept.25	"	Mar. 1		1
10	Gold Bridge, B.C.	2	Sept.19 Oct. 7	" "	Mar. 1 Mar. 3	 1	1

TABLE IX - EMERGENCE OF ADULTS FROM CONSTANT TEMPERATURE CABINET - 1941

No.	Place collected	No. of specimens	Pupated 1941	Incubated 1942	Emerged 1942	Sex	
						Male	Female
1	Fernie,B.C.	1	July 25	Jan. 31	Feb. 8		1
2	Kettle Valley,B.C.	1	Aug. 18	"	Feb.11	1	
3	W.end of Aleza Lake, B.C.	1	Aug. 8	"	Feb. 8	1	
4	S.W.part of Yoho Park	1	Aug.29	"	Feb. 8		1
5	Hansard Lake, B.C.	1	Aug.25	"	Feb. 8	1	
6	Glacier Nat'l Park,Alta.	1	Sept.2	"	Feb. 8	1	

TABLE X - EMERGENCE OF ADULTS FROM CONSTANT TEMPERATURE CABINET - 1942

No.	Place Collected	No. of Specimens	Pupated 1942	Incubated 1943	Emerged 1943	Sex Male	Sex Female
1	Barriere, B.C.	1	July 20	Jan. 13	Jan.22	1	
2	Hazelton, B.C.	1	Aug. 17	"	Jan.23		1
3	Sec.36, Alta.	1	Aug. 11	"	Jan.22		1
4	Bridge R. Valley B.C.	1	Aug. 11	"	Jan.22	1	
5	Arrow Park, B.C.	3	Aug.17	"	Jan.23	1	
			Aug. 24	"	Jan.23	1	
			Aug. 28	"	Feb.11	1	
6	Revelstoke, B.C.	1	Aug. 13	"	Jan.22	1	
7	Goat River, B.C.	1	Aug. 6	"	Jan.21		1
8	Kettle Valley, B.C.	2	Sept. 8	"	Jan.25	1	
			Sept.11	"	Feb. 7		1
9	Sugar Lake, B.C.	1	Aug. 17	"	Jan.26		1
10	103 Mile Lake, Cariboo dist., B.C.	1	Sept. 8	"	Jan.22	1	
11	Edgewood, B.C.	2	Aug.21	"	Jan.22	1	
			Aug.21	"	Jan.22	1	
12	Castlegar, B.C.	3	Sept. 8	"	Jan.22	1	
			"	"	Jan.23	1	
			"	"	Feb. 4	1	
13	Pemberton, B.C.	1	Sept.21	"	Mar.25		1
14	Fiddle Creek, Jasper Park, Alta.	1	Aug. 31	"	Jan.21	1	
15	Vernon, B.C.	3	Sept. 4	"	Jan.23		1
			Sept.14	"	Jan.24		1
			Sept.14	"	Jan.24	1	
16	Creston, B.C.	1	Aug. 24	"	Jan.25		1
17	Sugar Lake, B.C.	3	Sept. 4	"	Jan.22	1	
			Sept.16	"	Jan. 23	1	
			Sept.28	"	Jan.23	1	
18	Hazelton, B.C.	1	Sept.23	"	Jan.26	1	
19	Nelson, B.C.	1	Sept.19	"	Jan.22	1	
20	Barriere, B.C.	3	Sept.16	"	Jan.22	1	
			Sept.21	"	Jan.22	1	
			Sept.21	"	Jan.23		1
21	Louise Creek, B.C.	2	Aug. 31	"	Jan.23	1	
			Sept.23	"	Jan.23	1	1
22	Barriere, B.C.	2	Sept.11	"	Jan.23	1	
			Sept.23	"	Feb. 1		1
23	Hosmer, B.C.	1	Sept. 8	"	Jan.25		1

TABLE X continued --

No.	Place collected	No. of specimens	Pupated 1942	Incubated 1943	Emerged 1943	Sex	
						Male	Female
24	Edgewood, B.C.	3	Sept.17	Jan. 13	Jan.22	1	
25	Cranbrook, B.C.	1	Sept.28	"	Jan.23		1
26	St.Mary's Lake, B.C.	2	Aug. 31	"	Jan.22		1
			Sept.21	"	Jan.23	1	
27	Fernie, B.C.	1	Oct. 1	"	Jan.25	1	
28	Seebe, Alta.	1	Sept.17	"	Jan.22		1
29	Emery Creek, B.C.	1	Oct. 26	"	Jan.25		1
30	Westview, B.C.	1	Nov. 4	"	Jan.25	1	

TABLE XI - EMERGENCE OF ADULTS FROM CONSTANT TEMPERATURE CABINET - 1943

No.	Place collected	No. of specimens	Pupated	Incubated 1944	Emerged 1944	Sex	
						Male	Female
1	Cherryville, B.C.	2	Aug. 3/43	Jan. 12	Jan.22	1	
			Aug.20/43	"	Feb. 8		1
2	Renata, B.C.	1	Sept.8	"	Jan.21	1	
3	Lillooet Dist. B.C.	1	Sept.21	"	Jan.22	1	
4	Waldo, B.C.	1	Sept.27	"	Jan.21	1	
5	Nakusp Dist. B.C.	1	Sept.13	"	Jan.21	1	
6	Trinity Valley, B.C.	4	Sept. 8 -27/42	"	Jan.20	1	
				"	Jan.21	1	1
				"	Jan.23	1	
7	Yoho Park, B.C.	1	Sept. 8	"	Jan.22		1
8	Powell Lake, B.C.	1	Sept. 2	"	Jan.23		1
9	Donald, B.C.	1	Sept.21	"	Jan.21	1	
10	Arrowhead, B.C.	1	Sept.28	"	Jan.21	1	
11	Arrowhead, B.C.	1	Oct. 8	"	Feb.11		1
12	Succour L., B.C.	2	Sept.14	"	Jan.22	1	
			Oct. 5	"	Feb. 5		1
13	Marysville, B.C.	1	Aug. 28	"	Jan.21	1	
14	E. Barriere R., B.C.	2	Sept.14 -Oct.5	"	Jan.21	2	

TABLE XI continued --

No.	Place collected	No. of specimens	Pupated	Incubated 1944	Emerged 1944	Sex	
						Male	Female
15.	New Hazelton, B.C.	1	Sept. 14	Jan. 12	Jan.22		1
16.	Wasa, B.C.	1	Sept. 28	"	Feb. 3		1
17.	Malakwa, B.C.	1	Nov. 1	"	Mar. 2		1
18.	Nakusp Dist., B.C.	1	Oct. 5	"	Jan. 21	1	
19	Nelson Dist., B.C.	1	Aug. 28 1943	"	Jan.21		1
20	"	1	Sept. 14	"	Jan.21	1	
21	Clinton,B.C.	2	Oct. 5-12,1943	"	Jan.30 Apr. 6	1	 1
22	Waterton Park, Alberta	1	Sept. 9	"	Jan.21		1
23	Waldo, B.C.	1	Sept. 22	"	Jan.22	1	
24	Leanchoil,B.C.	2	Sept.28-Oct. 12	"	Jan.20	2	
25	Straight Lake, B.C.	2	Sept.29-Oct. 6	"	Jan.20 Feb. 3	1	 1
26	Kootenay Crossing, B.C.	1	Oct. 6	"	Jan.29		1
27	Rocky Mt. House Alberta	1	Sept.22	"	Feb. 2		1
28	Trinity Valley B.C.	1	Oct. 12	"	Jan.22	1	
29	Marion Valley,	1	Oct. 6	"	Jan.22	1	

An analysis of the above tables brings out the fact that the pupal incubation period usually varies between seven and thirteen days. However, the occurrence of rhythms which are discussed below may, in some cases, extend this period to 100 or more days. In 1938 the shortest incubation period was ten days. Of seventeen moths obtained in the first lot incubated, fifteen emerged within ten and eleven days; one required twelve days, and one thirteen days to incubate. In the second lot, which was incubated approximately one month later, the incubation period was comparatively shortened ranging between eight and eleven days. Of this latter group of thirteen adults, one required only eight days to emerge, three required nine days, eight required ten days, and only one required eleven days.

The material of 1939 was also incubated in two lots, one on February 5, and the other on March 4, 1940. Six adults were obtained in the first lot and these emerged in eight to eleven days; two were recovered within eight days, one within nine days, two within ten days, and one within eleven days. In the second lot, thirteen adults emerged in seven to ten days; two emerged in seven days, three in eight days, seven in nine days and one in ten days. Pupae of 1940 were incubated in February, the same month as the second lot of 1938 and the first lot of 1939. Again, except for one specimen, the incubation period was the same, varying between eight and eleven days; of eleven adults, eight emerged within eight days, and three required ten days. One adult required seventeen days. In 1941 the pupae were incubated January 31 and required eight to eleven days to emerge; of seven specimens, six emerged within eight days, and one within eleven days. In 1942, forty-seven pupae were all incubated beginning January 13, 1943. These emerged in what appeared to be three rhythms (to the author's knowledge emergence rhythms of Semiothisa granitata have not been found by other workers); the first of eight to thirteen days, the second of nineteen to twenty-nine days, and the third of seventy-one days. In the first rhythm forty-one adults were obtained; two emerged in eight days, sixteen in nine days, thirteen in ten days, two in eleven days, six in twelve days, and two in thirteen days. The second rhythm lasted from nineteen to twenty-nine days, and of five specimens obtained one emerged in each of the ninetaenth, twenty-second, twenty-fifth, twenty-eighth, and twenty-ninth day. Only one specimen was recovered from the third rhythm requiring seventy-one days to incubate.

This same phenomenon of three rhythms was noted in material of 1943. Here thirty-eight pupae were incubated on January 12, 1944. The first rhythm occurred between eight and eleven days, the second between seventeen and thirty days, and the third between fifty and eighty-five days. In the first rhythm twenty-eight adults were recovered; four emerged in eight days, fourteen in nine days, eight in ten days, and two in eleven days. In the second rhythm eight adults were taken between the seventeenth and thirtieth day. In the third rhythm one adult emerged in fifty days and one in eighty-five days. This information is summarized in Table XI. Brown (4) reports that occasional emergence may occur up to 101 days from pupae incubated at 75°F. and 95% relative humidity. In the experiments conducted at Vernon, British Columbia, moths were not obtained after eighty-five days incubation but several pupae remained alive for 115 days.

In conclusion several facts appear to be evident from the above data. Firstly, it seems quite definite that, with a few exceptions to be treated later, the time of pupation during the summer bears no relation to the time of emergence the following spring. This is very apparent in the material of 1942. To cite the extremes, larvae which pupated July 20 and September 28, 1942, emerged the same day, January 22, 1943. Even some of those which pupated October 1, and November 4, 1942, emerged only three days later (January 25, 1943). Secondly, the incubation period varies indirectly with the overwintering period; that is, the earlier incubation is started,

TABLE XI - INCUBATION PERIOD OF PUPAE

Year	Incubated	Incubation period	Emergence of adults and time required in days																					Total Emergence
			7	8	9	10	11	12	13	17	18	19	21	22	24	25	27	28	29	30	50	71	85	
1938-39	Jan.9,1939	10-13 days				8	7	1	1															17
	Feb.6,1939	8-11 "		1	3	8	1																	13
1939-40	Feb.5,1940	8-11 "		2	1	2	1																	6
	Mar.4,1940	7-10 "	2	3	7	1																		13
1940-41	Feb.21,1941	8-11 "		8		3																		11
		17 "								1														1
1941-42	Jan.31,1942	8-11 "		6			1																	7
1942-43	Jan.13,1943	8-13 "		2	16	13	2	6	2															41
		19-29 "										1		1		1		1	1					5
		71 "																				1		1
1943-44	Jan.12,1944	8-11 "		4	14	8	2																	28
		17-30 "								1	1		1	2	1		1			1				8
		50-85 "																			1		1	2

the longer will be the incubation period. This conclusion may not seem to be warranted from the data, but the trend does exist. For instance, incubation on January 9, 1939, produced the peak emergence within ten and eleven days, incubation on January 3, 1943, produced the peak within nine to ten days, on January 31, 1942, within eight days, on February 5, 1940, within eight to ten days, on February 6, 1939 within nine to ten days, on February 21, 1941, within eight days, and on March 4, 1940, within eight to nine days. This may be influenced, however, by the time at which overwintering was started and the duration of this period. Nevertheless, two lots of pupae overwintered at the same time, but incubated one month apart, gave results supporting the above statements, both in 1938 and 1939. In 1938, overwintering approximately one month longer from January 9 to February 6,1939, shortened the incubation period by two days both as to first and last adults to emerge. Similar conditions prevailed in 1939 but here the overwintering period was extended in one lot by about one month from February 5 to March 4,1940. This factor shortened the incubation period by one day, again, both as to first and last adults to emerge.

Comparing the four lots of the two years as a whole this phenomenon is even more striking; an extension of the overwintering period from January 9 to March 4 shortened the incubation period by three days (Table XI). Comparisons probably should not be made between two years' work because of environmental differences during the winter. Here, however, the pupae were overwintered under artificial conditions of a chamber in which the minimum temperature and humidity was approximately the same for the winters of 1938-39 and 1939-40 (Table V.); the duration of such factors, no doubt, was different. Minimum temperatures prevailing in the field differed by only 3°F. for the two years. And adding further support to the above, it should also be noted that pupae were overwintered around the same date in each year.

2. Sex Ratio.

Adult material recovered from experiments has exhibited a definite preponderance of males. As shown in Table XII the precentage of males varied from 56.25 to 76.92.

TABLE XII - SEX RATIO IN EXPERIMENTAL REARINGS.

Year	Sex		Total	Sex ratio	%	%
	male	female		males / females	males	females
1938-39	9	7	16	1.38/ 1	56.25	43.75
1939-40	10	3	13	3.33/1	76.92	23.08
1940-41	6	4	10	1.5 /1	60.00	60.00

Except for one year this observation has also been certified in adult specimens recovered from rearings of the Forest Insect Survey (Table XIII)

TABLE XIII - SEX RATIO IN SURVEY REARINGS

Year	Sex		Sex unknown	Total known sexes	Sex ratio	Percent	
	male	female			males/females	males	females
1938-39	5	24	2	29	1 / 4.8	17.24	82.76
1939-40	8	5	6	13	1.6/ 1	61.54	38.46
1940-41	7	5		12	1.4/ 1	58.33	41.67
1941-42	5	2		7	2.5/ 1	71.43	28.57
1942-43	29	18		47	1.6/ 1	61.70	38.30
1943-44	23	15		38	1.5/ 1	60.53	39.47

In 1938 the sex ratio of males to females was less than one but in all other years the ratio was reversed. During the years 1939 to 1942 inclusive the percentage of males varied between 58.33 and 71.43.

The sex ratio of adults from diapause material other than the spring emergence cannot be reliably stated because of the small amount of material recovered. Of the adults obtained in the second diapause rhythm produced in experiments, the ratio has been about equal. If the three rhythms of adult emergence from the constant temperature cabinet in 1943 can be likened to diapause material in the field, the sex ratio would be 1.7/1 for the first spring emergence, 1.5/1 for the summer emergence and 0/1 for the second spring emergence.

The corresponding figures for 1944 would be 3.7/1, 1/7, and 0/2 respectively (Table XIV).

TABLE XIV - SEX RATIO OF THREE INCUBATOR EMERGENCE RHYTHMS LIKENED TO FIELD DIAPAUSE RHYTHMS.

Year	Incubator emergence rhythm.	Corresponding field diapause rhythm.	Sex		Total	Sex ratio	Per cent	
			♂	♀		males/females	males	females
1942-1943	8-13 days	1st spring emergence	26	15	41	1.7/ 1	63.41	36.59
	19-29 "	summer emergence	3	2	5	1.5/ 1	60.00	40.00
	71 "	2nd spring "	0	1	1	0/ 1	0.00	100.00
1943-1944	8-11 "	1st " "	22	6	28	3.7/ 1	78.57	21.43
	17-30 "	summer "	1	7	8	1 / 7	12.50	87.50
	50-85 "	2nd spring "	0	2	2	0/ 2	0.00	100.00

No general statement can be made as to how the sexes emerge in relationship to each other from the point of view of time. Experimental rearings tend to indicate that the females emerge somewhat before the males (Table XV). This was particularly the case in 1940-41.

TABLE XV - COMPARISON OF TIME OF EMERGENCE OF MALES AND FEMALES FROM EXPERIMENTAL REARINGS

Day of Emergence	1938 - 39		1939 - 40		1940 - 41	
	male	female	male	female	male	female
1st		1	1	1		1
2nd	2	1	1			1
3rd	1		1		1	1
4th	2	3	2	1		1
5th		1	1		1	
6th	2		2		1	
7th		1	1		1	
8th	1		1		1	
9th	1			1	1	

Incubated males and females recovered from the Forest Insect have emerged, generally speaking, along with each other, there being no demarcated difference of time between the sexes (Table XVI).

TABLE XVI - COMPARISON OF TIME OF EMERGENCE OF MALES AND FEMALES FROM SURVEY REARINGS.

Day of Emergence	1938 -39		1939 - 40		1940 - 41		1941 - 42		1942 - 43		1943 -44	
	male	female	male	female	male	female	male	female	male	female	male	female
1st	2	4	2		4	4	4	2	1	1	4	
2nd	1	12	1	1	2	1	1		12	4	11	3
3rd	1	7	6	2	1				7	4	6	2
4th	1	1		1					2	2	1	1
5th									3	3		1
6th									1	1	1	

3. Longevity of Adults and Feeding.

Although the length of life of the adult was never accurately determined, several observations have shown that the female may survive for three weeks or more, and the male about two weeks. Even after oviposition the female does not die immediately. Some have lived for approximately ten to twelve days after the first eggs were laid. This is also true of the male, which, in some cases, has survived ten days after copulation.

All the above adults were provided only with water as food and for only part of the mentioned periods. A study of the anatomical structure of the mouth parts has revealed that both the male and female proboscis is well developed and functional and is armed distally by a number of short, stout spines. Such a structure would be capable of obtaining nourishment in the form of fluids. Under field conditions feeding on exudations and natural moisture probably does take place.

4. Mating and the Preoviposition Period.

As far as could be ascertained copulation occurs only after dusk, but whether it continues throughout the night is not known.

At least one of the ways in which copulation is enacted was noted under artificial conditions. In this procedure both the male and female hang by their legs from an overhead support, and facing each other, bring together the copulatory organs.

The copulatory period is apparently quite long, lasting in some cases for three hours or more. Fertilization in the field probably occurs more than once by different males; this point was never verified. However, it was observed that fertilization by one specific male was always attempted only once. Males which had been used previously in the fertilization of only one female were later placed in contact with other virgin females. Copulation might have occurred, but although eggs were always laid, they were never hatched.

The preoviposition period was found to vary between different years, but in each year it was very much the same. Most accurate observations pertaining to this fact were recorded in 1941. For example, on May 22, 1941, a newly emerged male and virgin female were placed together at 10:00 P.M. and the first eggs were laid at 3:00 P.M. May 23, 1941, thus making the preoviposition period less than one day. This same period was also noted in other cases. Opposed to this minimum period the maximum time required for deposition of the first eggs in 1941 was three days. In all instances, of experiments performed in 1940, the preoviposition period was also three days. In 1939 the shortest time recorded was seven days, while in one case twelve days passed before the eggs were laid.

E. DIAPAUSE.

The only diapause known to occur in this insect is found in the pupae. Granitata hibernates throughout the winter season in the pupal stage. It is not surprising therefore, that a pupal diapause may take place in addition to the regular quiescent period. The diapause exhibited here seems to hold no particular rhythm, the period varying considerably even in the progeny of one female.

The larvae of this coniferous feeder generally mature during the summer, pupation occurring in the summer months. Therefore, there is usually only one generation a year; the pupae passing through a hibernation period until the following spring. Evidence accumulated in these experiments and in eastern Canada (4) have shown that a small percentage of the larvae which pupate early in the season may develop without a rest period and produce moths in late summer of the same year. One such male moth, the larva of which had been reared on Douglas fir (Pseudotsuga taxifolia (Lamb.) Brit.) and which pupated as late as August 31, emerged October 1, 1942. This specimen was one of eight larvae collected in the field in the latter part of August, and from which a total of three pupae were obtained, two on August 31 and one on September 31. The remaining two pupae hibernated through the winter. A similar event occurred in 1941, but this time from rearings carried on in the insectary of material line-bred from 1939. In this particular case the larvae, which were fed on spruce (Picea engelmanni Engelm.) began to pupate on July 16, 1941, and continued to do so until July 25. An emergence of one male moth on August 5, 1941, was not expected. At the most, the duration of the pupal period was only twenty days, thus making the length of the entire life cycle about two and a half months.

These examples give some indication of the extreme variations which might exist in this insect. No explanation for these late summer emergences can be given at present. Enough specimens have not been obtained to carry on breeding experiments of their progeny to determine what change, if any, occurs in the life history. Presumably, eggs and larvae could be obtained, but whether or not they would hibernate over the winter and continue their development the following year is problemmatical. There is a possibility however, that if emergence occurred early in August enough time would be available for development to the pupal stage and hibernation could then proceed in its normal course. Such a development would obviously bring about two generations a year.

A second variation sometimes experienced is that in which emergence of moths may occur in mid-summer instead of with the general emergence in the spring. As in the previous variation, this diapause may exist in a small number of the total pupae from one female, the majority of which emerged in the spring and a few the previous summer as already stated. In this variation the pupae have thus gone through a period of almost a year. An example of such a diapause occurred in 1941 from larvae reared in 1940. These larvae, which were all of the same lineage, pupated between August 6 and 12, 1940. No exceptional early emergence took place the same summer, but in the following spring the normal development occurred giving rise to the usual percentage of moths. Some pupae remained alive throughout the summer and on September 3, 1941, a male moth was obtained. Here the pupal period was of over twelve months duration extending the life cycle to fifteen months.

There is also a possibility of a third variation in which a very small percentage of the pupae have survived throughout two winters. Although examples have been obtained no emergence has ever resulted in the second spring. This phenomenon has been experienced several times. The first occurred in material which pupated between August 8 and 21, 1939. Some pupae emerged the spring of 1940 but of those remaining, a few continued to show life throughout the summer and winter of the same year. In the spring of 1941, a small percentage still showed life but all had died by July 28. An examination of these specimens on the latter date revealed that half of the pupae contained dead adults. The other half had been attacked by some disease, probably bacterial. Of material reared in 1940, the same phenomenon was noted. In this case, larvae pupated August 6 to August 12, 1940. Some of these pupae remained alive throughout 1941 and into the first of June, 1942 at least. An examination made on September 24, 1942 revealed that they were dead. These examples show that some pupae may remain alive for as long as twenty-two months or more.

Including these three variations there is a possibility therefore, of pupae raised from the eggs of one female, emerging in four rhythms. In the first rhythm there is no diapause, the pupae emerge the same summer within a month or so of being formed. Pupae of the second rhythm are included in the normal life cycle. These pass through the normal rest period of the winter months and emerge the following spring. The third rhythm lengthens the diapause still further in some pupae, the period lasting until the next summer: a total of about fifteen months. The fourth and final rhythm, which so far has never been successfully completed, lasts for approximately twenty-two months.

The cause of the above variations of diapause is a problem which has not been investigated. Of the convincing physiological theories of diapause which have been propounded--self-intoxication, unfavourable environmental conditions, and inherited characteristics--the latter seems to be the most plausible explanation for this insect. Heller (30), working with the hawkmoth, Cerlerio cuphorbiae L., which has a life history similar to S. granitata, found that a percentage of the larvae pupated earlier and developed without a diapause as is the case in granitata. He was able to breed both kinds of individuals--pupae with and without diapause--through several generations, and attributed the variations to inheritance as a Mendelian character. Decoppet (30) in his investigations of the 3-year or 4-year cycle of Melolontha, was led to much the same conclusion, but thought that there are biological races of the insect, each with its fixed cycle. Both men agreed that the characteristic type of development cannot be influenced by climatic conditions. Such conclusions seem to be applicable to S. granitata. One reason for believing that environmental conditions do not influence the various types of development is to be seen from the experiments. Although these experiments cited were conducted under artificial conditions, in each case they consisted of line-bred individuals from the same parents, and were reared in one container making the climatic conditions for each specimen of one parent pratically identical. Yet from these individuals of one parent there developed, in some cases, all the diapause variations outlined previously. How different types of development could have been brought about by the influences of varying climatic factors seems to be out of the question. There is however, a possibility that pupae are susceptible to minute changes of the microclimate. But even this is a remote possibility, when it is considered that the microclimate of containers under artificial conditions is comparatively stable throughout compared to that of natural conditions.

Further evidence for believing that inherited characteristics are the cause of these diapauses was obtained from Forest Insect Survey material incubated in the constant temperature cabinet. The method of treatment of this material has already been outlined. Since all specimens were treated alike the results of emergences can be compared. These emergences occurred in three striking rhythms which are believed to be comparable to the diapause rhythms already discussed and which are thought to exist under natural conditions. Here, as in the field, the majority of adults of the 1942 generation emerged from incubation in one period, which under constant temperature conditions lasted from eight to thirteen days. There is no doubt that this emergence corresponds to the spring or second rhythm of emergence in the field which occurs from hibernating pupae of one winter. The second incubated rhythm of emergence took place within nineteen to twenty-nine days, this being analogous to the third rhythm of emergence in the field which occurs in the summer months about one year after pupation. As in the field, the percentage of specimens in this rhythm was also small. The third rhythm of incubated emergence was recovered in seventy-one days. Completing the comparisons, this emergence corresponds to the fourth rhythm of emergence in the field which gives support to the theory that it does occur under natural conditions. Only one specimen was obtained in the third rhythm of emergence, or a percentage of 2.12 of the total number of pupae incubated from the 1942 material. The pupa of this adult was not formed extremely late in the season, but on September 21, 1942, along with and before the others that emerged sixty-three days earlier. Several other specimens appeared to be progressing toward this third rhythm but died within forty to fifty days. One specimen lived for eighty days but at the end of that time was not allowed to emerge. The above comparisons can be applied also to the 1943 incubated material which produced three similar rhythms of emergence corresponding to field rhythms.

It is to be noted that the elapsed time between the incubated rythms is much greater from the second to the third than from the first to the second. These ratio of periods between emergence rhythms correspond somewhat to those which exist in the field; that is , the ratio of the periods between the second (first spring emergence) and third rhythms (second summer emergence) and between the third and fourth rhythm (second spring emergence). This fact adds further support to the view that rhythms of emergence obtained from incubation and from the field can be truly compared. Consequently, since all incubated specimens were given the same environmental treatment, the only explanation for three incubated rhythms of emergence--and therefore four field rhythms of emergence--is a genetical inherited factor.

V. NATURAL CONTROL.

A. CLIMATE.

As is the case with most life, the weather is a factor considerably affecting the development of the looper throughout its entire life history, and is without doubt the greatest natural control. The influence of this factor is most apparent in the incubation of the eggs, though the amount of control is probably small. This influence has already been discussed under the heading of the development of the egg.

Weather has its greatest control effect at the time of mating and during the early larval instars. Sunlight is probably not so important in the activities of the moth but the absence of warm weather materially affects oviposition. Mating is severely inhibited by an abnormal amount of precipitation or a wet, cold spring. These latter factors also tend to lengthen the emergence period of the adults preventing peak emergences and thus lessening the chance of moths finding mates.

There is no other time during the larval life as critical as that of the first instars. The mortality of that period is sometimes enormous. Cold weather is probably not so important as rain, the presence of which is peculiar to various parts of the province about the end of May and in June. About this time too, either the eggs are hatching, or young larvae are in their first, second, or third instars. It has been observed that drenching rains just after hatching will often account for a large percentage of the young larvae. These are beaten from the branches and seldom regain a feeding area on the tree before death occurs. This is possibly one of the factors to be considered in any explanation of the absence of epidemics of this insect.

Although no concrete evidence is at hand, weather continues to play an important role in the development of the larvae and of the mortality of such until pupation. In 1941, for example, the number of larvae dying from causes other than parasites and disease amounted to 50%. In 1942 this same mortality accounted for 37% of all larvae. The percentage of this mortality which can be attributed to weather is unknown.

The exact amount of control exacted by environmental conditions upon the pupae is also unknown. Apparently it is not so great as that of the larvae. Evidence shows that the mortality of the pupae may be as high as 33%, part of which may be due to adverse weather conditions. Indirectly environmental conditions, if considered to be at least partly responsible for diapause, help to maintain this insect at low populations.

B. PARASITES.

The only information at hand dealing with parasites of S. granitata is limited to larval parasitism; no knowledge has been obtained of egg and pupal parasites. This situation is due in part, to the fact that no field infestations of granitata have ever been known and it has been impossible, therefore, to make any collections of the various stages of the insect. Almost all material of the Forest Insect Survey has been received in the larval stages, and although the amount of this has not been large, it has produced a number of parasites which give some correlation as to the control effected by these insects.

The larval parasitic fauna so far known to occur in British Columbia is confined to the orders Hymenoptera and Diptera. The majority of these belong to the family Ichneumonidae of the former group. The following is a list of the determined hymenopterous species which have been bred from the larvae. A list of the few Diptera which have been recovered cannot be given here for as yet their determinations have not been made available.

B.C. Hymenopterous Larval Parasites of *Semiothisa granitata*

Ichneumonidae

Casinaria spp.
Casinaria eupitheciae Vier.
Casinaria semiothesiae Why.
Hyposoter sp.
Hyposoter near *geometra* Ashm.
Mesochrous sp. (Hyperparasite)
Rogas sp.

A list of Canadian parasites known to attack *S. granitata* was published in 1941 (4), but because of other parasites having been recovered since, the list may now be incomplete. This list, which is given below, consists of 19 hymenopterous genera represanting three families, and of 3 dipterous genera represanting one family. Possibly some of these genera are to be found in British Columbia in addition to those already listed for the province.

HYMENOPTERA

Ichneumonidae

Amblyteles spp.
Campoplex sp.
Campoplegidea lobata Why.
Campoplegidea vicina Prov.
Casinaria sp.
Chlorinaeus probably new sp.
Euceros couperii Cress.
Euceros frigidus Cress.
Hyposoter near *geometrae* Ashm.
Mesochrous spp. (Hyperparasite)
Ophion sp.
Paranomalon sp.
Platylabus orantus Prov.
Rogas spp.

Braconidae

Macrocentrus uniformis Prov.
Meterous reticulatus Mues.

Vipionidae

Apanteles spp.
Microgaster probably new sp.
Microplitis n. sp.

DIPTERA

Tachinidae

Chaetophlepsis orbitalis Web.
Madremyia saundersii Will.
Thelairodoria sp.

The survival potential of parasites in the field has not been determined. However, of those Hymenoptera which were recovered from field collections of larvae and reared to cocoons and adults in an insectary, or to adults in both an insectary and an incubator approximately 66.6% in 1942 and 75% in 1941 developed to the adult stage (Table XVII). These percentages are based on the known number of parasite larvae. Respective percentages for Diptera were 50% and 33%, based on the number of puparia formed.

TABLE XVII - SURVIVAL OF PARASITES

Year	Hymenoptera				Diptera		
	larvae	cocoons	adults	% adults of larvae	puparia	adults	% adults of puparia
1941	4	3	3	75.0	3	1	33.3
1942	15	13	10	66.6	4	2	50.0

Of all larvae collected under the Forest Insect Survey plan and reared to the adult stage in an insectary, 14.7% in 1942 and 20.0% in 1941 proved to be parasitized (Table XVIII). These percentages were calculated from observable signs of parasitism of host larvae actually known to have died from parasites. In some cases only the parasite larva was seen but the adult not obtained. In others only the cocoon was observed and not the adult. In still others all three stages were recovered of some parasite species.

TABLE XVIII - PERCENTAGE OF LARVAE PARASITISED

Year	Larvae received	Larvae pupated		Larvae parasitised		Larvae dead cause unknown		Maximum larval parasitism	
		No.	%	No.	%	No.	%	No.	%
1941	30	9	30.0	6	20.0	15	50.0	9	30.0
1942	127	62	48.82	18	14.17	47	37.01	24.7	19;37

If it be assumed that of the larvae dying from unknown causes a percentage the same as that calculated on the total larvae, were also parasitised then the maximum control affected by parasites for 1942 and 1941 would be 19.37% and 30.0% respectively. As these larvae were collected from a number of widespread points in the field this amount of control could be expected in endemic populations. These percentages represent factors of importance in preventing S. granitata from developing into epidemic proportions. Egg and pupal parasitism would undoubtedly increase the amount of control wrought by parasites.

It should be pointed out here that an unknown number of the larval parasites are not specific to granitata. Thus the amount of control by this natural factor may vary from year to year. It also partly explains why parasitism may be quite high, although the population of the host is relatively small. Furthermore, because of this same factor of non-specific parasitism, a reservoir of parasites may be maintained in the field though *granitata* may be at a low population.

C. PREDATORS.

Of the predators known to feed on insect life the only one recorded or noted by the author in the field was a spider. No doubt birds and other predators may feed on *granitata* but their importance as a control factor is probably negligible except where this insect is found in large numbers.

D. PATHOLOGICAL DISEASES.

No larval disease has ever been observed. Pupae, however, appear to be susceptible to a bacterial pathogen which is particularly prevalent in long diapause pupae. The survival of all pupae is not very high and it is considered that this disease accounts for a large percentage of pupae which do not emerge.

VI. MORPHOLOGY.

A. EGG.

The egg of granitata was described by Dyar in 1904 (10), as follows: "Elliptical, rounded, the ends very nearly alike, no distinct truncation; well flattened but without any flat areas; reticulations coarse, distinct, raised, hexagonal, the cell areas concave, resembling a thimble, about alike all over. Sordid bluish green; size .8 X .6 X .4 mm." McGuffin (17) said the egg was "ovate in shape, bluish green in colour, the surface divided by reticulations into small hexagonal areas." The egg is a relatively small object and resembles the eggs of many other geometrids in shape, size and color. To the naked eye it appears spherical in shape, but as shown in Fig. 28 it is ovate. Generally it is somewhat flattened on two opposite sides and especially so if the eggs are laid in small masses. It is on either one of these sides that the egg is attached to a needle or twig when laid singly, or to other eggs when laid in a mass. The micropyle end is also slightly flattened whereas the opposite end is more or less pointed or rounded.

The eggs do not vary much in size. The length ranged from .65 mm. to .76 mm. and the width from .38 mm. to .60 mm. The length, width and thickness of 50 eggs laid by different adults averaged, .712 mm., .507 mm., and .380 mm. respectively.

In color it is a flat bluish-green. Specifically the green is almost the shade of the stomatal rows of current year's spruce needles where they are often laid. The eggs have this same coloration in the ovarioles of a freshly emerged moth. A few days before the egg hatches, this color darkens to a dull greyish-green. The hatched egg is pearly-white and translucent.

The surface of the egg is profusely sculptured as a result of the impressions of the cells of the follicular epithelium. The ridges and depressions, which mostly form hexagonal areas, are comparatively conspicuous and quite prominent.

B. LARVA.

First Instar: Head width 0.277 mm. to 0.290 mm. Head heighth 0.252 mm. Body length 1.829 mm. Body width 0.230 mm.

Head: Light brown, smooth, shining, markings absent. Slightly bilobed. Suture depressed.

Thorax and abdomen: Brownish-green (green from food). Somewhat translucent. Membranous. Dorsal prothoracic shield often obscure. Markings absent. Anal feet project laterally; segments coasely annulate. Tubercles elevated, concolourous. Setae pale, rather short. Crochets developed only on anterior and posterior edges of prolegs; 8 on each proleg--4 on anterior edge and 4 on posterior edge.

Second Instar: Head width 0.462 mm. to 0.485 mm. Head heighth 0.395 mm. Body length 5.637 mm. Body width 0.510 mm.

Head: Brownish-green, smooth, shining. Eyes black. Mouthparts brown. Head markings becoming apparent but not yet definite.

Thorax and Abdomen: Muddy green. Rather stout. Prothoracic shield prominent, consisting of two small plates, one on each side of middorsal line; from each plate arise four setae--2 on anterior edge and 2 smaller ones on posterior edge. Markings present especially on dorsum; ventral markings not so prominent. Lined alternately with fine greyish-green and light green stripes. Spiracular line greenish-white. Thoracic feet blackish. Tubercles small, blackish. Setae short, dark. Crochets still developed only on anterior and posterior edges of prolegs; now 10 fully formed and strongly developed on each proleg--5 on anterior edge and 5 on posterior edge; other crochets forming but not easily distinguished.

Third Instar: Head width 0.690 mm. to 0.785 mm. Head heighth 0.606 mm. Body length 7.202 mm. Body width 0.638 mm.

Head: Light brownish-green with brown herring-bone markings passing over vertex apparently as a continuation of subdorsal body line. Sutures dark.

Thorax and Abdomen: Ground color, olivaceous-green. Blackish dotted geminate lines. Middorsal line light green, edged with gray. Addorsal line light green, edged with gray and separated from middorsal by a fine white line. Subdorsal line light green edged with dark gray or black lines. Spiracular line white or greenish-white, ending on anal proleg. Midventral line light green with light gray edging lines. Subventral line light green with gray edging lines. Thoracic feet blackish. Abdominal feet olivaceous. Tubercles small, black. Setae rather long, dusky.

Fourth Instar: Head width 1.076 mm. to 1.372 mm. Head heighth 1.030 mm. Body length 10.476 mm. to 14.841 mm. Body width 1.730 mm.

Head: Colored in much the same way as in third instar. Markings more pronounced and darker.

Thorax and Abdomen; Colored in much the same way as in third instar. Markings more pronounced and darker. Seventeen to 24 crochets on each proleg.

<u>Fifth Instar</u>: Head width 1.505 mm. to 2.165 mm. Head heighth 1.466 mm. Body length 18.769 mm. to 20.079 mm.

Head: Smooth, rounded, slightly bilobed. Ground color, greenish-brown. Dark chestnut-brown band on either side of head, running from vertex to base of frons; this dark band may occupy whole of vertex. Dark herringbone markings may also occur along epicranial stem. Ocellar area light. Adfrontals light green with slightly sinuate adfrontal sutures. Frons light green to rosy. Postclypeus light green to rosy or light brown. Preclypeus dirty white. Labrum light brown, deeply cleft at a right angle. Mandibles light brown, with three rides and nine teeth with the upper edges slightly crenulate. Spinneret slender, conical and pointed at tip.

Thorax and Abdomen: Subcylindrical, smooth, ground-color green. Middorsal line dark or brownish-green. Addorsal line green or whitish-green. Subdorsal line white bordered laterally by a greenish-black line fading out on 7th.abdominal segment. Supraspiracular line green. Spiracular line light green. Sometimes dark bands cross the supraspiracular and spiracular lines in the vicinity of the spiracles on abdominal segments 1 to 5. Subspiracular line green. Midventral stripe green. Adventral line fine, white. Subventral line geminate, dark gray, running between the metathoracic legs and the prolegs. Anal area green or purplish. Anal shield evenly rounded, green, with about 24 brown punctures arranged roughly in three groups. Prothoracic shield green with middorsal line crossing it. Setigerous tubercles consisting of brown papillae set directly on the integument; setae long, brown and conspicuous. Spiracles oblong-elliptical in shape with light brown centres and brown rims. Thoracic legs light green, brown or purplish distally. Prolegs greenish or purplish; each ventral proleg with 24 to 28 crochets and each anal leg bearing a lateral plate dotted with a few brown punctures.

Sixth Instar: Larvae of this instar closely resemble full-grown larvae of the fifth instar.

C. ADULT.

1. Head.

The adult head (Figs. 15, 16, 17) is an oval structure flattened dorsoventrally. It is covered with scales and supports the antennae, the compound eyes, and the mouthparts. In size it is about 1.36 mm. wide, 0.76 mm. long, and 0.96 mm. high. The great width of the head is largely due to the compound eyes which project considerably on each side. The antennae arise from the vertex just behind the frons. The vertex is arched dorsally. It is not divided into two parts by the middorsal coronal suture. This suture is entirely absent. The frons is an unpaired sclerite occupying almost the whole of the front of the head. It is rather rectangular in shape and projects anteriorly before the compound eyes for about 0.13 mm. Ventrally the frons overlaps slightly the clypeus obliterating the frontal-clypeal suture. The unpaired clypeus is a narrow sclerite. The clypeo-labral suture separating the clypeus from the labrum is very distinct.

a. eyes.

The compound eyes are the most prominent feature of the adult head. These round objects are shiny and blackish in color. From an anterior view each eye is about 0.81 mm. high and 0.45 mm. wide. Seen laterally, the width is approximately 0.58 mm. In addition to the compound eyes, there are three small ocelli. One of these is found medially in the upper part of the frons. The other two ocelli are paired and arise dorsally on either side of the midline of the vertex.

b. antennae.

The antennae (Figs. 25, 26) arise on the dorsal aspect of the head between the compound eyes near their medial limits. Those of the male (Fig. 25) are, on the average, about 6.5 mm. long, and contain 53 segments. The female antennae (Fig. 26) average about 7.5 mm. in length, and contain 59 segments.

The antennae are thread-like, consisting of a series of segments similar in thickness and not varying appreciably in length. They taper very little from the fourth segment to the last as shown in the following measurements of the male antennae.

Segment	Length	Width
1	.29 mm.	.22 mm.
2	.12 "	.18 "
3	.26 "	.13"
4	.14 "	.13 "
10	.14 "	.13 "
53	.10 "	.07 "

In many Insecta the antennae afford secondary sexual characters. In S. granitata, however, the sexual characters of the antennae are definite but are not particularly well exhibited. The antennae of the female are filiform but each segment, particularly the mesial ones, has on its inner surface, at the distal end, a very slight projection from which extends a spine-like hair. The male antennae on the other hand, are more or less of the serrate type; each segment being triangular in form and projecting on the lateral angles at the distal extremities. The triangulations are not readily observed dorsally for the lateral projections tend to curve somewhat ventrally. Spine-like hairs are borne on the projections of the male antennae. Also, each segment of the male antenna bears ventrally many long fine hairs; in the female these are short and comparatively few.

In both sexes the antennae are clothed only on the dorsal surface by long narrow scales. Each segment bears two transverse rows which do not extend ventrally beyond the midline of the lateral surface. One set arises near the proximal end, the second close to the middle of the segment. The first set overlaps the second, while the latter overlaps anteriorly the following segment. The scales are of two colours, either a silver-gray or a grayish-brown. Usually, but not always, the proximal row is of the lighter color.

c. mouthparts.

The labrum (Figs. 15, 16) is an unpaired, narrow, transverse structure. On its lateral extremities it bears a pair of small hairy lobes called the pilifers. Medially the epipharynx projects ventrally from the labrum forming a prominent lobe. The mandibles are entirely obliterated. The labium (Fig. 17) is also reduced to a very simple structure. Here it takes the form of a membranous area behind the base of the proboscis. It is supported posteriorly on a hypsotomal bar uniting postgenal areas of the epicranium. The labium supports a pair of three-segmented labial palpi (Fig. 19) which project anteriorly and are a prominent feature of the mouthparts. These palpi are well developed and covered with long hair-like scales. The first segment is particularly large.

The proboscis is the essential feeding apparatus. As in other Lepdioptera it is composed of two lateral pieces, probably the galeae of the maxillae, which are held together by interlocking grooves and ridges. The basal part (Fig. 18) of each maxilla is composed of a small cardo, and a large stipes which bears a rudimentary palpus. In situ only the maxillary palpus and proboscis are evident. The maxillary palpus projects ventrally and laterally of the pilifer. The proboscis is between four and five millimeters long. Distally it is armed with a number of spines and "spurs". True spines are found proximad of the end but close to the distal end the spines are borne on oblong six-ridged structures. Sharp, scale-like hairs are borne on the interlocking edges of the galea.

2. THORAX.

The thorax of granitata is greatly modified to support the two pairs of wings. A great reduction is apparent in the prothorax but the mesothorax and metathorax are enlarged to support the wings. The latter two segments are not at all equal in size as some authors have generalized for the Lepidoptera; the mesothorax is decidedly larger than the metathorax.

The prothorax (Figs. 20, 21) which bears only the fore legs is a small compressed and reduced segment, and assumes the form of a collar between the head and wing bearing segments. The pronotum of this segment is a small triangular dorsal plate which is produced on each side into a large, thin, erectile expansion. These lobe-like structures or patagia are somewhat membranous. Attached to the middorsal triangular plate on either side and ventrad of each patagium is a rod-like structure termed the "spange". This extends below the midlateral line where it is joined to the propleuron.

The propleuron is also very much reduced part of the prothoracic segment, Dorsally, however, the propleuron is produced into a lobe similar in shape to that of the patagium.

The mesothorax (Figs.5,20) is the largest segment of the thorax. The alinotum of this segment consists of a narrow acrotergite, a narrow prescutum, a very large longitudinally divided scutum, and a well developed more or less rhomboidal scutellum. The postnotum is made up of a narrow acrotergite which supports a well developed postalare arm on either side. In the pleuron both the episternum and epimeron are divided into dorsal and ventral areas. The metathorax (Fig.5, 20) is relatively small as compared with the mesothorax. It is shortened antero-posteriorly and greatly reduced.

a. wings.

Two pairs of wings (Figs. 23, 24, 38) are fully developed and functional in both sexes of granitata. These are entirely clothed with scales which give the coloration and patterns to these structures. The fore wings (Fig. 24) are triangular in shape, the hind wings (Fig. 23) are more oval. The most conspicuous features of the wings are the tegulae, the frenulum, the wing veins, and the wing patterns.

The tegula (Figs 5, 27) is an especially large scale-like plate overlapping the base of the wings. It arises at the base of the costal vein of the fore wing and is carried by special tegular plates of the notum.

The synchronous action of the fore and hind wings is provided not only by the overlapping of the former over the latter but also by the frenulum (Fig. 23). In this looper the organ is well developed. The frenulum is borne by the hind wing at the humeral angle. The structure in the male consists of one single strong spine-like organ. In the female the frenulum is composed of about six or seven bristles which arise from a common origin.

The type of wing venation shown by the moth is simple. In the fore wing the venation is unlike that of other common geometrids. Here, there appears to be a higher degree of coalescence. It is believed that veins Sc and R_1 have coalesced to form a single unit. Also, vein R_s and its branches have united to a certain degree. The other veins are characteristic of the family Geometridae. However, the first anal vein is partially formed, a characteristic uncommon in Geometridae. In the hind wing there are no variations of the veins, except for the partial formation of vein M_2.

With regard to wing patterns (Figs. 38,39) it has already been stated that a great deal of variation may occur in these. What is believed to be the general wing pattern is shown in Plate X. The background of the fore wing is gray, that of the hind wing grayish-white. Both wings have a brownish tint and both become slightly darker toward the outer margin. In the fore wing four brownish-black bands are superimposed upon the background. The outer bands are a little darker than the basal ones and all have a darker tint at the costal margin. The transverse anterior band, the median band, and the transverse posterior band are unbroken zig-zag lines. The subterminal band is complete only on the posterior half; the anterior half is broken and forms two large spots, one at the costal margin and one in the middle of the wing. The terminal line is broken into a number of small spots. In the hind wing there are only three transverse lines and one spot. When the wings are spread at right angles, these bands are in line with the median band, the transverse posterior band, and the subterminal band of the forewing. These bands of the hind wings are progressively darker towards the inner margin. As in the fore wing, the terminal band of the hind wing is broken into a few small spots. The round or orbicular spot lies in the anterior half of the wing just distad of the first basal band.

Variations in wing pattern are confined chiefly to the fore wing. Six of the more common types of variation are figured in Plate XI. The variations occur entirely in the bands by reduction or coalescence. In the process of reduction, the bands are broken down into parts or spots. Reduction appears to progress from the transverse anterior band to the subterminal band, the former being nearly complete in all cases. Coalescence is particulardy evident between the subterminalband and the transverse posterior band.

b. legs.

The legs (Fig. 4) are typical of other Hexapoda being composed of six independently movable segments, namely a coxa, one trochanter, a femur, a tibia, a tarsus and a pretarsus. Characteristically like many other adult Lepidoptera, the legs are long and slender. Each of the three pairs of appendages are different from each other either in structure, shape or size. The male segmental appendages also differ from the female especially in the structure of the metathoracic limbs which provide distinct characters for separating the two sexes.

The prothoracic legs (Fig. 4a) are the slenderest of the three pairs of thoracic limbs. This feature is particularly emphasized by the coxa which is long, slender, and tubuliferous. Longitudinally, it is divided into two almost equal parts by the coxal suture extending from the base on its anterior lateral face towards the trochanteral articulation.

However, its presence and position is not distinct towards the distal end of the segment.

The trochanter or basal segment of the telopodite, though definite and prominent, is comparatively small. It is freely movable on the coxa but the trochantero-femoral movement is rather restricted.

The femural segment is more limb-like in structure. It averages about 2.64 mm. in length and 0.32 in width; the greatest width being proximad of the centre, while the distal half gradually tapers towards the tibia.

The tibia is unlike its counterparts of other limbs. Here it is comparatively short, measuring about 1.64 mm. in length. Its greatest width of 0.20 mm. is found distad of the centre, and from there it tapers to both ends. On the inner face of this segment and towards the distal end there is borne a somewhat movable and lappet-like process or epiphysis. This process is about 0.66 mm. long and quite narrow. It is attached to the tibia at the latter's greatest width and reaches to the first sub-segment of the tarsus. Distally the epiphysis is slightly hooked and pointed. On the face of the tibia, adjacent to the epiphysis, are a number of stiff hairs which appear to make it a combing organ. Probably this structure is used in cleaning the antennae but this process has never been observed. The epiphysis is present in both sexes but the organ in the female is not so large as that in the male.

The tarsus consists of five sub-segments or tarsomeres which are freely movable on one another, and which gradually taper in width from the first to the fifth. All are long and thin; the first is by far the longest. The length of the first tarsomere is about 1.64 mm., of the second 0.76 mm., of the third 0.52 m.., of the fourth 0.36 mm., and of the fifth 0.32 mm. A number of short stout spines are borne on the inner face of all tarsomeres.

The terminal part of the leg, or pretarsal segment, bears a pair of movable lateral tarsal claws or ungues situated upon its base. These claws are shaped in the form of sharp hooks. The body of the segment is membranous and bears a median lobe, the arolium, which is also membranous.

The mesothoracic legs (Fig. 4b) resemble the prothoracic pair except in size and a variation in the tibia. The coxa is much stouter in this middle appendage. It is definitely divided into two parts by the coxal suture which extends to the anterior trochanteral articulation.

The femur is long and thin and measures approximately 3.20 mm. long and 0.30 mm. wide.

The tibia is also a long segment of the mesothoracic leg and is about 3.00 mm. long and 0.15 mm. wide. It bears no structure corresponding to the epiphysis of the fore tibia. Close to the distal end, however, are two strong tibial spurs about 0.72 mm. in length.

The tarsus is about the same length as that of the fore leg. The tarsomeres decrease in length from the first of 1.60 mm. to the fifth of 0.30 mm.

The metathoracic legs (Figs. 4d, 4e) show much modification. They differ not only from the fore and middle legs but also between the sexes. The coxa of the hind leg is almost identical in structure with that of the middle leg. The femur shows little variation. It is about 2.40 mm. long and 0.30 mm. wide.

The greatest modification of the hind leg occurs in the tibia. In the female (Fig. 4d) the modification is slight. The tibia of this sex is rather club-shaped, tapering from the proximal narrow end to near the midsection of the segment. At the femur-tibial articulation, the tibia measures

0.13 mm. wide. It is about 0.30 mm. wide at the midsection. At the distal end the segment is 0.15 mm. in width. The length of the segment is approximately 2.93 mm. The female hind tibia is mostly membranous; it is partly sclerotized proximad of the midsection. Two pairs of stout tibial spurs are borne on the inside face of the leg. One pair occurs at the distal end, the other about 0.83 mm. proximad of these. Both pairs of spurs are about the same length, that is, 0.60 mm., but in each pair one spur is slightly longer than the other; the shorter spur measures 0.30 mm. in length. These spurs are covered with a sparse number of hairs. A fine spine appears to terminate each spur.

The tibia of the male (Fig. 4c, 4e) is a very much enlarged segment measuring 4.00 mm. in length and 0.44 mm. in width. The shape of this segment is rather irregular. It tapers slightly towards the distal end where it has its greatest width. It bears two pairs of spurs as in the female. These are also clothed with fine hair and terminate in a spine-like structure. Each spur of the distal pair is the same size in length that is, 0.30 mm. The spurs of the proximal pair which occur about 1.73 mm. proximad of the above, differ in length, one being 0.60 mm. long, the other 0;40 mm. Except for the spurs the entire tibial segment of the male hind leg appears to be mostly membranous. On the latero-ventral face, there is a large sense organ which is thought to be a scent structure. This is situated in a delicate membranous sheath which runs the full length and width of the segment. The walls of the segment project slightly above the sheath so that the latter is found in a shallow crater. Covering the sheath are a sparse number of short, fine hairs. The outer manifestations of the actual scent organ in the membranous sheath show as a longitudinal depression about 1.5 mm. long and 0.2 mm. wide. The organ is delineated by a ridge formed only on either side from which arises a mat of scale-like hairs pointing to the base of the segment. A thick tuft of hair covers the entire membranous sheath. These long hairs all arise from the proximal end of the segment.

The hind tarsus is shorter than in the other legs. The subsegments decrease in length from 0.76 mm. to 0.24 mm.

3. ABDOMEN.

The abdomen of <u>S. granitata</u> consists of ten segments in the male and nine segments in the female. Usually the size of the male abdomen is smaller in length and width than that of the female. With the exception of the third segment and the genital segments to be described below, the abdomen is of the typical lepidopteran type. Each somite is for the most part simple and annular in form. The first abdominal segment is reduced in size. Posteriorly the abdomen enlarges slightly to about the fourth and fifth segments, after which it gradually tapers to the genital segments. The tympana (Fig. 20) which are so characteristic of Geometridae appear to be well developed in <u>granitata</u>. On the surface, the tympanum shows as a hollow bula opening against the coxa of the hind leg. It is situated, however, in the first abdominal segment immediately below the spiracle. The entire integument of theabdomen is clothed with a normal amount of scales. These vary in color from a silvery-gray to a grayish-brown and thus produce a mottled effect.

In thefemale, the adbominal segments other than the genital somites, are normal and bear no appendages or outgrowths. In the male these segments are also normal but the third abdominal one bears a special organ (Fig. 22) on the ventral surface which is not present in the female. This structure consists of a thick tuft of long hairs which arises from two strong integumental ridges located in the anterior half of the segment. These ridges meet laterally, run transversely across the segment and are shaped in the form of an arc. The arc thus enclosed is about 0.8 mm. long. It has its greatest width at the midventral point where it measures about 0.06 mm. wide. The outside ridge forming the convex surface of the arc, lies posterior to the concave surface or inside ridge. The true purpose of this organ is unknown. Possibly it may be a sex scent organ but in the opinion of the writer this is thought to be very unlikely. It is believed that the stout tuft of straight hairs makes it adapted for cleaning as a combing structure. The writer has observed male moths under natural conditions running the tibia of the hind legs over these hairs in somewhat the same fashion that house flies cross their legs to clean them of dust, etc. A microscopic examination of the hind tibia supported this view by revealing that a well developed sense organ occurs on the inside of this leg segment. This sense organ is covered by a long tuft of hairs and it is these hairs which are believed to be cleaned by running them through the structure on the ventral surface of the third abdominal segment.

a. female genitalia and reproductive system.

The ovipositor (Plate VIII) of Semiothisa granitata is of the substitutional type and, like other Lepidoptera, is tubuliferous in form. The posterior segments of the abdomen are so modified that this organ is in many ways non-functional. Functionally it is provided with two terminal lobes at the end of the egg exit which serve to grasp the issuing eggs and which, when spread out flat, form a disc for pressing the eggs against the surface to which they are attached by the secretion of the accessory glands.

The seventh abdominal segment is well developed in comparison with the other abdominal somites. It tapers posteriorly from its greatest width of approximately 2.3 mm. to about 1.0 mm. The dorsal surface (Figs. 30, 32) is complete but the venter (Figs. 31, 33) is medially reduced. Here the posterior margin of the segment is produced anteriorly in the shape of a "V", the apex of which lies less than 1 mm. from the intersegmental membrane separating the sixth and seventh abdominal segments. In the apex of this triangular area the external opening of the bursa copulatrix is located. It lies in the intersegmental membrane of the seventh and eighth abdominal segments. Particularly on the ventral surface the seventh abdominal segment is clothed distally by long scale-like setae.

In situ the ninth abdominal segment (Figs. 31, 32) is telescoped into the eighth and the latter into the seventh so that from the dorsal aspect in some specimens only the ninth segment protrudes noticeably beyond the distal margins of the seventh. The posterior margin of the eighth abdominal segment can seldom be seen from the dorsal aspect but its position can usually be observed from the ventral aspect upon close examination.

In cleared specimens the above observations become more evident. Also, in such treated insects the following organs can be observed: The position of the ductus bursae (Figs. 31, 32) can be seen from a ventral view through the integument of the seventh abdominal segment. In the same position the beginning of the bursa copulatrix can be noted. From the dorsal view (Figs. 30, 32) in such specimens the eighth abdominal segment can easily be discerned in position and sometimes part of the ninth. Viewed from the same aspect, the two dark rod-like pairs of apophyses show quite clearly. The anterior apophyses which arise from the lateral angles of the eighth abdominal segment are quite short and do not appear to reach the anterior margins of the seventh abdominal segment. The posterior apophyses arise from the ninth abdominal segment at the lateral margins of each of the two terminal lobes. These segmental rods are heavier in structure and longer than the former pair and lie mesad of them. Anteriorly the ends of the posterior apophyses reach the anterior margin of the seventh abdominal segment to which it seems to be attached. These rods serve for the attachment of muscles which move the ovipositor in and out of the seventh abdominal segment and probably aid materially in the deposition of eggs.

The form and structure of the ovipositor can best be seen when it is extruded, and it is from this position the following descriptions of its parts have been taken (Figs. 32, 33). The dorsum of the eighth abdominal segment is in the form of a true symmetrical shield. Its posterior margin is almost straight but close to the midline it is quickly drawn out posteriorly to form a short, sharp apex. Laterally the margins slope off smoothly and slowly to the anterior margin where a sharp, tooth-like process is formed, and from which the anterior apophyses arise. The anterior margin shows a pair of lobes, one on each side of the midline and equally spaced between the midline and the lateral margin. The ventral portion has quite a different structure. The posterior margin from the lateral angles runs anteriorly for a considerable distance forming a V-shaped figure, the apex of which is squared and fairly wide. From the positions of the anterior apophyses the anterior margin is produced forward so that the plate formed has the appearance of fitting into the ventral cut-away portion of the seventh abdominal segment. Immediately on leaving the anterior apophyses, the anterior margin curves in and then out, forming two round indentations on the latero-ventral surface of the segment.

The ninth abdominal segment consists principally of the two conspicuous terminal lobes. These are soft and cushion-like. Posteriorly they are somewhat pointed, anteriorly they are more blunt. On their outer surfaces they are armed with a number of stout spines. Each lobe is about 0.60 mm. long and 0.22 mm. wide. On the dorsal surface the inner margins facing each other are almost straight and parallel for most of their length but on the ventral side they slope away laterally from each other from the midsection toward the ends. Anterior to the terminal lobes,and associated with them,is found a sclerotic ring presumed to be part of the ninth abdominal segment. This ring is only slightly sclerotized. On the dorsal surface it has the shape of an inverted shield, the posterior margin being drawn out gradually into a blunt point. The lateral margins slope slightly outward to the anterior margin which is almost straight. The anterior margin on the ventral surface forms two round lateral lobes in the shape of a heart. Posteriorly the ventral surface is joined to the full width of the terminal lobes of the ovipositor.

The reproductive system (Fig. 29) of the female was examined in a number of specimens. Except for the bursa copulatrix,which is described in detail below, it was found to be fully developed and of the typical lepidopteran type. The system consists of a pair of ovaries, two lateral oviducts, a median oviduct or oviductus communis, two accessory glands, a spermatheca, a vagina, and a bursa copulatrix.

Each ovary contains four ovarioles united distally with one another in a suspensory ligament. The suspensory ligaments from the two ovaries are combined in a single median ligament which appears to be attached to the venter of the dorsal blood vessel. The ovarioles are suspended freely in the body cavity--no peritoneal sheath encloses the ovary. Each ovariole is covered by a thin structureless membrane, the tunica propria. The oecytes are a bright green resembling in color new needles of spruce. Each ovariole is supported by a stalk or pedicel the duct of which connects the ovariole to the lateral oviduct. In <u>granitata</u> the pedicels are not connected direcfly with the lateral oviduct. Instead two pedicels are first connected to form a short "lateral" pedicel. Therefore in the ovary a pair of "lateral" pedicels connect the pedicels of the four ovarides to the lateral oviducts. These "lateral" pedicels may be confused with the well known calyx found at the anterior end of each lateral duct, but in this insect the calyx shows as a definite tube and not as just an expanded receptacle. The writer has therefore termed this structure the lateral pedicel. Posteriorly the lateral oviducts lead into the oviductus communis which in turn opens into the vagina by the gonopore. The vagina appears to be a more rigid tube than the oviducfus communis and opens to the exterior at the ninth abdominal segment by the oviporous which serves only for the discharge of eggs. Copulation occurs through the vulva or ostium which opens into the bursa copulatrix or copulatory pouch. Sperm are transferred from the pouch to the main genital system by the ductus seminalis. This connecting tube arises from the pouch almost at its external opening and ends at the anterior part of the vagina on the ventral surface. In this same area, that is at almost the junction of the oviductus communis and the vagina, the receptacalum seminis or spermatheca opens on the dorsal surface of the vagina. The spermatheca is a single sac-like organ with a long slender duct. Only one pair of accessory glands is present. Before entering the vagina on its dorsal surface the glands join to form a single tube. Distally these glands are long and thin but their proximal parts are more enlarged.

The bursa copulatrix (Figs. 29, 37) of S. granitata is the copulatory pouch and temporary storing place of the male sperm. The entrance, the ostium,to the bursa, is well separated from the egg-laying opening and is found on the ventral side in the intersegmental skin between the seventh and eighth abdominal segments. The ostium is surrounded by a somewhat sclerotized genital plate. Copulation takes place through this opening, the tube-like male penis penetrating through it, and through the short ductus bursae into the expansive bladder-like bursa copulatrix where the sperm is deposited until it is later needed to fertilize the eggs.

The ductus bursae averages about 0.28 mm. wide and 0.48 mm. long. The size of the ostium is slightly smaller than the width of the ductus bursae which appears to be lipped at the opening by a small infolding rim. The walls of the ductus bursae are moderately sclerotized, the hardening of which affords easier penetration by the male. Additional support is provided for penetration by sclerotization extending into the neck of the bursa copulatrix for approximately 0.5 to 0.6 of its length. Sclerotization of the bursa is limited to this region but even here, it is very irregular and appears as longitudinal depositions except for a small area on one side of the neck where it is continous. The ductus bursae is joined abruptly to the bursa at its neck in the same manner that pipes fit into one another.

The neck of the bursa is about 0.35 mm. wide and seems to be attached by a membrane to the ductus bursae. Such an attachment permits of a slight sliding movement of the one over the other.

The bursa copulatrix (Fig. 37a, 37b) measures on the average 1.28 mm. wide and 2.62 mm. long. In shape it is rather urn-like but somewhat irregular in outline. In situ the anterior third is round and bulbous and gradually tapers posteriorly to the neck. The dorsal side is flat in contrast to the ventral portion which is rounded into a pimple-like structure. Except for the neck, the walls are made of a tough, milky-colored, slightly translucent membrane which is not easily penetrated by mechanical agencies. If not punctured or cut the bursa resumes its shape after the pressures of artificial indentations are released.

On the ventral wall of the bulbous portion, the bursa is always ornamented interiorly by a beautiful signum in the shape of a circular gear. This structure is specific for this insect; no other rods, plates, spines, or sclerotized structures are known to occur in this sperm receptacle. The signum is about 0.64 mm. in diameter and approximately 0.18 mm. thick at its central portion. It is a dark brown color. A surface view of the structure shows that it has small spine-like structures on its outer face. These are prominent but not numerous. The saw-like teeth which compose the rim and make it look like a gear, taper to a sharp point but are irregular in shape. Some are almost perfectly straight, others are slightly curved at the tips, while still others are curved throughout their length. Usually several teeth show evidence of branching into two supplementary teeth. As seen in Figure 37a, the degree of branching is not constant but may occur in all degrees from the tip toward the base, so that one or more original teeth may be almost completely subdivided. The teeth are about 0.11 mm. long.

At the centre, the signum appears to have a round hole, 0.18 mm. in diameter, running completely through it. Around this foramen the membrane of the bursa is mushroomed outwards to form a circular rimmed structure which is button-shaped in appearance. From the lateral view (Fig. 37b) it looks like the opening of a milk bottle. This protrusion of the membrane projects over the signum for approximately 0.04 mm. Viewed from the lateral aspect the signum is a thin structure for two thirds of its diameter at the outer edges. At the centre it quickly pyramids outwards to its greatest thickness where it forms a round, plateau-like, projecting knob.

b. male genitalia.

As in other Lepidoptera, the eight, ninth and tenth abdominal segments (Figs. 34, 35, 36) compose the genital complex of <u>granitata</u>. The eighth segment is almost normal except for modifications which occur entirely at the posterior margin. On the dorsal surface (Fig.34) this margin is practically normal. However, it does curve anteriorly for a small degree forming a smooth concave arc across the entire dorsum. Laterally, (Fig. 35) at the posterior regions a pair of small longitudinal lobes occurs on this segment. A rudimentary pair occurs dorsad of these. These lobes are comparatively heavily clothed with hair-like scales. On the ventral surface (Fig. 36) the posterior edge is cut away to form a V-shaped margin, the apex of the "V" being placed midventrally about 0.7 mm. anterior to the posterior limits of the edge of the segment. The eighth segment is approximately 2.0 mm. long and 1.5 mm. wide.

The ninth abdominal segment is greatly modified. Here the entire segment forms an irregular sclerotic ring. The tegumen is very much reduced medially and is only complete along the posterior regions of the segment.

Mid-dorsally there is a short ridge or crista running the full length of the tegumen. The vinculum forms the broadest part of this segment but the saccus formed on the sternal region of the arc is small and narrow and does not extend forward for any great distance. Two pairs of movable genital claspers or harpes are present. These are borne close to the coxopodite areas of the vinculum and are heavily spined. The anterior pair appears to be articulated ventrally to a slightly sclerotized median triangular plate.

The tenth segment is represented also by a complete sclerotic ring formed of the uncus, the gnathos, and the socii. The uncus which is a median dorsal process is heavily sclerotized and spined. In this insect it is shaped in the form of a spoon-like hook. Two very stout spines are borne on the dorso-lateral surface of the uncus. Ventrally the tenth segment is completed by the gnathos which supports a mandible-like midventral lobe. The paired lateral processes or socii which arise from the base of the tenth segment are small, undeveloped, and hairless.

The penis or phallus of granitata is divided into a distal part, the aedeagus, and a basal part, the phallobase. The aedeagus is situated below the gnathos and is enclosed in a membranous sheath or vesica. The differentiation between the aedeagus and the phallobase is distinct but not easily observed. The phallobase appears to form a pocket containing the base of the aedeagus. The phallus ends in a stout,apical,spine-like structure containing the gonopore. The vesica immediately surrounding this spine-like structure is somewhat sclerotized and supports a number of fine, short hairs.

VII. SUMMARY

The green spruce looper, Semiothisa granitata Gn. is the larva of a geometrid moth.

In British Columbia the preferred host of the larvae is Engelmann spruce, Picea engelmanni Engelm. The larvae also feed on the firs,the hemlocks, other spruces, and in a few instances, have been taken from western white pine, lodgepole pine, and western larch. Its distribution coincides with that of its hosts.

Usually the adults emerge in May and June. On the average, a moth lays about 120 eggs. These are generally deposited singly on the current year's growth. The incubation period of the eggs varies between 10 and 21 days, depending on weather conditions. The first and second instar larvae feed as needle miners on the new growth; in the later instars they feed externally on either the new or the old growth but prefer the former. Larvae may pupate directly from the fifth stage or from the sixth. The pupae are formed in the duff of the forest floor between the months of July and October inclusive, and overwinter as such, until the following late spring or early summer. Occasionally, moths emerge in late summer from pupae formed the same year.

Generally there is one generation every year but because there may be a pupal diapause from one to two years may be required to complete the life cycle in some instances. Besides the usual spring emergence, there may be an emergence the following summer and possibly another in the second spring. Moths obtained from pupae incubated in a constant temperature cabinet have emerged in three rhythms corresponding to the above emergences. It is believed that these variations of pupal diapause are due to inherited characters.

The existence of four moth emergence rhythms is considered to be an important factor in keeping this insect at a constant low level of population. It is also controlled by a comparatively large number of parasites--both Hymenoptera and Diptera, by a bacterial disease of the pupae, and by weather conditions

The egg is small, ovate in shape, bluish-green in color, and sculptured on the surface.

The young, brownish-green loopers are without markings and are about 1.8 mm. long. As development progresses the crochets on each proleg increase in number from eight in the first instar to 24 or 28 in the fifth instar. Fifth instar larvae are about 2 mm. long. green in color, and marked on the dorsum, pleura, and ventre by longitudinal stripes of light and dark green. The head is greenish-brown with a dark chestnut-brown band on either side. Dark herring-bone markings also occur along the frontal sutures.

The adult is a grey, somewhat mottled moth. The fore wing is also grey with dark bands, while the hind wing is greyish-white. The sexes are easily separated by the antennae, the metathoracic legs, the third abdominal segments, and the genital segments. The genital segments and the female reproductive system are discussed in detail.

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PLATE I.

Fig. 1. Anterior view of mature larval head.

Fig. 2. Lateral view of mature larval head.

Fig. 3. Posterior view of mature larval head.

PLATE 1

FIG. 1

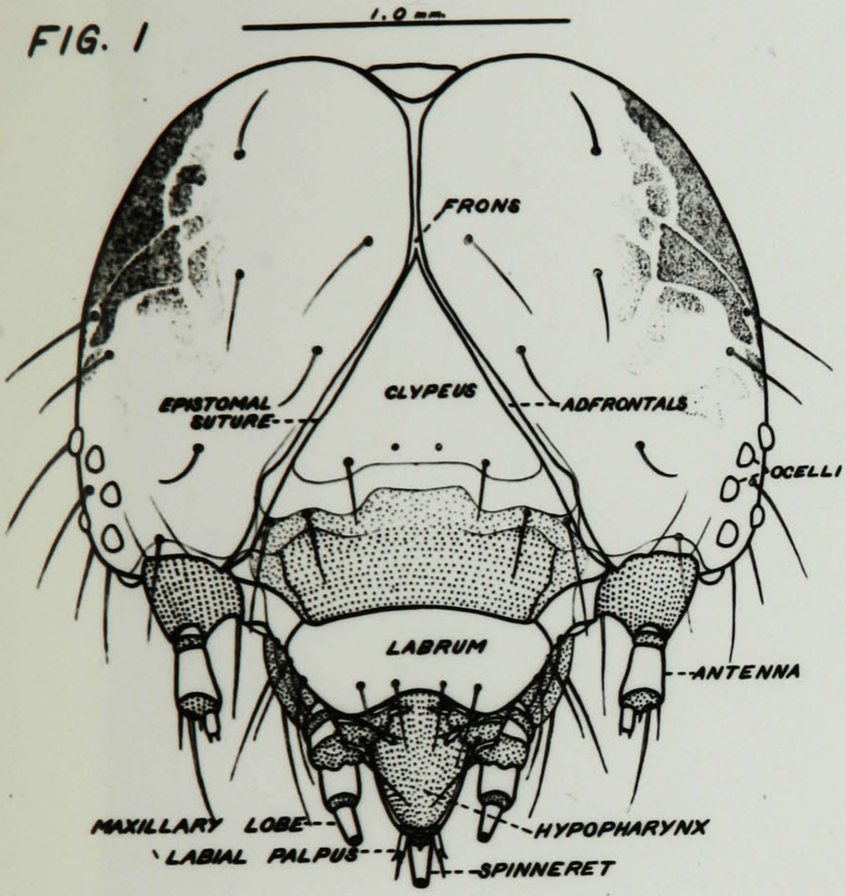
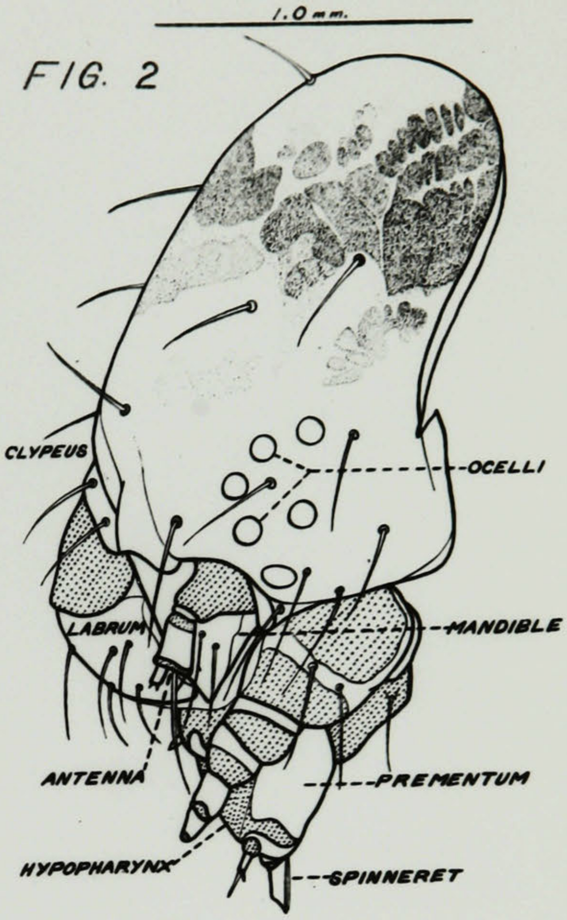


FIG. 2



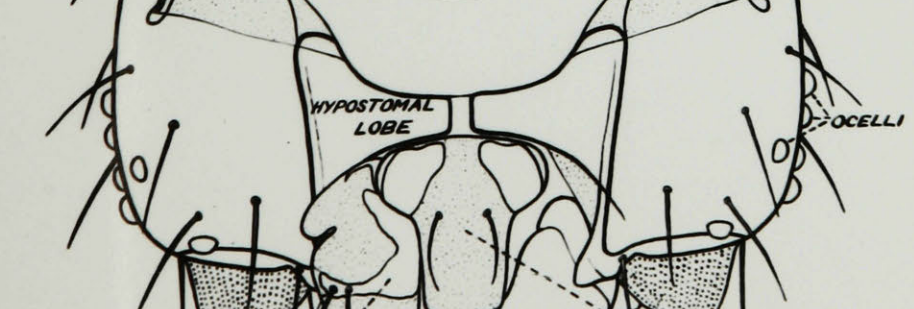


FIG. 3

PLATE II.

Fig. 4. Adult legs.
- A. Male prothoracic
- B. Male mesothoracic.
- C. Male metathoracic.
- D. Female metathoracic tibia.
- E. Male metathoracic tibia.

Fig.5. Dorsal view of adult thorax.

Fig.6. Setal map of the first five larval abdominal segments.

PLATE II

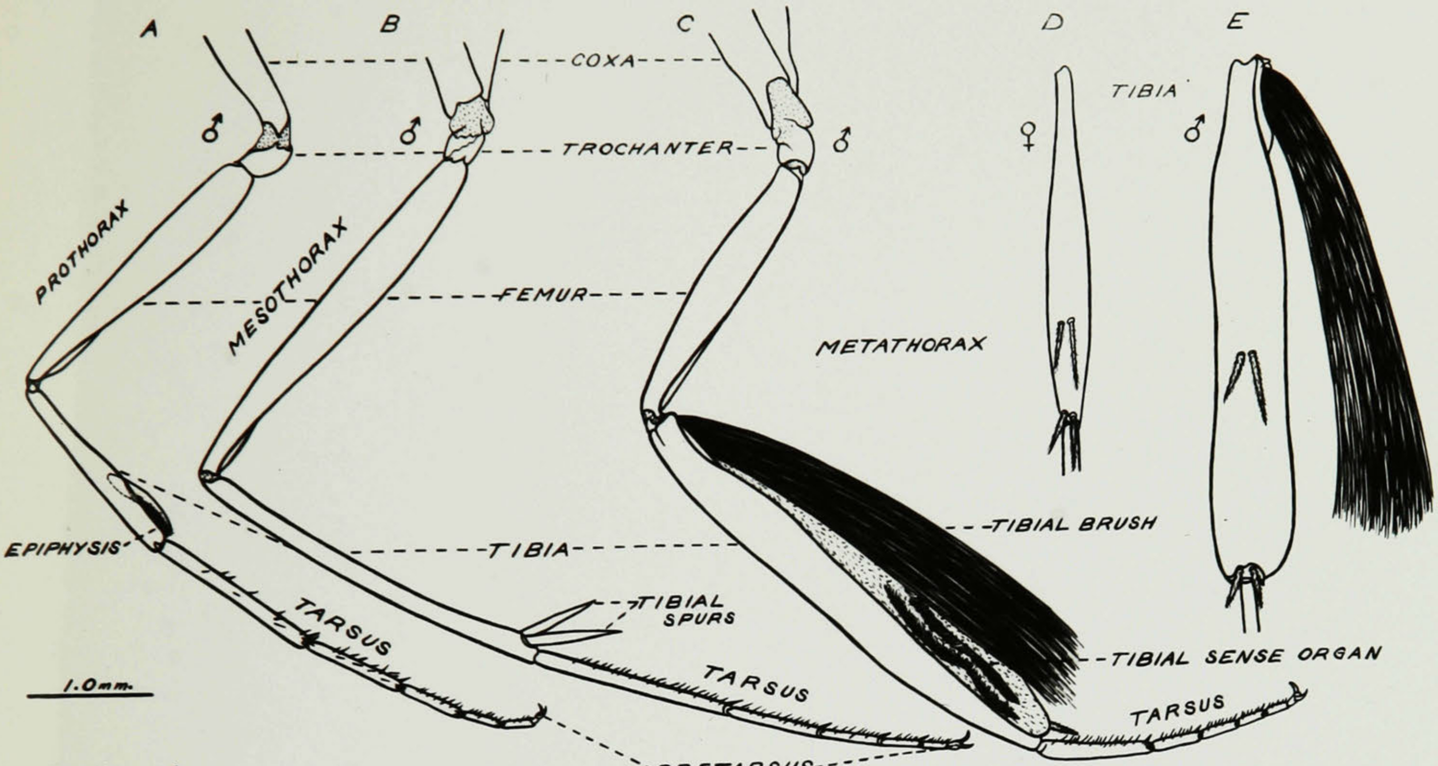


FIG. 4

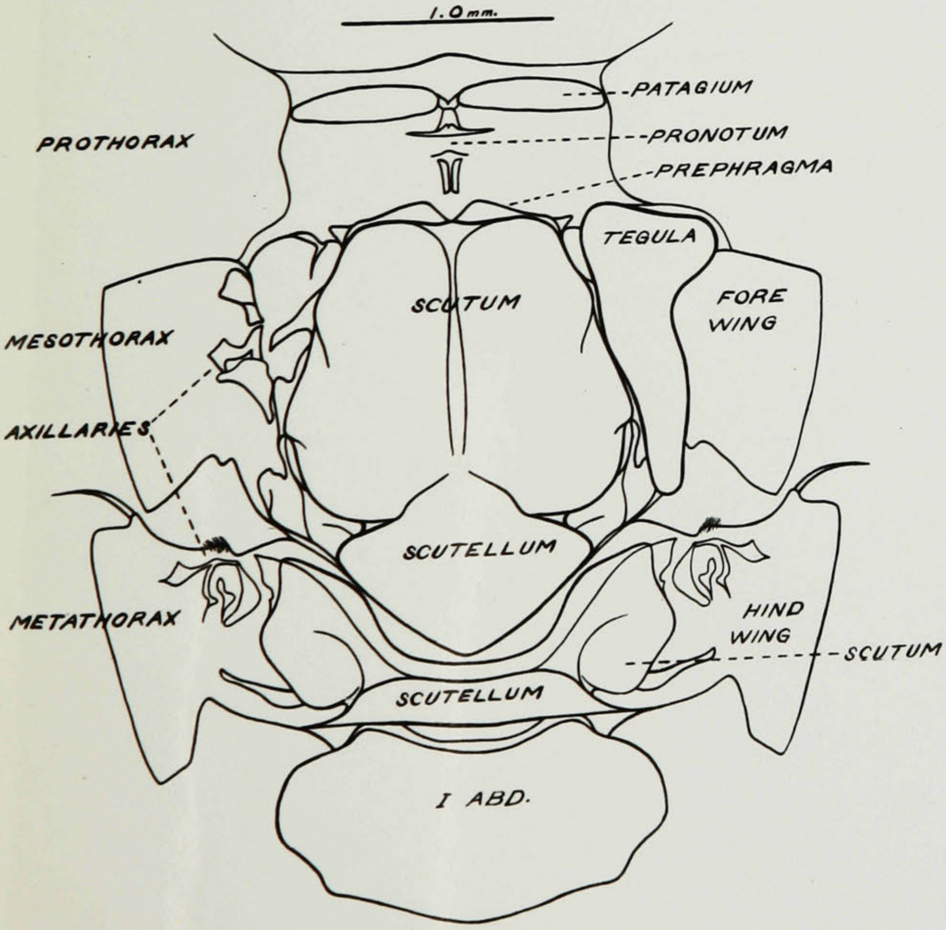


FIG. 5

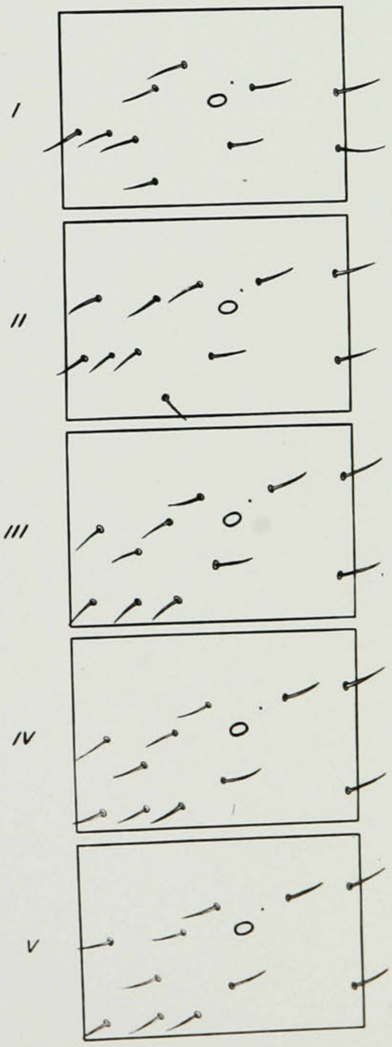


FIG. 6

PLATE III.

Fig. 7. Lateral view of thoracic and first abdominal segments of mature larva showing position of setae and spiracles.

Fig. 8. Lateral view of the four posterior abdominal segments of mature larva showing position of setae and spiracles.

PLATE III

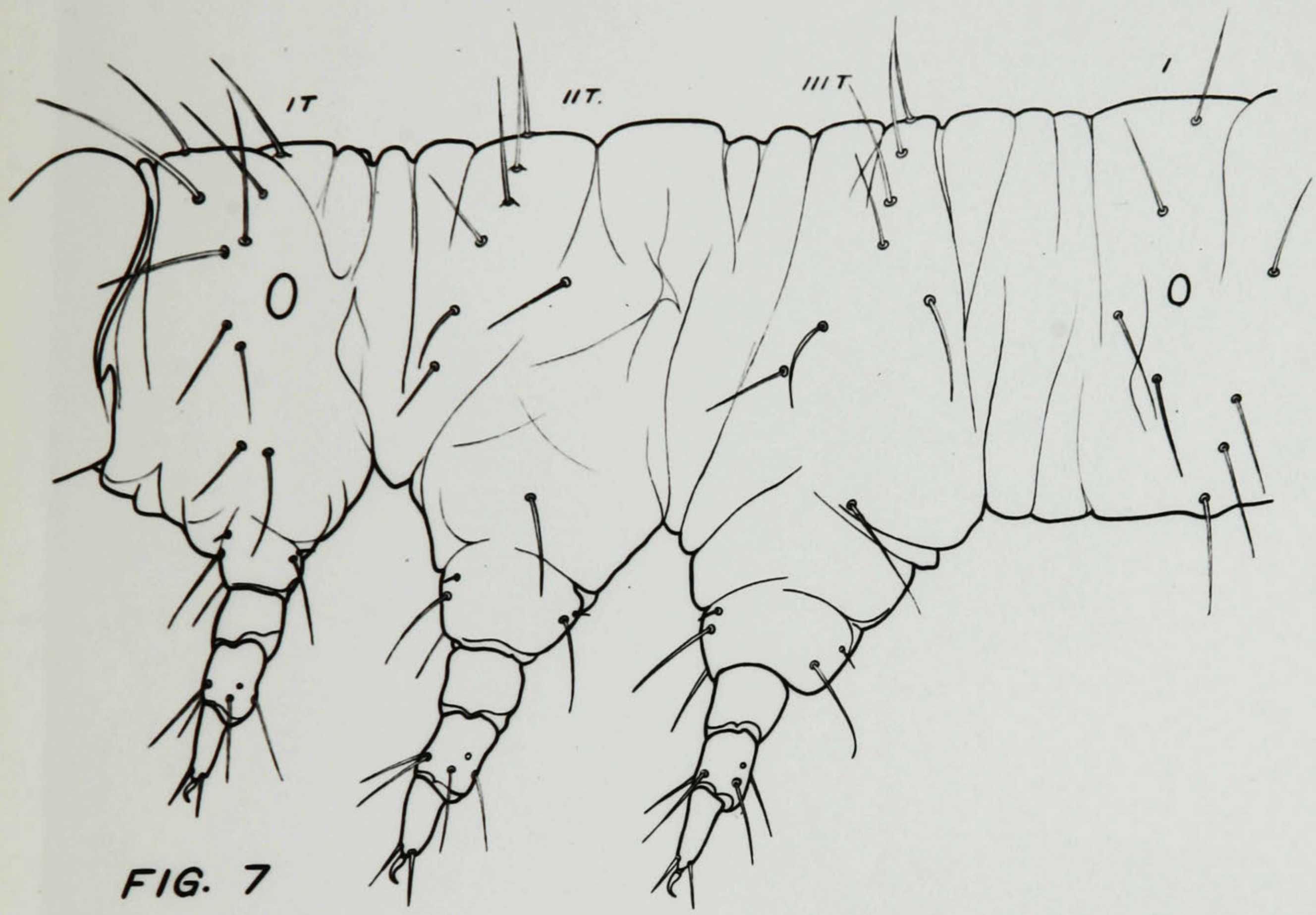


FIG. 7

1.0 mm.

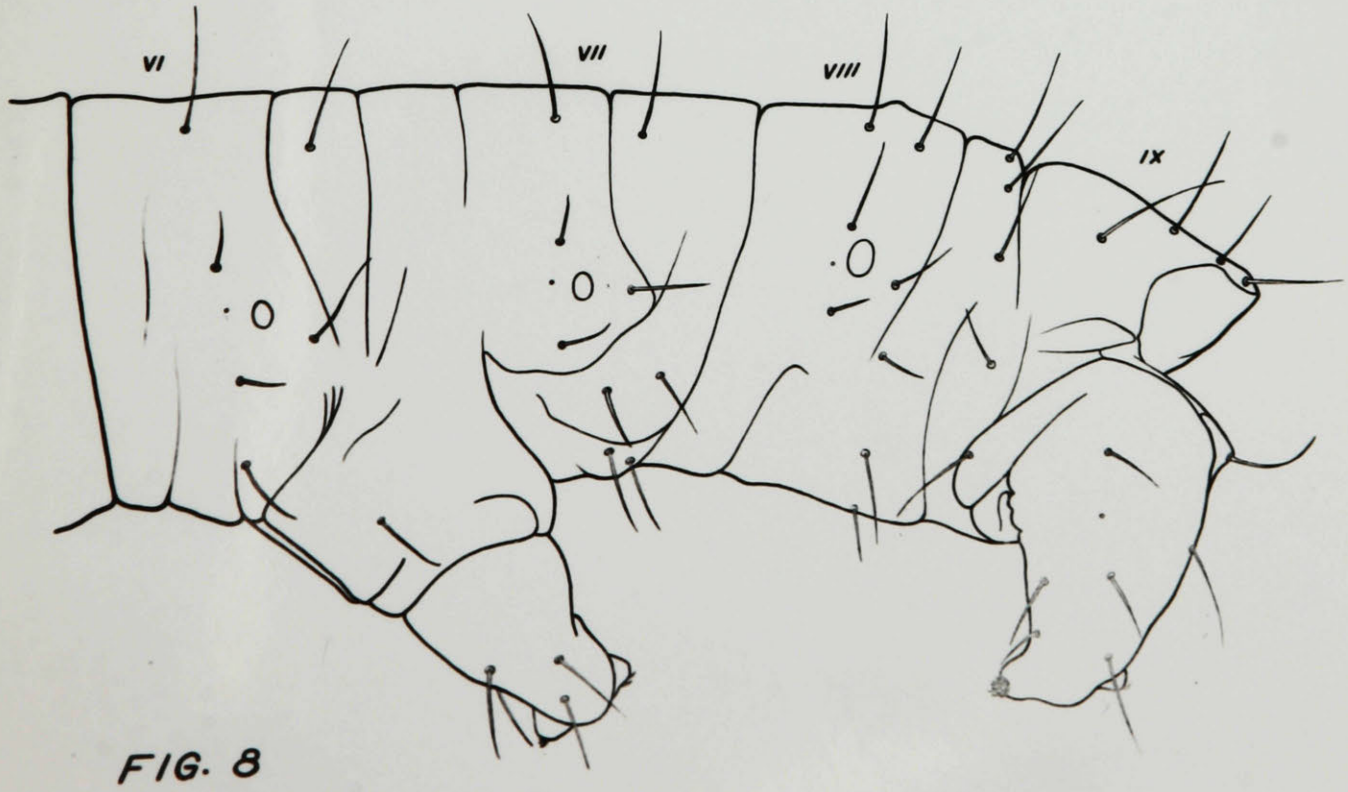


FIG. 8

PLATE IV.

Fig. 9- Inside view of larval thoracic leg.

Fig.10. Inside view of last abdominal larval leg.

Fig.11. Posterior view of last abdominal larval segment.

Fig.12 Inside view of larval proleg.

Fig.13. Crochets of larval abdominal legs.

Fig.14. Detail lateral view of a crochet.

PLATE IV

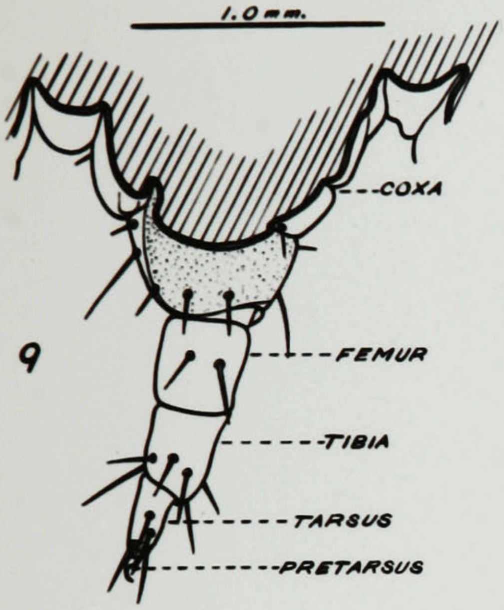


FIG. 9

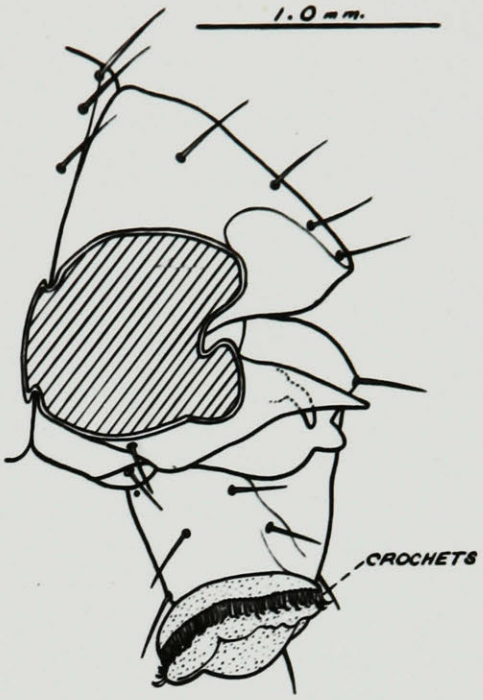


FIG. 10

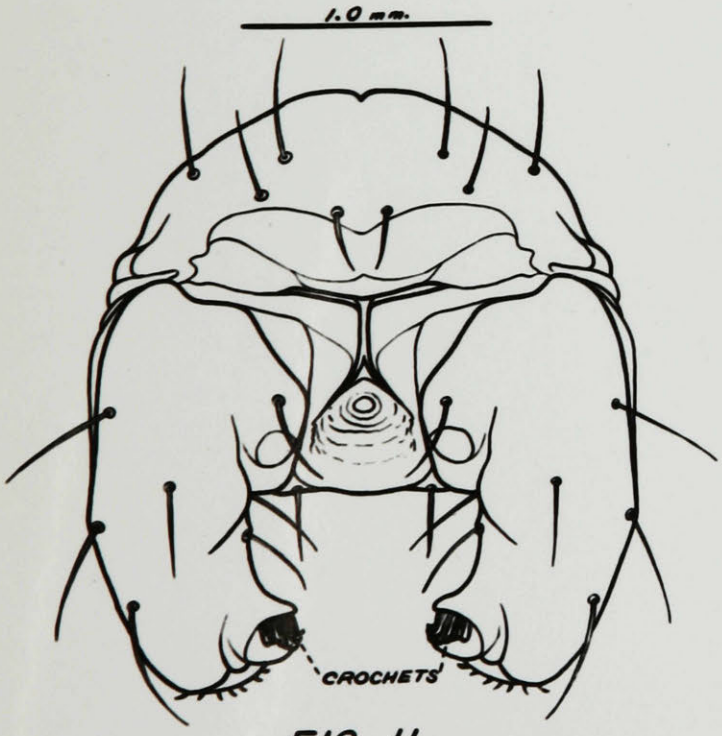


FIG. 11

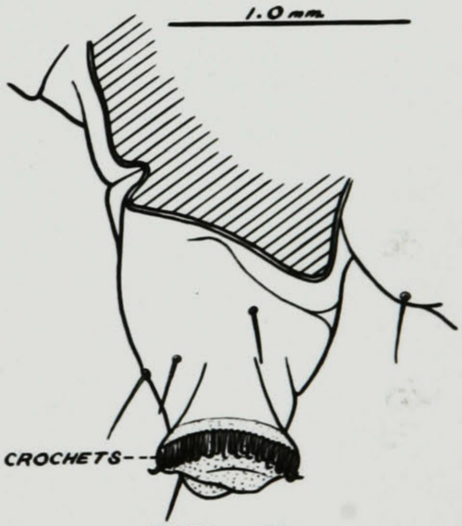


FIG. 12

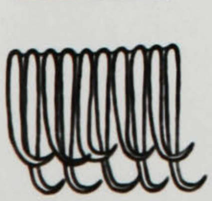


FIG. 13

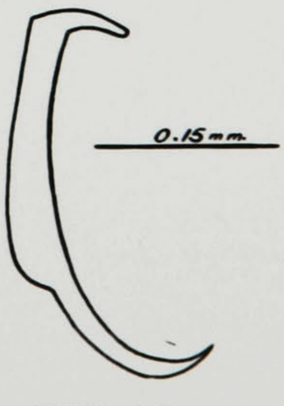


FIG. 14

PLATE V.

Fig. 15. Anterior view of adult head.

Fig. 16. Lateral view of adult head.

Fig. 17. Posterior view of adult head.

Fig. 18. Basal portion of maxilla.

Fig. 19. Lateral view of labial palpus.

PLATE V

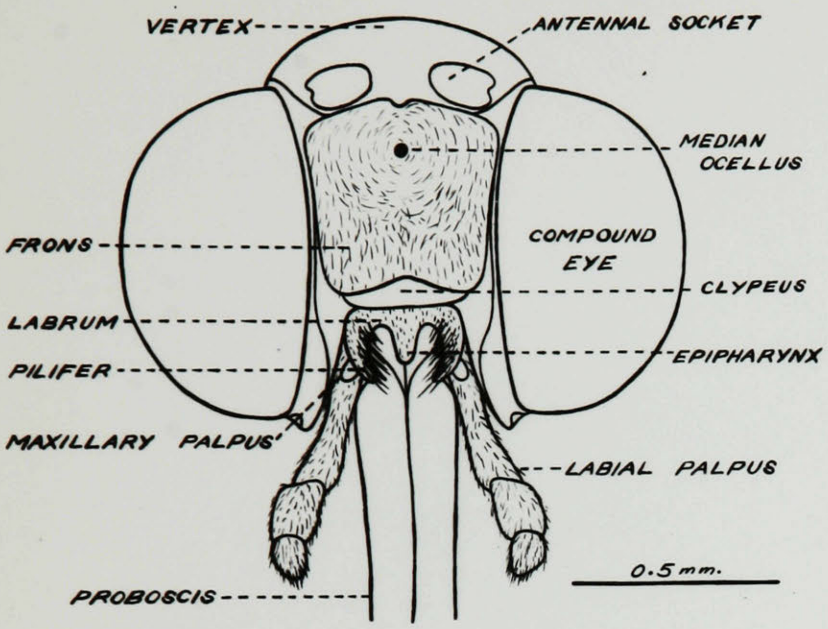


FIG. 15

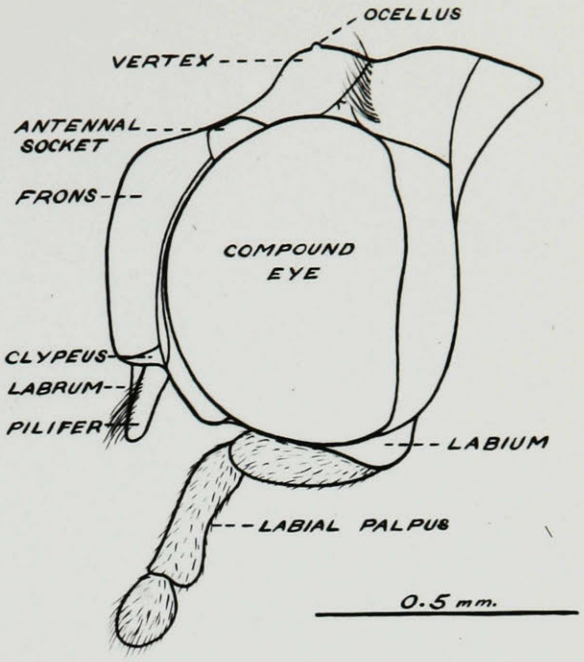


FIG. 16

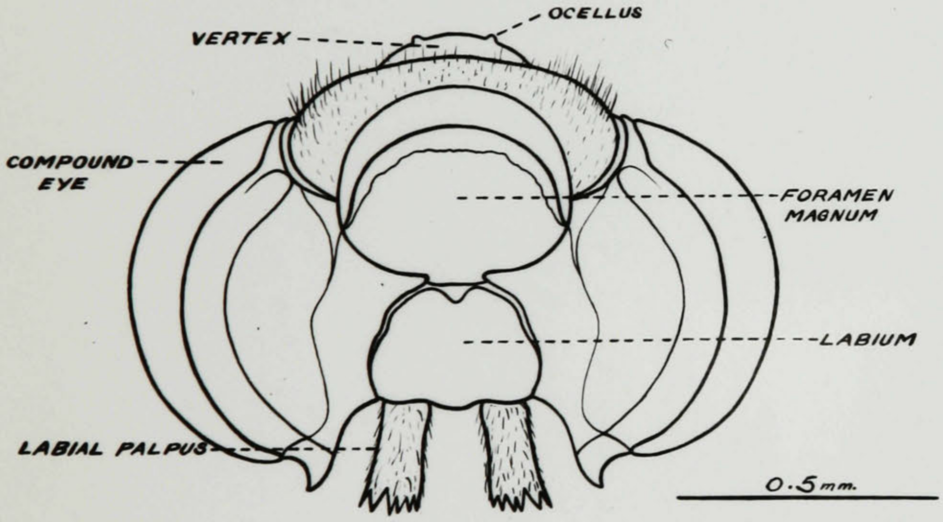


FIG. 17

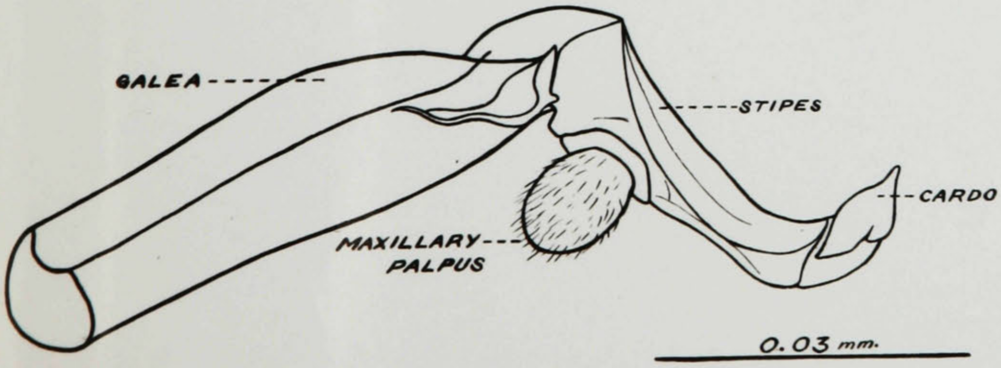


FIG. 18

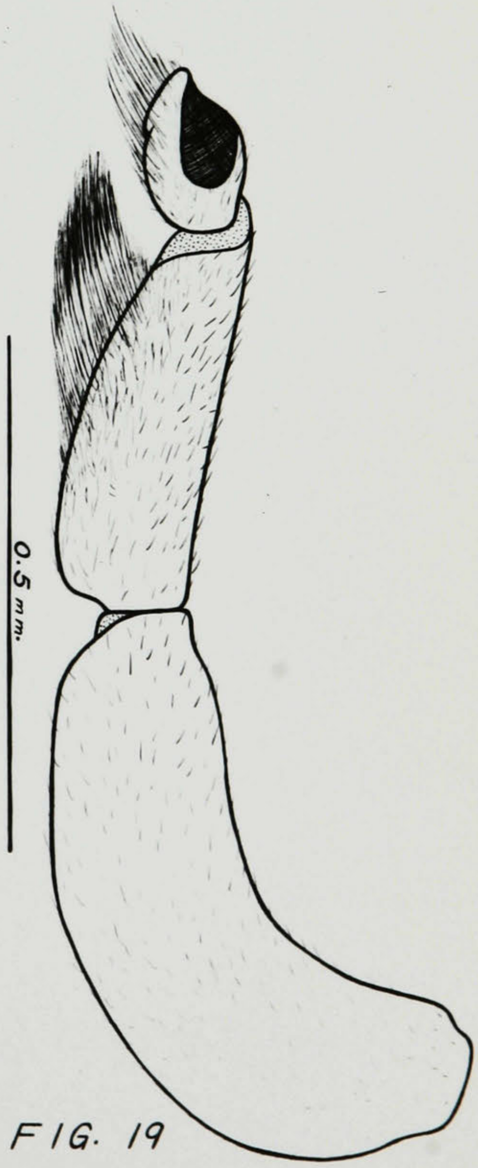


FIG. 19

PLATE VI.

Fig. 20. Lateral view of adult thorax.

Fig. 21. Anterior view of prothoracic segment of adult thorax.

Fig. 22. Ventral view of third abdominal segment of male adult.

PLATE VI

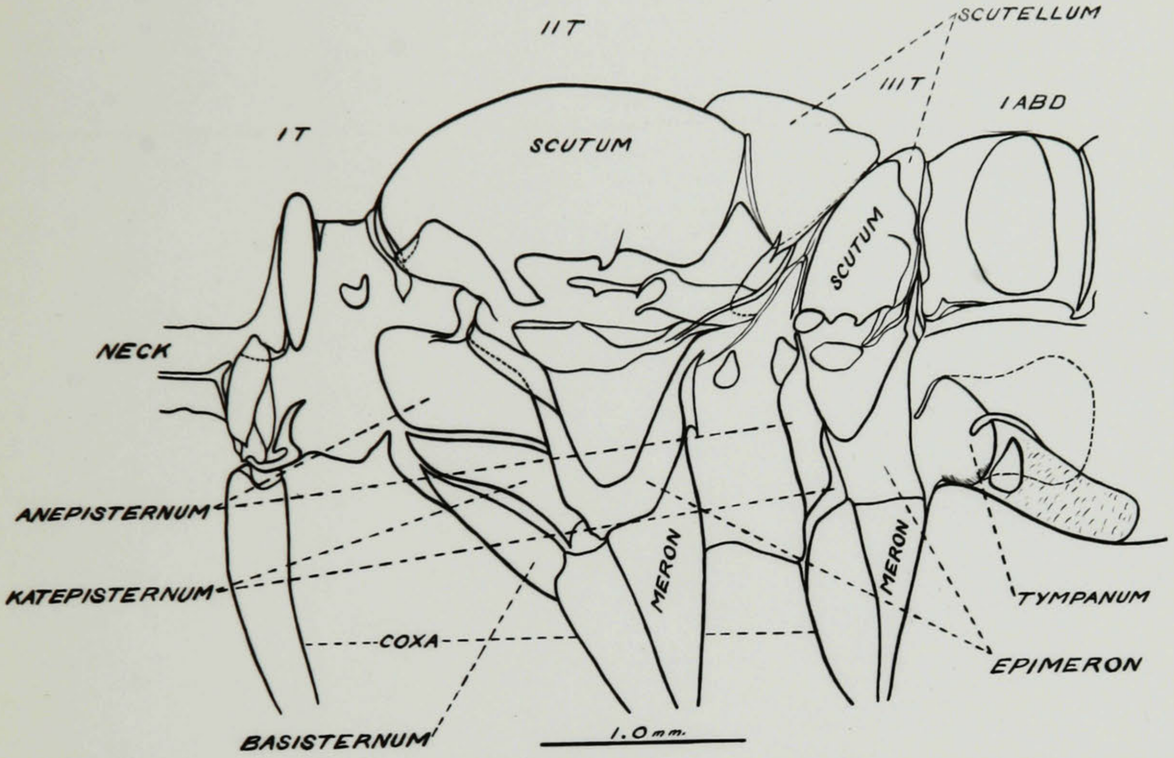
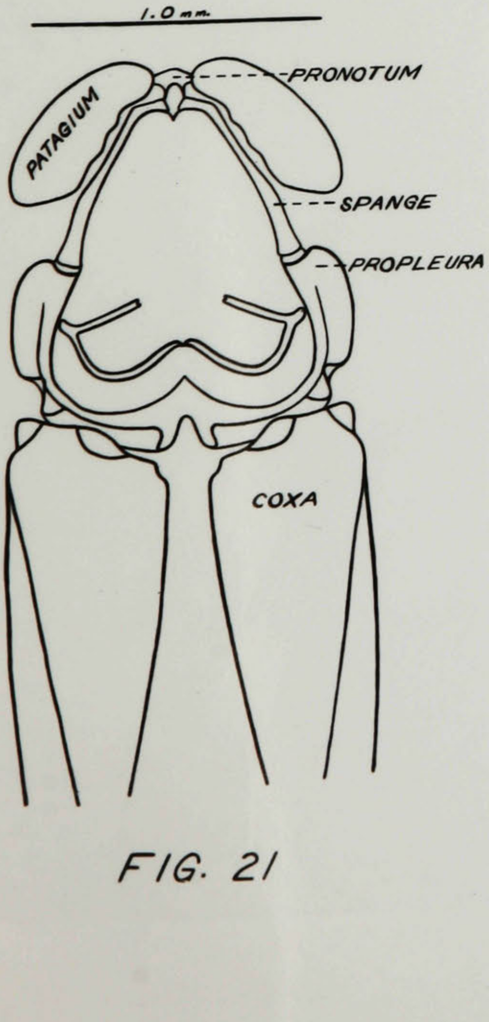


FIG. 20



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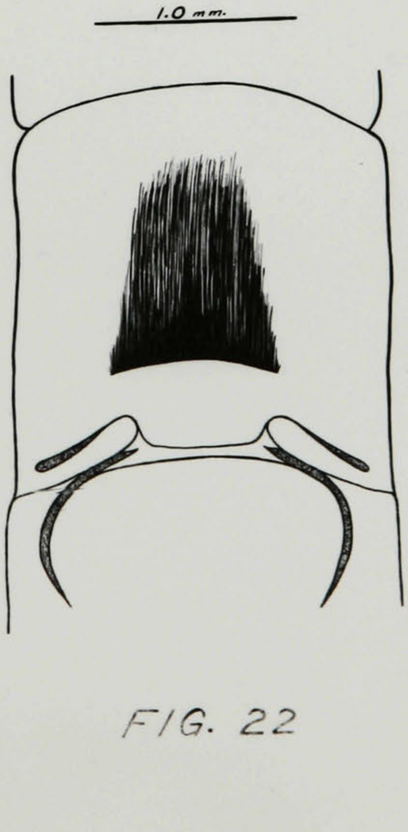

FIG. 22

PLATE VII.

Fig. 23. Hind wing of female moth.

Fig. 24. Fore wing of female moth.

Fig. 25. Ventral view of male antenna.

Fig. 26. Ventral view of female antenna.

Fig. 27. Dorsal view of tegula.

Fig. 28. Views of the egg when laid singly (top) and in a mass (bottom).

Fig. 29. Female reproductive system and posterior portion of digestive tract

PLATE VII

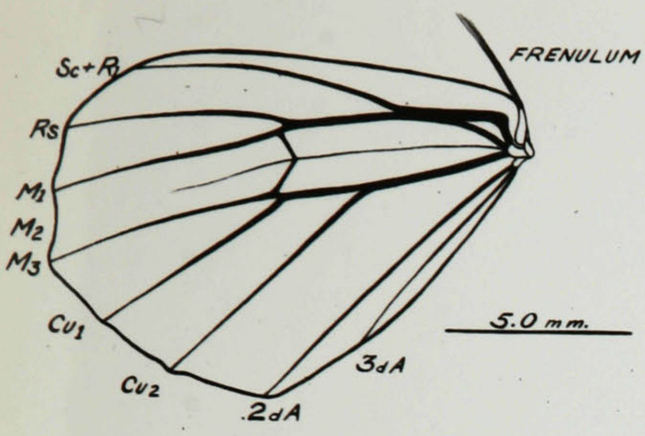

FIG. 23

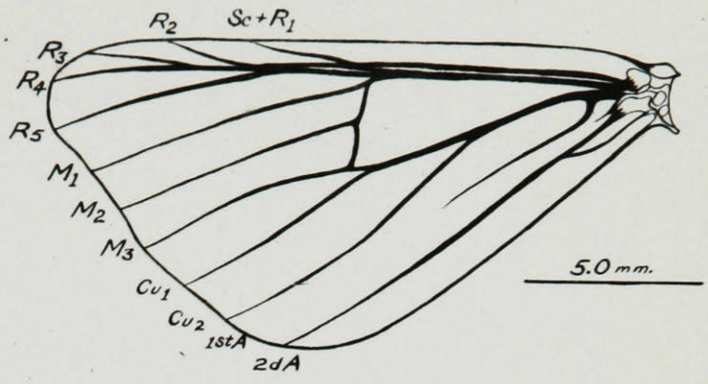

FIG. 24

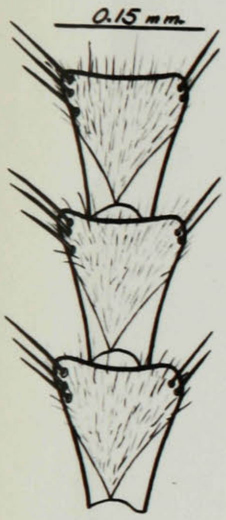

FIG. 25

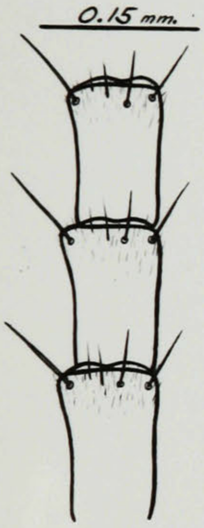

FIG. 26

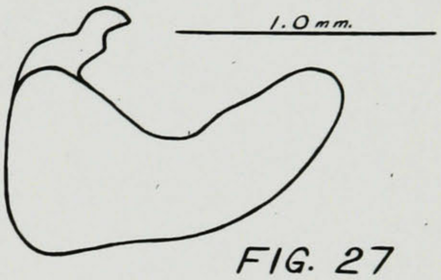

FIG. 27

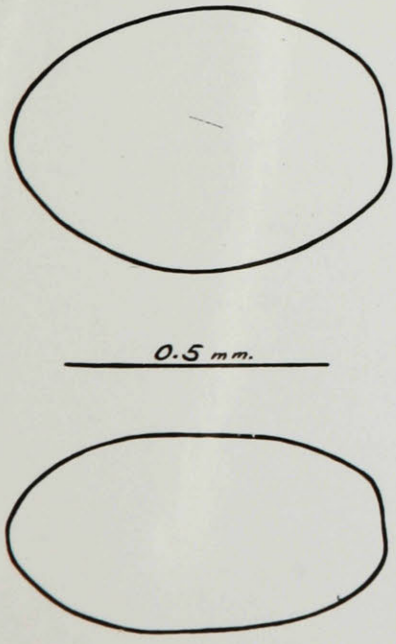

FIG. 28

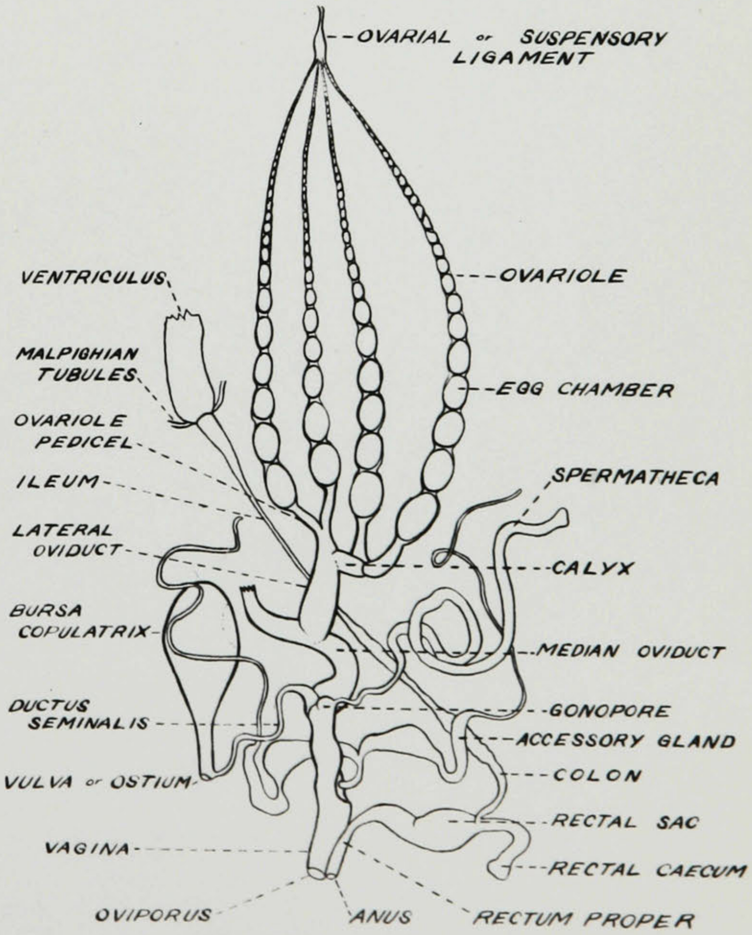

FIG. 29

PLATE VIII.

Fig. 30. Dorsal view of female genitalia in normal position.

Fig. 31. Ventral view of female genitalia in normal position.

Fig. 32. Dorsal view of female genitalia extruded.

Fig. 33. Ventral view of female genitalia extruded.

PLATE VIII

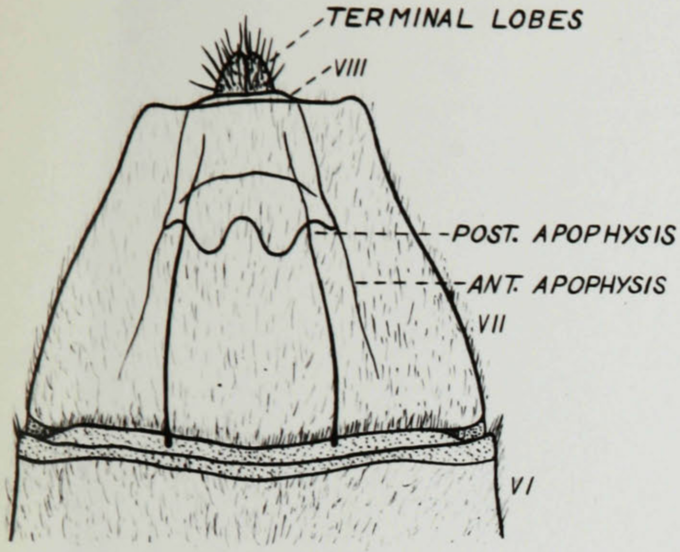

FIG. 30

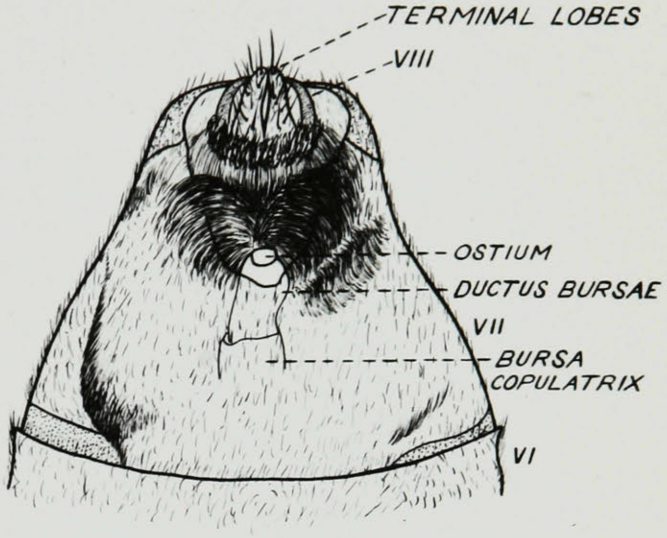

FIG. 31

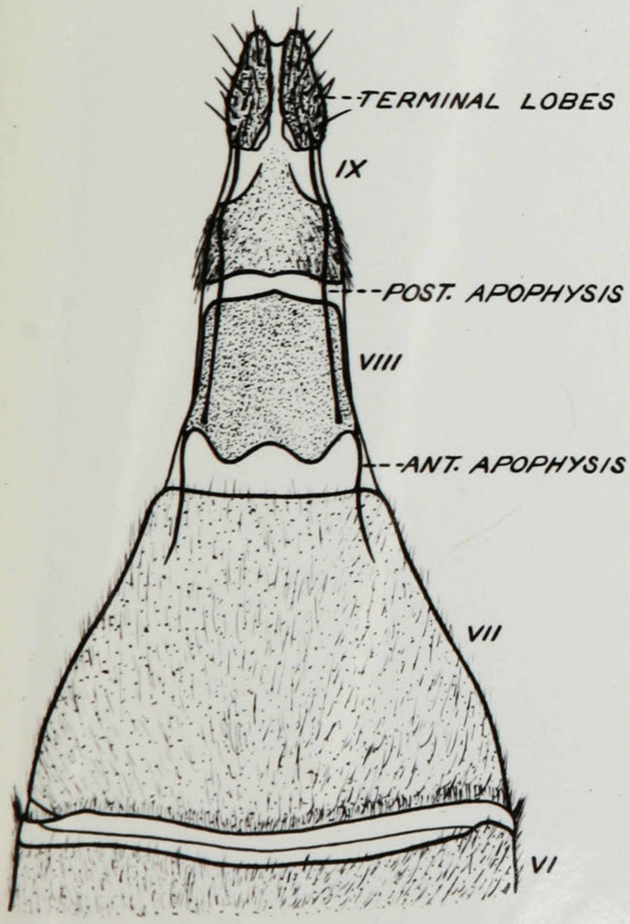

FIG. 32

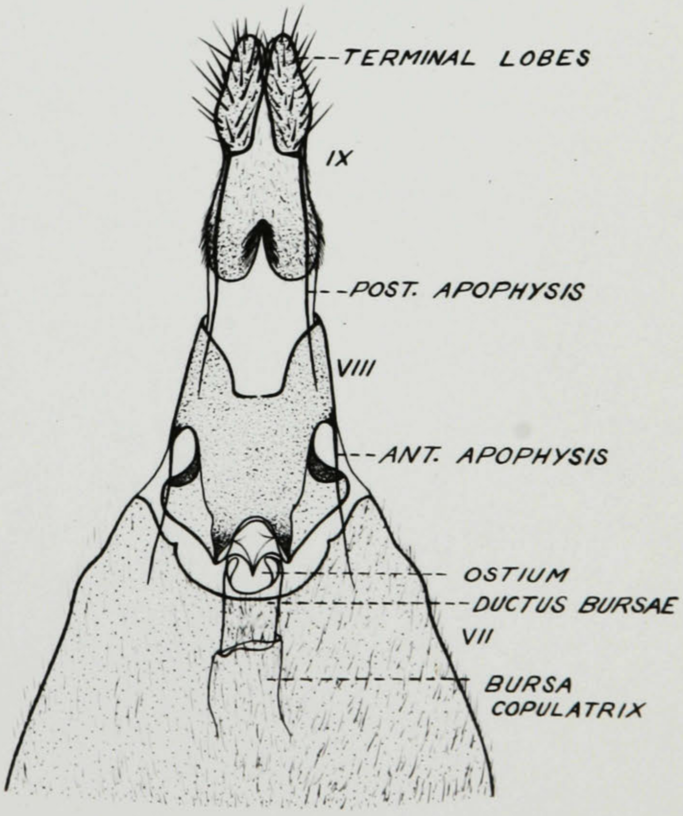

FIG. 33

2.0 mm.

PLATE IX.

Fig. 34. Dorsal view of male genitalia extruded.

Fig. 35. Lateral view of male genitalia extruded.

Fig. 36. Ventral view of male genitalia extruded.

Fig. 37.A Ventral view of bursa copulatrix.

Fig. 37B. Lateral view of signum.

PLATE IX

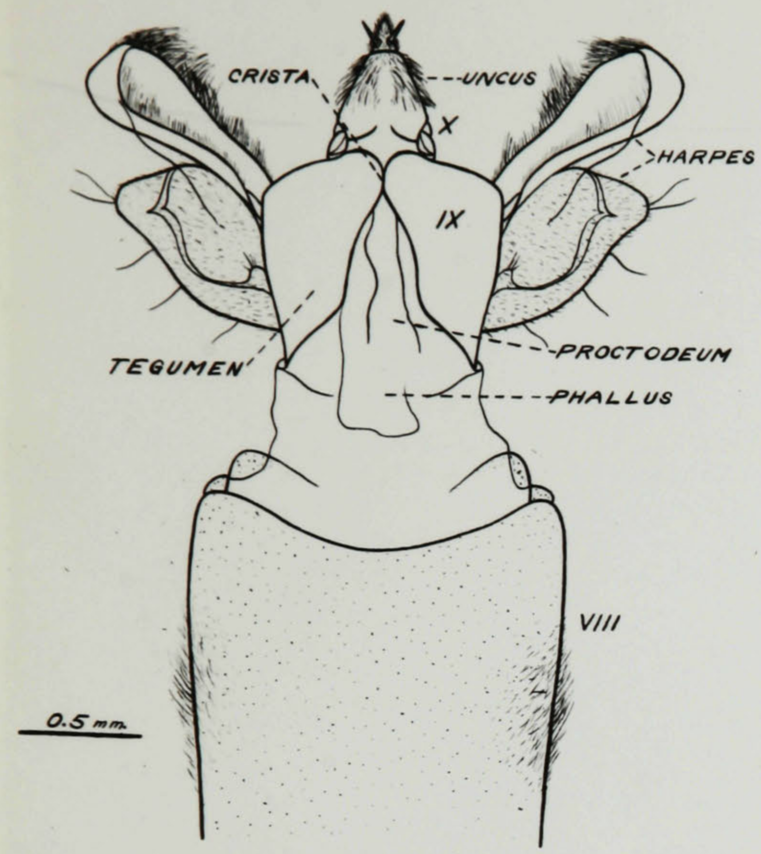

FIG. 34

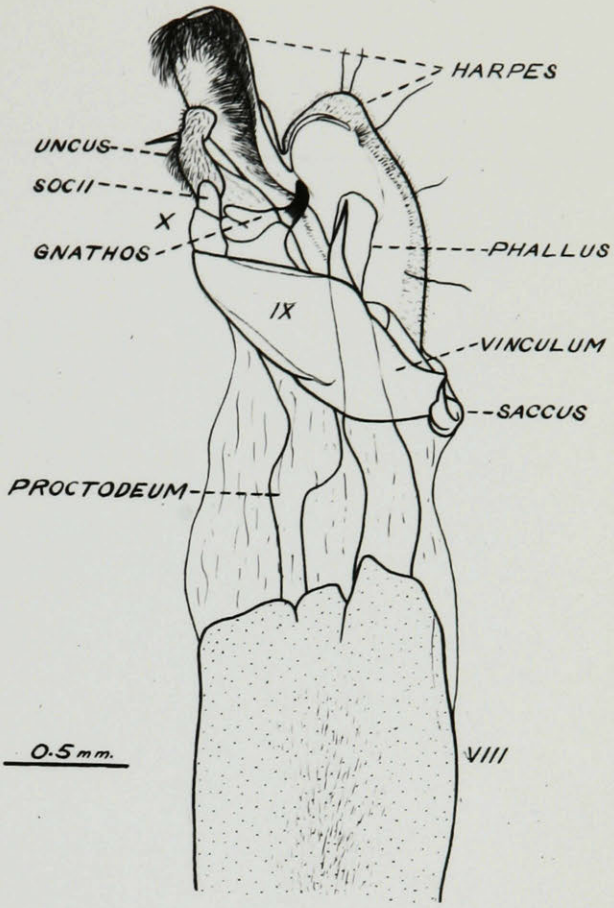

FIG. 35

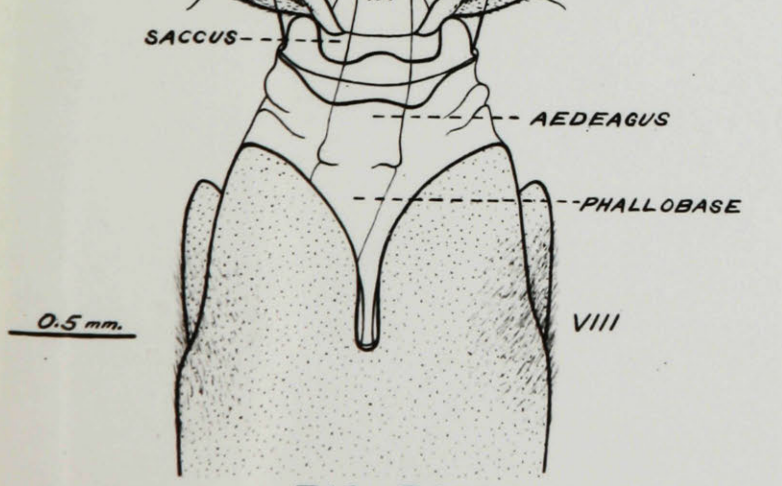

FIG. 36

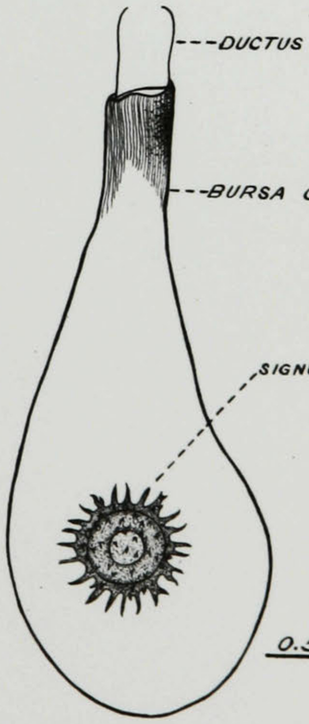

FIG. 37A

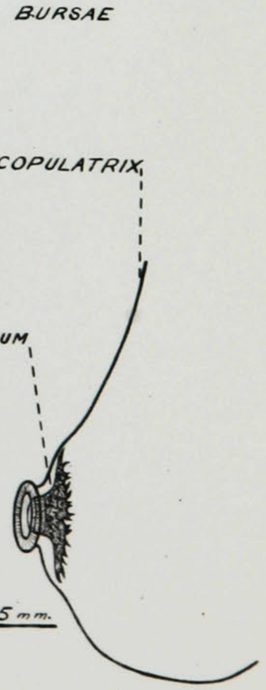

FIG. 37B

PLATE X.

Fig. 38. Dorsal view of fore and hind wings showing the general wing pattern.

PLATE X

FIG. 38

PLATE XI.

Fig. 39 Six fore wings showing variations of wing patterns.

PLATE XI

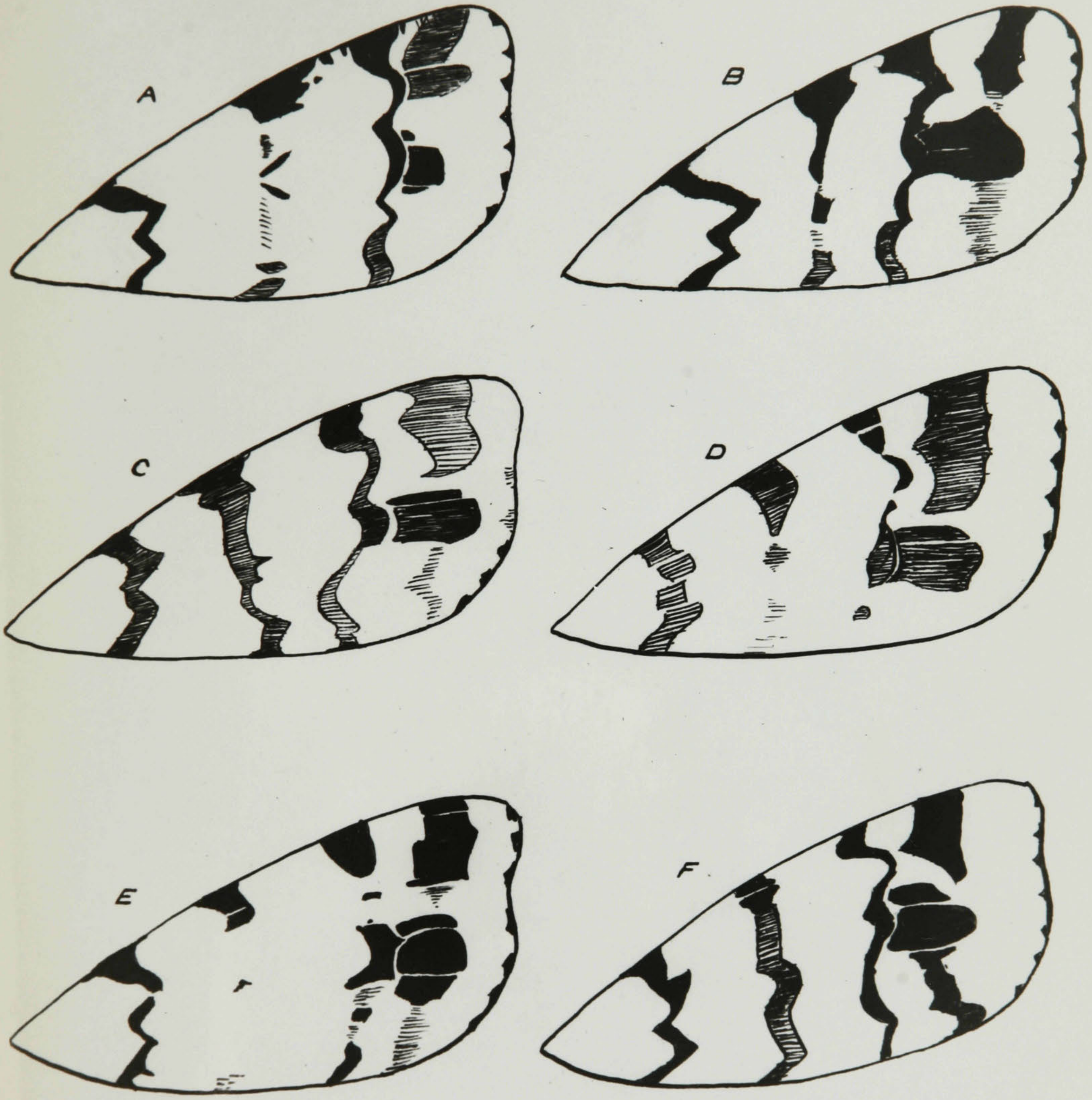

FIG. 39