OCCURRENCE OF THE SWAINE JACK-PINE SAWFLY AND EXTERNAL ANATOMY OF THE MATURE, FEEDING LARVAE

by

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A thesis submitted to the Faculty of
Graduate Studies and Research in partial
fulfilment of the requirements for the
degree of Master of Science.

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Montreal. April 1959.

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I. ACKNOWLEDGEMENTS

As a member of the Ontario regional staff of the Forest Insect Survey, Forest Biology Division, Canada Department of Agriculture, since 1951 I have taken an active part in the development of regional operations. Data from the Survey files have been used in preparing the portion of this thesis concerned with the occurrence of the Swaine jack-pine sawfly while the anatomical studies are a part of my specific research project. Permission has been granted for use of the information. I wish to thank M. L. Prebble and B. M. McGugan, Divisional Headquarters, Ottawa, for their assistance in the development of the research program.

Thanks are due to the staff of the Forest Insect Laboratory, Sault Ste. Marie, Ontario, particularly to R. M. Belyea, Officer-in-Charge, and research personnel of the Forest Insect Survey, for many helpful suggestions during the course of this work. I wish to acknowledge the invaluable contributions of the Forest Biology Rangers, technicians, and students who have collected material for me and assisted in the rearing programs. Original photography was by D. C. Anderson while final reproduction of the illustrations was by the Bio-Graphic Unit and Information Service, Canada Department of Agriculture.

Many people and organizations provided information for use in my distribution studies and to them I extend my sincere thanks, particularly to L. Daviault, Rene Martineau and Howard A. Tripp, all of the Forest Biology Laboratory, Quebec; R. S. Forbes, Forest

Biology Laboratory, Fredericton; R. M. Prentice and H. R. Wong, Forest Biology Laboratory, Winnipeg. Other co-operators were C. E. Atwood, University of Toronto; H. I. Baldwin, New Hampshire Forestry and Recreation Commission; D. M. Benjamin, University of Wisconsin; A. E. Brower, Maine Forest Service; B. D. Burks, U. S. National Museum; J. B. Cody, Kimberly-Clark of Michigan; E. F. Cook, University of Minnesota; A. T. Drooz, Pennsylvania Dept. of Forests and Waters; P. R. Flink, Michigan Dept. of Conservation; C. B. Gill, Manitoba Forest Service; S. A. Graham, University of Michigan; E. H. Huber, New York Conservation Dept.; J. E. Kapler, University of Wisconsin; R. Lambert, Entomology Division, Canada Dept. of Agriculture; B. Lexen, U. S. Forest Service; H. J. MacAloney, Lake States Forest Experiment Station; H. C. Miller, College of Forestry, Syracuse; A. D. Nutting, Maine Forest Service; J. O. Pepper, Pennsylvania State University; R. E. Pfeifer, Michigan Dept. of Conservation; D. R. Redmond, Canada Forestry Branch; H. H. Ross, Illinois Natural History Survey; H. W. Thorne, Wisconsin Conservation Dept.; E. B. Walker, Vermont Dept. of Forests and Parks; W. E. Waters, Northeastern Forest Experiment Station; J. A. Wilcox, New York State Museum; and the New Brunswick Dept. of Lands and Mines.

It is a special pleasure to acknowledge the inspiration and criticisms of E. M. DuPorte, Professor of Entomology, Macdonald College, Quebec.

II. GENERAL INTRODUCTION

The diprionid sawflies, the group to which Neodiprion swainei Middleton belongs, have been known to science for many years. Linnaeus listed two species in the Tenth Edition of his Systema Naturae published in 1758, and Ratzeburg in 1844 devoted thirty-four pages of his text to a discussion of the fifteen species he recognized. Thus long known as serious pests of the Pinaceae in Europe, the diprionids have attracted increasing attention in North America since the early decades of the twentieth century, coincident with the increased planting of large areas to pines and the rapid increase in exploitation of virgin forests. Some of the more destructive species have been introduced into North America from Europe while many more are native to this continent. Some species attack naturally occurring forest stands while others are mainly active in nurseries and plantations. In all they pose an important problem to the forest entomologist. It is necessary, however, that before many aspects of investigation may be pursued, the species must be adequately segregated and classified. Although valuable contributions to this end have been made in recent years, the prerequisite knowledge is not at all complete.

The present study represents the starting point of a larger comprehensive project dealing with the biology and larval anatomy of the Neodiprion sawflies. This in turn is integrated with an anatomical study of the sawfly adults and with cytological and genetical studies in the hope that a general systematic work of lasting value may be achieved.

The Swaine jack-pine sawfly was chosen for this work because by virtue of its habits it is readily distinguishable from other sympatric *Neodiprion* species. At the same time it shows some of the characteristic types of variation to be found among *Neodiprion* sawflies. The following sections deal in turn with an introduction to *N. swainei*, being mainly a literature review, a discussion of the occurrence of *N. swainei*, and finally descriptions of the mature, feeding larvae.

III. INTRODUCING THE INSECT

The Swaine jack-pine sawfly, *Neodiprion swainei*, is but one of the forty-odd species of sawflies placed in the genus *Neodiprion* Rohwer (Diprionidae: Hymenoptera). It was described and named by Middleton in 1931 from adults reared from larvae collected on jack pine, *Pinus banksiana* Lamb., in the Mont Laurier area of Quebec by M. B. Dunn. The type, allotype and paratypes are retained in the United States National Museum, Washington, D. C., under catalogue number 43468.

Also both Dunn (1931) and Schedl (1931) gave brief descriptions of the seasonal history and larvae under colloquial names, the jack pine sawfly and the twin-egg sawfly, respectively. Schedl carried out an extensive field investigation of jack pine sawflies, including *N. swainei*, at Biscotasing, Ontario, during the years 1930 and 1931, while similar studies were undertaken by Dunn at Laniel, Quebec, at about the same time. Schedl (1933) discussed the change in width of the larval head capsule during postembryonic development. Dunn (1934) briefly described sampling procedures used for pine sawflies at Laniel. Schedl (1935) described two new species of pine sawflies, including swainei in his keys (also keying abietis Harr., nanulus Schedl, and dubiosus Schedl), and in 1937 he published a major paper on the biology of swainei, dubiosus (= virginianus complex) and nanulus. Atwood (1938) revised the 1931 circular by Dunn, adding notes on other Neodiprion species. Schedl (1939) published a long paper on the population dynamics of N. swainei and two other species. Brown and Daviault (1942) reported results of their work on the influence of temperature on postdiapause development in swainei and several other sawflies. Smith (1942) gave information on the cytology of the Swaine jack-pine sawfly.

Atwood and Peck (1943) included swainei in their keys to adults and larvae of native sawflies of the genus Neodiprion attacking pines in eastern Canada, and gave the main points of the biology of this species. Ross (1951) listed N. swainei in the Hymenoptera of America North of Mexico, Synoptic Catalogue, and treated the species in his revision of the genus in 1955. The internal larval anatomy was described by Maxwell (1955). Raizenne (1957) included swainei in an annotated list of forest sawflies of southern Ontario and it was again listed in Hymenoptera of America North of Mexico, First Supplememt, 1958, giving distribution and host tree. Notes on distribution were published by Benjamin and Underwood (1953), Wallace and Sippell (1953), and Franklin

(1959). Ghent and Wallace (1958) discussed the oviposition habits of *N. swainei*. The cytology has been described by Maxwell (1958).

Records of occurrence and population changes are found in Twinn (1935, 1937), Brown (1938, 1939), and in the Annual Reports of the Forest Insect Survey for 1938 and 1940 to date.

The female adults of *N. swainei* are reddish (Peck, 1943) and may be distinguished from those of other species found in eastern and central Canada by the form of the scopal pads which are three times as long as wide; raised and wedge-shaped; their mesal aspects vertical. The males are mostly black in colour and are indistinguishable from those of other species on the basis of current information. The mature, feeding larvae are described in part V of this manuscript.

Hymenoptera of America North of Mexico, First Supplement, 1958, lists the distribution as northeastern United States, southeastern Canada, and Wisconsin. The occurrence of this species is more fully discussed in part IV.

The only authenticated host tree for *N. swainei* is jack pine, *Pinus banksiana* Lamb. Some early records (Brown, 1938) also include red pine, *Pinus resinosa* Ait., but over 800 samples made in Ontario from 1950 to 1958 were all on jack pine. In 1957 (unpublished records) I was successful in obtaining *swainei* oviposition on red pine in three out of five trials with pairs of adults caged over developing red pine shoots. Red pine needles did not appear as satisfactory for oviposition as those of jack pine, there being a tendency for them to break at the egg slit. The eggs hatched, but all the larvae died in the first or second stadium. It is probable that the small number of field reports of N. swainei on red pine are valid, although it appears that red pine is not a particularly suitable host tree for this species.

N. swainei has one generation a year and overwinters as a cocooned, prepupal larva in the duff. Pupation takes place in the cocoon in late spring and the adults emerge from June through to late July (Schedl, 1937; Benjamin and Underwood, 1953). Brown and Daviault (1942) in laboratory studies calculated that the theoretical threshold for morphogenesis in overwintered material is 9.1°C for males and 9.0°C for females. They found the respective thermal constants for development to adults to be 352 and 362 day-degrees. It is likely that the theoretical thresholds given by them are high, because they were calculated assuming a straight line relationship between development rate and temperature while their plotted points indicate a sigmoid curve. It should also be noted that the length of the developmental period varies depending upon the conditions under which the cocoons are overwintered, decreasing as the storage time and temperature are increased (Wallace, unpublished records).

Mating and oviposition usually occur soon after eclosion. The females lay their eggs singly in the outer edges of the paired, elongating, jack pine needles at the level of needle exposure from the basal sheath. Ghent and Wallace (1958) have shown that the characteristic paired appearance of eggs in opposite needles of a fascicle apparently results from a purely chance occurrence of oviposition on both needles. If both are selected for oviposition without appreciable delay, say during the same day, the eggs will be well matched in distance from the needle tip (ie.,"paired") because they will have been laid using the basal sheath as a common reference point. Subsequent needle growth carries the egg slits away from the basal sheath, but the original distance between egg slit and needle tip is preserved.

Embryological development takes three to four weeks under field conditions and Schedl (1937) showed the mean date of hatching as determined by field sampling at Biscotasing in 1930 and 1931 to have been July 30 and July 18, respectively. I have found viable but unhatched eggs in late August (Lake St. John area, Quebec, 1956). Feeding larvae are present on the trees through July in Wisconsin (Benjamin and Underwood, 1953) and in eastern Canada they may be found from late July into early October. Peak collecting of late-stage, feeding larvae in Ontario occurs in mid-to-late August (Fig. 15). Schedl (1937) gave a feeding period of about 45 to 60 days under field conditions and indicated that there were six stadia. In his 1933 paper he stated that a proportion of the larval population completed its feeding in five stadia while the remainder required six. He also said that this was a sex difference in some instances, while in others, larvae which spun cocoons after five feeding stages later transformed to female adults the same as the larvae having an additional one. It is now established that male larvae generally have one less feeding instar than the females, but that the number of feeding stages is not constant, resulting in instances in which some males and females have the same number of feeding instars. The factors causing the variation in number of larval stages have not been determined. In the material reared for the anatomical studies male larvae appeared to have four feeding instars, while female larvae had five. The larvae develop their characteristic colour pattern at the moult preceding the final feeding stage and thus it is usually possible to divide a family according to sex because of the difference in number of feeding instars.

When feeding is completed the prepupal larvae spin cocoons in the duff and enter an obligatory diapause in which condition they commence the overwintering period. Laboratory studies undertaken from 1956 to 1958 (Wallace, unpublished records) show that the physiological processes of the diapause condition are more rapidly completed at about 6°C than at any other temperature between 0 and 12°C that was tested. At 6°C about 100-120 days treatment fulfill the diapause requirements. In 1958 it was found possible to eliminate the diapause in a high proportion (86%) of an experimental population by providing a photoperiod of 16 hours. Experience indicates that the critical period for sensitivity to light duration occurs just after hatching or during the early stadia.

Observations on the cytology of N. swainei have been made by Smith (1942) who found the haploid chromosome number to be seven. Maxwell (1958), however, states that it is eight. Smith (personal communication) suggests that material examined by him may have been misidentified. Parthenogenetic reproduction may occur in which case the progeny are all males.

In summary it may be stated that _N. swainei_ may be readily identified on the basis of oviposition pattern and by coloration of the final feeding-stage larvae. Seasonal history and host tree also play important parts in identification, but are not in themselves diagnostic.

IV. OCCURRENCE OF THE SWAINE JACK-PINE SAWFLY

A. INTRODUCTION

Since one of the objectives of the *Neodiprion* larval project is to reach an understanding of anatomical variation, possibly involving differences in material from different geographic areas, the first prerequisite was to define the distribution of *Neodiprion swainei*, the species under study. As already indicated this species may be identified with certainty thus making possible a reasonable assessment of its occurrence.

B. MATERIALS AND METHODS

The distribution of *N. swainei* was determined from a number of different sources. Records from the files of the Forest Insect Survey were used for data covering the Maritime Provinces, Ontario, and Manitoba. The objectives and principal methods of this organization have been described by McGugan (1958). Important to the problem at hand is the fact that extensive sampling of insects on pines has been carried out. The data for Quebec were obtained from reports based on information from the files of the Forest Insect Survey, Bureau of Entomology, Quebec Department of Lands and Forests (Daviault, 1953), and from special surveys for sawflies on jack pine undertaken by Forest Biology Division personnel since 1954 (Tripp, 1955, and Martineau, 1956, 1957). Literature references were used to determine the distribution in the United States of America and unpublished records were solicited from conservation agencies in the northeastern and central states.

Records for the areas concerned used in drafting the distribution map covered different time intervals as follows:

Maritime Provinces: 1937-1958.
Quebec: 1940-1949, 1954, 1955.
Ontario: 1952-1958.
Manitoba: 1938-1958.
U.S.A.: all to April, 1959.

The Forest Insect Survey distribution data are in the form of seven-digit numbers referring to grids four miles on a side. Quebec information uses a zone system whereby each degree of latitude and longitude is divided at ten minute intervals thus giving thirty-six zones for each one degree area. Combining thirty-six grids for the Survey data and six zones for the Quebec data produces grids of 24 by 24 and 22.9 by 22.5 to 25.0 miles depending on latitude, respectively. There is little difference in the areas of the two grids. A base map was made according to this system and the records were plotted. One collection of N. swainei from any of the thirty-six grids or six zones constituted a record for that area and any additional collections were disregarded. Occurrences in the United States were plotted on a county basis.

Two groups of data were checked for distribution records not given in the sources already listed. Locality labels of all specimens in the Canadian National Collection, Ottawa, were checked as were Ontario Survey records covering the period 1938-1951 inclusive. All those for marginal or sparsely represented areas were plotted on the map. This method was used because the records older than 1950 do not bear grid references and locating them would be a laborious and time consuming task. It was also evident that a very high proportion of the older records was already represented in the groups considered in total. Finally the distribution map and published records were compared to find any discrepancies that might need checking.

Other data have been drawn from the files of the Forest Insect Survey and their accumulation has been in accordance with the principles outlined by McGugan (1958).

C. RESULTS AND DISCUSSION

1. THE KNOWN DISTRIBUTION OF *N. SWAINEI*

Figure 1 shows the known distribution of *N. swainei* plotted according to the system already outlined. The extreme northern limit is about 51°30' North latitude, but few collections are recorded over a large area of Ontario north and east of Lake Superior.

There is a definite southern limit in Ontario and Quebec between Georgian Bay of Lake Huron and the St. Lawrence River. From Georgian Bay it arches north to the Ottawa River south of Lake Timiskaming, follows the Ottawa River to the City of Ottawa, turns northward, extends eastward south of the Mattawin River to the St. Maurice River and then parallels the St. Lawrence as far as the mouth of the Saguenay River. Elsewhere the southern limit appears to be difficult to define. There are four known occurrences of *N. swainei* in Minnesota, one near Little Forks, just south of Rainy Lake (MacAloney, and Burks, personal communications), and the other three in central Minnesota in the Chippewa National Forest, Hubbard, and Crow Wing counties (Franklin, 1959)[1]. Wisconsin has records in four counties,

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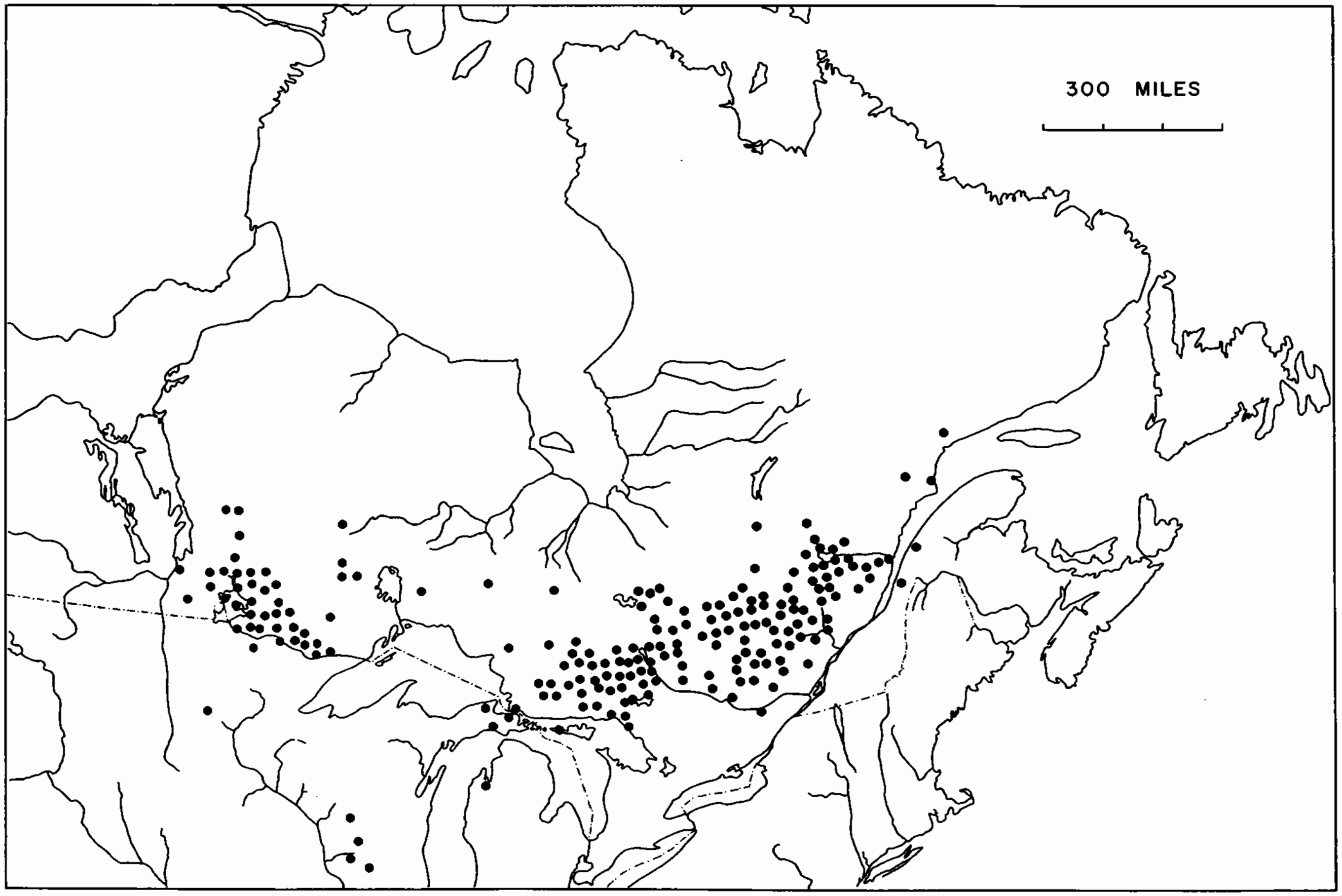
[1] Only the Chippewa National Forest record is shown on the distribution map because the author had identified larvae from this locality for R. T. Franklin who subsequently has published this and two additional records.

Fig. 1. Known distribution of the
Swaine jack-pine sawfly,
Neodiprion swainei Midd.


300 MILES

viz., Sauk (Benjamin and Underwood, 1953), Iowa and Juneau (Shenefelt and Benjamin, 1955), and Green (Kapler, personal communication). Wallace and Sippell (1958) found larvae on jack pine in Chippewa, Luce and Mackinac counties at the eastern end of Michigan's Upper Peninsula. Flink (personal communication) reported the presence of this species from Grand Traverse County in lower Michigan. Although Hymenoptera of America North of Mexico, First Supplement, 1958, lists northeastern United States under the distribution for *swainei*, Burks who compiled the records was unable to supply any information other than a reference to New York State, source unknown (personal communication). Extensive correspondence with conservation workers in the area has failed to bring to light any additional information. The occurrence of *N. swainei* in Quebec south of the St. Lawrence River near Rimouski and Riviere du Loup was confirmed by Martineau (1957). A reference by Hawboldt (1938) to this species in the Salmon and Canaan valleys of New Brunswick appears to be in error, referring to other species of *Neodiprion*.

The main features of *swainei* distribution are seen to be a large concentration of records in central Quebec and adjacent northeastern Ontario and a second but smaller group in northwestern Ontario extending into southeastern Manitoba.

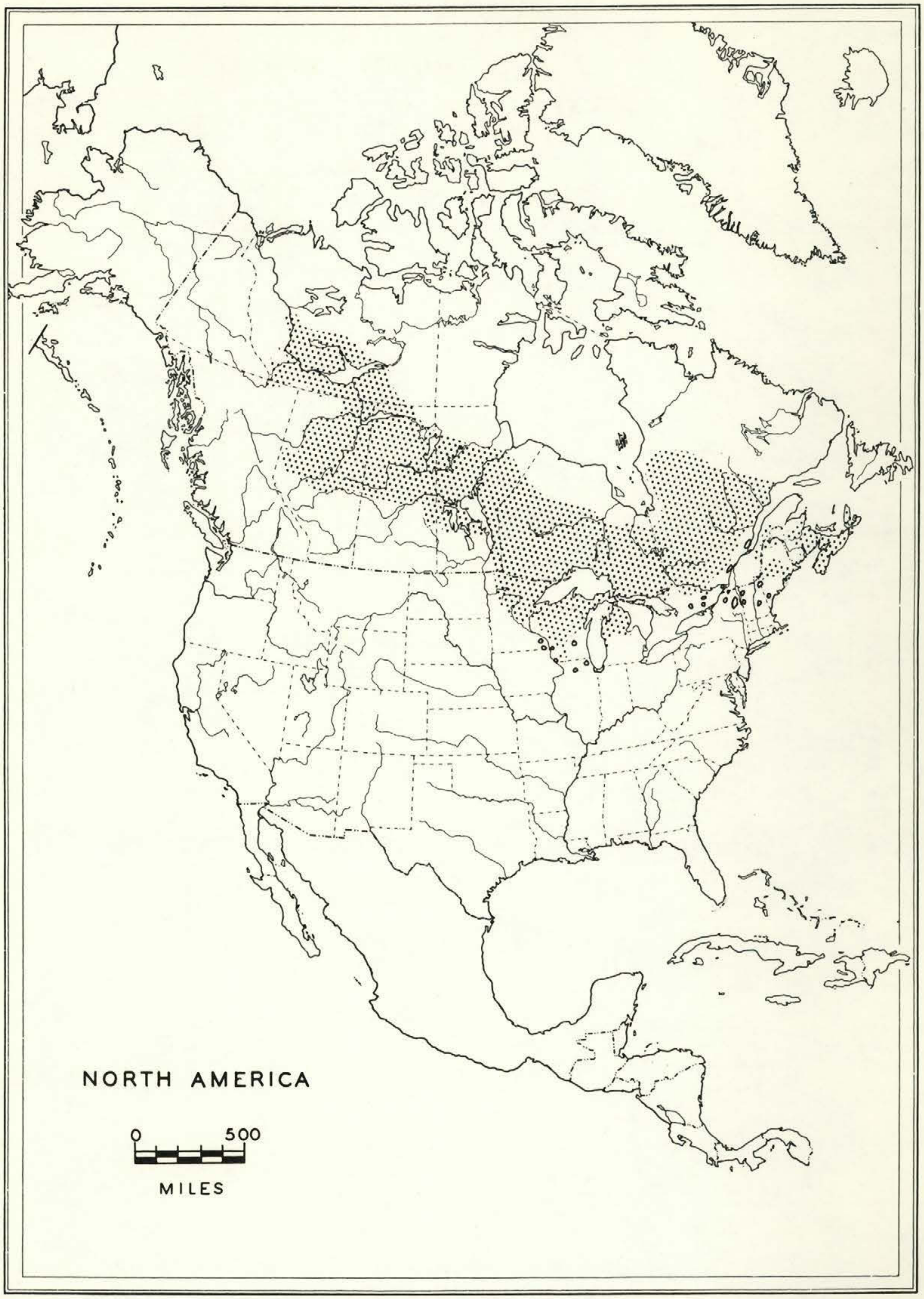
The western limit of the Swaine jack-pine sawfly distribution is Lake Winnipeg.

2. OCCURRENCE IN RELATION TO DISTRIBUTION AND ABUNDANCE OF JACK PINE

It proves interesting to compare the ranges and abundance of N. swainei and jack pine since the latter is virtually the sawfly's only host tree. Figure 2 illustrates the distribution of jack pine and it is obvious that there is little similarity between the northern limits of the two species. The southern limits of insect and host east from Georgian Bay of Lake Huron to the St. Lawrence at the mouth of the Saguenay show great similarity, and even the few records from the American Lake States seem to image the natural occurrence of jack pine in that region. Note the fragmentary nature of the jack pine distribution east of the Great Lakes-St. Lawrence system.

It is not enough to compare simply the distributions; the relative abundance of the species in different areas shows interesting features. The few records for Manitoba are all in the southeastern corner of the province. According to Gill of the Manitoba Forest Service (personal communication) recent surveys show jack pine to comprise some sixteen per cent of all net merchantable timber in the 4 inch D. B. H. class and up in the surveyed area of the Province. Particularly heavy concentrations of jack pine, over thirty per cent by volume, are indicated northwest of lakes Winnipeg and Winnipegosis, an area where swainei has not been found.

Fig. 2. Distribution of jack pine, Pinus banksiana Lamb. Based on a map compiled by Elbert L. Little Jr. and supplied through the courtesy of Bert Lexen, both of the United States Forest Service.


NORTH AMERICA
0
500
MILES

The Ontario situation, being better documented, will be considered in more detail. The Province is divided into twenty-two administrative districts by the Ontario Department of Lands and Forests (Fig. 3) and these same districts are used in the work of the Forest Insect Survey. Sixteen of these, all except the six bordering Lake Erie, Lake Ontario and the St. Lawrence River, are taken into consideration in the discussion to follow. It has already been noted that *swainei* records are scarce in an area north and east of Lake Superior. This is strikingly evident in Fig. 4 where the total number of insect collections made on jack pine in each district during the years 1952 to 1958, inclusive, is represented by a circle and the proportion of these containing some stage of *N. swainei* is indicated by the shaded portion of the circle. The figure gives this value in per cent. The abundance of jack pine has been illustrated in a similar manner in Fig. 6, each circle representing a forest district also represents the total volume of jack pine primary growing stock in all sixteen districts as compiled from Forest Resources Inventories (Anonymous, 1953). This value amounts to 17,129,117 thousand cubic feet, or 14 per cent of the primary growing stock for all tree species. The proportion of this total volume for each district is indicated by the shaded sector and the figure in the circle. It is evident that districts in the central group are not lacking in jack pine yet *swainei* is rare.

Fig. 3. Ontario forest districts

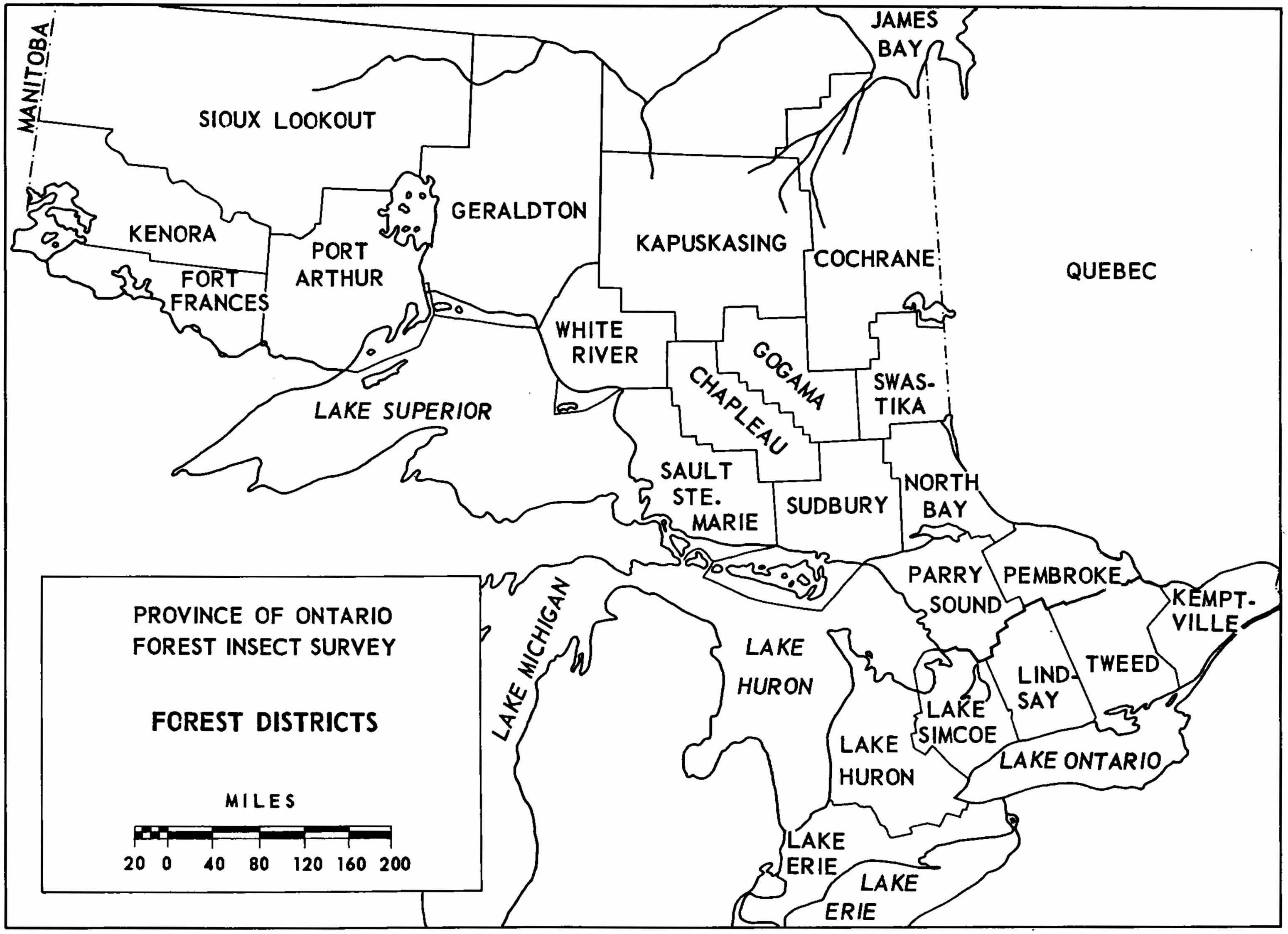
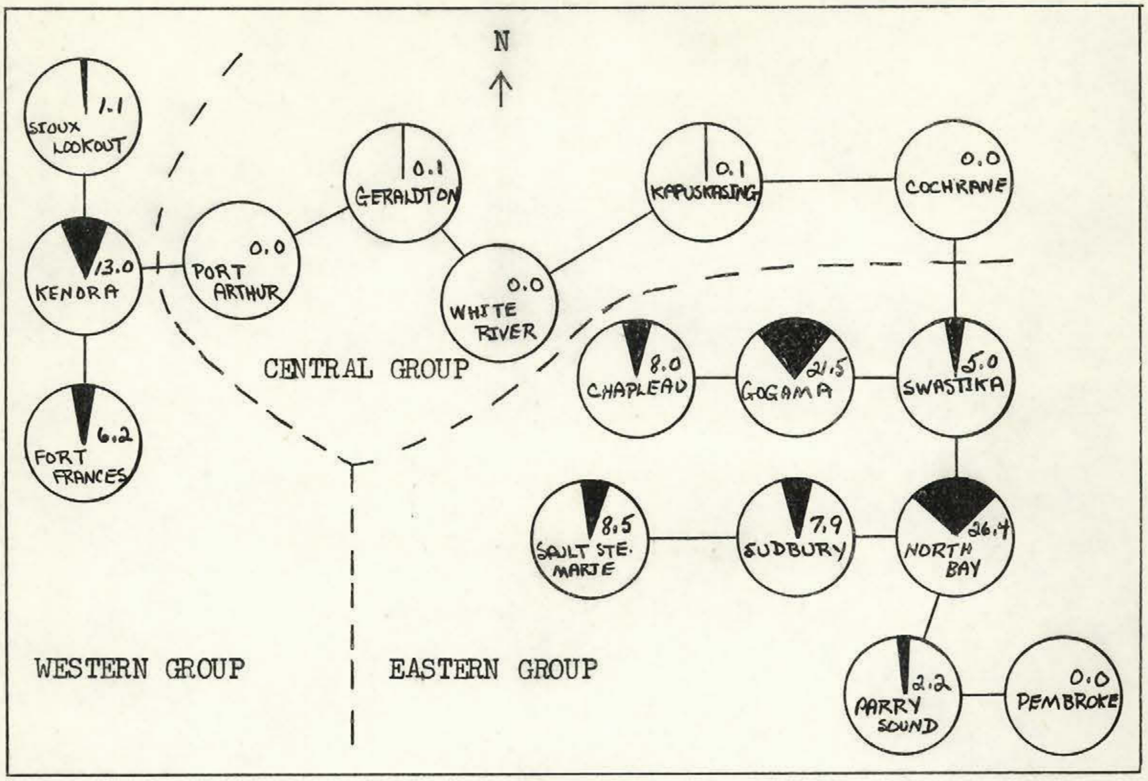

PROVINCE OF ONTARIO
FOREST INSECT SURVEY
FOREST DISTRICTS
MILES
20 0 40 80 120 160 200
MANITOBA
SIOUX LOOKOUT
KENORA
FORT FRANCES
PORT ARTHUR
GERALDTON
KAPUSKASING
COCHRANE
JAMES BAY
QUEBEC
WHITE RIVER
GOGAMA
CHAPLEAU
SWAS-TIKA
LAKE SUPERIOR
SAULT STE. MARIE
SUDBURY
NORTH BAY
PARRY SOUND
PEMBROKE
KEMPT-VILLE
LAKE MICHIGAN
LAKE HURON
TWEED
LIND-SAY
LAKE SIMCOE
LAKE HURON
LAKE ONTARIO
LAKE ERIE
LAKE ERIE

Fig. 4. Cartograph showing the proportion of collections from jack pine containing N. swainei for northern Ontario forest districts, 1952 - 1958, inclusive.

Fig. 5. Cartograph showing the proportion of collections from jack pine containing N. virginianus complex for northern Ontario forest districts, 1952 - 1958, inclusive.


N
1.1
SIOUX LOOKOUT
0.1
GERALDTON
0.1
KAPUSKASING
0.0
COCHRANE
13.0
KENORA
0.0
PORT ARTHUR
0.0
WHITE RIVER
CENTRAL GROUP
8.0
CHAPLEAU
21.5
GOGAMA
5.0
SWASTIKA
6.2
FORT FRANCES
8.5
SAULT STE. MARIE
7.9
SUDBURY
26.4
NORTH BAY
WESTERN GROUP
EASTERN GROUP
2.2
PARRY SOUND
0.0
PEMBROKE

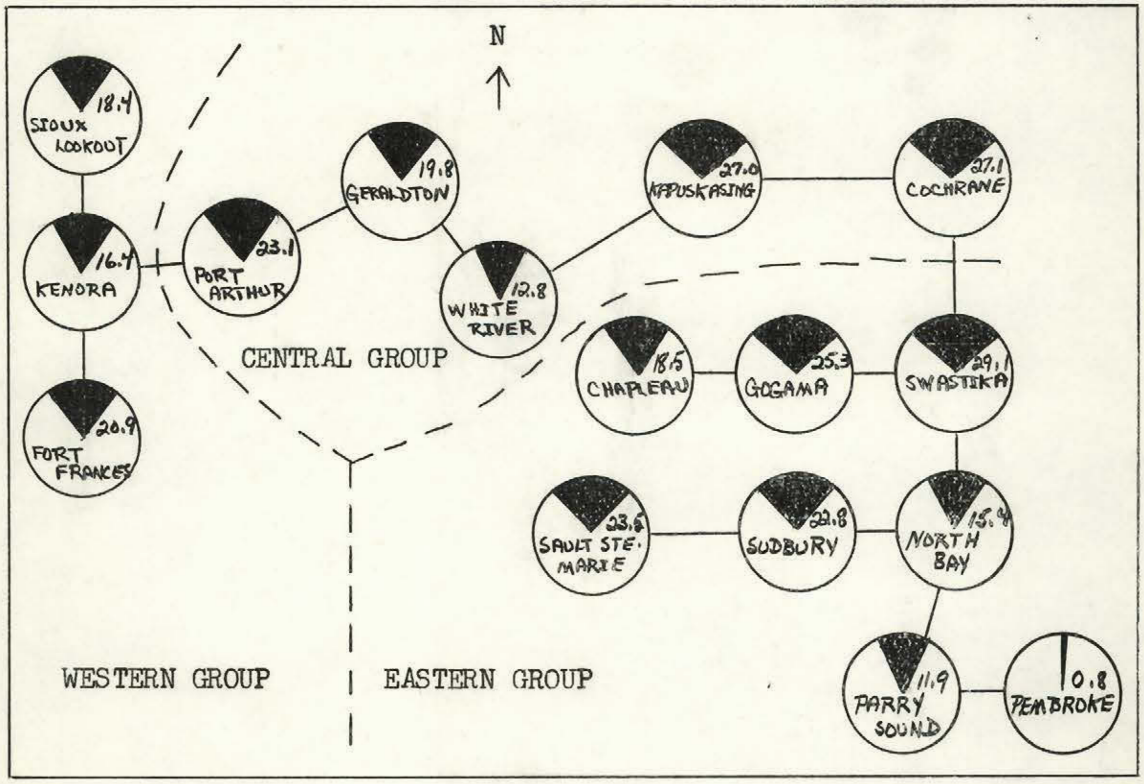
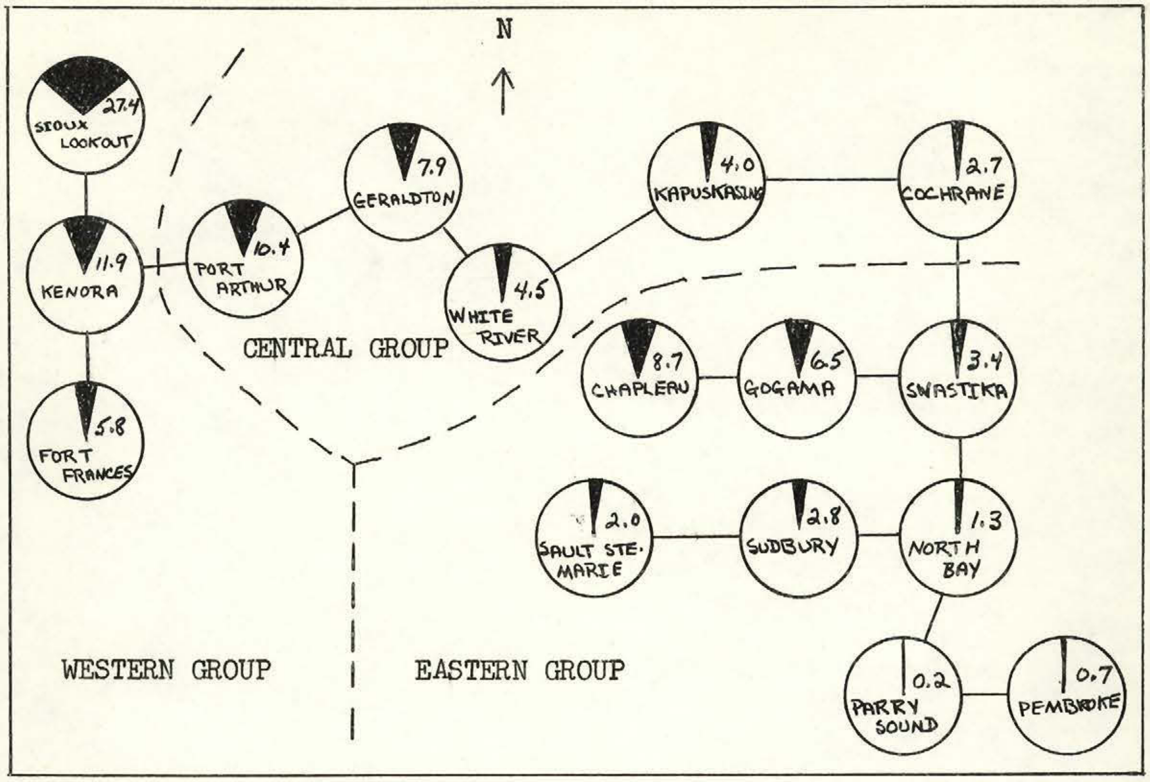
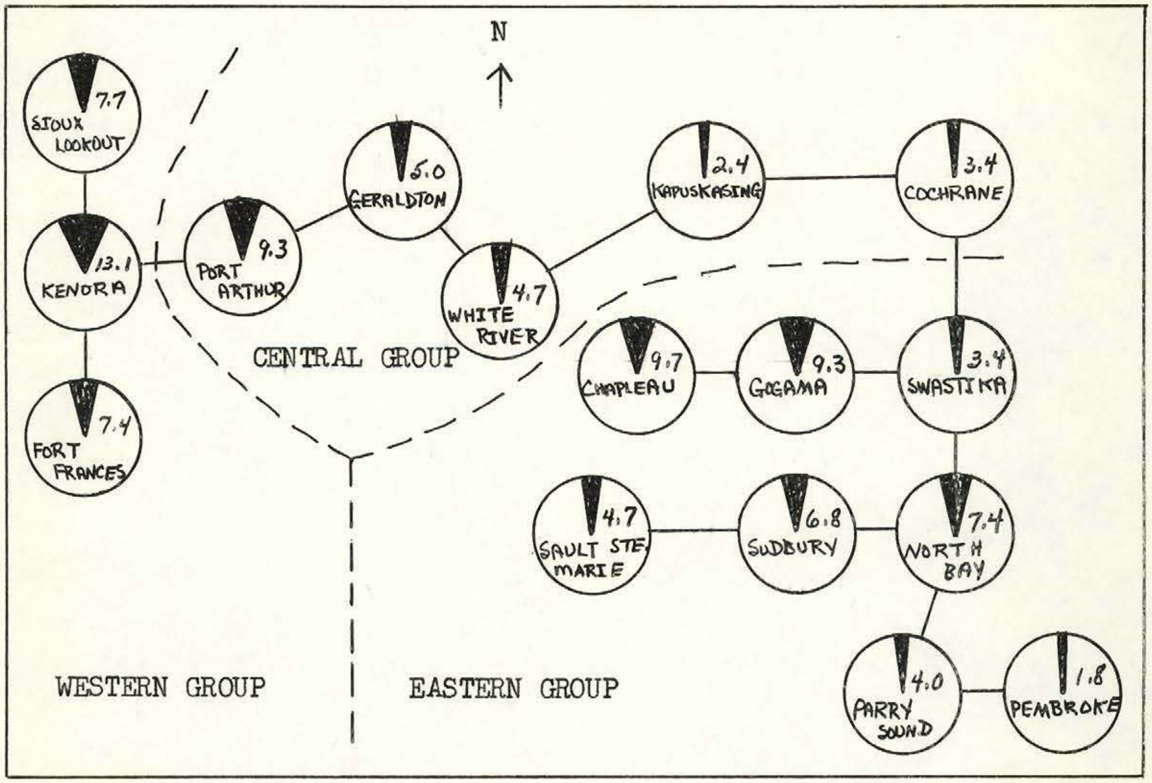

N
18.4
SIOUX LOOKOUT
19.8
GERALDTON
27.0
KAPUSKASING
27.1
COCHRANE
16.4
KENORA
23.1
PORT ARTHUR
12.8
WHITE RIVER
CENTRAL GROUP
18.5
CHAPLEAU
25.3
GOGAMA
29.1
SWASTIKA
20.9
FORT FRANCES
23.6
SAULT STE. MARIE
22.8
SUDBURY
15.9
NORTH BAY
WESTERN GROUP
EASTERN GROUP
11.9
PARRY SOUND
0.8
PEMBROKE

Fig. 6. Cartograph showing the proportion of total jack pine primary growing stock occurring in northern Ontario forest districts.

Fig. 7. Cartograph showing the proportion of total collections from jack pine, 1952-1958, inclusive, occurring in northern Ontario forest districts.


N
SIOUX LOOKOUT 27.4
KENORA 11.9
FORT FRANCES 5.8
PORT ARTHUR 10.4
GERALDTON 7.9
WHITE RIVER 4.5
KAPUSKASING 4.0
COCHRANE 2.7
CENTRAL GROUP
CHAPLEAU 8.7
GOGAMA 6.5
SWASTIKA 3.4
SAULT STE. MARIE 2.0
SUDBURY 2.8
NORTH BAY 1.3
WESTERN GROUP
EASTERN GROUP
PARRY SOUND 0.2
PEMBROKE 0.7

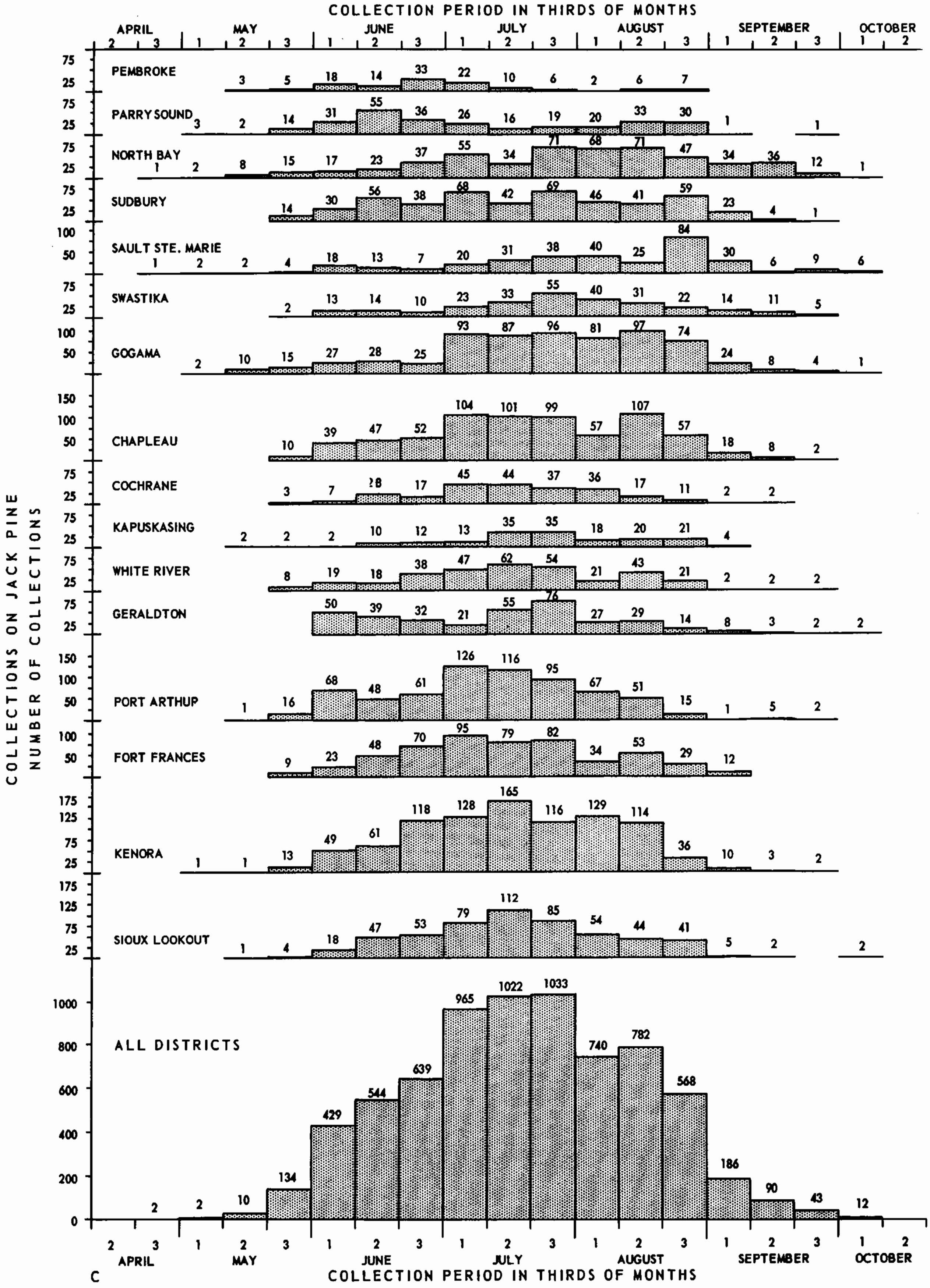

N
SIOUX LOOKOUT 7.7
KENORA 13.1
FORT FRANCES 7.4
PORT ARTHUR 9.3
GERALDTON 5.0
WHITE RIVER 4.7
KAPUSKASING 2.4
COCHRANE 3.4
CENTRAL GROUP
CHAPLEAU 9.7
GOGAMA 9.3
SWASTIKA 3.4
SAULT STE. MARIE 4.7
SUDBURY 6.8
NORTH BAY 7.4
WESTERN GROUP
EASTERN GROUP
PARRY SOUND 4.0
PEMBROKE 1.8

It may be argued that this distribution feature is an artifact resulting from causes such as lack of sampling in the area, or, if sampling in the area took place, that the timing was such that swainei was missed. From 1952 to 1958, inclusive, some 7,200 collections were made on jack pine in northern Ontario. In Fig. 7 each circle represents the total number of collections for all districts and the shaded sector the proportion of that total received from the respective district. It may be concluded that there was no lack of sampling on jack pine in the central group of districts. The seasonal distribution of sampling on jack pine is shown in Fig. 8 and there is little difference between districts where sampling has indicated swainei to be scarce and those where it has been found commonly. A consideration of records for years previous to 1952 would not change the picture appreciably and it may be concluded that there is some factor other than host tree abundance restricting the occurrence of N. swainei in Ontario north and east of Lake Superior.

Recent forest inventories for Quebec are lacking, the best information available appearing to be that of Halliday and Brown (1943), and also the sawfly records do not permit the kind of analysis undertaken for Ontario.

In the American Lake States, Minnesota has a large area within the natural range of jack pine. Cunningham, Horn and Quinney (1958) have published a recent forest inventory for this state,

Fig. 8. Seasonal distribution of collection dates for jack pine sampling in Northern Ontario forest districts, 1952 - 1958, inclusive.


COLLECTION PERIOD IN THIRDS OF MONTHS
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
2 3 1 2 3 1 2 3 1 2 3 1 2 3 1 2 3 1 2
COLLECTIONS ON JACK PINE
NUMBER OF COLLECTIONS
PEMBROKE
3 5 18 14 33 22 10 6 2 6 7
PARRY SOUND
3 2 14 31 55 36 26 16 19 20 33 30 1 1
NORTH BAY
1 2 8 15 17 23 37 55 34 71 68 71 47 34 36 12 1
SUDBURY
14 30 56 38 68 42 69 46 41 59 23 4 1
SAULT STE. MARIE
1 2 2 4 18 13 7 20 31 38 40 25 84 30 6 9 6
SWASTIKA
2 13 14 10 23 33 55 40 31 22 14 11 5
GOGAMA
2 10 15 27 28 25 93 87 96 81 97 74 24 8 4 1
CHAPLEAU
10 39 47 52 104 101 99 57 107 57 18 8 2
COCHRANE
3 7 18 17 45 44 37 36 17 11 2 2
KAPUSKASING
2 2 2 10 12 13 35 35 18 20 21 4
WHITE RIVER
8 19 18 38 47 62 54 21 43 21 2 2 2
GERALDTON
50 39 32 21 55 76 27 29 14 8 3 2 2
PORT ARTHUP
1 16 68 48 61 126 116 95 67 51 15 1 5 2
FORT FRANCES
9 23 48 70 95 79 82 34 53 29 12
KENORA
1 1 13 49 61 118 128 165 116 129 114 36 10 3 2
SIOUX LOOKOUT
1 4 18 47 53 79 112 85 54 44 41 5 2 2
ALL DISTRICTS
2 2 10 134 429 544 639 965 1022 1033 740 782 568 186 90 43 12
0 200 400 600 800 1000
25 50 75 100 125 150 175
2 3 1 2 3 1 2 3 1 2 3 1 2 3 1 2 3 1 2
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
C
COLLECTION PERIOD IN THIRDS OF MONTHS

dividing it into three divisions, Northeastern, Southeastern, and Western. Nearly all of the natural range of jack pine in the state falls within their Northeastern division, and the commercial range of jack pine in the state as given by Rudolf (1958) appears to be entirely in this division. The net volume of live, jack pine sawtimber on commercial forest land is distributed among the three divisions as follows: Northeastern, 97 per cent; Southeastern, 1 per cent; Western, 2 per cent. Jack pine constitutes about 11 per cent of all live sawtimber and growing stock on commercial forest land in the state. Lack of jack pine cannot be the reason for so few <u>swainei</u> records in Minnesota. The concentration of records in northwestern Ontario stops abruptly at the Ontario-Minnesota border and it must be concluded that insufficient sampling is the cause of poor representation in the sawfly's distribution in Minnesota.

In Wisconsin, also with few <u>swainei</u> records, jack pine represents about 3 per cent of the net volume of growing stock on commercial forest land, according to Cunningham et <u>al</u> (1956). Here as in Minnesota it is evident that <u>swainei</u> is more common than existing records indicate. Michigan presents essentially the same situation.

In Canada and United States east of the Great Lakes-St. Lawrence system there is little jack pine and the distribution is very broken. Eastern New Brunswick has the highest proportion of jack pine in the section with 3 to 4 per cent of the timber volume (4 inches and up) being represented by this species (New Brunswick Dept. Lands and Mines, personal communication). In northwestern

New Brunswick and west to the St. Lawrence River near Rimouski in Quebec there are only widely separated stands. *Neodiprion swainei* is present in the Quebec portion, but absent from all of New Brunswick.

Jack pine is a rare tree throughout its range in Nova Scotia except in Cumberland County where it is common (Roland, 1945). New York, New Hampshire, Vermont and Maine officials all reported that jack pine is a rare tree in these states, in fact in Vermont it is a protected plant under the state Rare Plant Law. It is unlikely that *N. swainei* occurs in any of these areas and the vague New York reference must be considered invalid unless more evidence is forthcoming. Pitch pine, *Pinus rigida* Mill., is a more common species in these areas and harbours another species of *Neodiprion* that may have been confused with *swainei*, particularly until the publication of Ross' 1955 generic revision.

Also of interest is the fact that while *N. swainei* is known to occur in jack pine plantations located within the natural range of this tree, many large and long established plantings in southern Ontario are free of the sawfly despite intensive surveys.

In summary it may be said that the southern limit of *N. swainei* distribution from lake Winnipeg to the mouth of the Saguenay River coincides with the natural limit of its host tree, the jack pine. In the north the sawfly appears to be checked before extending to the northern limit of the distribution of jack pine and is uncommon in some areas where jack pine is an abundant species.

3. OCCURRENCE IN RELATION TO FOREST COMPOSITION

It seemed that a consideration of forest composition might lead to a better understanding of N. swainei distribution, particularly in its northern extensions. Again because of better information the Ontario conditions are described.

Figure 9 illustrates the forest composition in northern Ontario. The value for each species in a district was calculated from the volumes given in the Forest Resources Inventories. The most evident feature is the great diversity of the forest in the districts comprising the eastern group where swainei is common. Sugar maple and yellow birch are abundant while black spruce does not comprise as large a proportion of the primary growing stock as in the remaining districts. In the central group of districts black spruce is the most abundant species and the number of major tree species is reduced. Districts in the western group appear to be intermediate between the two conditions already described. It seems that the Swaine jack-pine sawfly is not common where more boreal conditions exist.

4. OCCURRENCE IN RELATION TO THAT OF NEODIPRION VIRGINIANUS COMPLEX IN ONTARIO

Forest Insect Survey records in Ontario indicate that N. virginianus complex (= rugifrons Midd., = dubiosus Schedl in

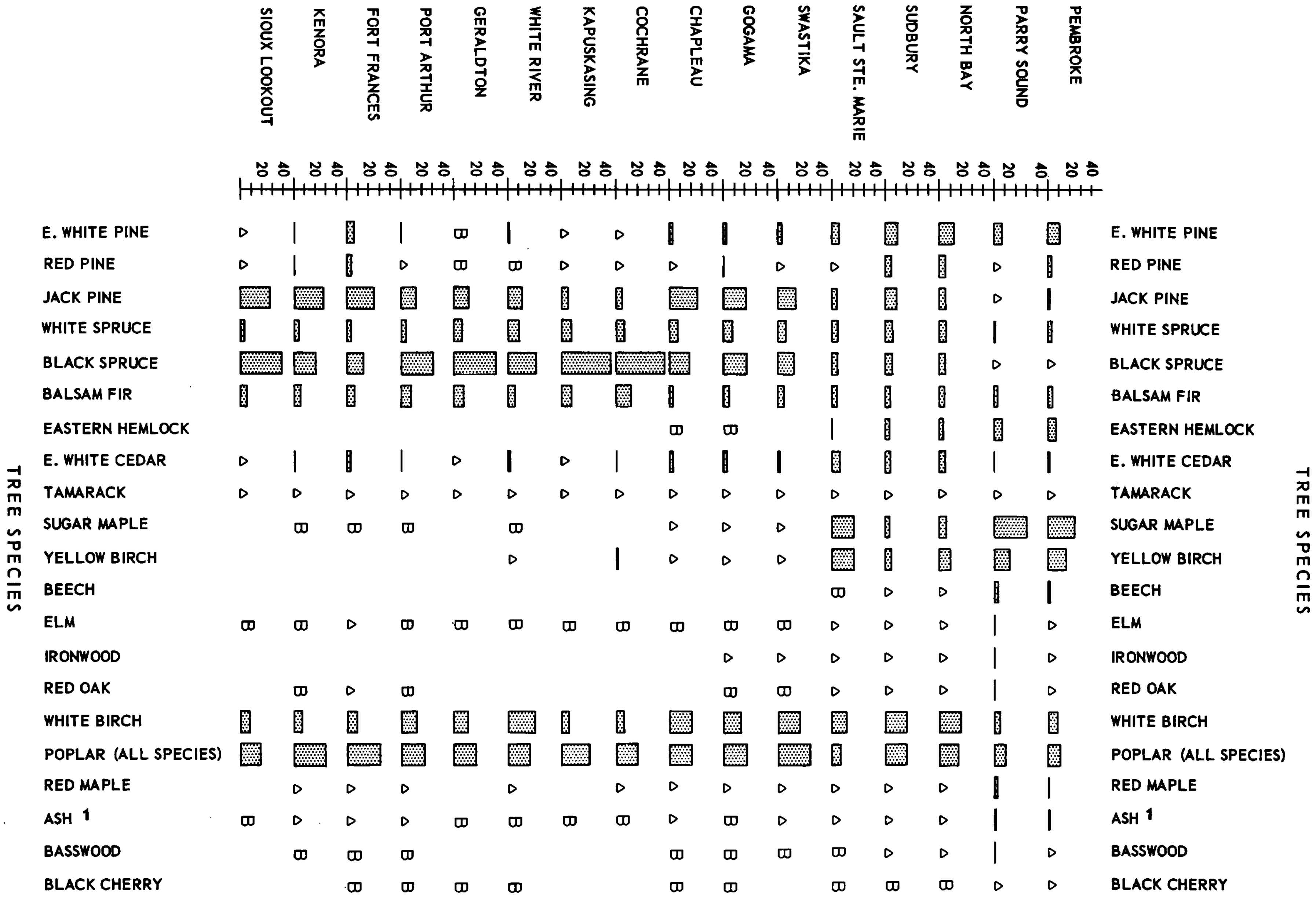
Fig. 9. Forest composition in northern Ontario forest districts, volume of primary growing stock for each species expressed as per cent of total district primary growing stock.

B indicates that the district is within the botanical range of the species, but that the species is not present in suitable form or sufficient quantity to be inventoried.

△ indicates less than 1.0 per cent.

[1] The botanical range of black ash was used for the ash range.

PER CENT PRIMARY GROWING STOCK BY FOREST DISTRICT



Ontario) occurs all across the northern part of the Province even where *swainei* is rare. *N. virginianus* is almost entirely restricted to jack pine in the area in question and it seemed profitable to investigate the differences between the two species responsible for the differences in distribution.

Figure 5 is a cartograph prepared from *virginianus* records for the years 1952 - 1958 in the same manner as that for *swainei* shown in Fig. 4. The uniform occurrence on a district basis is evident. A map of *virginianus* distribution (Fig. 10) in Ontario was prepared as for *swainei* to make certain that the records were not clumped.

The next step was to see if the stand conditions where collections of *swainei* and *virginianus* were made were comparable. Figures 11A, B, and C show the percentage distribution of sample trees for diameter at breast height (4.5 feet above ground level) for *swainei* samples, *virginianus* samples, and all jack pine sampled, respectively. *N. swainei* has been collected less frequently on small trees than *virginianus*. Values for stand form are illustrated in the same manner in Figs. 12A, B, and C. Here it is noticeable that *swainei* has been found considerably more frequently in immature-pole type stands than *virginianus*, the latter being more common than *swainei* on reproduction and in plantations. The conditions of exposure of the feeding sites are shown in Figs. 13A, B, and C. No differences are apparent. Figures 14 A to C illustrate the data

Fig. 10. Map showing the Ontario distribution of N. virginianus complex. Compiled from records for the period 1952-1958, inclusive.

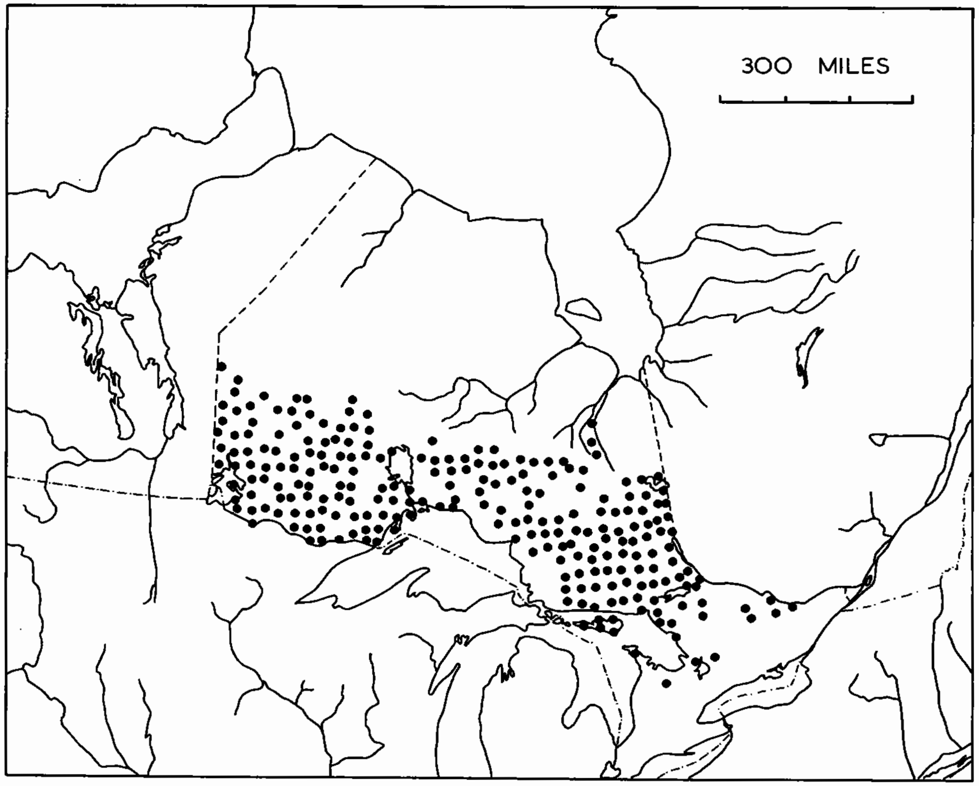

300 MILES

Fig. 11A. Per cent frequency distribution of D.B.H. for all collections from jack pine containing _N. swainei_, 1952-1958, inclusive.

B. Per cent frequency distribution of D.B.H. for all collections from jack pine containing _N. virginianus_, 1952-1958, inclusive.

C. Per cent frequency distribution of D.B.H. for all collections from jack pine, 1952-1958, inclusive.

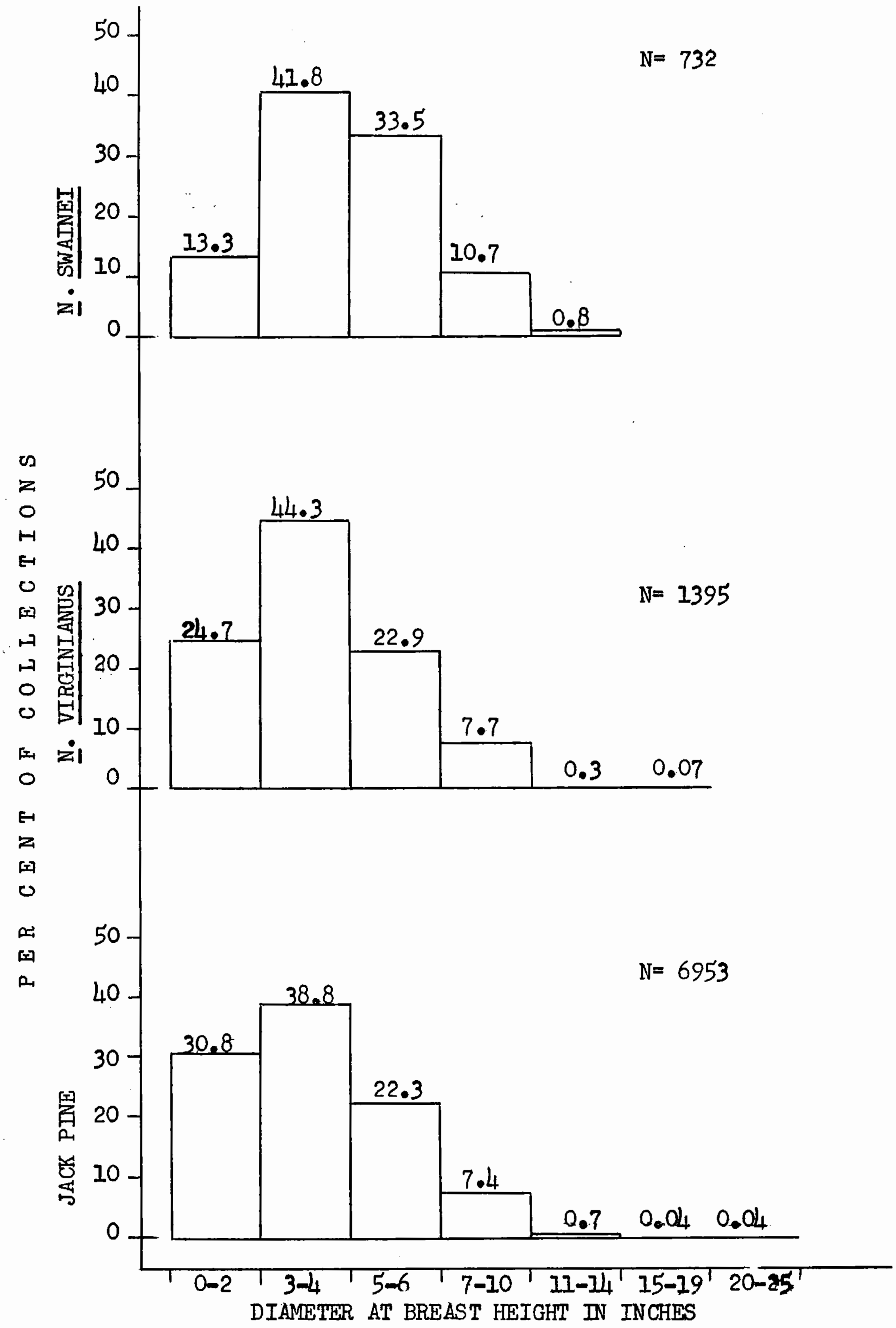

PER CENT OF COLLECTIONS
N. SWAINEI
N= 732
50
40
30
20
10
0
13.3
41.8
33.5
10.7
0.8
N. VIRGINIANUS
N= 1395
50
40
30
20
10
0
24.7
44.3
22.9
7.7
0.3
0.07
JACK PINE
N= 6953
50
40
30
20
10
0
30.8
38.8
22.3
7.4
0.7
0.04
0.04
0-2
3-4
5-6
7-10
11-14
15-19
20-25
DIAMETER AT BREAST HEIGHT IN INCHES

Fig. 12A. Per cent frequency distribution of stand form for all collections from jack pine containing _N. swainei_, 1952-1958, inclusive.

B. Per cent frequency distribution of stand form for all collections from jack pine containing _N. virginianus_, 1952-1958, inclusive.

C. Per cent frequency distribution of stand form for all collections from jack pine, 1952-1958, inclusive.

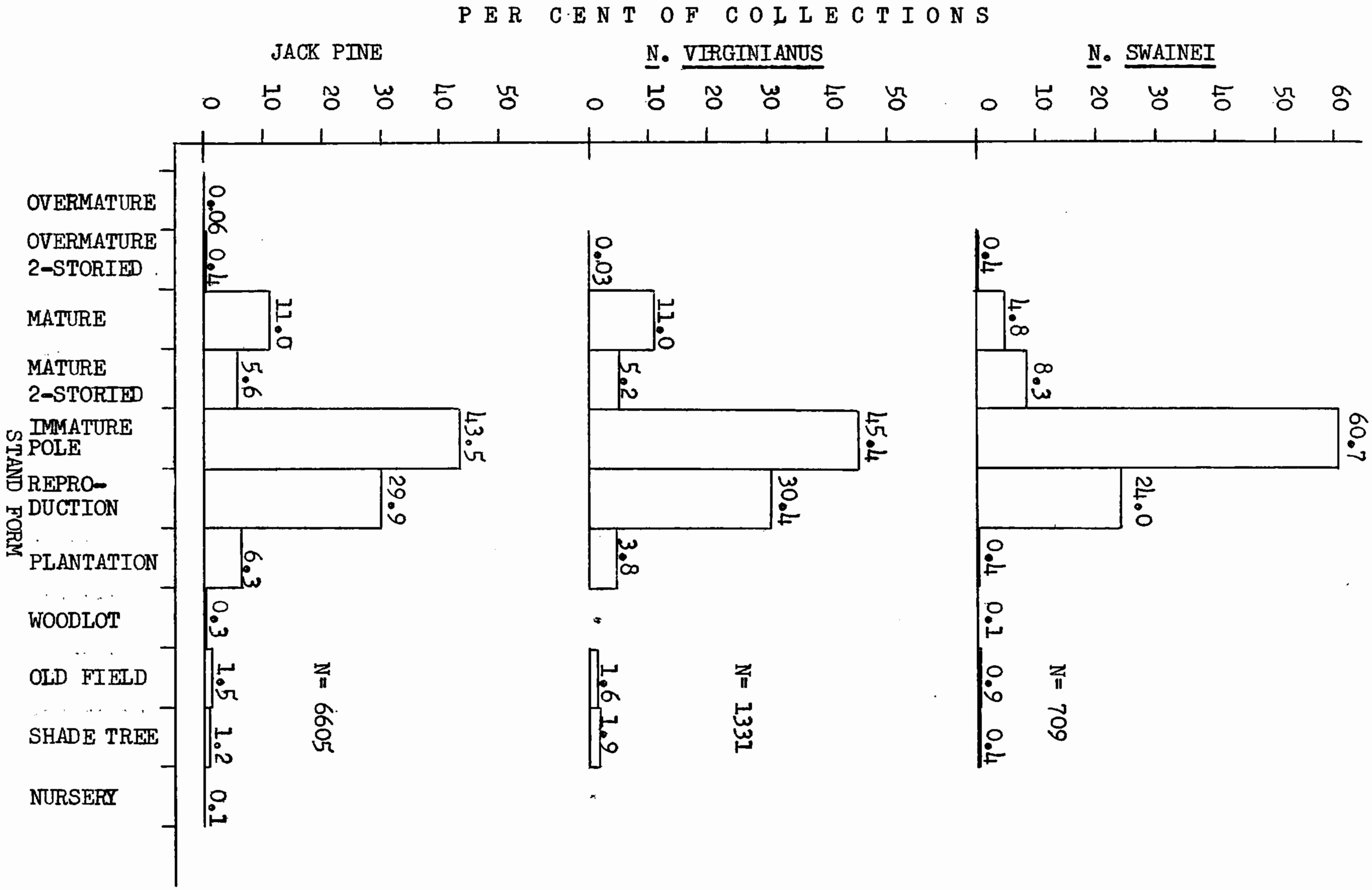

PER CENT OF COLLECTIONS
JACK PINE
N. VIRGINIANUS
N. SWAINEI
0
10
20
30
40
50
60
STAND FORM
OVERMATURE
OVERMATURE 2-STORIED
MATURE
MATURE 2-STORIED
IMMATURE POLE
REPRO-DUCTION
PLANTATION
WOODLOT
OLD FIELD
SHADE TREE
NURSERY
0.06
0.4
11.0
5.6
43.5
29.9
6.3
0.3
1.5
1.2
0.1
N= 6605
0.03
11.0
5.2
45.4
30.4
3.8
1.6
1.9
N= 1331
0.4
4.8
8.3
60.7
24.0
0.4
0.1
0.9
0.4
N= 709

Fig. 13A. Per cent frequency distribution of exposure for all collections from jack pine containing N. swainei, 1952-1958, inclusive.

B. Per cent frequency distribution of exposure for all collections from jack pine containing N. virginianus, 1952-1958, inclusive.

C. Per cent frequency distribution of exposure for all collections from jack pine, 1952-1958, inclusive.

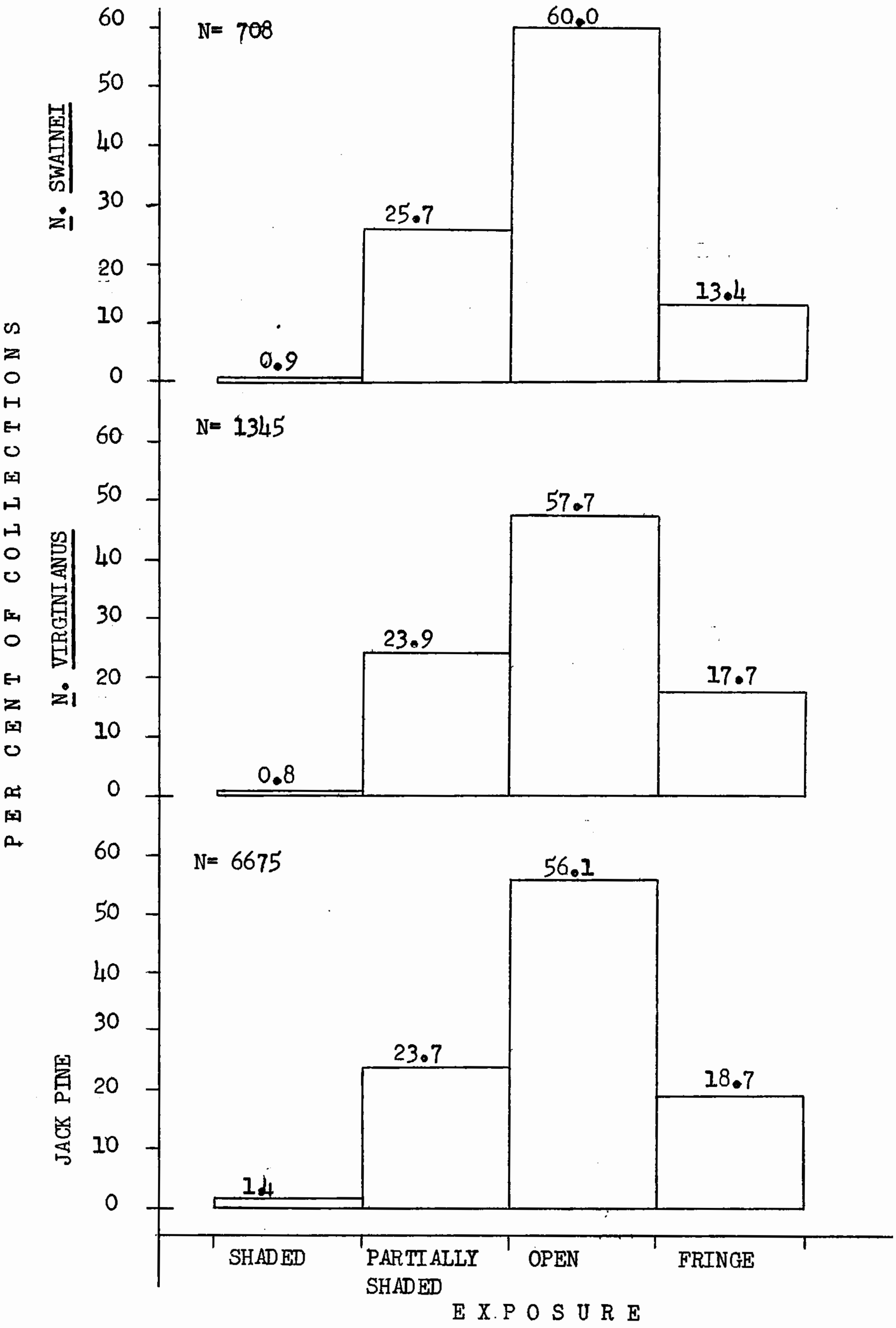
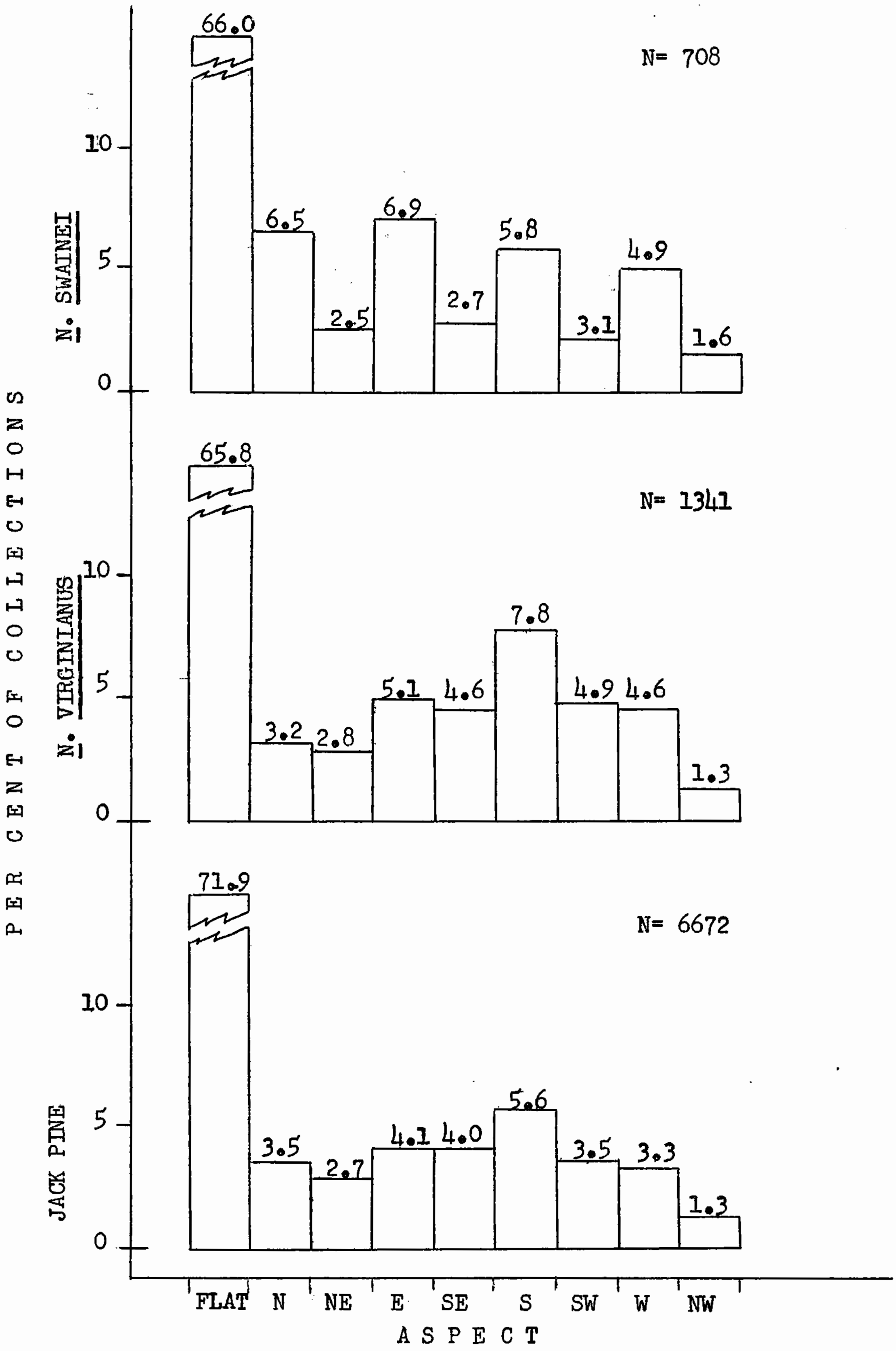

PER CENT OF COLLECTIONS
N. SWAINEI
N= 708
60
50
40
30
20
10
0
0.9
25.7
60.0
13.4
N. VIRGINIANUS
N= 1345
60
50
40
30
20
10
0
0.8
23.9
57.7
17.7
JACK PINE
N= 6675
60
50
40
30
20
10
0
1.4
23.7
56.1
18.7
SHADED
PARTIALLY SHADED
OPEN
FRINGE
EXPOSURE

Fig. 14A. Per cent frequency distribution of aspect for all collections from jack pine containing _N. swainei_, 1952-1958, inclusive.

B. Per cent frequency distribution of aspect for all collections from jack pine containing _N. virginianus_, 1952-1958, inclusive.

C. Per cent frequency distribution of aspect for all collections from jack pine, 1952-1958, inclusive.


PER CENT OF COLLECTIONS
N. SWAINEI
N= 708
0
5
10
66.0
6.5
2.5
6.9
2.7
5.8
3.1
4.9
1.6
N. VIRGINIANUS
N= 1341
0
5
10
65.8
3.2
2.8
5.1
4.6
7.8
4.9
4.6
1.3
JACK PINE
N= 6672
0
5
10
71.9
3.5
2.7
4.1
4.0
5.6
3.5
3.3
1.3
FLAT
N
NE
E
SE
S
SW
W
NW
ASPECT

for aspect of the collecting sites. The greatest proportion, about 65 per cent, of records for both species have been made from trees growing on flat sites. The remaining third in swainei was about equally distributed over all slopes while in virginianus it shows a concentration for south slopes. These records were examined when grouped according to three regions, east, central and west, and no great differences were found.

It may be concluded from these comparisons that swainei and virginianus often occur on the same type of tree growing under similar conditions, in fact in the eastern and western groups of districts they may occur together on jack pine at the same time.

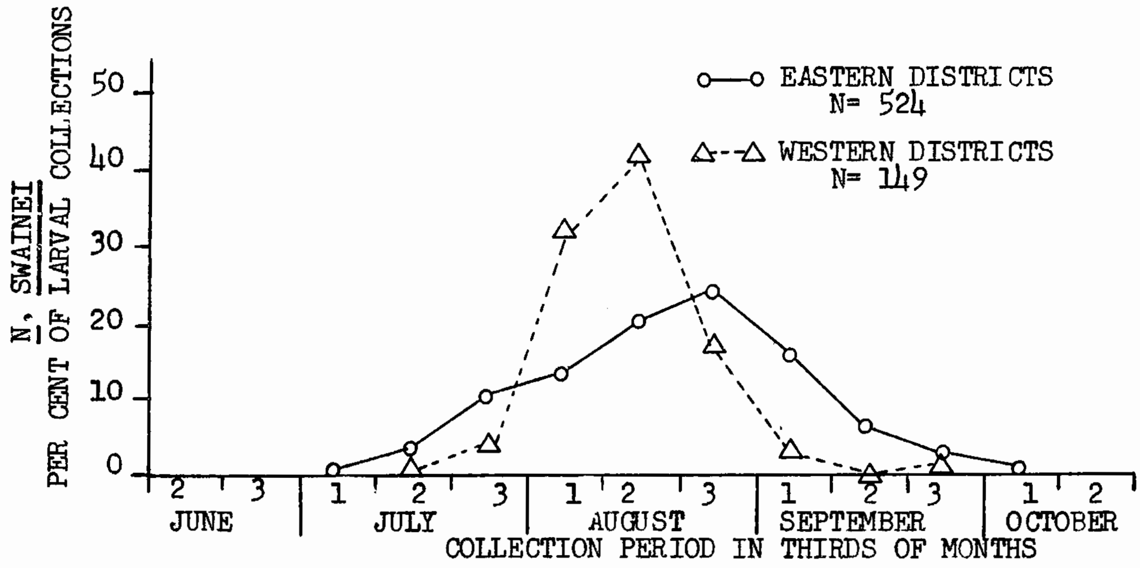
A brief discussion of the general similarity of the two species is necessary at this point. They are distinct anatomically; the female adults and mature feeding larvae are easily distinguished. While swainei lays single eggs in new foliage, virginianus lays rows of eggs in the year-old needles. They belong to distinct evolutionary stems (Ross, 1955). Despite these differences there is an important similarity in that both overwinter as cocooned, prepupal larvae and have a similar seasonal history (Schedl, 1937).

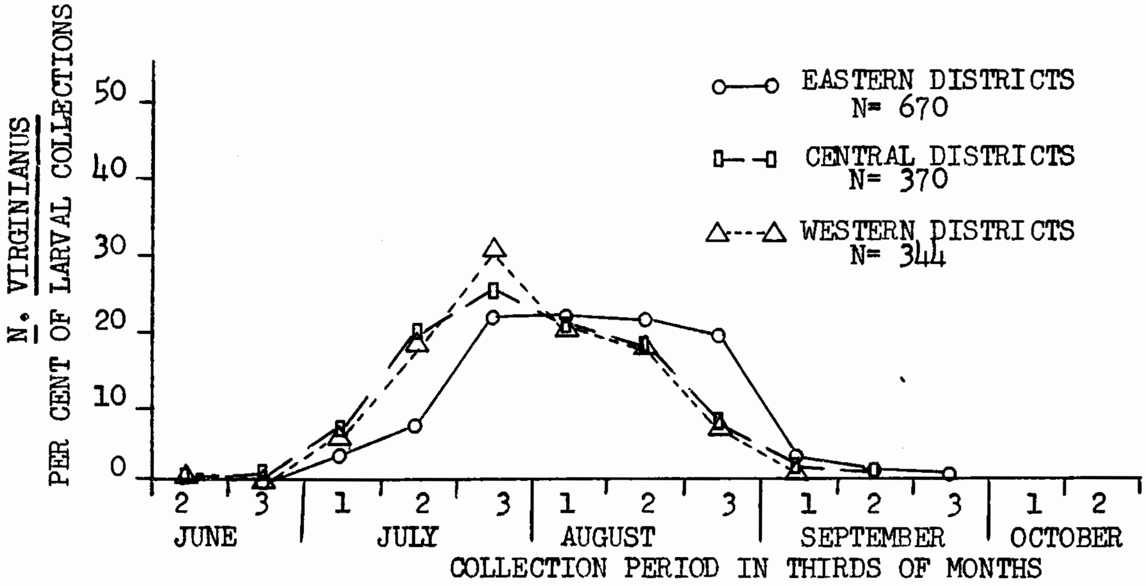
It is in the slight differences in seasonal history between the two species that the key to swainei occurrence may be found. The majority of Survey collections contain nearly mature larvae because these reach the laboratory in better condition than younger larvae and usually do not require rearing for identification as is in the case of young larvae or cocoons. Figures 15 and 16 illustrate

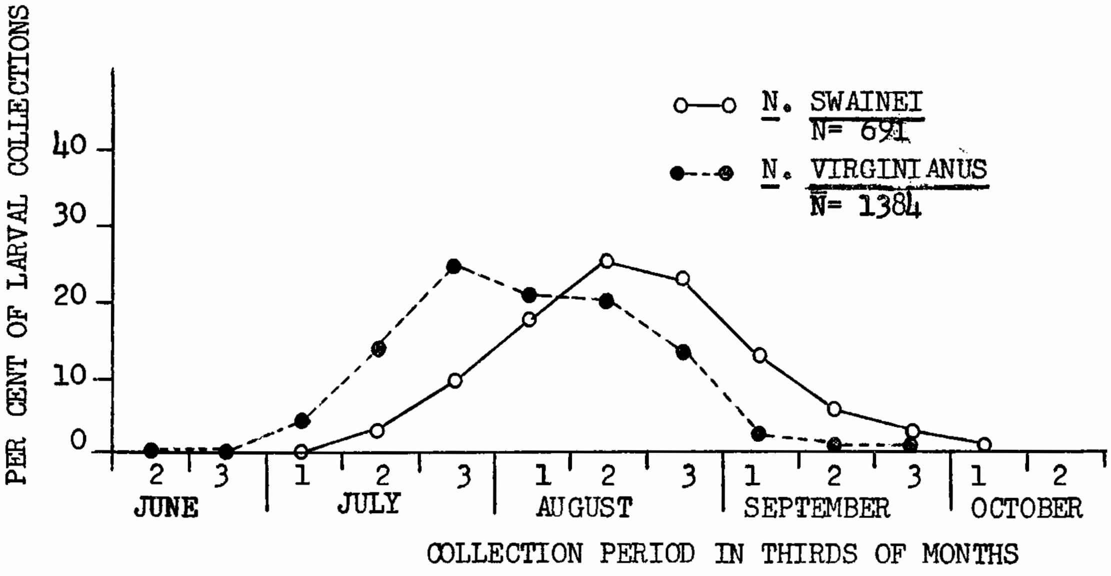
Fig. 15. Per cent frequency distribution for seasonal occurrence of larval collections of *N. swainei* for eastern and western groups of northern Ontario districts, 1952-1958, inclusive.

Fig. 16. Per cent frequency distribution for seasonal occurrence of larval collections of *N. virginianus* for eastern, central, and western groups of northern Ontario districts, 1952-1958, inclusive.

Fig. 17. Per cent frequency distribution for seasonal occurrence of larval collections of *N. swainei* and *N. virginianus* for all northern Ontario districts, 1952-1958, inclusive.


EASTERN DISTRICTS
N= 524
WESTERN DISTRICTS
N= 149
N. SWAINEI
PER CENT OF LARVAL COLLECTIONS
50
40
30
20
10
0
2
3
1
2
3
1
2
3
1
2
3
1
2
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
COLLECTION PERIOD IN THIRDS OF MONTHS

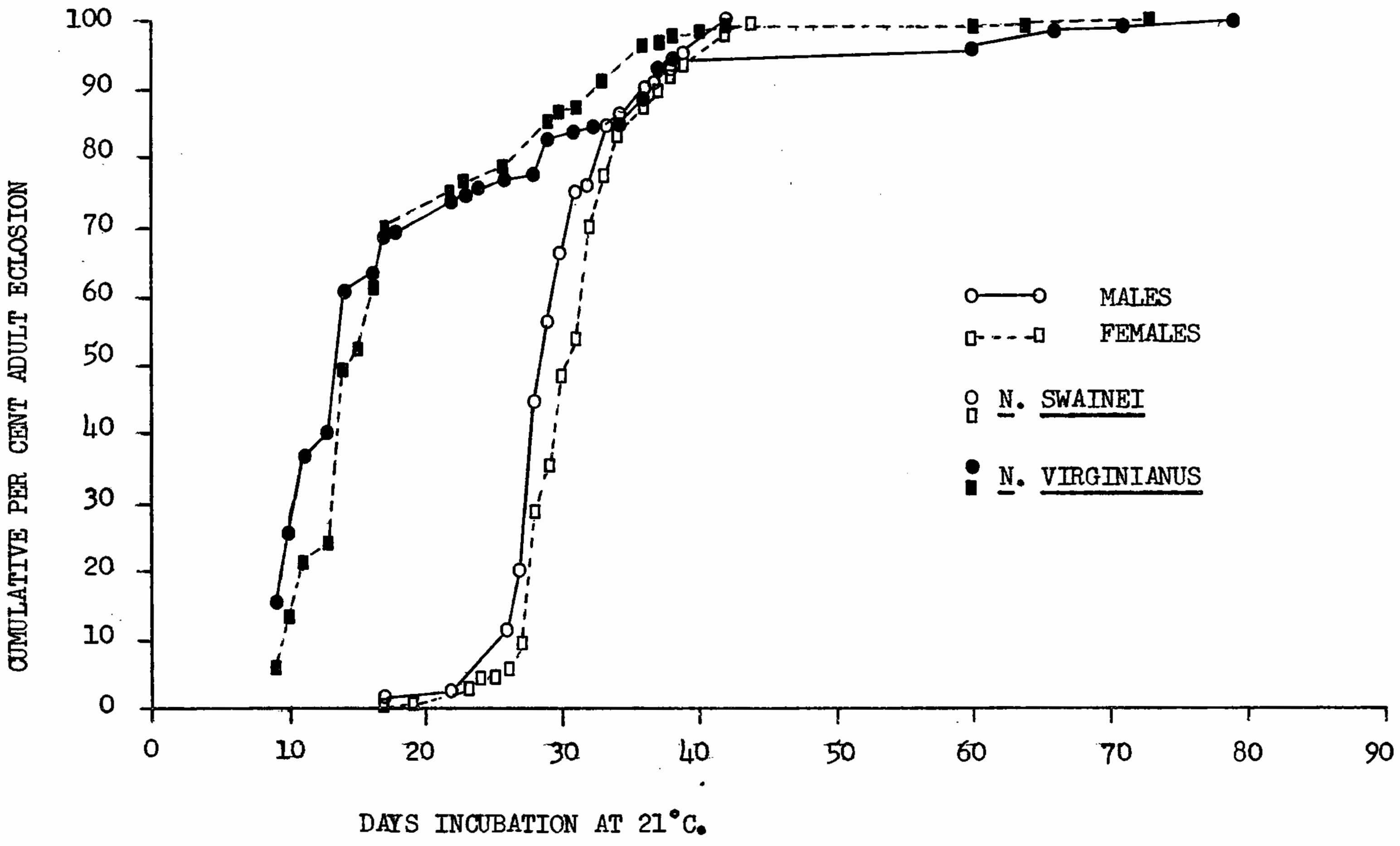

EASTERN DISTRICTS
N= 670
CENTRAL DISTRICTS
N= 370
WESTERN DISTRICTS
N= 344
N. VIRGINIANUS
PER CENT OF LARVAL COLLECTIONS
50
40
30
20
10
0
2
3
1
2
3
1
2
3
1
2
3
1
2
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
COLLECTION PERIOD IN THIRDS OF MONTHS


N. SWAINEI
N= 691
N. VIRGINIANUS
N= 1384
PER CENT OF LARVAL COLLECTIONS
40
30
20
10
0
2
3
1
2
3
1
2
3
1
2
3
1
2
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
COLLECTION PERIOD IN THIRDS OF MONTHS

the seasonal distribution of larval collections of swainei and virginianus, respectively. Data for each of the three regions is plotted separately. In Fig. 15 note the peaked form of the distribution with maxima occurring in the second and last thirds of August for western and eastern districts, respectively. Figure 16 for virginianus shows a different picture with a distinct plateau in larval occurrence, particularly for the eastern districts. The maxima are in the third portion of July. Data for all districts are combined in Fig. 17 for a comparison of the two species. The early nature of virginianus in relation to swainei is evident as is the difference in form already described.

Brown and Daviault (1942) showed a slightly higher (10.9°C as against 9°C) theoretical threshold for morphogenesis following overwintering in dubiosus (=virginianus)than in swainei, but gave a thermal constant of 157 day-degrees against 352 to 362 day-degrees for swainei. Analysis of Survey rearing records for 1956 (all areas) for material of these two species treated identically in the laboratory supports Brown and Daviault's conclusions. Figure 18 shows cumulative per cent adult eclosion curves calculated from these data. The swainei curves show normal sigmoid forms while the generally more rapidly developing virginianus has a more skewed distribution of eclosion with many stragglers. This ties in with the extended seasonal distribution of the larvae as shown in Figs. 16 and 17 and with data presented by Schedl (1937). The small variation in

Fig. 18. Cumulative per cent eclosion for adults reared from identically treated samples of _N. swainei_ and _N. virginianus_ from various Ontario localities, 1956.


MALES
FEMALES
N. SWAINEI
N. VIRGINIANUS
CUMULATIVE PER CENT ADULT ECLOSION
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
DAYS INCUBATION AT 21°C.

development rate in swainei is again illustrated in Figs. 19 and 20 using data from two large samples collected within 20 miles of one another in 1957. Schedl (1937) also showed that even allowing for microclimatic differences between locations and years, postembryonic development in virginianus is much more rapid than in swainei (39 days against 58 in 1931 at Biscotasing).

Development rate is thus seen to be one great difference between these two species.

5. OCCURRENCE IN RELATION TO CLIMATE

Chapman (1953) has provided a suitable characterization of the climate of northern Ontario for one to see if there is evidence for factors that might exclude a slow-developing species such as swainei from areas to the north and east of Lake Superior. Studying the figures showing isotherms of monthly normal temperature one sees that the areas where swainei is scarce have lower values for most months of the year. Winter temperatures probably have little direct effect on the insect because the cocoons are protected by a snow cover and the winter period appears to be more than ample to fulfill the diapause requirements even at relatively low temperatures. Colder winter temperatures do favour snow retention and coupled with lower spring temperatures, a later spring breakup results. There is evidence of this occurring in the central part of northern Ontario in the summaries of snow cover data published by the

Fig. 19. Mean incubation times for males and females in individual colonies of two samples of *N. swainei* compared with the mean incubation times for males and females in each sample irrespective of colony, 1957.

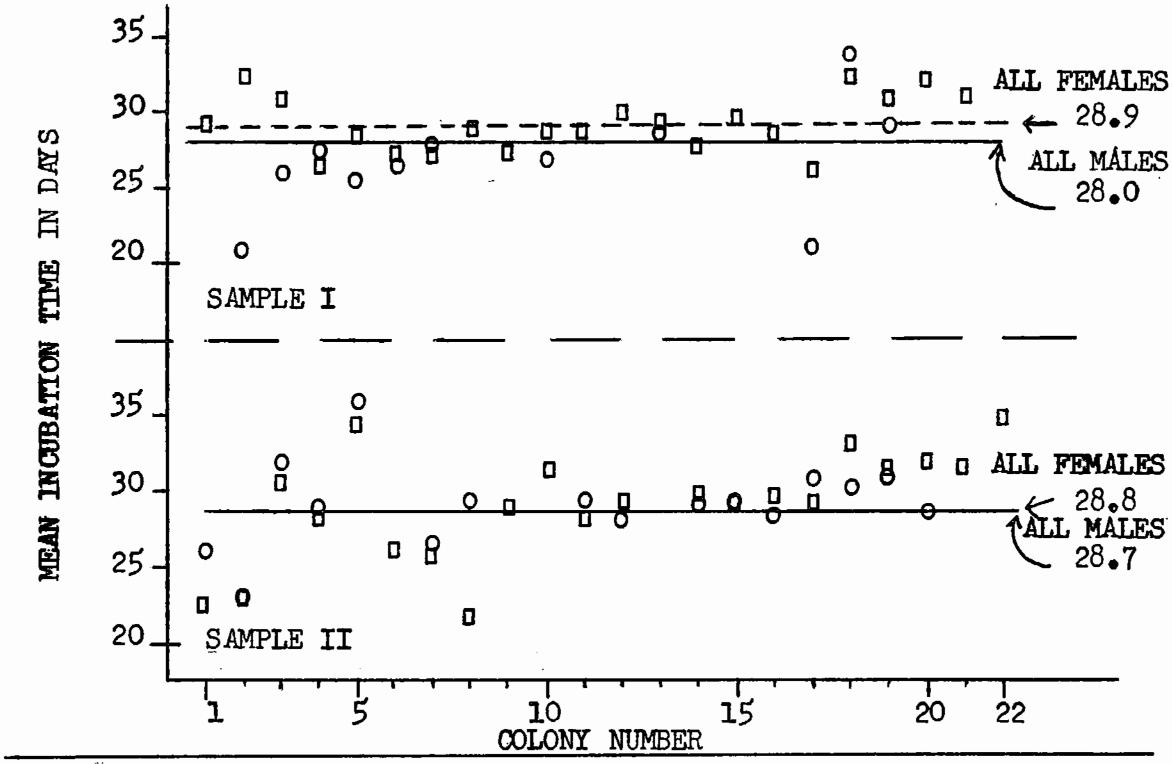
0 Males

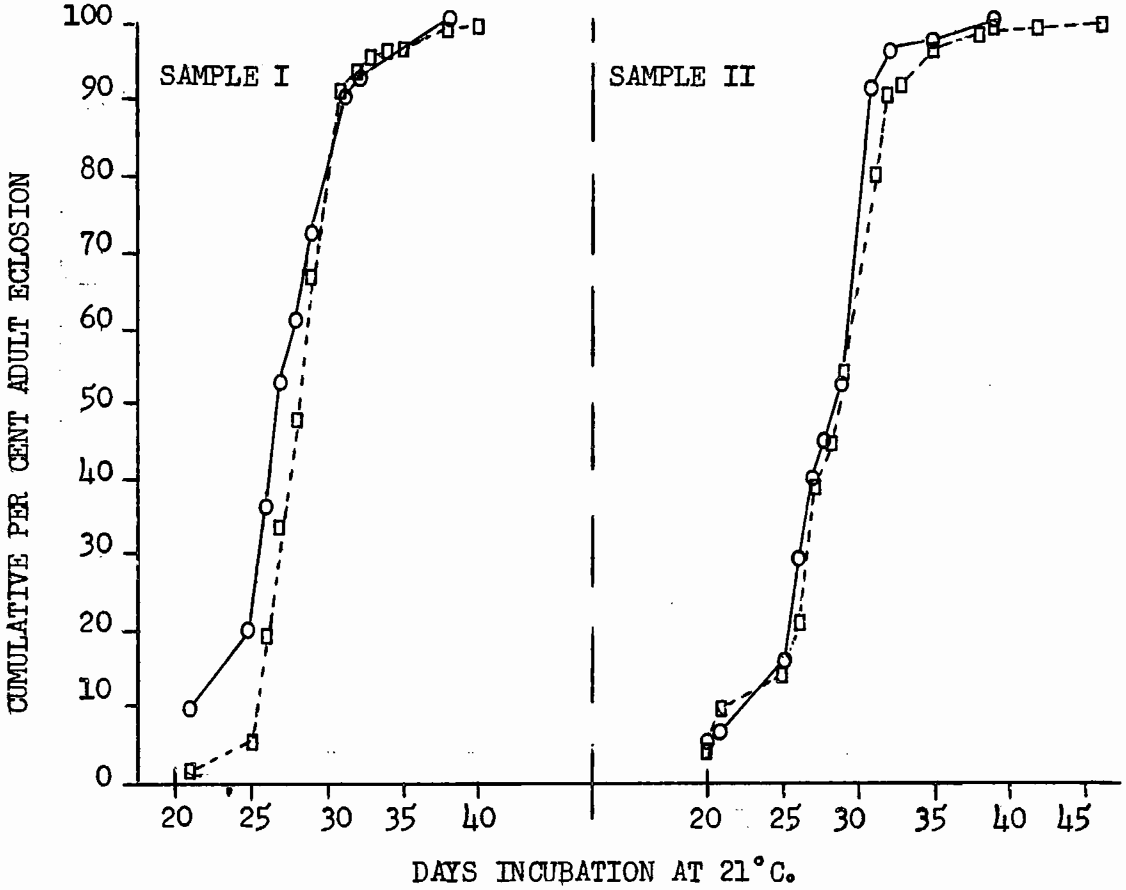
▯ Females

Fig. 20. Cumulative per cent eclosion for adults reared from two samples of *N. swainei*, 1957.

0——0 Males

▯---▯ Females


MEAN INCUBATION TIME IN DAYS
35
30
25
20
SAMPLE I
ALL FEMALES
28.9
ALL MALES
28.0
35
30
25
20
SAMPLE II
ALL FEMALES
28.8
ALL MALES
28.7
1
5
10
15
20
22
COLONY NUMBER


CUMULATIVE PER CENT ADULT ECLOSION
100
90
80
70
60
50
40
30
20
10
0
SAMPLE I
SAMPLE II
20
25
30
35
40
20
25
30
35
40
45
DAYS INCUBATION AT 21°C.

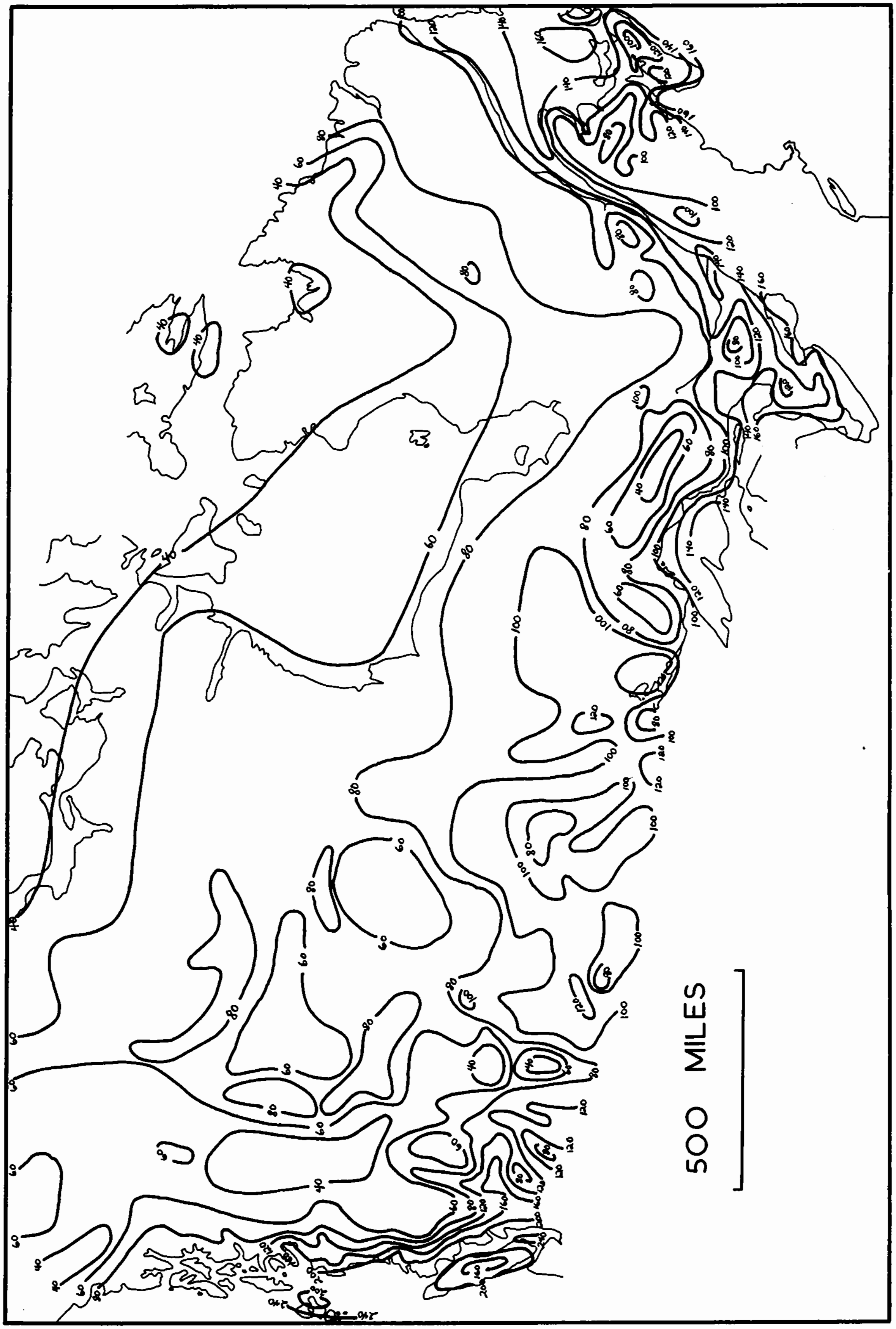
Meterological Branch, Canada Dept. of Transport, for the winters 1954-55 to 1957-58.

After a slower start, lower late spring and summer temperatures result in slowed development. Larvae present late in the season are adversely affected by cool weather since the main factor influencing feeding is temperature. This has been shown for *N. swainei* by Schedl (1939) and for *N. lecontei* (Fitch) and *N. pratti banksianae* Roh. by Green and DeFreitas (1955). In fact Schedl (1939) indicated that a proportion of the *swainei* population at Biscotasing in the two study years was overtaken by cool weather and unable to complete its development to prepupal larvae. Martineau and Beique (1956) stated that the short season in Quebec in 1956 was responsible for declines in population density of the Swaine jack-pine sawfly.

The area of northern Ontario in which *swainei* is uncommon comprises most of Chapman's Height of Land Region with a very short growing season in comparison to those of the Timiskaming-North Bay-Sault Ste. Marie and Rainy River-Thunder Bay regions where the insect is common. Figure 21, showing the mean annual frost free period (from Boughner, Longley and Thomas, 1956), has been chosen to illustrate the climatic differences in areas of potential *swainei* distribution.

It may be concluded that shortness of the warm season is the factor preventing *N. swainei* from utilizing jack pine in central northern Ontario. It is also suggested that *N. swainei* may be more widespread in northwestern Ontario and northern Manitoba than indicated

Fig. 21. Map showing mean annual frost free periods in Canada. From Boughner, Longley and Thomas, 1956.


500 MILES
40
60
80
100
120
140
160
200
40
60
80
100
120
140
160
40
60
80
100
120
140
40
60
80
100
120
140
160
200
240

in Fig. 1. The reasons for its absence in eastern New Brunswick are uncertain, but may involve a short-season area (Putnam, 1940) and discontinuous distribution of jack pine in the northwestern part of the province.

V. EXTERNAL ANATOMY OF THE MATURE, FEEDING LARVAE OF NEODIPRION SWAINEI

A. INTRODUCTION

The literature of entomology contains many descriptions of sawfly larvae, but few discuss any one species in detail. MacGillivray (1914) presented a general discussion of sawfly larval anatomy and biology, dealing with various features of many different species. Yuasa (1922) gave an account of sawfly larval anatomy in his systematic study of the larvae of the Tenthredineidea. This is one of the most valuable contributions in the field, but unfortunately he used the largely unacceptable system of nomenclature devised by MacGillivray. Middleton (1922) in his paper on Neodiprion lecontei (Fitch) proposed a useful system of nomenclature for the thorax and abdomen of sawfly larvae. Eliescu (1932) has given us another of the few anatomical works on diprionids, while Parker (1934) made a valuable contribution to our knowledge of larval anatomy in sawflies, dealing more fully with the head than other tagmata. Keys to the larvae of the families of Nearctic Symphyta and details of structure in many species have been presented by Peterson (1948). Lorenz and Kraus (1957) have made a major contribution to knowledge in their systematic treatise on European sawfly larvae.

In the description to follow I have used the terminology of DuPorte (1946, 1953) and DuPorte and Bigelow (1953) for the facial region of the head. Other head structures were named in accordance with Snodgrass (1935). The term epipharynx as generally applied has been replaced by palatum as suggested by Cook (1944). Integumental folds and protuberances of the thorax and abdomen have been named using Yuasa (1922) and Middleton (1922) as sources. The dorsal annulets of each segment have been consecutively numbered proceding caudad, while for lateral segmental areas I have used Middleton's terminology with some modification. He used the ending "ite" for indefinitely bounded, unsclerotized integumental areas. This is unacceptable and I have substituted the adjectival ending "al" and used his terms as modifiers of words such as area, lobe, and fold. Nomenclature of the thoracic legs follows Snodgrass (1935).

The quantitative expression of anatomical characteristics has been used where possible so that these results combined with those from continuing studies on all larval stages, on material from several geographic sources, and on other species may be treated mathematically using linear discriminant functions (Bigelow and Reimer, 1954) or multiple correlation analysis (Olson and Miller, 1958). It is hoped that quantitative techniques like the forementioned and those of Michener and Sokal (1957) may aid in clarifying the taxonomy of the genus Neodiprion.

B. MATERIALS AND METHODS

1. GENERAL

The larvae on which the anatomical investigation was based were reared from a group of egg clusters collected in the Lake Timagami area of Ontario (46° 57', 80° 00') on July 25, 1956. The collection is recorded as number 05-56-5553-01 at the Forest Insect Laboratory in Sault Ste. Marie. Each egg-bearing twig was placed in water in a suitable container and incubated at about 21°C and 65-70 per cent relative humidity. The majority of larvae hatched from the eggs on August 2 and rearing was continued in family groups placed on freshly-cut, year-old, jack pine foliage in eight ounce clear-glass ointment jars with ventilated lids. All rearing was done in as large groups as possible without mixing families because mortality among individually reared larvae is extremely heavy. This group rearing complicated observations on the number of stadia during larval development, but with careful attention it was possible to obtain suitable preserved material of each instar. Observations were made daily and fresh food supplied at least every second day. Up to ten larvae of each instar from each family were placed in Peterson's (1948) K. A. A. D. mixture and after twenty-four hours were rinsed with 95 per cent ethyl alcohol and placed in alcohol of the same strength for storage.

Additional mature, feeding, female larvae were preserved from four collections made on October 3, 1956, near Rocky Island Lake, Ontario (46°53', 83°00'). This material is recorded under numbers 05-56-8870-01, -8871-01, -8872-01, and -8873-01 at the Sault Ste. Marie laboratory. These larvae were used for dissection and in the preparation of the illustrations. The latter, however, were carefully checked against the Lake Timagami material so that they conform in all respects with specimens used for taking counts and measurements. Female larvae, also in the mature, feeding stage, from collection 05-58-8092-01 made on August 20, 1958, near Rocky Island Lake were used for sectioning.

Examinations were carried out using a Leitz stereo binocular microscope equipped with 1x, 2x, 4x, 8x, and 12x objectives, and 8x and 12.5x oculars. Drawings were made using a Whipple disk in one ocular and reproducing the image on five-to-the-inch (every fifth line accentuated) grid paper. Measurements were made with a Leitz screw micrometer incorporating a 12.5x ocular. Calibration of the ocular micrometer is given in Table I. It is possible to estimate to tenths of a drum interval when taking readings. Slides were examined using a Leitz "Ortholux" microscope. Only one set of measurements was taken with this instrument and the screw micrometer. A low power objective (3.5:1) was employed, giving a calibration factor of 0.0008907 millimeters per drum interval.

Each larva listed in Table II was examined according to the following routine. Observations on over-all length, head colour and pigmentation of the thorax and abdomen were recorded first. Structures on the ventral side of the prothorax were examined and then each thoracic leg was removed carefully and measurements of the leg segments taken. The head was removed next and set aside. The body of the larva was split along the ventral side on the left leg line with the slit continuing around the posterior end, through the anus, and into the epiproct on the middorsal line. This continuation of the ventral slit around the posterior end of the larva on to the dorsal surface was necessary because the larva is somewhat j-shaped, making flattening of the integument difficult. After completing the slit, the body of the larva was boiled for a few minutes in five per cent potassium hydroxide. With the specimen under water internal tissues were removed and the cuticula cleaned of adhering tracheal remains. The portion of the gut bearing the rectal teeth was retained for possible future examination. The clean cuticula was rinsed with water and flattened under a thin water covering. Then a few drops of acid fuchsin stock solution (0.5 gm. acid fuchsin, 25 ml. 10% HCl, 300 ml. distilled water) were added and mixed in by a gentle rocking of the Syracuse watchglass. The stain appeared to set the cuticula slightly, a factor facilitating subsequent handling. After about a minute the stain was removed with a pipette, being careful not to disturb the arrangement of the flattened cuticula. Rapid dehydration of the specimen was carried out using 50 per cent, 95 per cent, and absolute ethyl alcohol. During dehydration care was taken to ensure that the specimen remained flat since the alcohol caused hardening. After absolute alcohol, carbol-xylol was pipetted onto the specimen. This brought about a further setting of the cuticula in the desired arrangement. Finally the specimen was carried through xylol and mounted in Canada balsam with the ectal surface uppermost. Counts of sensilla styloconica were made using the Ortholux.

Cranial measurements and counts of setae on the frons, postantennal area and the genal margin were taken next. Then the labiomaxillary complex was removed and placed in five per cent potassium hydroxide on a warmplate overnight. The whole complex was mounted in Hoyer's Fluid with enough pressure placed on the coverslip to produce slight flattening. The labrum and labral palatum were dissected from the head and mounted in Hoyer's Fluid with the palatum uppermost. Slivers of coverglass were used to block up the coverslip thus ensuring uniform positioning of the specimen. The mandibles were removed from the head and their measurements taken. The cranium, although damaged, was retained, as were the thoracic legs and mandibles.

Larvae for sectioning were killed and fixed in Modified Kahle's fixative by dropping them living into the cold mixture and then heating gently until the fixative began to give off vapour, but did not bubble. While in the warm fixative the heads and legs were removed, the larvae slit down the midventral lines and the guts removed. Dehydration and clearing was by the n-butyl alcohol method outlined by Smith (1943). The material was embedded in 60-63°C Tissuemat. The tissue was sectioned at five microns and sections were stained in Mallory's triple connective tissue stain.

Counts of sensory structures were made when the type, size and area of occurrence were such that the variable could be defined with reasonable precision. For example, it was possible to make accurate counts of the sensilla styloconica on all of the body areas except the suranal and subanal areas which were usually torn and distorted during preparation of the slide. Counting them on the whole specimen would be difficult because of their position. The true setae, on the other hand, are much smaller than the sensilla styloconica, and are sparingly distributed. They are more numerous on the ventral areas of each segment, but there appears to be more than one general size and areas of occurrence are hard to define. No detailed counts of body setae were made in this study.

Measurements were restricted to the more heavily sclerotized parts and to dimensions for which the specimen could be well aligned. The magnification used was the greatest with which the dimension being measured would lie within the range of the micrometer and at the same time provide sufficient depth of field to allow the whole part being measured to be seen clearly.

All measurements refer to a plane projection of the structures being measured and this introduces one of the major errors. This error is termed foreshortening and occurs when the imaginary line joining the two end points of the dimension being measured is not parallel to the optical plane of measurement. It is always a negative error. A second and almost equally important error of the same type is introduced if the micrometer index line is not exactly at right angles to the imaginary line joining the two end points of the dimension being measured. A third error, that of starting and stopping the travel of the micrometer index line exactly at the end points of the dimension being measured, may be either positive or negative and usually is small, although the magnitude does depend on the exactness of the end points that have been chosen. In order that the best results may be obtained, the final value should be selected from those taken in several series of measurements. After alignment of the specimen, a number of pairs of readings should be made with adjustment of the micrometer between each pair. The specimen should be realigned a few times and sets of measurements made after each change. With each alignment the aim should be to achieve the ideal relation between object, the optical plane of measurement, and the micrometer index line. Then the largest reading obtained will be the closest to the actual dimension on the specimen, unless the smaller third source of error mentioned previously is positive and such high accuracy has been achieved that it is greater than all the foreshortening errors. Several series of length measurements of the anterior aspect of the right prothoracic coxite of specimen number seven, a fifth instar female larva, were made at 50x magnification and may be used to illustrate the foregoing statements. Four measurements were taken without changing the alignment of either specimen or micrometer and the variation among them represents error from positioning the micrometer index line. The range of these four values was from 597.2 to 597.8, or 0.5 micrometer divisions. Four measurements were made without realigning the specimen, but the micrometer index line was adjusted for normalacy to the dimension being evaluated. The range in this series was from 595.7 to 598.1, or 2.4 micrometer divisions. Then four measurements were made with both alignments being adjusted between each. Here the range was from 586.2 to 597.9, or 11.7 micrometer divisions. Finally the same measurement was made with four different alignments of the specimen and with four different alignments of the micrometer for each positioning of the specimen. The greatest length obtained was 600.4 micrometer divisions. Assuming this latter value to be the true size of the dimension being measured, the error for the smallest (586.2) of any of the 28 values obtained is only 2.4 per cent, a negligible proportion. It must be remembered, however, that the error component will vary with the part being measured.

It was decided that specimen and micrometer be aligned as carefully as possible and only a single measurement made. Holes and grooves in the wax bottom of the dissecting dish were indispensable to proper alignment. Some difficulty was encountered with vibrations from various sources and a special microscope stand would be a benefit if measurements are to be made on long series of specimens.

2. DESCRIPTION OF COUNTS AND MEASUREMENTS

1. Number of setae on the frons. The area of the frons was taken to be bounded by the frontal suture and the transclypeal sulcus.
2. Number of setae on the genal margin. Recorded for right and left sides.
3. Number of setae on the postantennal area. Includes all setae below the ventral margin of the ocellus and ventral and posterior to the antenna, excepting the setae on the genal margin. Recorded for right and left sides.
4. Number of blade sensilla on the lacinia. Recorded for right and left sides.
5. Number of small rods on the membranous portion of the third segment of the maxillary palpus. Recorded for right and left sides.
6. Number of blade sensilla in the main group on labral palatum. Recorded for right and left sides.
7. Number of additional blade sensilla on labral palatum.
   (a) Inner group.
   (b) Outer group, marginal, ventral.
   (c) Outer group, marginal, dorsal.
   Recorded for right and left sides.
8. Number of ventral, outer, peg sensilla on labral palatum. Recorded for right and left sides.

9. Number of ventral, inner, peg sensilla on labral palatum. Recorded for right and left sides.

10. Number of dorsal, peg sensilla on labral palatum. Recorded for right and left sides.

11. Number of sensilla styloconica on thoracic and abdominal segments by abdominal segments by segmental areas. Counted on all areas of both right and left sides except the suranal and subanal areas.

12. Distance between the dorsal and clypeal margins of the cranium (height). Magnification 25x. Orientation of the head to prevent foreshortening could be considered as two problems, viz., one of orientation about the longitudinal axis of the sawfly larva and the other of orientation about the saggital plane. The latter was found not to be difficult because the ocelli provide suitable landmarks and as a result foreshortening error in width measurements probably is very low. It must be remembered that this orientation like all others has to be checked through the single ocular which subsequently is replaced with the ocular micrometer. This is so because the optical axes of the objectives in a stereo birocular microscope are converging, not parallel. Orientation of the head about the longitudinal axis is not easy as there are no good reference structures. The frontal surface was placed in as level a position as possible. Any measurements involving dorsoventral dimensions (Plate I, a) contain more error due to foreshortening. Once the

head had been well oriented, all cranial measurements were made without moving the specimen.

13. Distance between the dorsal margin of the cranium and the forking of the ecdysial line. Magnification 25x.

14. Distance between the dorsal margin of the cranium and the level of the anterior tentorial pits. Magnification 25x.

15. Distance between dorsal margin of the cranium and level of the genal margin at the clypeus. Magnification 25x.

16. Distance between the inner margins of the ocelli. Magnification 25x.

17. Distance between the vertical portions of the ecdysial line at the level of the ocelli. Magnification 25x.

18. Width of the cranium. Magnification 25x.

19. Distance between outer setae on clypeus. Magnification 50x. The micrometer index line was set to bisect the trichopore in this set of measurements and in any others involving setae.

20. Distance between inner setae on clypeus. Magnification 50x.

21. Distance between outer setae on labrum. Magnification 100x.

22. Distance between inner setae on labrum. Magnification 100x.

23. Labrum symmetry index. The outline of the labrum was traced on a sheet of cardboard using a Bausch and Lomb projection microscope. A line was drawn across the outline at the bases of the tormal sclerites (Plate I,b). This line was bisected with respect to the outer labral margins and a perpendicular

dropped from the centre point, thus dividing the labrum into two halves. An Allbrit compensating planimeter was used to measure the whole area of the labrum under the base line and also the area of the left half. The planimeter readings were used to calculate the ratio area of left half over area of whole. This has been termed the symmetry index.

24. Width of the right mandible. Magnification 50x. See Plate I,c.

25. Right mandible. Distance between the setal base and the posterior margin. Magnification 50x. See Plate I,c.

26. Right mandible. Distance between the setal base and the tip of the anterior tooth. Magnification 50x. See Plate I,c.

27. Right mandible. Distance between the setal base and the tip of the posterior tooth. Magnification 50x. See Plate I,c.

28. Right mandible. Distance between the tips of the anterior and posterior teeth. Magnification 50x. See Plate I,c.

29-33. Measurements for the left mandible as in 24-28.

34. Length of coxa - thoracic legs. Magnification 50x. Measured on the anterior aspect between the processes articulating with the prehypopleurite and the trochanter (Plate I,d). Both right and left coxae were measured and the largest of the two values taken as closest to the true size. This convention was followed for all leg measurements.

35. Length of trochanter - thoracic legs. Magnification 50x. The micrometer index line was aligned parallel to the straight

portion of the heavy basal sclerotization of the femur (Plate I,d). The measurement was taken between the dorsomesal projection of the heavy sclerotization at the base of the femur and the ventral articulatory process of the coxa. Thus the length of the trochanter is a difference value, including membranous areas, and results are apt to be more variable than measurements of wholly sclerotized parts.

36. Length of femur - thoracic legs. Magnification 50x. See Plate I,d.

37. Length of tibia- thoracic legs. Magnification 50x. See Plate I,d.

38. Length of claw - thoracic legs. Magnification 100x. See Plate I,d.

Statistics derived from these counts and measurements are given in Appendix I, Tables I - XXXII.

C. RESULTS

1. DESCRIPTION OF THE FIFTH INSTAR FEMALE LARVA

The mature, feeding female larva of N. swainei (Plate II, a, b) is eruciform and about 18 millimeters long in the preserved state. The body is subcylindrical in cross section, slightly tapered and j-shaped caudad. It is well differentiated into head, thorax and abdomen. The three thoracic and ten abdominal segments are distinct. Each thoracic segment bears a pair of highly developed legs while abdominal segments two to eight and ten each have a pair of prolegs.

a. Head

The head is hemispherical in shape, frontal outline subcircular with slight dorsoventral elongation, profile flattened posteriorly and weakly rounded anteriorly, tapering ventrad (Plate III, a-c). Orientation is hypognathous to slightly opisthognathous. The sclerotized cranium, comprising the major portion of the head exoskeleton, is shaped as described for the head in general except for being truncated and open ventrally with the mouthparts articulated around the margin and closing the ventral opening (Plate III, d). Anteriorly the clypeus forms a short, visor-like projection.

For descriptive purposes the cranium may be divided into two general regions, the fronto-parietal and the occipital regions. The occipital region comprises the posterior surface of the cranium while the extensive lateral, dorsal and anterior areas form the fronto-parietal region.

The fronto-parietal region is divided into three main areas. Dorsally a narrow line suture, the coronal suture (Plate III, a, b), extends anteriorly and ventrally to a point about one third of the distance to the ventral margin. Here it bifurcates, forming the frontal suture (Plate III, a, b) which runs ventrolaterally on either side of the midcranial line to about the mid-level of the facial area, then assumes a vertical orientation and extends toward the ventral margin, finally curving mesad and ending in a small, somewhat rectangular, unsclerotized patch a little more than one-quarter of the width in from the lateral cranial margins at that level. The coronal and frontal sutures are part of an ecdysial line which extends posteriorly through the occipital region and part way along the middorsal line of the thorax. From the lateral angles of the visor-like clypeus the clypeogenal sulci (Plate III, b) run dorsolaterally to the anterior tentorial pits. From the anterior tentorial pits another pair of sulci, the frontogenal sulci, extend dorsally and for a short distance closely parallel the vertical portions of the frontal suture. The coronal suture, the frontal suture to the points where paralled by the frontogenal sulci, and, ventrally from this point, the frontogenal and clypeogenal sulci form a system which divides the fronto-parietal region of the cranium into an anterior frontoclypeal area and two lateral and dorsal areas, the parietals. Dorsolaterally, two short, subparallel sulci, the vertical furrows (Plate III, a, c) extend anteriorly from the posterior margin of the cranium. The general dorsal area of the cranium bearing the vertical furrows is the vertex. The lateral area of each parietal is the gena. Each gena bears a single ocellus (Plate III, a-d) about opposite the straight vertical portion of the frontal suture and closer to this suture than to the posterior margin of the gena. Just posterior to the ocellus at about the level of the mesal bends of the frontal suture each gena bears an antenna.

Table III gives the results of the cranial measurements. Values are presented for sample size, mean, standard deviation, standard error, range and coefficient of variation. The mean width of the cranium was 1.611 millimeters while the mean height was 1.711 millimeters. The ratio of width to height, also in Table III, was 0.943. It is interesting to note that the distance between the dorsal margin of the cranium and the forking of the ecdysial line had the highest coefficient of variation of all dorsoventral measurements. Table IV shows the relative size of the cranial dimensions expressed as per cent of height or width as may be appropriate. The distance from the dorsal margin of the cranium to the forking of the ecdysial line comprised 33.66 per cent of the total height, from the forking of the ecdysial line to the anterior tentorial pits 48.94 per cent, from the anterior tentorial pits to the genal margin 8.33 per cent, and from the genal margin to the clypeal margin 6.06 per cent.

The frons (Plate IV, a) may be defined as the facial area bounded ventrally by the imaginary line joining the anterior tentorial invaginations (there is no frontoclypeal sulcus running between the pits), laterally by the frontogenal sulci and dorsally by the oblique portions of the frontal suture. The clypeus is bounded dorsally by the imaginary line joining the anterior tentorial pits, laterally as far as the genal margins by the clypeogenal sulci, and then extending ventrally it is a free lobe. There is a dorsally arched, shallow, transclypeal sulcus. The enlarged terminal areas of the ecdysial line lie approximately in the transclypeal sulcus.

The sclerotized frontal cuticula has groups of irregular, cell-like markings with the central portion of each lighter in colour than the general colour of the surrounding area and the marginal colour slightly darker than the general colour of the surrounding area. Each "cell" (Plate XVII, a) corresponds with the attachment of a muscle bundle. This phenomenon has been described by Parker (1934).

The frons is gently arched dorsoventrally in profile (Plate V, a) and also across its lateral expanse (Plate VI,e). There is a shallow depression for a short distance along each arm of the frontal suture just laterad from thejunction with the coronal suture (Plate IV,a). Below the level of the ocelli and opposite the "vertical" portions of the frontal suture is a pair of obtusely bent, oblique depressions somewhat closer to the midline than to the frontal suture. Plate VI,e shows these depressions in section. A second pair of oblique depressions occur below the lateral arms of the ones first described. The surface of the frons is smooth and shining. There are four groups of markings indicating the internal attachments of the major head muscles which are shown in Plate V. Just above the level of the ventral bends in the frontal suture and on either side of the midline is a compact grouping of markings associated with the anterior retractor muscles of the labrum. Muscles are also attached on the inner ridges formed by the two pairs of external, oblique depressions and externally the reticular markings are visible. The more dorsal set has a small grouping slightly dorsal and lateral to the main area of attachment. These all belong to dorsal, precerebral dilator muscles of the pharynx. On either side of the frons between the attachments of the anterior labral retractor muscles, the dorsal precerebral dilators of the pharynx, and the frontal suture is a crook-shaped scatter of muscle bundle attachments with their characteristic markings. These belong to the posterior retractor muscles of the labrum, or tormal muscles.

The frons bears 27-30 (mean 28.1, Table V) stiff setae in about equal numbers in roughly oval configurations on either half (Plate III, b). The size of the setae increases ventrad.

The clypeus, as already indicated, is partially enclosed by the genae and divided by a dorsally arched transclypeal sulcus into ante- and postclypeus. The transclypeal sulcus runs between the two anterior mandibular articulations which are on the interior aspect of the lateral marginal inflection of the clypeus just ventral to the level of the genal margin. The lateral extremities of the transclypeal sulcus are not well developed externally and at its most dorsal point it is at the level of the imaginary line joining the anterior tentorial pits forming the dorsal limit of the clypeus. Thus the clypeus consists of a definite anteclypeus and two lateral postclypeal areas merging with the frons. The central third of the anteclypeus is faintly depressed and only weakly sclerotized. Lateral to this area is a raised, heavily sclerotized band and finally a membranous ventrolateral lobe. Dorsally along the transclypeal sulcus a band of sclerotized cuticula extends to the lateral margin. The lateral extent of the labrum approximates the lateral edges of sclerotization of the anteclypeus. There is a small median projection on the anteclypeus and two pairs of long setae are borne just below the transclypeal sulcus, the inner pair at about the middle of the sclerotized ridge and the outer pair above the lateral margin of the unsclerotized ventrolateral lobes. Table VI gives statistics based on measurements of the distances between the members of the two pairs of clypeal setae. The ratio of distance between the inner pair over distance between the outer pair was 0.545, but shows a higher coefficient of variation than for either of the two basic components. Two groups of dorsal dilators of the cibarium (Plate V, a, b, c) have their attachments to the cuticula just below the internal ridge marking the transclypeal sulcus, one on either side of the midline above the inner clypeal setae.

The sclerotized cuticula of the parietals is also smooth and shining and has numerous stiff setae. These are small and widely dispersed on the vertex, but increase in size to the genal margin. There are particularly dense groupings anterior and dorsal to the ocellus just outside the dark eye ring. The width of the latter is about equal to the diameter of the ocellus. The externally visible portion of each ocellus is a clear, lens-like, cuticular thickening. A fairly discrete group of large setae is found on the postantennal area of the gena below the level of the ocellus. The number of setae in this group, excluding the row of still larger setae along the ventral margin of the gena, ranged from 7 to 10 with the mean at 8.864 (Table V). The row on the genal margin was comprised of 3-5 setae with the mean at 4.046 (Table V).

The whole inner surface of each parietal dorsal to the ocellus, excluding a narrow margin around the dark eye ring and along the frontal suture, is taken up by the attachments of the mandibular muscles. The small abductor muscle is attached in a narrow curved, tapering band along the posterolateral margin of the parietal; the base of this area is at the level of the ventral ocellar margin and its apex just below the vertical furrow. The very large adductor muscle of the mandible occupies the remainder of the dorsal attachment area.

The antenna (Plate IV, b) consists of a number of sclerotized structures borne on an oval, membranous hump which has its long axis parallel to the longitudinal axis of the head. The membranous hump is situated on a short, truncated, sclerotized cone rising from an oval depression in the gena. The depression is deepest anteroventrally and has its long axis tilted in the same direction with respect to the orientation of the head. The principal antennal sclerite is a blunt-tipped cone situated at the anterior end of the membranous area. Posterior to it are two irregular, crescentic sclerites having small membranous areas within them. There is a variable number of variously joined or separate, narrow, curved sclerites extending anteriorly around the sclerotized cone. These sclerites may be joined to one or other of the larger crescent-shaped sclerites either dorsally or ventrally and may make a complete ring. Occasionally the narrow sclerites appear to be remnants of two narrow rings.

The major feature of the posterior surface or occipital region of the head (Plate VI, a) is the large occipital foramen through which the head and thoracic cavities communicate. The occipital suture forms a lateral boundary for the ventral portions of the occipital region, thus separating the concave postgenae from the genae. This suture is manifested as a ridge both externally and internally (Plate VI, c), originates at the hypostomal inflection near the posterior mandibular articulation and extends dorsally in a gentle arc, tapering and becoming less distinct. The dorsal portion or occiput is very narrow and not separated from the vertex by a distinct suture. The coronal suture is present in the dorsal midline.

Ventrally the occipital foramen is closed by the tentorial bridge. The remainder of the margin is marked by a strong internal ridge, showing externally as the postoccipital sulcus. The postocciput is a narrow, lightly sclerotized collar closely appressed to the postgenae and occiput, and grading into the cervical membrane. Laterally it has somewhat flexible, widened, triangular lobes to which cervical sclerites are attached along the ventral edge. Another point of articulation of the cervical sclerites is found just ventromesal to the flaps, also on the postocciput. The posterior tentorial pits are obscure, being merely slit-like pockets at either side of the tentorial bridge.

The tentorial bridge is about one-quarter of the cranial height dorsal from the postgenal margin and a broad mesal extension of each postgena occurs at the same level. The posterior mandibular articulations are at the ventromesal angles of the postgenae and thus the mandibles close the cranium ventrally (Plate X, a) and there is a posterior opening to the head below the tentorial bridge. This second posterior opening is closed by the labiomaxillary complex. Ventrally, the inner surface of this structure is continuous with the membranous lining of the intergnathal cavity. Laterally, membranous portions of the maxillae are continuous with the postgenal margin to the posterior tentorial pits. The cardines of the maxillae are articulated with the ventral margin of the postgenae lateral to the posterior tentorial pits. Dorsally the labiomaxillary complex is continuous with the cervical membrane. Thus the tentorial bridge is internal and there is a sort of ventral bypass to the connection of the head to the thorax. An ecdysial line extends across the tentorial bridge in the midline.

The surface of the postgenae and occiput is smooth, shining, and devoid of setae.

The cranium gains much of its strength as an exoskeleton from internal strengthening inflections which externally are the sulci or groove sutures. All the sutures of the head, except the ecdysial line (coronal and frontal sutures) and the occipital suture, are of the groove type. Thus there are frontogenal, clypeogenal and transclypeal inflections serving mainly for support, as do the marginal subgenal and hypostomal inflections (Plate V,b; VI, b,c). The vertical furrows, the occipital, and the postocciptal ridges, as well as providing strength, also serve as areas from muscle attachment. An important component of this strengthening framework is the tentorium, an internal structure arising through invagination of the cranium. In the Swaine jack-pine sawfly larva the tentorium is a very simple structure having a pair of anterior arms extending from the anterior tentorial pits to the small body of the tentorium on the anterior surface of the tentorial bridge. The anterior arms slope slightly dorsad posteriorly because the posterior tentorial pits are more dorsally located than the anterior ones. There are no dorsal tentorial arms.

The general relations of the mouthparts in closing the ventral cranial opening may be seen in Plate X, a, b. Anteroventrally there is the labrum, laterally and ventrally the mandibles, and posteriorly the maxillae and labium.

The labrum is a well sclerotized, bilobed flap articulated to the central portion of the ventral margin of the anteclypeus by an infolded membrane (Plate IV,c). This clypeolabral inflection is slightly convex dorsally. The labrum is round in both transverse and saggital section, that is, the edges are rolled inward. There is a faint median depression. The ventral emargination is shallow and asymmetrical, the left margin having a sharper slope. The two lobes of the labrum are not symmetrical and the left is the smaller of the two, being both shorter and narrower. The symmetry index (Table VII) was 0.481, indicating that the plane projection area of the left half was about 48 per cent of the area of the whole labrum. There is a pair of setae on either half of the labrum. The ratio of the separation of the inner two over separation of the outer two was 0.389 and again as for the clypeal setae there was a high coefficient of variation (Table VII). The labral surface is smooth and shining and there are numerous thin walled pegs set in pores in the sclerotized cuticula (Plate XI,c). These are particularly numerous around the ventral margin, but the marginal ones are not indicated in Plate IV, c. At the dorsolateral angle on either side the labral sclerite is continued internally as a short curved rod, the tormal sclerite, and the two groups of anterior labral retractor muscles have their insertions at the apex of the tormae.

The mandibles, Plate VII, are more heavily sclerotized than all the other mouthparts and in general are shaped like chisels with triangular basal sections. The basal margins are heavily thickened; the lateral side is slightly convex and a little longer than the two other basal dimensions. The anterior and posterior articulatory structures are at either end of this longer side while the strong tendon of the adductor muscle is attached at the mesal apex. The distance from the apical margin to the base on the inner surface is much less than the same dimension on the outer surface so the adductor tendon is inserted at the bottom of a deep hollow. The anterior articulation is by a long groove which interlocks with a condyle on the ventral margin of the cranium. The posterior mandibular articulation is by a bicondylic process which fits corresponding depressions in the hypostomal inflection. The anterior and posterior articulations are at about the same level, the posterior one being slightly dorsal. The slender abductor tendon has its insertion on the outer margin of the base near the posterior articulation. There is a small sclerite associated with this tendon and it is clearly visible in the integument connnecting the mandible to the genal margin. It appears as though the cuticula of this connecting area may be lightly sclerotized.

The mandibles are only slightly longer than the outer dimensions of the base and have their greatest extension anteriorly; the smallest posteriorly. Their apical margins are dentate and when closed they overlap, the left mandible being outermost. The lateral aspect of both mandibles is convex anteroposteriorly and has a single long seta near the base posteroventral to the anterior articulation.

The right mandible is the smaller of the two with a mean width of 0.414 against 0.428 millimeters for the left (Table VIII). It has four dentes grading in size from the large anterior tooth to the small posterior one. The lateral aspect is generally convex anteroposteriorly, but has distinct protuberances anteromesally and posteriorly. Each dens has a low median ridge with slightly concave surfaces rising from the groove between adjacent dentes. In outline the dentes are truncated with concave margins. This is particularly true of the anterior dens. Table VIII gives dimensions for the triangle formed by the centre of the setal base and the apices of the anterior and posterior dentes. The mesal aspect is concave anteromesally to an oblique ridge continuous with the crown of the posterior dens and in line with the basal margin and the anterior articulation. Posterior to this ridge the mesal surface is convex. Each dens has a strong median ridge.

The left mandible has five dentes and its lateral aspect is uniformly convex anteroposteriorly. The dentes have only shallow depressions between them, except for the posterior two where the small fifth dens is slightly inside the fourth. The anterior dens is low and subrectangular, with an excavated anterior margin, a blunt anteromesal projection and a concave mesal or apical edge. The other dentes have straight to slightly concave anterior margins and convex posterior margins. The medial dens has the farthest apical extension. Measurements of the triangle formed by the center of the setal base and the apices of the anterior and posterior dentes are shown in Table

VIII. Comparing these values with those for the right mandible it appears that the seta is placed about the same distance from the posterior margin in both; the left mandible has a shorter apical extension than the right; the body of the left mandible is only slightly wider than that of right, but the additional dens on the left results in a considerable difference in the distances between anterior and posterior teeth; and that the fifth or posterior dens of the left mandible is much smaller than the others. The mesal aspect of the left mandible is essentially the same as described for the right.

The maxillae and the labium (Plate VIII) together form the posterior closing of the intergnathal cavity and of the cranial cavity below the tentorial bridge. Anteriorly only the lateral and ventral margins of the complex are free. Posteriorly the maxillae and labium are largely enclosed in a deep membranous pocket of the prothorax.

Each maxilla consists of a basal sclerite, the cardo; a large sclerite, the stipes; two unsegmented processes, the galea and the lacinia; and a segmented palpus. The cardo is a U-folded sclerite with the open face oriented ventrally. Posteriorly it is narrowly articulated with the postgenal margin and anteriorly there is a broad articulation with the stipes. A dorsolateral lobe is largely membranous, rounded anteriorly and flat on the posterior surface. The stipes is a rounded, laterally projecting lobe, the major portion of it sclerotized. The lateral margin of the sclerite curves anteriorly and overlaps the posterior articulation of the mandible. The inner surface of this lobe is concave and membranous. A stout arm of the stipital sclerite extends ventromesad (Plate VIII, a; IX,a). Separated from the stipital sclerite by a large membranous area is the conical, five-segmented maxillary palpus (Plate IX,a). The first segment is large, flattened and sclerotized on the posterior and lateral surfaces only. Mesal to the sclerite is a rectangular, membranous flap. The second palpal segment is also incompletely sclerotized and is the smallest of the five segments. The third segment has a complete sclerotic ring as has the fourth. Posteromesally the distal margin of the ring sclerite of the fourth segment is deeply and circularly emarginate. The terminal segment is a roundly truncated cone with the apex only lightly sclerotized. The galea (Plate IX, a, b) is a heavily sclerotized, digitate process set in membranous integument anteromesad to the maxillary palpus and overlapped by the membranous flap. Again just anteromesad to the galea and articulated with one process of the bifurcate stipital arm is the lacinia (Plate IX, a, b, c). This structure is somewhat triangular in section, and has an irregular surrounding sclerite which is incomplete anteromesally and distally. A posterior dorsal extension of this sclerite articulates with the stipes, and a similar process extends into the membrane on the anterior aspect. The terminal membranous area bears a large, blunt, conical peg at its mesal apex. There is also a row of large, blade-like setae along the posterior margin of the membranous area. This has been termed the lacinial raster (Parker, 1934) and consists of 5 or 6 blade sensilla (Table IX) with the mean value of 5.476.

Other sensilla on the maxilla are as follows: two obliquely positioned setae on the main body of the stipes; two short stout setae near the tip of the stipital arm; two setae on the sclerite of the first segment of the maxillary palpus, one near the ventromesal angle on the anterior surface and one laterally near the distal margin of the sclerite; laterally a long seta on the distal margin of the sclerite of the third segment of the maxillary palpus; and a group of three or four blunt rods (Plate XI, h) on the membranous area in the emargination of the sclerite of the fourth palpal segment. The latter are usually four in number, the mean being 3.95 (Table IX). There are also many thin walled pegs set in pores in the cuticula. These are particularly common on the distal portion of the galea (Plate XI, g).

The labium consists of two flattened lobes situated between and slightly posterior to the maxillae, overlapping them a little. The proximal lobe, the postmentum, is largely membranous. Its position is anteromesad to the cardines and stipites of the maxillae and it is joined to them along its infolded lateral margins. Proximally it is continuous with the cervical membrane at the deepest part (most dorsal) of the pocket encompassing the maxillae and labium posteriorly. The postmentum has an irregular, short, transverse, U-shaped sclerite about opposite the articulations of the cardinal and stipital sclerites. The well sclerotized U-shaped portion is complemented by weakly sclerotized areas to form a subrectangular structure. The distal lobe of the labium consists of a generally U-shaped premental sclerite, two lateral and distal (ventral) labial palpi, and a median, fleshy lobe, the spinneret, with a triangular ligular sclerite between the two arms of the premental sclerite. The latter is anteriorly reflexed along its arched dorsal margin and has a very irregular outline around the anterolateral margins and around the median excavation. Distal to each lateral arm of the premental sclerite and separated from it by a membranous area which is broad laterad and narrow mesad, is a three-segmented labial palpus. The proximal segment is incompletely sclerotized mesally; the second has a completely sclerotized collar, and the distal segment is a roundly truncated cone with the apex only weakly sclerotized. Between the labial palpi and slightly anterior to them is the membranous spinneret lobe with its centrally located meatus of the labial or silk glands. The spinneret lobe is strengthened laterally by two small, irregular sclerites each of which appears to be loosely articulated with one of the terminal processes of the stipital sclerites of the maxillae. In the midline at the base of the spinneret between the arms of the premental sclerite is a triangular ligular sclerite with its apex directed proximad. Anteriorly the spinneret lobe is continuous with the posterior surface of the hypopharynx.

Sensory structures on the labium are as follows: thin-walled pegs set in pits in the cuticula on the postmentum (Plate XI,e), premental and palpal sclerites; two stout setae near the lateroventral margin of each arm of the premental sclerite; a small seta situated laterally near the proximal margin of the sclerite of the first palpal segment; a long seta borne antero-mesally on the distal margin of the sclerotized ring of the second palpal segment; a number of blunt, thin-walled setae on the spinneret (Plate XI,f); and numerous small, probably-scale-like spinules on the postmental membrane (Plate XVII,b). The latter are directed ventrad.

The palatum, or membranous inner integument of the labrum and dorsal cibarial wall, bears a considerable assemblage of cuticular structures. The labral portion (Plate X,c) has a lightly sclerotized, marginal band and dorsolateral to the apex of each lobe is an irregular pedestal-like sclerite oriented ventromesally with the head of the pedestal ventral in position. There are usually three blade-like setae borne along the ventral margin of this sclerite. Occasionally only two of these blade sensilla are found and the mean number is 2.955 (Table X, blade sensilla, main group). Just dorsomesal to the pedestal-like sclerite is a row of smaller blade sensilla. There may be two or three members in each row and the mean is 2.682 (Table X, additional blade sensilla, inner group). Again just mesad from these latter blade sensilla is a row of two or three thin-walled pegs set in pits in the cuticula (Plate XI,d). The mean number of these structures was 2.955 (Table X, ventral, outer pegs). Above the ventral emargination on either side of the midline is a group of two to four smaller thin-walled pegs set in pits (Mean=3.273, Table X, ventral, inner pegs). Dorsal to all the sensory structures so far described and approximately in line with the apex of each lobe of the labrum is a group of two or three small, thin-walled pegs. The mean number was 2.818 (Table X, dorsal pegs). Close to the margin of each lobe near the pedestal-like sclerite a small, blade-like seta was found on about three out of four labral lobes examined, regardless of right and left sides (Table X, additional blade sensilla, marginal, ventral). In addition there may be a more dorsal blade sensillum. This was present on the right lobe in about one half of the specimens examined and on the left lobe in about one third (Table X, additional blade sensilla, marginal, dorsal). The cibarial portion of the palatum has numerous small, posteriorly directed denticles.

The hypopharynx (Plate X, b; XI, a) is a median, fleshy, tongue-like lobe projecting ventrally from the roof of the intergnathal cavity between the posterior portions of the mandibles. In anterior aspect there is a basal elongated protuberance with its lateral edges continuous with the integument of the intergnathal cavity and a bilobed, slightly expanded distal structure which is free for a short distance. The stalk-like portion has a subrectangular sclerite and the ventrolateral areas of the distal free lobes are weakly sclerotized. Each lateral wall of the hypopharynx is supported by a curved, rod-like sclerite just dorsal to the free lobes. Dorsally this sclerite has a flexible attachment to the inner angle of the margin of the mandible in association with the adductor muscle tendon. The anterior faces of the free lobes have areas bearing robust, sharp denticles directed dorsad (Plate XI,b).

b. Thorax

The prothorax is the smallest of the three thoracic segments, being constricted anteriorly (Plate XII,a,b) where the cervical membrane is continuous with the postoccipital margin of the cranium and the postmentum. The declivous dorsal and dorsolateral area has three distinct ridges, or annulets, which have been numbered 2,3 and 4 in Plate XII,b. It is considered that annulet 1 forms part of the cervical membrane. The whole prothoracic segment is tilted anteriorly so that the lateral spiracular area, although in line with the fold between annulets 2 and 3, is ventral to the dorsal area of annulet 4. The spiracle is like the abdominal ones (Plate XVII, c), except that it is about one and one half times as large. The peritreme is bivalved, long and narrow and flanked by two weakly sclerotized wings that are apparent only after staining. The fine hairs lining the atrium may be seen readily. Anteroventral to the spiracular field is the raised preepipleural area and ventral to these two, the postepipleural lobe. Ventral to the latter and just above the prothoracic coxa is the crescentic posthypopleural fold. Anteroventral to the posthypopleural fold and anterior to the basal portion of the prothoracic coxa is a second lobe which bears the slender prehypopleurite. Anterior to the pre-and postepipleural areas and the pre-and posthypopleural areas is a fold which is continuous ventrally and forms the lip of the anterior prothoracic pocket housing the labiomaxillary complex. Laterally this ventral cervical fold is complex and ventrolaterally it bears the cervical sclerites (Plate XII, a, b, c; XIII,a) which are roughly X-shaped and flexed over the fold at about their midpoints. The two anterior arms articulate with the postocciput; the posterolateral arm extends into the deep basal fold cephalic to the prothoracic coxa, and the posteromesal arm ends on the posterior aspect of the ventral cervical fold about halfway between the midventral line and the lateral margin. Ventrally between the prehypopleural lobes mesad to the prothoracic coxae is a complex series of folds and protuberances. There is a pair of anterior, obliquely-positioned, tear-shaped lobes situated on either side of the depressed midventral area. Posterolaterally from these is a pair of narrow triangular folds and then a pair of crescent-shaped folds. Collectively the three pairs of ventral lobes described are protuberant and have a broad V-shaped, posterior emargination. The sternal integument between the two lateral, raised, leg bases so formed has three transverse folds.

The integumental folds which have been described appear to be constant and are produced by the constricting effect of attached muscles. The position of muscle attachments on unsclerotized cuticula is indicated by smooth, reticularly marked areas (Plate XVII,c) which do not have spiniform denticles.

The unsclerotized integument (Plate XVIII,a) consists of cellular epidermis and the non-cellular cuticula, and is about 25 microns thick. The epidermis is a single layer of columnar cells about 16 microns thick. The cells have distinct nuclei and boundary membranes (the material sectioned was likely approaching a moulting phase). The cuticula consists of a relatively thin epicuticle and a thick endocuticle. The surface is marked with fine striae (Plate XVIII,d,e). There is also a general covering of small, spiniform denticles on the cuticula (Plate XVI, d; XVIII, a-e). Each denticle is about 8 microns in length.

Pigmented integument (Plate XVIII, b) has a slightly thicker cuticula with the black pigment in its outer layers. The surface is rougher and appears to consist of platelets.

Certain areas bear groups of truncate, conical, sensory structures (Plate XVI, d) (Glandubae of Yuasa, 1922, p. 45, 46). These sensilla styloconica are about 50 microns in length, about 5 microns in diameter near the apex, and about 25 microns in diameter at the base. They are tubular, slightly concave at about the midlevel and have the cuticula sclerotized, usually more heavily on one aspect than the others in the basal portion

(Plates XIX, XX). There is no definite articulatory structure. Their apical ends are membranous and may be protuberant with a small, spike-like, terminal projection (not well shown in photomicrographs) or may be hollowed with the terminal spike at the bottom of the chamber and only its tip visible. The method of preservation and subsequent treatment apparently determine which of the two conditions is observed. When invaginated the membrane rests against an internal, subterminal, sclerotic ridge. In the epidermis underlying each of these sensilla is a large, elongated sensory cell with a nerve process extending inward through the basement membrane. Distally the sensory cell surrounds a sense rod, both being enveloped by at least one additional large cell. The surrounding cells taper out at about the midlevel of the sensillum, but the sense rod is continuous with the external apical spike. It appears that the sense rod may be convolute and have contact with the sensillum wall at the level of the the convolution. This would produce a lever action with the fulcrum nearer the termination of the sense cell than to the apical spike.

In addition to the sensilla styloconica just described, the dorsal and lateral areas of the integument bear sparsely distributed setae (Plate XVI, e). The trichopores are distinct, usually considerably larger than the base of the seta and often on a small protuberance. The conical setae are about 25 microns in length.

The prothorax bears sensilla styloconica on several areas, viz., the supraspiracular portions of annulet 2 and 3, the preepipleural, postepipleural and posthypopleural areas. The arrangement of the sensilla is not constant from individual to individual, but the areas involved are. Table XIV gives the statistics for the number of sensilla styloconica found on the prothorax as follows: annulet 2, 5-8 ($\bar{x}$, 6.27); annulet 3, 13-19 ($\bar{x}$, 15.18); preepipleural, 5-8 ($\bar{x}$, 6.00); postepipleural, 4-6 ($\bar{x}$, 4.95); posthypopleural, 3-5 ($\bar{x}$, 3.91); one complete side, 32-42 ($\bar{x}$, 36.32). A few small setae are found on the same lateral and dorsal areas as the sensilla styloconica. Other setae are located on the prehypopleurite, 4 - 6 on the central portion of each cervical sclerite, 4 - 7 on the ventral cervical fold, and 2 - 4 (usually 2) on the tear-shaped protuberance anteromesad to the leg bases. The cuticular spiniform denticles are found on all areas excepting those overlying muscle attachments.

The mesothorax (Plate XII, a-c) is much larger than the prothorax in all dimensions and is declivous anterodorsally. There are four dorsal annulets and a much enlarged preepipleural area comprising the main lateral expanse in and below the spiracular line. Posteroventral to it are the postepipleural and posthypopleural folds while anterior to these latter is the prehypopleural lobe with its sclerite. Ventral to the anterior portion of the preepipleural lobe are two folds more or less continuous from side to side across the sternal area. The mesothorax does not have a spiracle and the spiracular area is not defined. The segment is somewhat flattened ventrally and the leg bases are on the lateral margins of the area, relatively close together and directed ventrally. There are three transverse folds anterior to the bases of the legs. In the midventral area of the second of these two folds is an oblong pit (Plate XII, c; XIII, a-c) which marks a sclerotized invagination with an expanded terminal surface serving as a place of muscle attachment. Between each leg base and the sunken midventral area is an oblong protuberance.

Styloconic sensilla are located as follows (see Table XIV): annulet 1, 4-8 ($\bar{x}$, 6.36) in a dorsolateral row and 1-3 ($\bar{x}$, 2.14) in a lateral group; annulet 2, 6 - 11 ($\bar{x}$, 9.00); annulet 3, 11 - 16 ($\bar{x}$, 13.50); anterior ventrolateral fold, 2 - 5 ($\bar{x}$, 2.73); preepipleural area, 9 - 13 ($\bar{x}$, 10.50); postepipleural area, 1-3 ($\bar{x}$, 2.00); posthypopleural area, 3 - 6 ($\bar{x}$, 4.05); and total for one side, 45 - 54 ($\bar{x}$, 50.27). As in the prothorax there are small setae on the same dorsal and lateral areas as the sensilla styloconica. There are several setae on the anteromesal aspect of the prehypopleurite and prehypopleural fold. The oblong protuberance mesad to each leg base bears 3 - 5 setae and the transverse fold anterior to these also bears setae.

The metathorax (Plate XII, b, c) is essentially the same size as the mesothorax. The integumental folds and lobes are much as in the mesothorax except for a small lateral fold below annulet 1, bearing on its posterior border the minute metathoracic spiracle (less than one half the size of the abdominal spiracles).

Sensilla styloconica on the metathorax are located as follows (see Table XIV): annulet 1, 4 - 8 ($\bar{x}$, 6.27) in a dorsolateral row and 1 - 2 ($\bar{x}$, 1.45) in a lateral group; annulet 2, 5-10 ($\bar{x}$, 7.73); annulet 3, 10-15 ($\bar{x}$, 11.73); anterior ventrolateral fold, 1-3 ($\bar{x}$, 1.82); preepipleural area, 7 - 12 ($\bar{x}$, 9.50); postepipleural area, 1-2 ($\bar{x}$, 1.77); posthypopleural area, 3 - 5 ($\bar{x}$, 3.82); and one complete side, 39-49, ($\bar{x}$, 43.95). Setae are located on the same areas as on the mesothorax and in about the same numbers.

The three pairs of thoracic legs (Plate XIV) are well developed and have five definite segments, coxa, trochanter, femur, tibia and claw, all of which are at least partially sclerotized. The prothoracic, mesothoracic and metathoracic legs are basically the same except for size differences and the description that follows refers to a left metathoracic leg.

The coxa is the largest leg segment and is subcylindrical with an obliquely cut base. Sclerotization is heavy on the anterior, posterior, and lateral aspects, but the mesal aspect has only an irregular, narrow, sclerotic bar across the basal portion and in some instances this bar is not complete. The articulation with the prehypopleurite is situated anterolaterally and from it a deep sigmoid sulcus runs posteroventrally. Anterior to this groove the distal end of the coxal sclerite is deeply and rectangularly emarginate, while posteriorly there is a narrow sclerotized area grading irregularly into unsclerotized cuticula along a deep arcuate infolding running roughly parallel to the sulcus. Posterior to this infolding the soft cuticula grades irregularly into the coxal sclerite which has a narrow arm directed distally and a main somewhat triangular basal part. The proximal margin of the coxa in lateral aspect is excavated in a broad V. It may be seen that if the coxal sclerite is incomplete mesally then it is divided into anterior and posterior halves.

The coxite in anterior aspect is subrectangular and its posterior distal angle greatly strengthened and produced as an articulatory process for the trochanter.

The posterior face of the coxal sclerite also appears roughly rectangular with the anterodorsal corner demarcated by a sulcus and infolding mesad to it. The anteroventral angle is strengthened and produced as an articulatory process for the trochanter.

The coxa is adorned with numerous, large, stiff setae, particularly on the anterior aspect of the coxal sclerite. There are a few smaller, thin-walled setae on the membranous areas, mainly on the mesal aspect.

The trochanter is articulated anteriorly and posteriorly with the distal end of the coxa. It is shaped like a truncated cone with the smaller diameter proximally at the articulation with the coxa. The lateral aspect shows a broad sclerotized band curving onto the anterior and posterior aspects where distally it ends in digitate processes. Proximally the sclerite is continuous around the base of the trochanter. The mesal aspect is mainly membranous. The sclerotized portion of the trochanter bears a large number of stout setae, most of them being arranged around the distal margin of the sclerite. The mesal membranous area has numerous, slender, thin-walled setae arranged for the most part in anterior and posterior groups.

The femur is quite similar to the trochanter in structure except that it is much smaller and the basal sclerotic ring is incomplete on the mesal aspect, the membranous portion of which is expanded into an empodium-like pad. There are only a few, relatively small setae on the femur, arranged irregularly along the distal margin of the sclerite.

The tibia is a slender, bitruncated, ovoid segment with the lateral, anterior, and posterior aspects sclerotized. The mesal aspect is entirely membranous. There are four irregular rows of setae, two on the lateral aspect of the sclerite, and one along each of its margins.

The heavily sclerotized claw is the smallest leg segment and consists of a bulbous proximal portion and a curved, tapering, distal process.

The articulatory axes of all four terminal leg segments, the trochanter, femur, tibia and claw, are cephalocaudal in orientation.

Table XI gives the basic statistics derived from thoracic leg measurements. By adding the mean lengths of the five leg segments a nominal total leg length is obtained. Table XII shows the relative length of each podite expressed as per cent of this value. The great size of the coxa in all three pairs of thoracic legs is obvious for it comprises some 40-45 per cent of the nominal length. It may be noted that the coxae comprise a relatively smaller proportion of the length of the prothoracic legs. Conversely the trochanter is relatively longer in the prothoracic legs than in the other two pairs.

When the nominal total length for the prothoracic leg is used as base, the relative lengths of the thoracic legs are 1.0, 1.1579 (meso), and 1.2018 (meta), as shown in Table XIII. The meso-and metathoracic legs are about equal in size and considerably larger than the prothoracic. Table XIII also shows the comparable relative values for each podite. These indicate that the increase in size is not uniformly distributed over all segments. The main feature appears to be that the trochanter is approximately the same size in all three pairs of legs.

c. Abdomen

The abdomen is j-shaped posteriorly and consists of ten segments, numbers two to eight inclusive each having a pair of prolegs. The terminal, or apparent tength segment bears the anal prolegs. Segments one to eight inclusive also have a laterally located pair of spiracles, the eighth being slightly larger than the rest. Upon examination it was found that the first, ninth, and tenth segments should be described, but that only one of the midabdominal segments two to eight need be considered since they are all about the same. For convenience segment two was illustrated.

Abdominal segment one is much longer dorsally than ventrally with an oblique anterior margin. There are six well-defined, dorsal annulets (Plate XV, b). The anteriormost four of these terminate laterally at about the supraspiracular level, the fifth at the subspiracular level and the sixth or posteriormost on the ventrolateral aspect of the segment. The spiracular area is ventral to annulets 1 and 2 and at about the midlevel of the segment in lateral view. The postspiracular area is directly posterior to the spiracular field and ventral to annulets 3 and 4. The large preepipleural lobe is ventral to the spiracular and postspiracular areas in line with dorsal annulets 2 and 3. Posteroventral to the preepipleural area is the postepipleural fold. The sternal surface of abdominal segment one has an anterior transverse ridge, a pair of protuberances on either side of the midventral area and in line with the ventrolateral postepipleural folds. There is a short transverse fold caudal to these bulges while a larger transverse annulet is present posterior to the latter.

Sensilla styloconica are present on the dorsal and lateral areas of abdominal segment one as follows (see Table XIV): annulet 1, 3-5 ($\bar{x}$, 3.50) in a dorsolateral row and 1 - 2 ($\bar{x}$, 1.09) in a lateral group; annulet 2, 3-6 ($\bar{x}$, 5.27); annulet 4, 6 - 8 ($\bar{x}$, 7.14);

postspiracular area, 4-7 ($\bar{x}$, 5.59); preepipleural area, 4-7 ($\bar{x}$, 4.91); postepipleural area, 3 - 5 ($\bar{x}$, 3.68); and one complete side, 28-36 ($\bar{x}$, 31.18). Small numbers of inconspicuous setae are present on the same areas. Ventrally there are several setae of various sizes distributed over the anterior annulet and groups of several setae on each of the protuberances posterior to this fold.

Abdominal segments two to eight are all very similar in general appearance. They are subcircular in transverse section (Plate XV, a) with the pair of prolegs set close together much more ventrally than laterally. The anterior and posterior margins are roughly parallel to each other and are not obliquely sloped. There are six well defined annulets on the dorsum. Annulet 1 extends to the ventrolateral aspect of the segment and is tapered below the level of the spiracle. The spiracular area is situated ventral to annulet 2 at about the midlevel of the segment in lateral view. Posterior to the spiracular area is the large postspiracular area lying ventral to annulets 3 and 4. Annulets 5 and 6 are continued below the postepipleural fold on the ventrolateral aspect. Between the levels of the postspiracular and postepipleural areas and anterior to them in line with dorsal annulets 2 and 3, is the preepipleural lobe. Below the postepipleural fold at the posterior end of the segment and mesal to it is the large rounded protuberance, the hypopleural lobe, bearing the proleg on its ventral aspect. There are two distinct annulets on the sternum anterior to the hypopleural lobes, a median depressed area between them and a single annulet posterior to them.

The number of sensilla styloconica (Table XV) increases through abdominal segments two to seven and is slightly lower for abdominal segment eight. It is also notable that abdominal segment one (and also abdominal segment nine) which does not have a proleg has considerably fewer of these sensory structures. Considering the basic statistics for the distribution of sensilla styloconica on abdominal segments two to eight, it appears that abdominal segment five was the most uniform in this respect, giving results as follows: annulet 1, 6-9 ($\bar{x}$, 7.59); annulet 2, 6-9 ($\bar{x}$, 7.45); annulet 4, 6-8 ($\bar{x}$, 6.95); postspiracular area, 4-7 ($\bar{x}$, 5.45); preepipleural area, 6-10 ($\bar{x}$, 8.09); postepipleural area, 5 - 9 ($\bar{x}$, 7.05); and one complete side, 37-49 ($\bar{x}$, 42.59).

It should be noted that there is considerable variation between right and left sides in the number of sensilla styloconica on the different areas of each segment. Family differences are, however, greater than those between sides and between individuals.

The dorsal and lateral areas of abdominal segment five bear small setae on the same areas as the sensilla styloconica. Ventrally there are two or three setae near the midline on the annulet anterior to the hypopleural lobes and about a dozen setae, not all the same size, on the anteromesal and mesal aspects of the hypopleural lobe.

It was noted in the description of the thorax that the surface of the cuticula is adorned with closely set, spiniform denticles except on areas overlying muscle attachments. The distribution of these denticles on the abdominal segments shows an interesting difference. Here as in the thorax they are absent over muscle attachments, but in addition they may be absent on the subdorsal bands which are lightly pigmented. This condition is only slightly apparent on abdominal segment one, more so on two and strongly so on the mid-and posterior abdominal segments. Plate XVIII, c shows the denticles evenly distributed over the subdorsal area of the left side of the metathorax while Plate XVIII, d shows them grading smaller and less numerous onto the naked subdorsal area of annulet 5, right side of abdominal segment five, being an annulet free of sensilla **styloconica.** Plate XVIII, e shows the condition on the same area of annulet 4 which bears sensilla styloconica. The denticles are present around the bases of these latter structures when they occur on the pigmented subdorsal area. The dorsal, unpigmented band has the denticles normally distributed as has any pigmented areas in the supraspiracular area.

It was felt that the absence of denticles on the pigmented subdorsal areas of the mid-and posterior abdominal segments might in some way be related to the method of preparation of the material so single specimens of Neodiprion sertifer Geoff. and Neodiprion maurus Rohwer were prepared in the routine manner as was a single specimen of N. swainei from a different source. The swainei cuticula showed the same condition as already described, but sertifer and maurus both had the spiniform denticles normally distributed on all unsclerotized pigmented areas.

Abdominal segment nine (Plate XVI, a) is shaped somewhat differently from the preceding ones. It is narrowed caudad in dorsal profile and has its greatest dorsoventral dimension at its posterior margin. There are only five annulets on the dorsum. The first tapers out on the ventrolateral aspect of the segment while the second is continued on the ventral aspect. Annulet 3 and 4 are terminated at the supraspiracular level, and number 5 extends to an indistinct ventral fold which appears to represent the postepipleural area. Below annulets 3 and 4 which together form a ventrally truncated V are two small, rounded protuberances believed to represent the postspiracular area (dorsal one) and the preepipleural area (ventral one). It appears that annulet 4 of segment nine corresponds to combined annulets 4 and 5 of the preceding segments while annulet 5 of segment nine corresponds to annulet 6 of the preceding segments. There are two broad annulets on the ventral aspect.

Sensilla styloconica are found on certain dorsal and lateral areas as in the preceding segments and the numbers for each area (Table XIV) were as follows: annulet 1, 4-8 ($\bar{x}$, 5.90) in a dorsolateral row and 1-2 ($\bar{x}$, 1.45) in a lateral group; annulet 2, 6-9 ($\bar{x}$, 7.43); annulet 4, 7-11 ($\bar{x}$, 8.86); postspiracular area, 2-5 ($\bar{x}$, 3.43); preepipleural area, 3-6 ($\bar{x}$, 4.33); postepipleural area, 2-5 ($\bar{x}$, 3.14); and one complete side, 30-40 ($\bar{x}$, 34.60). A few small setae are located on these same areas. The anterior ventral annulet has a few small setae while the posterior one has two groups of several setae on slight protuberances either side of the midventral line.

The tenth abdominal segment (Plate XVI, a, b) bears no resemblance to the other abdominal segments in its external organization. The curve in the abdomen results in the dorsal surface of the segment being sharply sloped ventrad and the ventrally borne anal prolegs being directed cephalad. The description that follows refers to the segment oriented as though the abdomen were straight. The anus is large and medially situated in a deep, transverse furrow. The dorsal and dorsolateral surface is a single, slightly raised, shield -like area, the epiproct, Between the depression posteroventral to the epiproct and the anus is a large lobe having its posterodorsal aspect particularly protuberant. The posteroventral aspect forms the suranal lobe. Below the anus and comprising the entire ventral portion of the tenth abdominal segment is a large transverse lobe, sloped anteriorly and rounded posteriorly. Ventrally this lobe bears the anal prolegs set with their bases contiguous in the midline and splayed slightly laterad. The dorsal part of this protuberant posterior area forms the subanal lobe. Anterior to the anal furrow and ventral to the edges of the epiproct is a lateral protuberance roughly triangular in basal section.

Sensilla styloconica are found in profusion on the epiproct and may be counted on right and left sides. The value obtained (one side) was 29-40 with a mean of 31.47 (Table XIV). The same type of sensory structure is found posterolaterally on the ridge dorsal to the suranal lobe and also posterolaterally above the anal proleg. Counts of the sensilla in these two groups were not made. The lateral protuberances also bear sensilla styloconica, 3-5 (with a mean of 4.09) being found on this area. The areas bearing sensilla styloconica also have a few small setae. A large number of setae are found on the anterior and anteromesal surfaces of the ventral lobe bearing the anal prolegs. Some are also present on the anterior and anteromesal aspects of the basal portion of the proleg.

The suranal and subanal areas both have brushes of large spines (Plate XVI, f).

d. Colour

Plate XXI a and b show the main features of coloration in mature, feeding larvae of N. swainei.

The cranium is usually orange-brown, but may be a darker brown or on occasion black. There is a large dark, reddish-brown, almost black ring around each ocellus. Diffuse, darker brown markings are present on the frons along the oblique arms of the frontal suture and may be present on a narrow border of the adjoining parietals. The two pairs of frontal depressions are also often slightly darker than the general cranial colour and the whole cranium dorsal to the antennae may be darker, particularly the frons.

The antennal sclerites are dark brown and narrow brownish ring markings are present on the sclerotized truncated cone bearing the antennal membrane. The genal margin is brownish as are the large genal setae. The central, depressed area of the clypeus is pale, yellowish-brown while the lateral lobes are whitish. The raised areas on either side of the median depression are medium brown as is a band just below the transclypeal sulcus. The clypeal margins at the anterior mandibular articulations are dark brown tinged with black. The labrum is medium brown, darker around the margin, and has a slight yellow-green tinge. The mandibles are medium-to-dark brown, much darker toward the dentes and posteriorad, and have a yellow-green tinge. The sclerotized portions of the maxillae and labium are all medium brown.

The general colour of the thorax and abdomen is a pale, greenish-yellow, resulting from the haemolymph and fat body colour showing through the translucent integument. Actively feeding larvae show a central greener region produced by food in the gut. The subdorsal area on either side of the thorax and abdomen bears a grey-green stripe which is often faint, but varies greatly in intensity. The subdorsal stripes are wider and heavier cephalad, becoming indistinct caudally and do not merge with the epiproct markings. Laterally in the supraspiracular area certain segments of the thorax and abdomen may have a series of dark, blackish markings. In the specimens examined, if any segments were marked laterally, then abdominal one bore a spot. As frequency of spotting increased abdominal eight would have a pair of spots followed by thoracic segments two and three. Other pairs of spots were often found on segments posterior to abdominal one and anterior to abdominal eight, but were usually poorly developed or absent on the midabdominal segments. Abdominal segment nine may bear a pair of lateral markings while thoracic segment one was not seen to have any. The intensity of pigmentation was greatest on abdominal segment one followed by abdominal eight and thoracic two and three. A high incidence of spotting was accompanied by increased intensity of the subdorsal stripes.

The lateral spots were found on the supraspiracular area of annulets 2, 3, and sometimes 4 in the thoracic segments. When the intensity of pigmentation was low occasionally only annulet 3 was involved while annulet 4 was marked only when pigmentation was heavy. On the abdominal segments annulets 2, 3, and 4 were again the ones to be marked and the same relation with intensity as for the thorax was observed. The pigmentation on annulet 3 extended onto the anterodorsal and dorsal margins of the postspiracular area in some instances.

The most distinctive and constant markings were a pair of large, ovoid, black blotches occupying most of the epiproct surface but being well separated medially (Plate XVI, a, c).

A pair of small irregular grey-to-black markings (Plate XIII, a) were usually present on the sternal protuberances between the prothoracic legs.

The thoracic leg sclerites, prehypopleurites, and cervical sclerites were usually a medium reddish brown, but varied to almost black. The coxites were the darkest coloured, especially along the deep inflections.

2. DESCRIPTION OF THE FOURTH INSTAR MALE LARVA

The mature, feeding male larva of N. swainei, being one stage younger than the mature, feeding female larva, is smaller with a length of about 13 millimeters. In all respects except size it is very little different from the mature, feeding female and the following paragraphs will mention points of difference only. Tables XVI to XXVIII give the results of counts and measurements made on fourth instar males.

The cranial dimensions of mature, feeding male larvae, apart from being generally smaller, show some proportional changes, the ratio of width to height (Table XVII) being lower and in Table XXIX the apparent differences in cranial dimensions between the two stages have been expressed as ratios. The ratio for width is 1.2062 and that for height 1.1864. The measurements taken were such that apparent differences between different sections of the overall dimensions could be checked and the results are shown in Table XXIX also. Note that most of the apparent difference in width was the result of lateral expansion in the posterior portions of the cranium, that is, the regions behind the ocelli. Of the height components the greatest apparent difference was in the distance from the anterior tentorial pits to the genal margin while the smallest was in the distance from the anterior tentorial pits to the clypeal margin. Combined, these two conditions result in fourth stage male larvae having more of the clypeus free below the genal margins. The ratio of free clypeus in fifth instar female larvae to that in fourth instar male larvae was 0.88. The differences in proportion also are evident in comparing Tables IV and XVII.

Ratios given in Table XXX indicate that the mandibles in fourth stage male larvae are slightly less stubby than in the fifth stage female. Otherwise they are very similar.

In the mature, feeding male larva the ligular sclerite is of the same general shape as in the female, but is slenderer and joined at its apex to the premental sclerite.

The thoracic legs are proportioned about the same in both stages, but the coxae are relatively smaller and the trochanters relatively larger in the fourth stage male larvae (Tables XII and XXV).

The numbers of sensilla styloconica (Table XXVII) are similar to those for the fifth instar female, but may be slightly lower. In Table XXXII the statistics for the total number counted on each side and for the whole larva are shown. Lower values for the fourth stage male larvae are evident. It is possible that the differences in number of sensilla styloconica are the result of differing proportionate representation of families in the two samples.

The colour of the mature, feeding male larva is much like that of the mature feeding female, except that the subdorsal stripes are less distinct and the supraspiracular spots are so weakly developed as to be invisible to the naked eye. The epiproct markings are distinct and the same as in the female.

3. DISCUSSION

Few differences are evident when my results are compared with published studies of other Neodiprion larvae, but the comparison is difficult, because the published descriptions are less detailed.

Table XXXIII and the various tables giving count and measurement statistics indicate that the sample size used for mature, feeding larvae provided a reasonable estimate of the mean for most characters. Additional mature, feeding male larvae should be examined to define the mean more closely for some characters.

The differences in proportions of the cranium shown for fourth instar males and fifth instar females is interesting in the light of Bigelow's (1954) study of the face in the Hymenoptera, the male larvae having a greater extent of free clypeus. This brings up the point that any differences between fourth stage male larvae and fifth stage female larvae cannot be related to sexual or to developmental differences until the fourth stage female larva has been examined.

Yuasa (1922) refers to integumental glands called glandubae and his characterization of the genus Neodiprion leaves little doubt that his "glandubae" are the same structures I have called sensilla styloconica. My preparations indicate a sensory rather than a glandular function. Use of the term glandubae is misleading and it appears that there is already confusion in the literature regarding the application of this term. It seems preferable to me to substitute the general term sensilla styloconica for these structures.

Judgement of the value of this work in a systematic study awaits its extension to other species of Neodiprion.

VI. GENERAL SUMMARY

The literature pertaining to *Neodiprion swainei* Midd. has been reviewed briefly and an outline of the major characteristics presented, both as background to the two original contributions.

1. A study of the occurrence of *N. swainei* Midd. resulted in the following conclusions:

   (a) Valid records of *N. swainei* are from southeastern Manitoba, northern Ontario, Quebec north of the St. Lawrence River and near Rimouski and Riviere du Loup on the South Shore, Minnesota, Wisconsin, and Michigan. A record for New York State could not be verified and must be considered invalid.

   (b) The southern distribution limit is determined by the southern limit of the natural range of jack pine, *Pinus banksiana* Lamb., from Lake Winnipeg to the mouth of the Saguenay River.

   (c) *N. swainei* has a slower developmental rate than *N. virginianus* complex which is more widespread and abundant in certain areas in northern Ontario and the northern limit of *swainei* occurrence is determined by the length of the warm season rather than by the presence of jack pine.

   (d) *N. swainei* has not been recorded in New Brunswick perhaps due to discontinuous host tree distribution combined with a short-season area.

(e) Jack pine plantations within the natural range of jack pine may be invaded by _N_. _swainei_, but plantings in southern Ontario not greatly removed from areas of natural occurrence of the same tree species are free of _swainei_.

2. A detailed study of the external larval anatomy was made, but until the larvae of other species are examined in similar detail no conclusions may be made as to the usefullness of the information in clarifying the systematics of the genus _Neodiprion_.

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VIII. APPENDIX I, TABLES I - XXXIII

TABLE I

Calibration of Leitz screw micrometer in conjunction with Leitz stereo binocular microscope.

Objective	Magnification	1 drum interval in millimeters
1x	12.5	0.003938
2x	25.0	0.001969
4x	50.0	0.0009934
8x	100.0	0.0005064
12x	150.0	0.0003339

TABLE II

Material examined for anatomical purposes.

Family	Number of specimens	
	Female V	Male IV
2	4	1
3	2	1
4	1	2
5	4	0
TOTAL	11	4

TABLE III

Summary of data for cranial measurements, fifth instar females.

n	Statistic	Variable Distance between inner margins of ocelli	Distance between vertical portions ecdysial line at ocelli	Width (W)	Distance between dorsal margin and forking of ecdysial line
11	$\bar{x}$	1.426 mm.	0.894 mm.	1.611 mm.	0.627 mm.
	s	0.034	0.025	0.029	0.068
	$s_{\bar{x}}$	0.010	0.008	0.009	0.020
	R	1.389-1.488	0.847-0.931	1.562 - 1.665	0.474-0.685
	C.V. (%)	2.39	2.79	1.81	10.78

n	Statistic	Distance between dorsal margin and ant. tent. pits	Distance between dorsal margin and genal margin	Distance between dorsal margin and clypeal margin (H)	W/H
11	$\bar{x}$	1.465 mm.	1.607 mm.	1.711 mm.	0.943
	s	0.059	0.052	0.069	0.034
	$s_{\bar{x}}$	0.018	0.016	0.021	0.010
	R	1.343 - 1.519	1.509 - 1.660	1.559 - 1.774	0.906 - 1.025
	C.V.(%)	4.02	3.24	4.05	3.58

TABLE IV

Relative size of cranial dimensions in fifth instar female larvae expressed as per cent of height or width (Based on means).

Dimension	Per Cent
Dorsal margin to forking of ecdysial line	33.66
Forking of ecdysial line to anterior tentorial pits	48.94
Anterior tentorial pits to genal margin	8.33
Genal margin to clypeal margin	6.06
Lateral margin to inner margin of ocellus X2	11.46
Inner margin of ocellus to vertical portion of ecdysial line X2	33.05
Distance between vertical portions of ecdysial line.	55.49

TABLE V

Number of setae on three areas of the fronto-parietal region of the cranium in fifth instar females.

		Statistic				
Area	n	$\bar{x}$	s	$s_{\bar{x}}$	R	C.V.(%)
Genal margin	22	4.046	0.375	0.080	3-5	7.43
Postantennal area	22	8.864	0.990	0.211	7-10	11.17
Frons	10	28.1	0.994	0.315	27-30	3.54

TABLE VI

Summary of data for clypeal measurements on fifth instar females.

n	Statistic	Distance between outer setae (O)	Distance between inner setae (I)	I/O
11	$\bar{\bar{x}}$	0.644 mm.	0.351 mm.	0.545
	s	0.013	0.015	0.088
	$s_{\bar{\bar{x}}}$	0.004	0.004	0.027
	R	0.621-0.662	0.333-0.378	0.513-0.595
	C.V. (%)	1.94	4.15	16.20

TABLE VII

Summary of data for labral measurements, fifth instar females.

Variable

n	Statistic	Width	Symmetry Index	Distance between outer setae (O)	Distance between inner setae (I)	I/O
11	$\bar{x}$	0.531 mm.	0.481	0.409 mm.	0.159 mm.	0.389
	s	0.011	0.009	0.016	0.011	0.079
	$s_{\bar{x}}$	0.003	0.003	0.005	0.003	0.024
	R	0.515-0.549	0.469-0.492	0.393-0.428	0.144-0.178	0.357-0.437
	C.V. (%)	2.13	1.97	4.02	7.00	20.26

TABLE VIII

Summary of data for measurements of mandibles, fifth instar females.

Side	n	Statistic	Width	Distance between setal base and posterior margin	Distance between setal base and tip of anterior tooth	Distance between setal base and tip of posterior tooth	Distance between tips of anterior and posterior teeth
Right	11	$\bar{x}$	0.414 mm.	0.232 mm.	0.417 mm.	0.412 mm.	0.246 mm.
		s	0.011	0.012	0.024	0.028	0.010
		$s_{\bar{x}}$	0.003	0.004	0.007	0.009	0.003
		R	0.397-0.428	0.205-0.251	0.369-0.454	0.371-0.480	0.228-0.263
		C.V.(%)	2.56	5.11	5.63	6.89	4.02
Left	11*	$\bar{x}$	0.428 mm.	0.230 mm.	0.394 mm.	0.375 mm.	0.279 mm.
		s	0.007	0.014	0.020	0.026	0.009
		$s_{\bar{x}}$	0.002	0.004	0.006	0.008	0.003
		R	0.420-0.441	0.196-0.249	0.350-0.411	0.325-0.408	0.269-0.297
		C.V.(%)	1.67	6.05	5.08	6.85	3.39

* n = 10 for width

TABLE IX

Number of sensilla on certain maxillary structures in fifth instar females.

Structure and location	n	Statistic $\bar{x}$	s	$s_{\bar{x}}$	R	C.V. (%)
Blade sensilla on lacinia	21	5.476	0.559	0.122	5-6	10.20
Rods on membrane of third segment of maxillary palpus	20	3.950	0.224	0.500	3-4	5.66

TABLE X

Number of sensilla on the labral palatum of fifth instar female larvae.

Group		n	Statistic				
			$\bar{x}$	s	$s_{\bar{x}}$	R	C.V. (%)
Blade sensilla, main group		22	2.955	0.213	0.046	2-3	7.22
Ventral, outer pegs		22	2.955	0.213	0.046	2-3	7.22
Ventral, inner pegs		22	3.273	0.631	0.135	2-4	19.28
Dorsal pegs		22	2.818	0.395	0.084	2-3	14.01
Additional blade sensilla	Inner group	22	2.682	0.477	0.102	2-3	17.78
	Marginal, ventral	22	0.727	0.456	0.097	0-1	62.68
	Marginal, dorsal						
	right	11	0.546	0.522	0.158	0-1	95.73
	left	11	0.364	0.505	0.152	0-1	138.75

TABLE XI

Summary of measurement data for thoracic legs of fifth instar female larvae.

			Statistic				
Segmental Appendage	Podite	n	$\bar{x}$	s	$s_{\bar{x}}$	R	C.V. (%)
TI	Coxa	11	0.596 mm.	0.019 mm.	0.006 mm.	0.551-0.620 mm.	3.18
	Trochanter	"	0.282	0.029	0.009	0.268-0.304	10.12
	Femur	"	0.184	0.014	0.004	0.165-0.210	5.58
	Tibia	"	0.228	0.007	0.002	0.218-0.241	3.14
	Claw	"	0.122	0.005	0.002	0.110-0.130	4.27
TII	Coxa	10	0.720	0.010	0.003	0.703-0.732	1.42
	Trochanter	11	0.296	0.012	0.004	0.271-0.316	3.99
	Femur	"	0.216	0.013	0.004	0.198-0.234	5.79
	Tibia	"	0.259	0.014	0.004	0.233-0.277	5.34
	Claw	"	0.144	0.007	0.002	0.134-0.158	4.61
TIII	Coxa	10	0.756	0.015	0.005	0.723-0.771	1.97
	Trochanter	11	0.295	0.012	0.004	0.272-0.313	4.06
	Femur	"	0.228	0.011	0.003	0.212-0.247	4.85
	Tibia	"	0.270	0.011	0.003	0.250-0.281	4.10
	Claw	"	0.148	0.004	0.001	0.141-0.153	2.53

TABLE XII

Relative length of podites in fifth instar females expressed as per cent of nominal total leg length (Based on means).

Segmental Appendage	Podite	Per Cent
TI	Coxa	42.21
	Trochanter	19.97
	Femur	13.03
	Tibia	16.15
	Claw	8.64
TII	Coxa	44.04
	Trochanter	18.10
	Femur	13.21
	Tibia	15.84
	Claw	8.81
TIII	Coxa	44.55
	Trochanter	17.38
	Femur	13.44
	Tibia	15.91
	Claw	8.72

TABLE XIII

Relative size of the thoracic legs in fifth instar female larvae with length of the prothoracic appendage used as base. Ratios determined from means.

Segmental Appendage	Podite					
	Coxa	Trochanter	Femur	Tibia	Claw	Nominal Total
TI	1.0	1.0	1.0	1.0	1.0	1.0
TII	1.2081	1.0496	1.1739	1.1360	1.1803	1.1579
TIII	1.2685	1.0461	1.2391	1.1842	1.2131	1.2018

TABLE XIV

Number of sensilla styloconica on thoracic and abdominal segments of fifth instar female larvae by segment and area (sides of individual specimens treated as independent variables).

			Statistic				
Segment	Area	n	$\bar{x}$	s	$s_{\bar{x}}$	R	C.V.(%)
TI	a2	22	6.27	0.83	0.18	5-8	13.18
	a3	22	15.18	1.59	0.34	13-19	10.49
	Preep	22	6.00	0.82	0.17	5-8	13.61
	Postep	22	4.95	0.79	0.17	4-6	15.85
	Posthyp	22	3.91	0.68	0.15	3-5	17.49
	Total (side)	22	36.32	2.23	0.48	32-42	6.15
	Whole seg.	11	72.64	3.83	1.16	68-79	5.31
TII	aldorsolat	22	6.36	1.18	0.25	4-8	18.50
	allat	22	2.14	0.47	0.10	1-3	21.88
	a2	22	9.00	1.38	0.29	6-11	15.33
	a3	22	13.50	1.30	0.28	11-16	9.63
	avlatf	22	2.73	0.77	0.16	2-5	28.13
	Preep	22	10.50	1.06	0.23	9-13	10.07
	Postep	22	2.00	0.69	0.15	1-3	34.51
	Posthyp	22	4.05	0.79	0.17	3-6	19.41
	Total (side)	22	50.27	2.66	0.57	45-54	5.29
	Whole seg.	11	100.55	4.59	1.38	92-106	4.57

TABLE XIV Cont'd.

			Statistic				
Segment	Area	n	$\bar{x}$	s	$s_{\bar{x}}$	R	C.V.(%)
TIII	aldorsolat	22	6.27	0.94	0.20	4-8	14.91
	allat	22	1.45	0.51	0.11	1-2	35.04
	a2	22	7.73	1.24	0.26	5-10	16.07
	a3	22	11.73	1.24	0.26	10-15	10.59
	avlatf	22	1.82	0.66	0.14	1-3	36.55
	Preep	22	9.50	1.14	0.24	7-12	12.05
	Postep	22	1.77	0.39	0.08	1-2	20.90
	Posthyp	22	3.82	0.85	0.18	3-5	22.34
	Total (side)	22	43.95	3.17	0.68	39-49	7.21
	Whole seg.	11	87.91	4.29	1.29	81-94	4.88
AI	aldorsolat	22	3.50	0.60	0.13	3-5	17.07
	allat	22	1.09	0.29	0.06	1-2	26.98
	a2	22	5.27	0.83	0.18	3-6	15.68
	a4	22	7.14	0.56	0.12	6-8	7.85
	Postsp	22	5.59	0.73	0.17	4-7	13.13
	Preep	22	4.91	0.75	0.16	4-7	15.28
	Postep	22	3.68	0.78	0.17	3-5	21.18
	Total (side)	22	31.18	2.13	0.45	28-36	6.83
	Whole seg.	11	62.36	3.64	1.10	57-69	5.84

TABLE XIV Cont'd.

			Statistic				
Segment	Area	n	$\bar{x}$	s	$s_{\bar{x}}$	R	C.V.(%)
AII	a1	20	7.40	0.82	0.18	6-9	11.09
	a2	21	7.14	0.65	0.14	6-8	9.17
	a4	22	7.05	1.00	0.21	5-9	14.18
	Postsp	22	5.23	0.75	0.16	4-7	14.38
	Preep	22	8.18	0.96	0.20	6-10	11.71
	Postep	21	6.81	1.17	0.25	5-9	17.14
	Total (side)	20	41.75	2.43	0.54	37-46	5.81
	Whole seg.	9	83.89	4.40	1.47	76-90	5.25
AIII	a1	22	7.14	0.77	0.17	5-8	10.85
	a2	22	6.95	0.65	0.14	6-8	9.39
	a4	22	6.86	0.94	0.20	5-9	13.71
	Postsp	22	5.27	0.63	0.13	4-6	11.97
	Preep	22	8.36	1.00	0.21	6-10	11.98
	Postep	22	7.18	1.10	0.23	5-9	15.27
	Total (side)	22	41.77	2.37	0.51	38-45	5.67
	Whole seg.	11	83.55	3.83	1.15	78-88	4.58

TABLE XIV Cont'd.

Segment	Area	n	Statistic $\bar{x}$	s	$s_{\bar{x}}$	R	C.V.(%)
AIV	a1	22	7.55	0.67	0.14	7-9	8.89
	a2	22	7.45	0.74	0.16	6-9	9.91
	a4	22	7.18	0.73	0.16	6-8	10.20
	Postsp	22	5.05	0.79	0.17	3-6	15.57
	Preep	22	8.18	0.96	0.20	7-10	11.71
	Postep	22	6.95	1.00	0.21	5-8	14.36
	Total (side)	22	42.36	2.84	0.61	37-46	6.70
	Whole seg.	11	84.73	4.61	1.39	78-92	5.44
AV	a1	22	7.59	0.67	0.14	6-9	8.77
	a2	22	7.45	0.67	0.14	6-9	9.00
	a4	22	6.95	0.65	0.14	6-8	9.39
	Postsp	22	5.45	0.86	0.18	4-7	15.73
	Preep	22	8.09	0.92	0.20	6-10	11.38
	Postep	22	7.05	1.09	0.23	5-9	15.47
	Total (side)	22	42.59	2.38	0.51	37-49	5.60
	Whole seg.	11	85.18	4.51	1.36	77-94	5.30

TABLE XIV Cont'd.

Segment	Area	n	Statistic				
			$\bar{x}$	s	$s_{\bar{x}}$	R	C.V.(%)
AVI	a1	22	7.50	0.80	0.17	6-9	10.69
	a2	22	7.55	0.96	0.21	6-9	12.76
	a4	22	7.23	0.69	0.15	6-8	9.48
	Postsp	22	5.45	0.91	0.19	4-7	16.71
	Preep	22	8.14	1.08	0.23	6-10	13.30
	Postep	22	6.64	0.90	0.19	5-8	13.59
	Total (side)	22	42.50	2.44	0.52	38-46	5.75
	Whole seg.	11	85.00	3.92	1.18	77-90	4.62
AVII	a1	22	7.86	0.64	0.14	7-9	8.13
	a2	22	7.68	0.84	0.18	6-9	10.92
	a4	22	7.73	0.88	0.19	6-9	11.42
	Postsp	22	5.59	0.80	0.17	4-7	14.24
	Preep	22	8.27	1.03	0.22	6-10	12.47
	Postep	22	5.36	1.14	0.24	5-9	17.85
	Total (side)	22	43.50	2.60	0.55	38-48	5.97
	Whole seg.	11	87.00	4.29	1.29	80-93	4.93

TABLE XIV Cont'd.

			Statistic				
Segment	Area	n	$\bar{x}$	s	$s_{\bar{x}}$	R	C.V.(%)
AVIII	a1	22	7.50	0.74	0.16	6-9	9.87
	a2	22	7.09	0.75	0.16	6-9	10.58
	a4	22	7.55	0.86	0.18	6-9	11.37
	Postsp	22	5.18	1.18	0.25	3-7	22.78
	Preep	21	7.52	0.87	0.19	6-9	11.60
	Postep	21	6.19	0.87	0.19	4-8	14.10
	Total (side)	21	41.24	2.51	0.55	37-45	6.08
	Whole seg.	10	82.60	4.55	1.37	76-89	5.51
AIX	a1dorsolat	21	5.90	0.94	0.21	4-8	15.98
	a1lat	22	1.45	0.51	0.11	1-2	35.04
	a2	21	7.43	0.93	0.20	6-9	12.46
	a4	22	8.86	1.21	0.26	7-11	13.62
	Postsp	21	3.43	0.68	0.15	2-5	19.72
	Preep	21	4.33	0.80	0.17	3-6	18.36
	Postep	21	3.14	0.79	0.17	2-5	25.23
	Total (side)	20	34.60	2.30	0.52	30-40	6.66
	Whole seg.	9	69.33	3.46	1.04	65-74	5.00
Epiproct		19	31.47	2.80	0.64	29-40	8.88
Lateral protuberance		22	4.09	0.75	0.16	3-5	18.34

TABLE XV

Mean number of sensilla styloconica on abdominal segments I to IX of fifth instar female larvae by segment and area (Sides of individuals treated as independent variables).

	Area						
Segment	a 1	a 2	a 4	Postsp	Preep	Postep	Total
AI	4.59	5.27	7.14	5.59	4.91	3.68	38.18
AII	7.40	7.14	7.05	5.25	8.18	6.81	41.75
AIII	7.14	6.95	6.86	5.27	8.36	7.18	41.77
AIV	7.55	7.45	7.18	5.05	8.18	6.95	42.36
AV	7.59	7.45	6.95	5.45	8.09	7.05	42.59
AVI	7.50	7.55	7.23	5.45	8.14	6.64	42.50
AVII	7.86	7.68	7.73	5.59	8.27	6.36	43.50
AVIII	7.50	7.09	7.55	5.18	7.52	6.19	41.24
AIX	7.38	7.43	8.86	3.43	4.33	3.14	34.60

TABLE XVI

Summary of data for cranial measurements, fourth instar males.

n	Statistic	Variable			
		Distance between inner margins of ocelli	Distance between vertical portions ecdysial line-at ocelli	Width (W)	Distance between dorsal margin and forking of ecdysial line
4	$\bar{x}$	1.229 mm.	0.778 mm.	1.336 mm.	0.540 mm.
	s	0.071	0.024	0.050	0.036
	$s_{\bar{x}}$	0.035	0.012	0.025	0.018
	R	1.130-1.299	0.743-0.798	1.262-1.371	0.486-0.563
	C.V.(%)	5.77	3.14	3.71	6.66

n	Statistic	Distance between dorsal margin and ant. tent. pits	Distance between dorsal margin and genal margin	Distance between dorsal margin and clypeal margin	W/H
4	$\bar{x}$	1.225 mm.	1.324 mm.	1.442 mm.	0.926
	s	0.042	0.055	0.038	0.031
	$s_{\bar{x}}$	0.021	0.027	0.019	0.015
	R	1.181-1.277	1.297-1.360	1.365-1.483	0.892-0.964
	C.V.(%)	3.43	4.12	2.62	3.31

TABLE XVII

Relative size of cranial dimensions in fourth instar male larvae expressed as per cent of height or width (Based on means).

Dimension	Per Cent
Dorsal margin to forking of ecdysial line	37.42
Forking of ecdysial line to anterior tentorial pits	47.55
Anterior tentorial pits to genal margin	6.86
Genal margin to clypeal margin	8.18
Lateral margin to inner margin of ocellus X2	7.97
Inner margin of ocellus to vertical portion of ecdysial line X2	33.75
Distance between vertical portions of ecdysial line	58.28

TABLE XVIII

Number of setae on three areas of the fronto-parietal region of the cranium in fourth instar males.

Area	n	Statistic $\bar{x}$	s	$s_{\bar{x}}$	R	C.V.(%)
Genal margin	8	4.25	0.463	0.164	4-5	10.89
Postantennal area	8	10.0	0.756	0.267	9-11	7.56
Frons	4	30.0	1.412	0.706	29-32	4.71

TABLE XIX

Summary of date for clypeal measurements on fourth instar males.

		Variable		
n	Statistic	Distance between outer setae (O)	Distance between inner setae (I)	I/O
4	$\bar{x}$	0.558 mm.	0.306 mm.	0.548
	s	0.021	0.030	0.051
	$s_{\bar{x}}$	0.010	0.015	0.025
	R	0.528-0.577	0.284-0.349	0.506-0.621
	C.V.(%)	3.73	9.80	9.21

TABLE XX

Summary of data for labral measurements, fourth instar males.

n	Statistic	Variable				
		Width	Symmetry Index	Distance between outer setae (O)	Distance between inner setae (I)	I/O
4	$\bar{x}$	0.449 mm.	0.484	0.342 mm.	0.135 mm.	0.396
	s	0.016	0.008	0.013	0.017	0.048
	$s_{\bar{x}}$	0.008	0.004	0.007	0.008	0.024
	R	0.436-0.471	0.473-0.494	0.326-0.353	0.118-0.152	0.334-0.436
	C.V.(%)	3.56	1.72	3.84	12.25	11.99

TABLE XXI

Summary of data for measurements of mandibles, fourth instar males.

Side	n	Statistic	Variable				
			Width	Distance between setal base and posterior margin	Distance between setal base and tip of anterior tooth	Distance between setal base and tip of posterior tooth	Distance between tips of anterior and posterior teeth
Right	4	$\bar{x}$	0.346 mm.	0.194 mm.	0.359 mm.	0.350 mm.	0.205 mm.
		s	0.008	0.012	0.014	0.013	0.010
		$s_{\bar{x}}$	0.004	0.006	0.007	0.006	0.005
		R	0.336-0.354	0.178-0.204	0.347-0.378	0.336-0.361	0.190-0.211
		C.V.(%)	2.29	6.43	3.83	3.66	4.93
Left	4	$\bar{x}$	0.361 mm.	0.191 mm.	0.336 mm.	0.326 mm.	0.231 mm.
		s	0.011	0.008	0.014	0.016	0.018
		$s_{\bar{x}}$	0.005	0.004	0.007	0.008	0.009
		R	0.347-0.372	0.185-0.202	0.323-0.350	0.308-0.340	0.207-0.250
		C.V.(%)	2.95	4.19	4.04	5.00	7.77

TABLE XXII

Number of sensilla on certain maxillary structures in fourth instar males.

		Statistic				
Structure and location	n	$\bar{x}$	s	$s_{\bar{x}}$	R	C.V.(%)
Blade sensilla on lacinia	8	5.750	0.463	0.164	5-6	8.05
Rods on membrane of third segment of maxillary palpus	8	3.625	0.518	0.183	3-4	14.28

TABLE XXIII

Number of sensilla on the labral palatum of fourth instar male larvae.

Group		n	Statistic				
			$\bar{x}$	s	$s_{\bar{x}}$	R	C.V.(%)
Blade sensilla, main group		8	3.0	0.0	0.0	-	0.0
Ventral, outer pegs		8	3.125	0.354	0.125	3-4	11.32
Ventral, inner pegs		8	3.125	0.354	0.125	3-4	11.32
Dorsal pegs		8	2.625	0.518	0.183	2-3	19.72
Additional blade sensilla	Inner group	8	2.50	0.535	0.890	2-3	21.38
	Marginal, ventral	8	1.0	0.0	0.0	-	0.0
	Marginal, dorsal right	4	0.75	0.50	0.25	0-1	66.67
	left	4	0.0	0.0	0.0	-	0.0

TABLE XXIV

Summary of measurement data for thoracic legs of fourth instar male larvae.

Segmental Appendage	Podite	n	Statistic $\bar{x}$	 s	 $s_{\bar{x}}$	 R	 C.V.(%)
TI	Coxa	4	0.464 mm.	0.018 mm.	0.009 mm.	0.447-0.484 mm.	3.95
	Trochanter	"	0.240	0.006	0.003	0.234-0.246	2.51
	Femur	"	0.135	0.006	0.003	0.128-0.141	4.10
	Tibia	"	0.191	0.006	0.003	0.187-0.199	2.89
	Claw	"	0.105	0.003	0.001	0.103-0.108	2.44
TII	Coxa	4	0.556	0.022	0.011	0.540-0.588	3.96
	Trochanter	"	0.242	0.010	0.005	0.227-0.248	4.25
	Femur	"	0.170	0.012	0.006	0.154-0.182	7.06
	Tibia	"	0.216	0.003	0.002	0.212-0.220	1.55
	Claw	"	0.118	0.005	0.003	0.111-0.124	4.54
TIII	Coxa	4	0.583	0.017	0.009	0.567-0.600	2.98
	Trochanter	"	0.245	0.009	0.005	0.232-0.253	3.86
	Femur	"	0.174	0.006	0.003	0.167-0.181	3.40
	Tibia	"	0.222	0.012	0.006	0.210-0.233	5.26
	Claw	"	0.123	0.007	0.003	0.118-0.133	5.34

TABLE XXV

Relative length of podites in fourth instar males expressed as per cent of nominal total leg length (Based on Means).

Segmental Appendage	Podite	Per Cent
TI	Coxa	40.88
	Trochanter	21.15
	Femur	11.89
	Tibia	16.83
	Claw	9.25
TII	Coxa	42.70
	Trochanter	18.59
	Femur	13.06
	Tibia	16.59
	Claw	9.06
TIII	Coxa	43.28
	Trochanter	18.19
	Femur	12.92
	Tibia	16.48
	Claw	9.13

TABLE XXVI

Relative size of the thoracic legs in fourth instar male larvae with length of the prothoracic appendage used as base. Ratios determined from means.

	Podite					
Segmental Appendage	Coxa	Trochanter	Femur	Tibia	Claw	Nominal Total
TI	1.0	1.0	1.0	1.0	1.0	1.0
TII	1.1982	1.0083	1.2593	1.1309	1.1238	1.1471
TIII	1.2565	1.0201	1.2889	1.1623	1.1714	1.1868

TABLE XXVII

Number of sensilla styloconica on thoracic and abdominal segments of fourth instar male larvae by segment and area (sides of individual specimens treated as independent variables).

			Statistic				
Segment	Area	n	$\bar{x}$	s	$s_{\bar{x}}$	R	C.V.(%)
TI	a2	8	6.13	0.99	0.35	5-8	16.18
	a3	8	14.50	1.41	0.50	13-17	9.75
	Preep	8	5.50	1.07	0.38	4-7	19.44
	Postep	8	4.13	0.64	0.23	3-5	15.54
	Posthyp	8	3.63	0.52	0.18	3-4	14.28
	Total (side)	8	33.88	2.59	0.91	29-38	7.64
	Whole seg.	4	67.75	3.30	1.65	62-72	4.88
TII	aldorsolat	8	5.63	0.74	0.26	5-7	13.23
	allat	8	2.25	0.46	0.16	2-3	20.57
	a2	8	8.13	1.73	0.61	5-10	21.25
	a3	8	12.25	1.39	0.49	11-15	11.34
	avlatf	8	2.75	0.71	0.25	2-4	27.71
	Preep	8	9.50	1.31	0.46	7-11	13.78
	Postep	8	2.00	0.76	0.27	1-3	37.80
	Posthyp	8	3.75	0.71	0.25	3-5	18.86
	Total (side)	8	46.25	3.85	1.36	41-51	8.31
	Whole seg.	4	92.50	7.55	3.77	83-101	8.16

TABLE XXVII Cont'd.

Segment	Area	n	Statistic				
			$\bar{x}$	s	$s_{\bar{x}}$	R	C.V.(%)
TIII	a1dorsolat	8	6.38	0.74	0.26	5-7	11.67
	a1lat	8	1.38	0.52	0.18	1-2	37.64
	a2	8	7.25	0.89	0.31	6-8	12.23
	a3	8	11.38	0.74	0.26	10-12	6.54
	avlatf	8	1.88	0.83	0.30	1-3	44.51
	Preep	8	8.25	1.39	0.49	7-10	16.83
	Postep	8	1.50	0.93	0.33	0-3	61.73
	Posthyp	8	2.88	0.64	0.23	2-4	22.29
	Total (side)	8	40.88	1.81	0.64	38-43	4.42
	Whole seg.	4	80.00	5.48	2.74	74-86	6.85
AI	a1	8	5.25	0.46	0.16	5-6	8.82
	a2	8	5.00	0.93	0.33	4-7	18.52
	a4	8	7.25	0.89	0.31	6-9	12.23
	Postsp	8	4.25	0.71	0.25	3-5	16.64
	Preep	8	4.50	1.20	0.42	3-6	26.56
	Postep	8	3.88	1.13	0.40	2-6	29.06
	Total (side)	8	30.13	2.10	0.74	28-34	6.97
	Whole seg.	4	60.25	3.30	1.65	58-65	5.48

TABLE XXVII Cont'd.

			Statistic				
Segment	Area	n	$\bar{x}$	s	$s_{\bar{x}}$	R	C.V.(%)
AII	a1	8	6.75	0.71	0.25	6-8	10.48
	a2	8	6.38	0.92	0.32	5-7	14.37
	a4	8	7.25	0.71	0.25	7-9	9.75
	Postsp	8	3.75	0.89	0.31	3-6	23.64
	Preep	8	7.25	1.04	0.37	6-9	14.28
	Postep	8	6.38	1.19	0.42	5-8	18.63
	Total (side)	8	38.75	2.92	1.03	35-44	7.52
	Whole seg.	4	77.50	5.69	2.84	71-84	7.34
AIII	a1	8	7.00	0.76	0.27	6-8	10.80
	a2	8	6.75	0.46	0.16	6-7	6.86
	a4	8	7.00	1.07	0.38	5-8	15.27
	Postsp	8	4.63	0.64	0.23	4-6	15.03
	Preep	7	7.14	0.69	0.26	6-8	9.66
	Postep	8	6.63	0.92	0.32	5-8	13.83
	Total (side)	7	39.57	2.07	0.78	36-42	5.23
	Whole seg.	3	80.33	2.08	1.04	78-82	2.59

TABLE XXVII Cont'd.

			Statistic				
Segment	Area	n	$\bar{x}$	s	$s_{\bar{x}}$	R	C.V.(%)
AIV	a1	8	6.75	0.89	0.31	6-8	13.13
	a2	8	7.38	0.74	0.26	7-9	10.09
	a4	8	6.88	1.13	0.40	6-9	16.38
	Postsp	8	5.00	0.76	0.27	4-6	15.12
	Preep	8	7.25	1.58	0.56	5-10	21.81
	Postep	8	6.63	0.74	0.26	6-8	11.23
	Total (side)	8	39.88	3.87	1.37	36-48	9.71
	Whole seg.	4	79.75	7.68	3.84	76-91	9.62
AV	a1	8	7.00	0.76	0.27	6-8	10.79
	a2	8	7.13	0.74	0.26	6-8	10.44
	a4	8	7.13	0.99	0.35	6-9	13.91
	Postsp	8	5.00	0.53	0.19	4-6	10.69
	Preep	8	7.50	1.69	0.60	5-11	22.54
	Postep	8	7.13	0.99	0.35	5-8	13.91
	Total (side)	8	40.88	2.85	1.01	38-46	6.97
	Whole seg.	4	81.75	5.56	2.78	78-90	6.80

TABLE XXVII cont'd.

			Statistic				
Segment	Area	n	$\bar{x}$	s	$s_{\bar{x}}$	R	C.V.(%)
AVI	a1	8	7.25	0.71	0.25	7-9	9.75
	a2	8	7.63	0.74	0.26	7-9	9.76
	a4	8	7.25	1.04	0.37	5-8	14.28
	Postsp	8	5.50	0.76	0.27	5-7	13.74
	Preep	8	7.50	1.41	0.50	5-9	18.86
	Postep	8	6.38	1.06	0.38	5-8	16.64
	Total (side)	8	41.50	2.39	0.85	38-46	5.76
	Whole seg.	4	83.00	3.83	1.91	80-88	4.61
AVII	a1	8	7.75	0.46	0.16	7-8	5.97
	a2	8	7.13	0.83	0.30	6-8	11.71
	a4	8	8.00	0.76	0.27	7-9	9.45
	Postsp	8	5.75	0.71	0.25	5-7	12.30
	Preep	8	8.00	1.07	0.38	6-9	13.36
	Postep	8	7.00	0.76	0.27	6-8	10.80
	Total (side)	8	43.63	2.67	0.94	38-47	6.12
	Whole seg.	4	87.25	5.12	2.56	80-92	5.87

TABLE XXVII Cont'd.

			Statistic				
Segment	Area	n	$\bar{x}$	s	$s_{\bar{x}}$	R	C.V.(%)
AVIII	a1	8	7.38	0.74	0.26	6-8	10.09
	a2	8	6.25	0.46	0.16	6-7	7.41
	a4	8	8.13	0.64	0.23	7-9	7.89
	Postsp	8	5.00	0.76	0.27	4-6	15.12
	Preep	8	7.25	1.16	0.41	6-9	16.07
	Postep	8	5.88	1.13	0.40	4-7	19.17
	Total (side)	8	39.88	2.10	0.74	37-44	5.27
	Whole seg.	4	79.75	3.86	1.93	76-85	4.87
AIX	aldorsolat	8	6.00	1.07	0.38	4-7	17.82
	allat	8	1.13	0.35	0.13	1-2	31.43
	a2	8	7.63	1.01	0.36	6-9	13.23
	a4	8	9.88	1.13	0.40	8-11	11.40
	Postsp	8	3.13	0.64	0.23	2-4	20.51
	Preep	8	3.63	0.52	0.18	3-4	14.28
	Postep	8	3.25	0.71	0.25	2-4	21.76
	Total (side)	8	34.63	2.42	0.85	32-37	6.98
	Whole seg.	4	69.25	1.89	0.95	68-72	2.73
Epiproct		8	30.13	2.53	0.90	27-35	8.40
Lateral protoberance		8	3.75	0.71	0.25	3-5	18.86

TABLE XXVIII

Mean number of sensilla styloconica on abdominal segments I to IX of fourth instar male larvae by segment and area (Sides of individuals treated as independent variables).

	Area						
Segment	a1	a2	a4	Postsp	Preep	Postep	Total
AI	5.25	5.00	7.25	4.25	4.50	3.88	30.13
AII	6.75	6.38	7.25	3.75	7.25	6.38	38.75
AIII	7.00	6.75	7.00	4.63	7.14	6.63	39.57
AIV	6.75	7.38	6.88	5.00	7.25	6.63	39.88
AV	7.00	7.13	7.13	5.00	7.50	7.13	40.88
AVI	7.25	7.63	7.25	5.50	7.50	6.38	41.50
AVII	7.75	7.13	8.00	5.75	8.00	7.00	43.63
AVIII	7.38	6.25	8.13	5.00	7.25	5.88	39.88
AIX	7.13	7.63	9.88	3.13	3.63	3.25	34.63

TABLE XXIX

Apparent difference in cranial dimensions between fourth instar male larvae and fifth instar female larvae. Determined using means.

Dimension	Ratio V/IV
Dorsal margin to forking of ecdysial line	1.1625
Forking of ecdysial line to anterior tentorial pits	1.2212
Anterior tentorial pits to genal margin	1.4408
Anterior tentorial pits to clypeal margin	1.1244
Genal margin to clypeal margin	0.8800
Dorsal margin to clypeal margin (Height)	1.1864
Lateral margin to inner margin ocellus	1.7349
Inner margin of ocellus to vertical portion of ecdysial line	1.1812
Distance between vertical portions of ecdysial line	1.1484
Width	1.2062

TABLE XXX

Apparent difference in the dimensions of mandibles between fourth instar male larvae and fifth instar female larvae. Determined using means.

Side	Dimension	Ratio V/IV
Right	Width	1.1971
	Setal base to posterior margin	1.1970
	Setal base to tip of anterior tooth	1.1610
	Setal base to tip of posterior tooth	1.1775
	Distance between tips of anterior and posterior teeth	1.2003
Left	Width	1.1873
	Setal base to posterior margin	1.2080
	Setal base to tip of anterior tooth	1.1724
	Setal base to tip of posterior tooth	1.1510
	Distance between tips of anterior and posterior teeth	1.2105

TABLE XXXI

Relation of leg length of fifth instar female larvae to that of fourth instar male larvae (Based on means).

	Ratio V/IV		
	Segmental Appendage		
Podite	TI	TII	TIII
Coxa	1.2845	1.2950	1.2967
Trochanter	1.1750	1.2231	1.2041
Femur	1.3630	1.2706	1.3103
Tibia	1.1937	1.1991	1.2162
Claw	1.1619	1.2203	1.2033
Nominal Total	1.2441	1.2558	1.2598

TABLE XXXII

Number of sensilla styloconica.

Stage	Area	n	Statistic $\bar{x}$	s	$s_{\bar{x}}$	R	C.V.(%)
Female V	Right side	8	526.0	14.609	5.165	504-543	2.78
	Left side	7	524.457	19.130	7.230	497-552	3.65
	Total	5	1051.4	35.218	15.745	1012-1095	3.35
Male IV	Right side	4	503.0	21.056	10.528	487-534	4.19
	Left side	4	505.333	27.392	15.814	481-535	5.42
	Total	3	1013.667	48.952	28.262	976-1069	4.83

TABLE XXXIII

Fiducial interval in per cent of mean at the one per cent confidence level (Equation is $p = \sqrt{t^2 C.V.^2}$ .t = 2.6, Snedecor, 1946).

	Coefficient of Variation				
n	1	5	10	15	20
3	1.50	7.51	15.01	22.52	30.02
4	1.30	6.50	13.00	19.50	26.00
5	1.16	5.81	11.63	17.44	23.26
7	0.98	4.91	9.83	14.74	19.65
8	0.92	4.60	9.19	13.79	18.38
9	0.87	4.33	8.67	13.00	17.33
10	0.82	4.11	8.22	12.33	16.44
11	0.78	3.92	7.84	11.76	15.68
15	0.67	3.36	6.71	10.07	13.43
19	0.60	2.98	5.96	8.95	11.93
20	0.58	2.91	5.81	8.72	11.63
21	0.57	2.84	5.67	8.51	11.35
22	0.55	2.77	5.54	8.31	11.09

IX. PLATES I - XXI

PLATE I

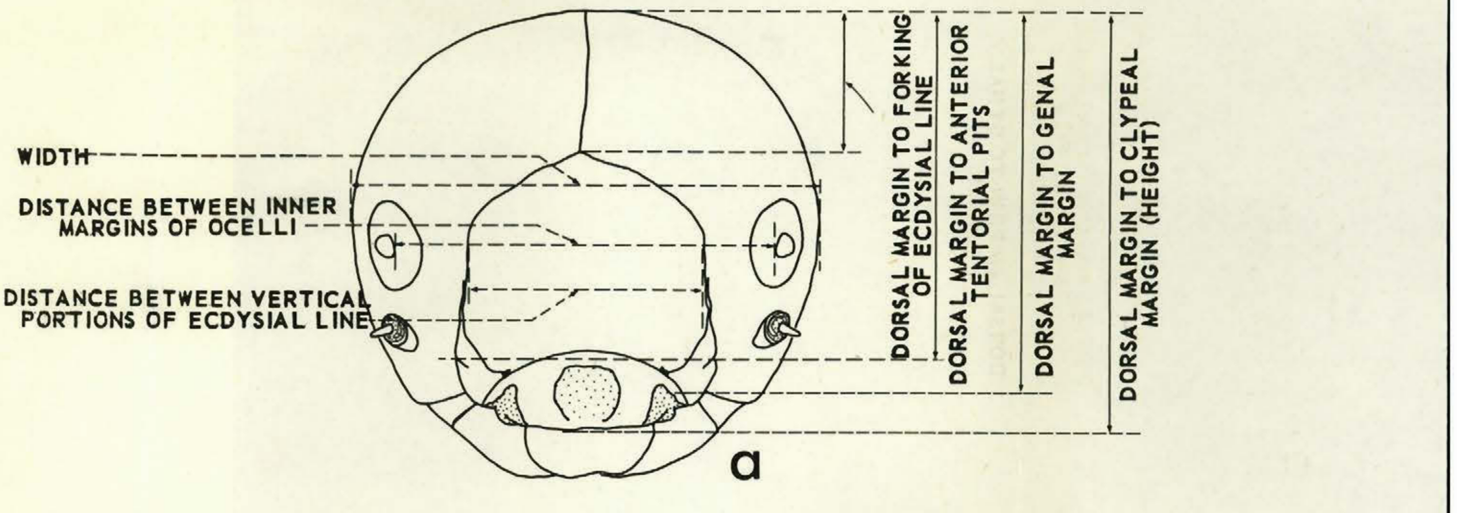
Diagrams illustrating measurements.

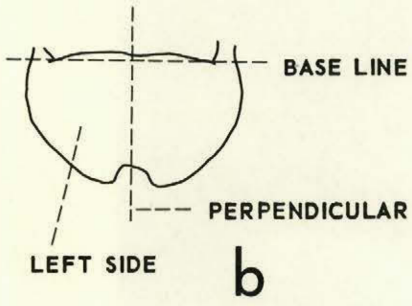
a. Frontal aspect of the head.

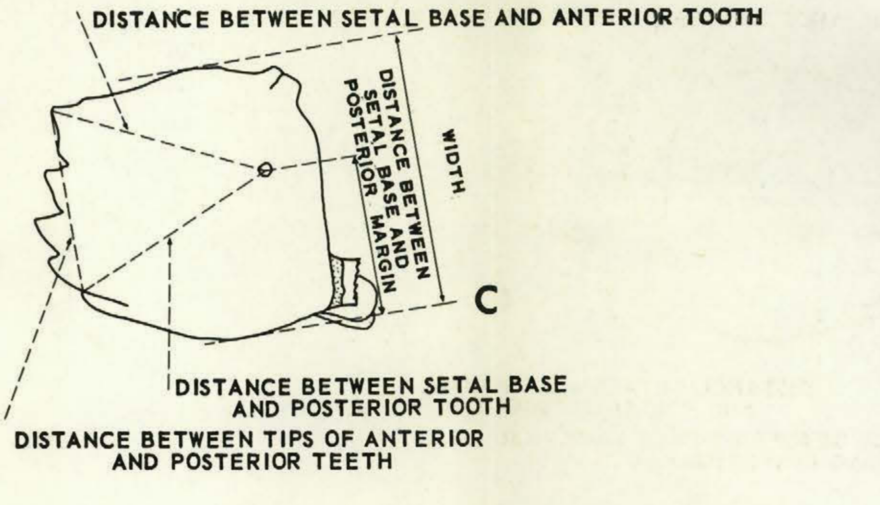
b. Labrum, symmetry index.

c. Left mandible.

d. Left metathoracic leg.


WIDTH
DISTANCE BETWEEN INNER MARGINS OF OCELLI
DISTANCE BETWEEN VERTICAL PORTIONS OF ECDYSIAL LINE
DORSAL MARGIN TO FORKING OF ECDYSIAL LINE
DORSAL MARGIN TO ANTERIOR TENTORIAL PITS
DORSAL MARGIN TO GENAL MARGIN
DORSAL MARGIN TO CLYPEAL MARGIN (HEIGHT)
a


BASE LINE
PERPENDICULAR
LEFT SIDE
b


DISTANCE BETWEEN SETAL BASE AND ANTERIOR TOOTH
DISTANCE BETWEEN SETAL BASE AND POSTERIOR MARGIN
WIDTH
c
DISTANCE BETWEEN SETAL BASE AND POSTERIOR TOOTH
DISTANCE BETWEEN TIPS OF ANTERIOR AND POSTERIOR TEETH

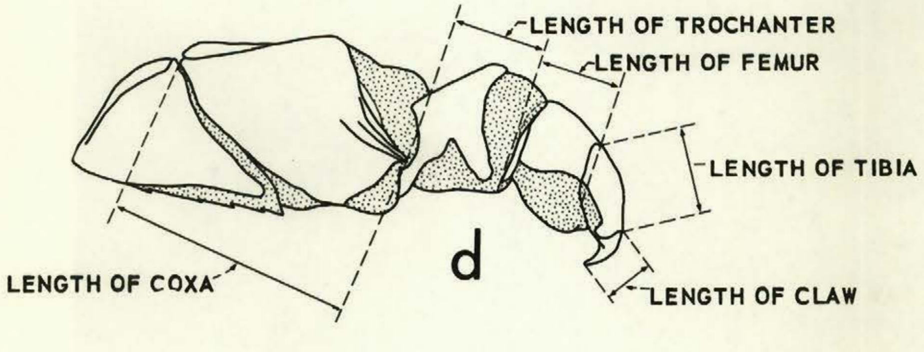

LENGTH OF TROCHANTER
LENGTH OF FEMUR
LENGTH OF TIBIA
LENGTH OF COXA
d
LENGTH OF CLAW

PLATE II

a. Dorsal aspect of a mature, feeding, female larva.

b. Lateral aspect of a mature, feeding, female larva.

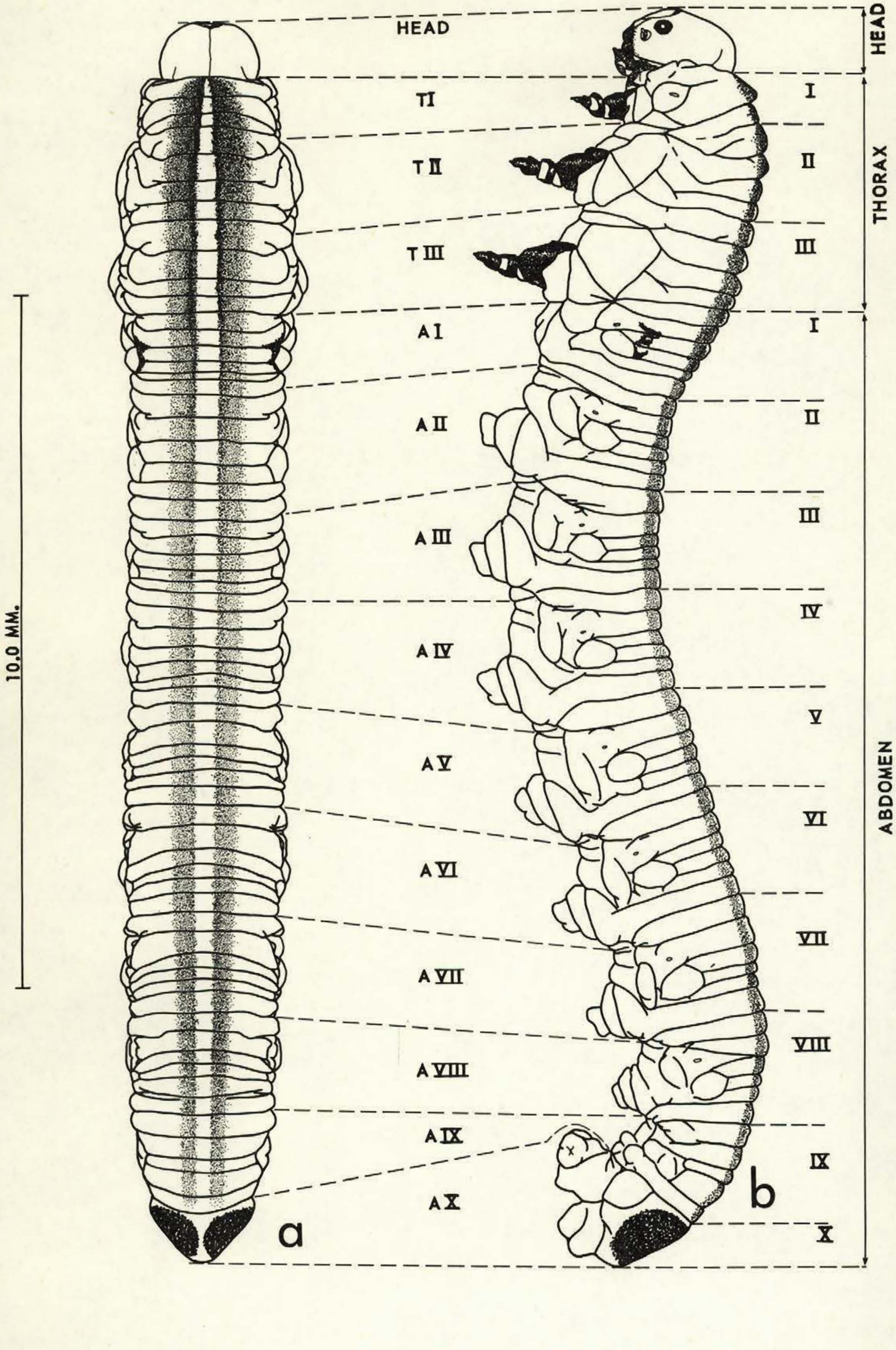

HEAD
TI
TII
TIII
AI
AII
AIII
AIV
AV
AVI
AVII
AVIII
AIX
AX
a
b
I
II
III
I
II
III
IV
V
VI
VII
VIII
IX
X
HEAD
THORAX
ABDOMEN
10.0 MM.

PLATE III

a. Dorsal aspect of the head.

b. Frontal aspect of the head.

c. Lateral aspect of the head.

d. Ventral aspect of the head.

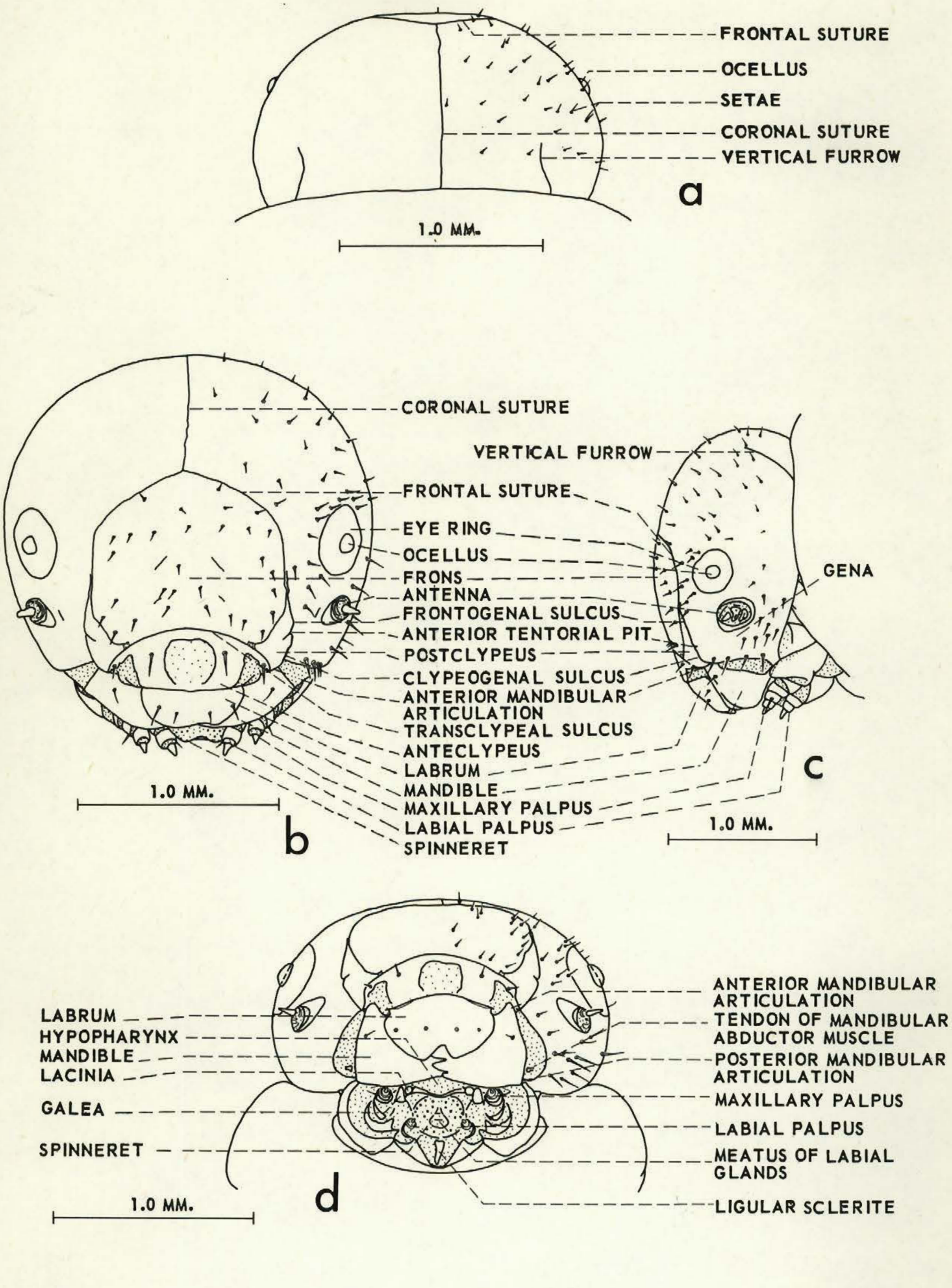
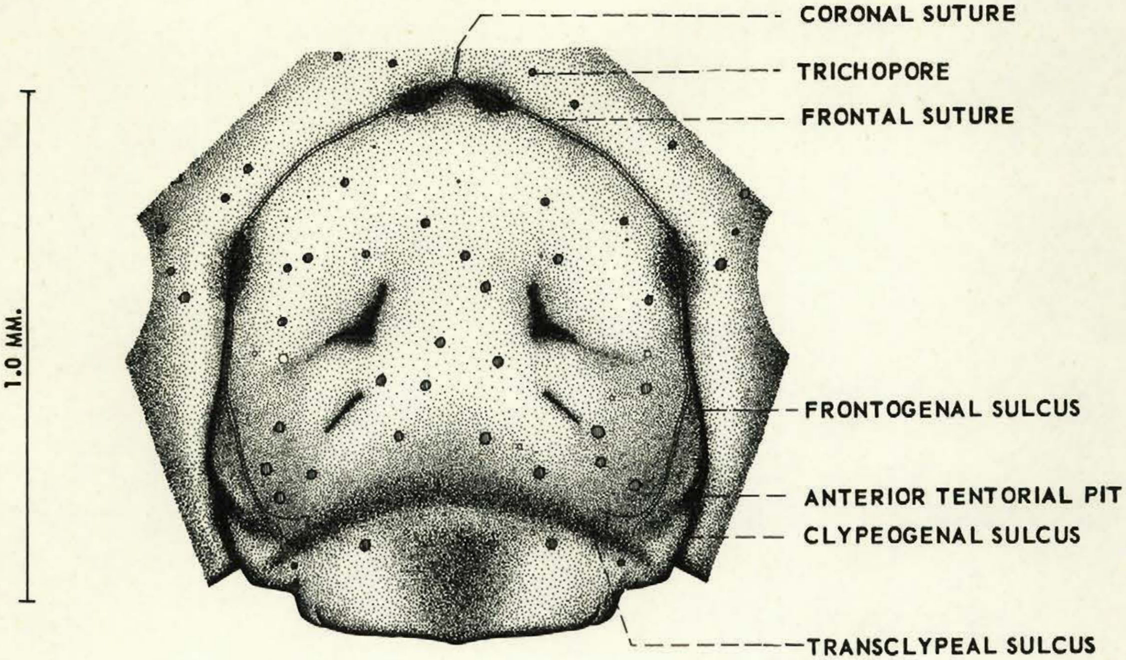

FRONTAL SUTURE
OCELLUS
SETAE
CORONAL SUTURE
VERTICAL FURROW
a
1.0 MM.
CORONAL SUTURE
VERTICAL FURROW
FRONTAL SUTURE
EYE RING
OCELLUS
FRONS
ANTENNA
FRONTOGENAL SULCUS
ANTERIOR TENTORIAL PIT
POSTCLYPEUS
CLYPEOGENAL SULCUS
ANTERIOR MANDIBULAR ARTICULATION
TRANSCLYPEAL SULCUS
ANTECLYPEUS
LABRUM
MANDIBLE
MAXILLARY PALPUS
LABIAL PALPUS
SPINNERET
GENA
1.0 MM.
b
c
1.0 MM.
LABRUM
HYPOPHARYNX
MANDIBLE
LACINIA
GALEA
SPINNERET
ANTERIOR MANDIBULAR ARTICULATION
TENDON OF MANDIBULAR ABDUCTOR MUSCLE
POSTERIOR MANDIBULAR ARTICULATION
MAXILLARY PALPUS
LABIAL PALPUS
MEATUS OF LABIAL GLANDS
LIGULAR SCLERITE
1.0 MM.
d

PLATE IV

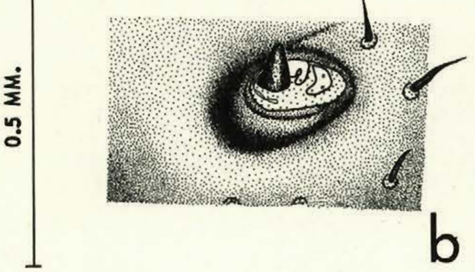
a. Sketch of frontoclypeal area and a portion of the adjoining parietals showing surface features.

b. Left antenna.

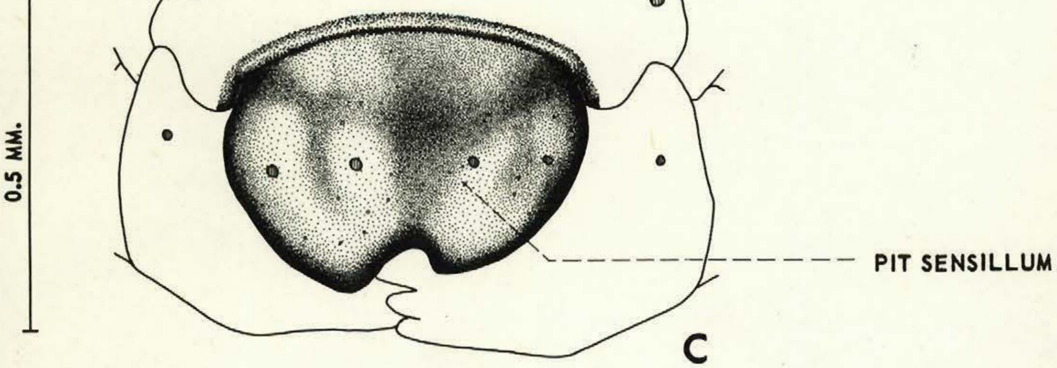
c. Sketch of labrum and a portion of the clypeus showing surface features.


CORONAL SUTURE
TRICHOPORE
FRONTAL SUTURE
1.0 MM.
FRONTOGENAL SULCUS
ANTERIOR TENTORIAL PIT
CLYPEOGENAL SULCUS
TRANSCLYPEAL SULCUS

a


0.5 MM.

b


0.5 MM.
PIT SENSILLUM

c

PLATE V

a. Saggital section of the head.

b. Internal structure of the fronto-parietal region of the head.

c. Sketch of the facial region of the head in frontal view with portions of the frons and clypeus removed. Anterior and posterior labral retractors removed.

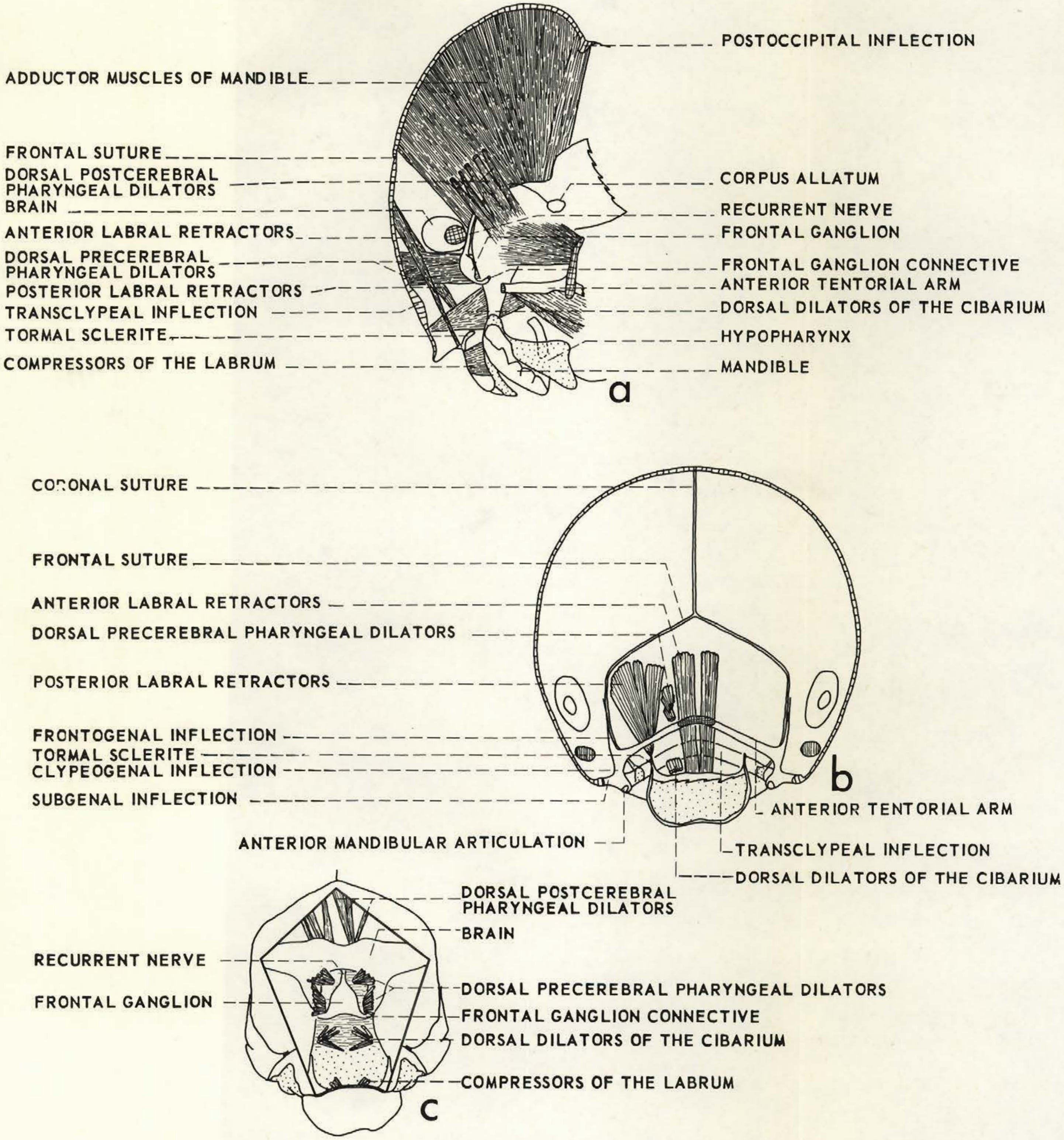

ADDUCTOR MUSCLES OF MANDIBLE
FRONTAL SUTURE
DORSAL POSTCEREBRAL PHARYNGEAL DILATORS
BRAIN
ANTERIOR LABRAL RETRACTORS
DORSAL PRECEREBRAL PHARYNGEAL DILATORS
POSTERIOR LABRAL RETRACTORS
TRANSCLYPEAL INFLECTION
TORMAL SCLERITE
COMPRESSORS OF THE LABRUM
POSTOCCIPITAL INFLECTION
CORPUS ALLATUM
RECURRENT NERVE
FRONTAL GANGLION
FRONTAL GANGLION CONNECTIVE
ANTERIOR TENTORIAL ARM
DORSAL DILATORS OF THE CIBARIUM
HYPOPHARYNX
MANDIBLE
a
CORONAL SUTURE
FRONTAL SUTURE
ANTERIOR LABRAL RETRACTORS
DORSAL PRECEREBRAL PHARYNGEAL DILATORS
POSTERIOR LABRAL RETRACTORS
FRONTOGENAL INFLECTION
TORMAL SCLERITE
CLYPEOGENAL INFLECTION
SUBGENAL INFLECTION
b
ANTERIOR TENTORIAL ARM
ANTERIOR MANDIBULAR ARTICULATION
TRANSCLYPEAL INFLECTION
DORSAL DILATORS OF THE CIBARIUM
DORSAL POSTCEREBRAL PHARYNGEAL DILATORS
BRAIN
RECURRENT NERVE
FRONTAL GANGLION
DORSAL PRECEREBRAL PHARYNGEAL DILATORS
FRONTAL GANGLION CONNECTIVE
DORSAL DILATORS OF THE CIBARIUM
COMPRESSORS OF THE LABRUM
c

PLATE VI

a. Caudal aspect of the head.

b. Internal surface of the occipital region of the cranium.

c. Internal structures of the ventral portion of the cranium which has been sectioned just dorsal to the antennae.

d. Section of the cranium ventral to the juncture of coronal and frontal sutures.

e. Section of the cranium just ventral to the ocelli.

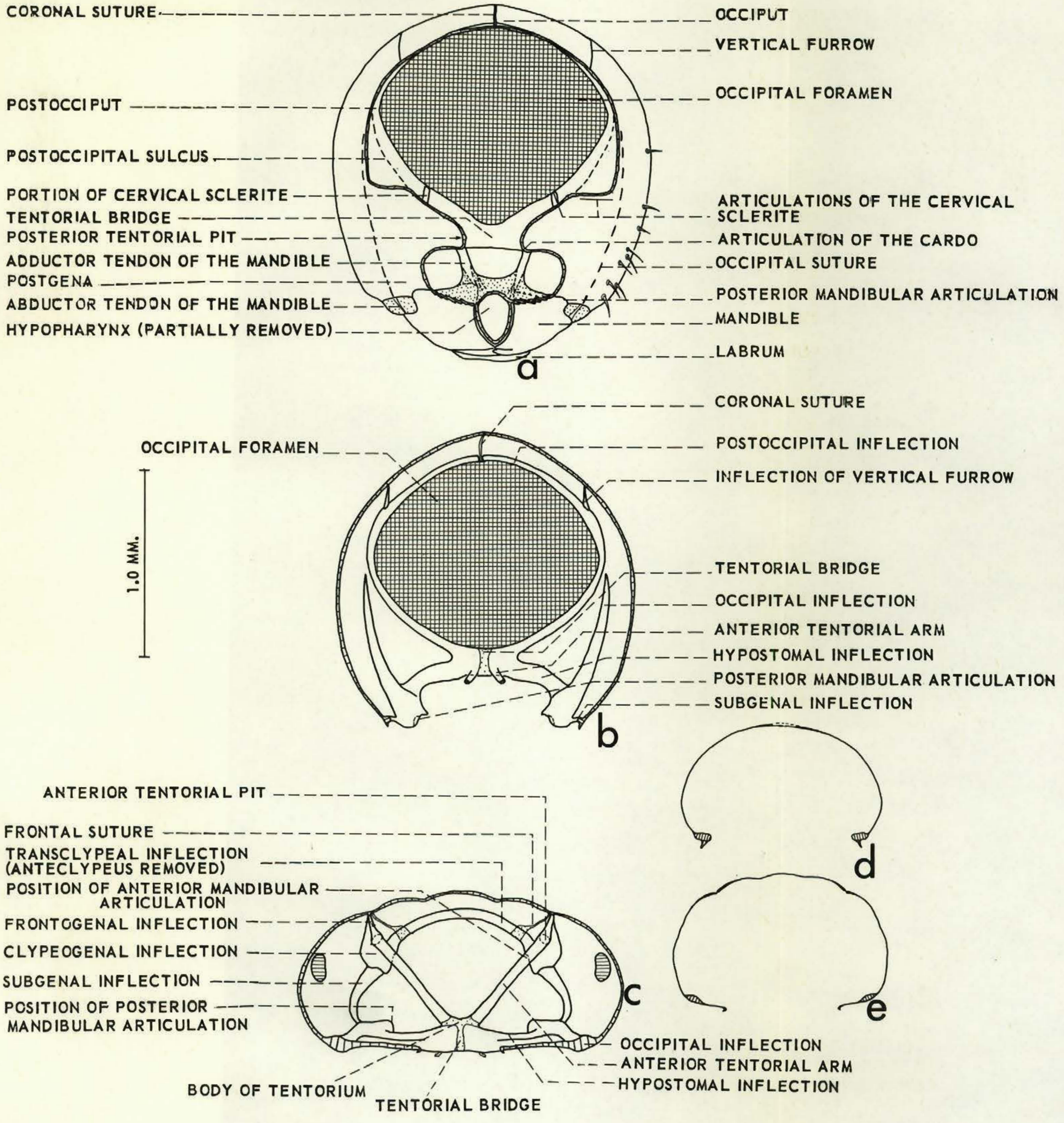

CORONAL SUTURE
OCCIPUT
VERTICAL FURROW
OCCIPITAL FORAMEN
POSTOCCIPUT
POSTOCCIPITAL SULCUS
PORTION OF CERVICAL SCLERITE
TENTORIAL BRIDGE
POSTERIOR TENTORIAL PIT
ADDUCTOR TENDON OF THE MANDIBLE
POSTGENA
ABDUCTOR TENDON OF THE MANDIBLE
HYPOPHARYNX (PARTIALLY REMOVED)
ARTICULATIONS OF THE CERVICAL SCLERITE
ARTICULATION OF THE CARDO
OCCIPITAL SUTURE
POSTERIOR MANDIBULAR ARTICULATION
MANDIBLE
LABRUM
a
CORONAL SUTURE
OCCIPITAL FORAMEN
POSTOCCIPITAL INFLECTION
INFLECTION OF VERTICAL FURROW
1.0 MM.
TENTORIAL BRIDGE
OCCIPITAL INFLECTION
ANTERIOR TENTORIAL ARM
HYPOSTOMAL INFLECTION
POSTERIOR MANDIBULAR ARTICULATION
SUBGENAL INFLECTION
b
ANTERIOR TENTORIAL PIT
FRONTAL SUTURE
TRANSCLYPEAL INFLECTION (ANTECLYPEUS REMOVED)
POSITION OF ANTERIOR MANDIBULAR ARTICULATION
FRONTOGENAL INFLECTION
CLYPEOGENAL INFLECTION
SUBGENAL INFLECTION
POSITION OF POSTERIOR MANDIBULAR ARTICULATION
c
OCCIPITAL INFLECTION
ANTERIOR TENTORIAL ARM
HYPOSTOMAL INFLECTION
BODY OF TENTORIUM
TENTORIAL BRIDGE
d
e

PLATE VII

a. Lateral aspect of the mandibles.

b. Mesal aspect of the mandibles.

c. Posterior aspect of the left mandible.

d. Anterior aspect of the left mandible.

e. Proximal end of the left mandible.

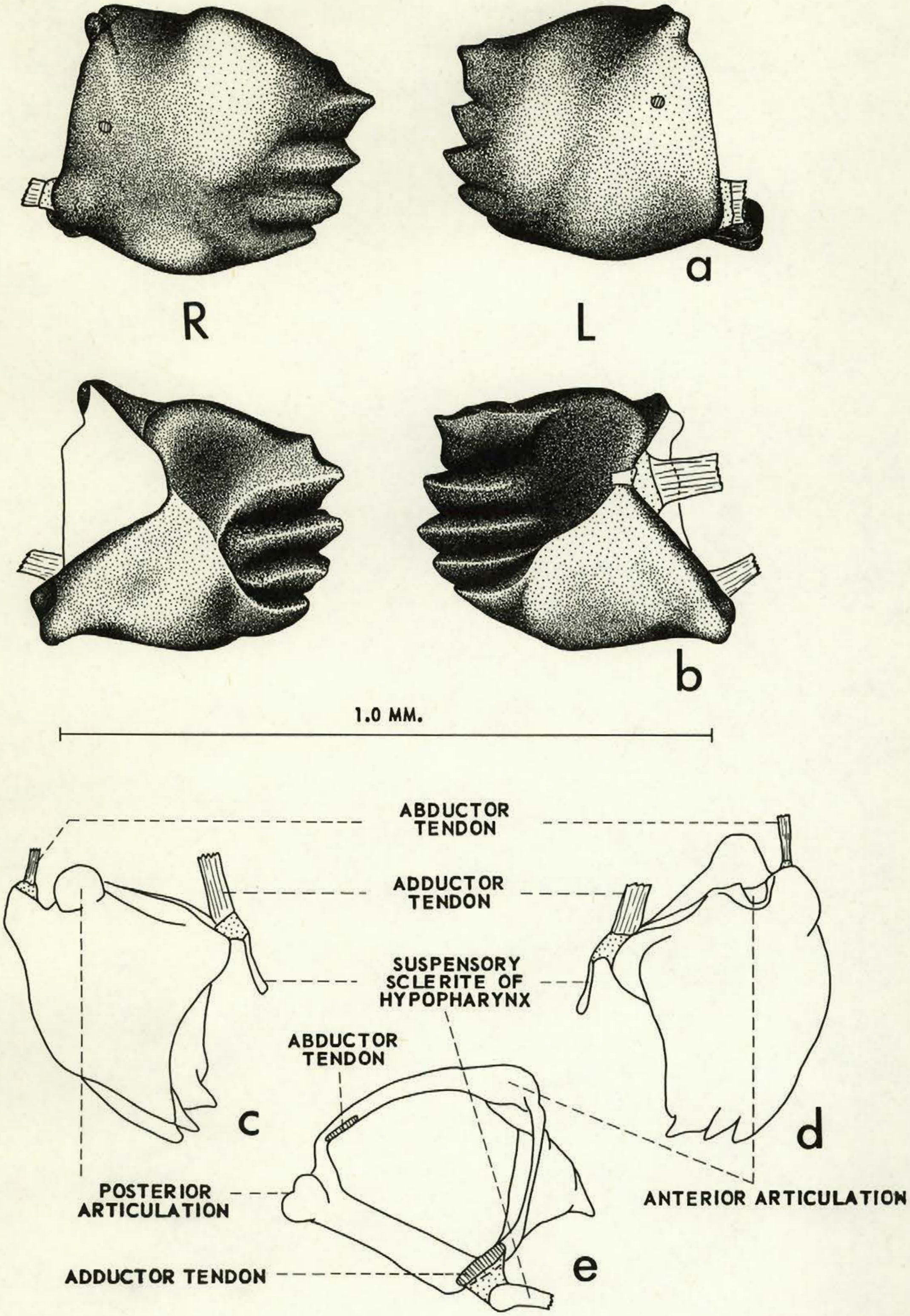

R
L
a
b
1.0 MM.
ABDUCTOR TENDON
ADDUCTOR TENDON
SUSPENSORY SCLERITE OF HYPOPHARYNX
ABDUCTOR TENDON
c
d
POSTERIOR ARTICULATION
ANTERIOR ARTICULATION
ADDUCTOR TENDON
e

PLATE VIII

a. Caudal aspect of the labiomaxillary complex.

b. Anterior aspect of the labiomaxillary complex.

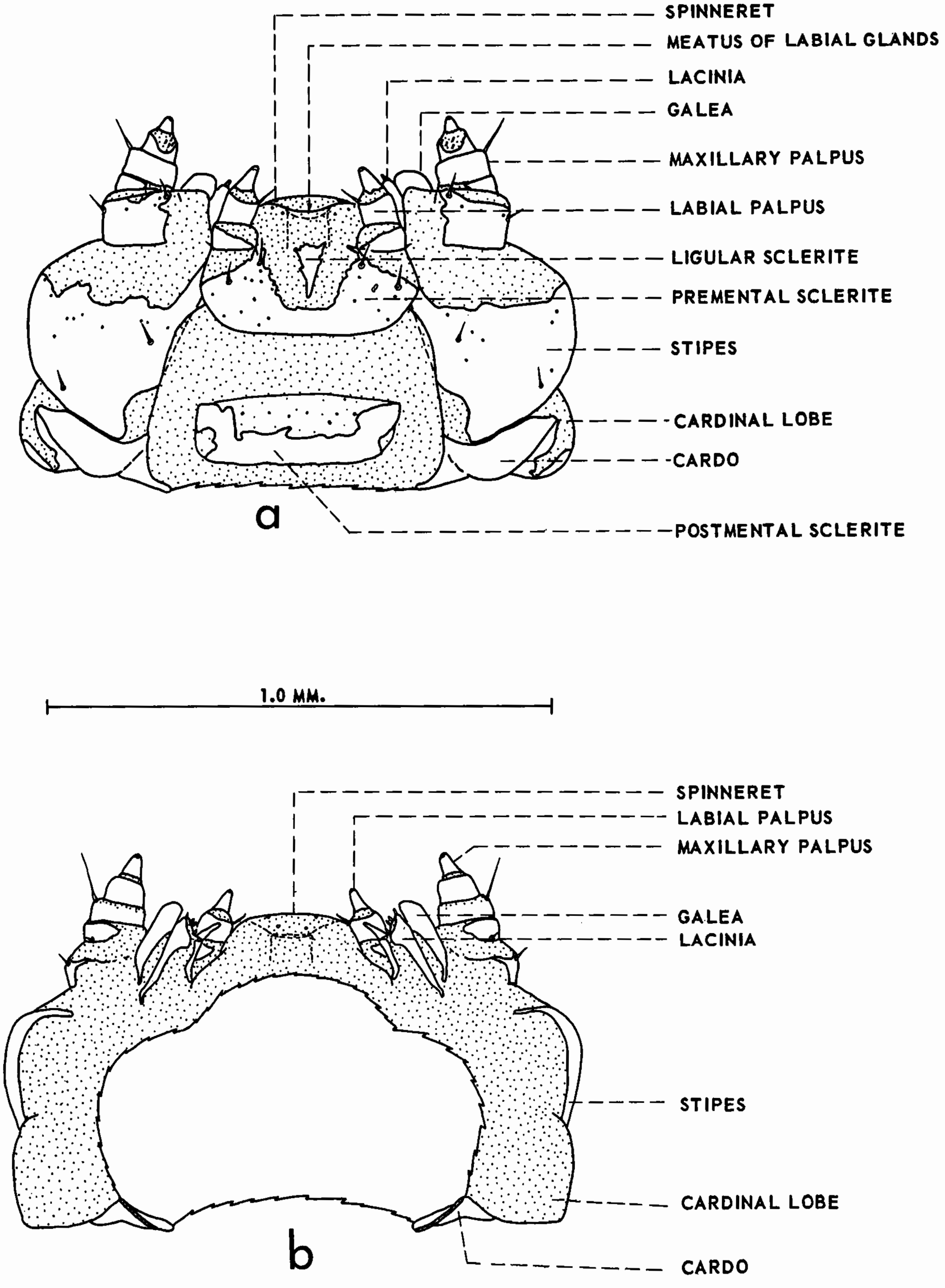
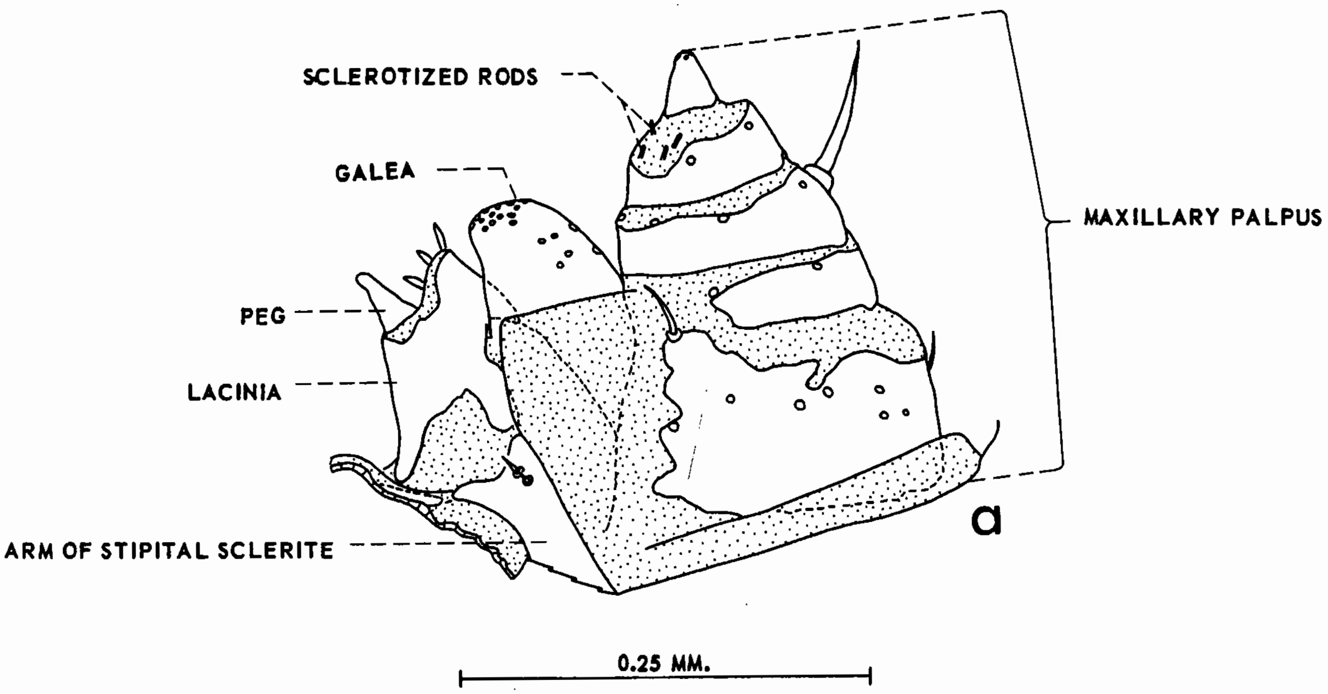

SPINNERET
MEATUS OF LABIAL GLANDS
LACINIA
GALEA
MAXILLARY PALPUS
LABIAL PALPUS
LIGULAR SCLERITE
PREMENTAL SCLERITE
STIPES
CARDINAL LOBE
CARDO
POSTMENTAL SCLERITE
a
1.0 MM.
SPINNERET
LABIAL PALPUS
MAXILLARY PALPUS
GALEA
LACINIA
STIPES
CARDINAL LOBE
CARDO
b

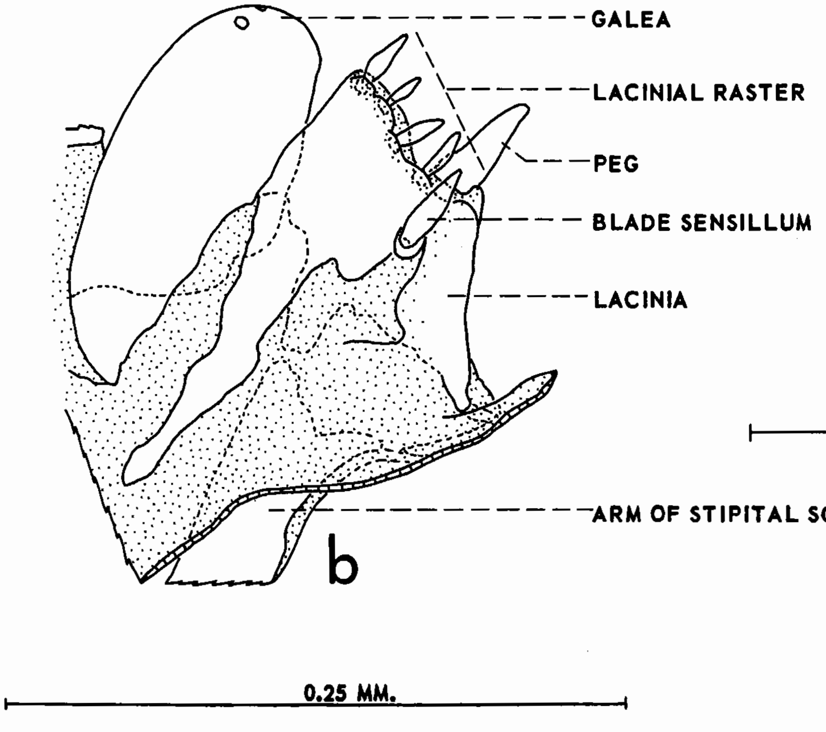
PLATE IX

a. Caudal aspect of the maxillary palpus, galea and lacinia.

b. Anterior aspect of the galea and lacinia.

c. Apical end of the lacinia.


SCLEROTIZED RODS
GALEA
PEG
LACINIA
ARM OF STIPITAL SCLERITE
MAXILLARY PALPUS
a
0.25 MM.


GALEA
LACINIAL RASTER
PEG
BLADE SENSILLUM
LACINIA
ARM OF STIPITAL SCLERITE
b
0.25 MM.

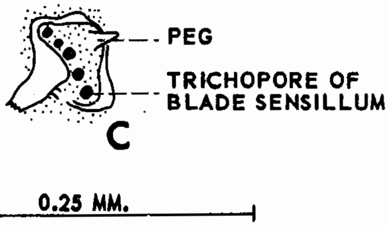
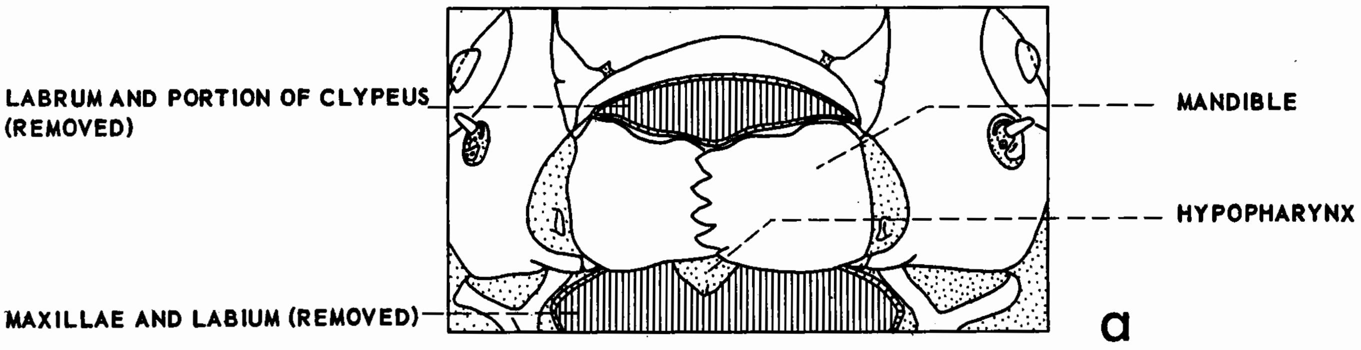

PEG
TRICHOPORE OF BLADE SENSILLUM
c
0.25 MM.

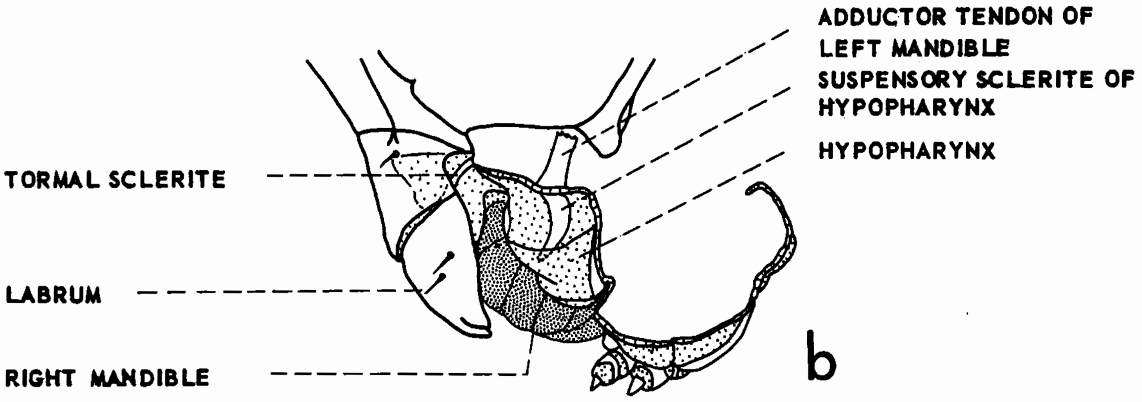
PLATE X

a. Ventral aspect of the head with labrum, maxillae and labium removed.

b. Lateral aspect of the ventral portion of the head, left mandible, maxilla and left half of labium removed.

c. Labral palatum.


LABRUM AND PORTION OF CLYPEUS (REMOVED)
MANDIBLE
HYPOPHARYNX
MAXILLAE AND LABIUM (REMOVED)
a


ADDUCTOR TENDON OF LEFT MANDIBLE
SUSPENSORY SCLERITE OF HYPOPHARYNX
HYPOPHARYNX
TORMAL SCLERITE
LABRUM
RIGHT MANDIBLE
b

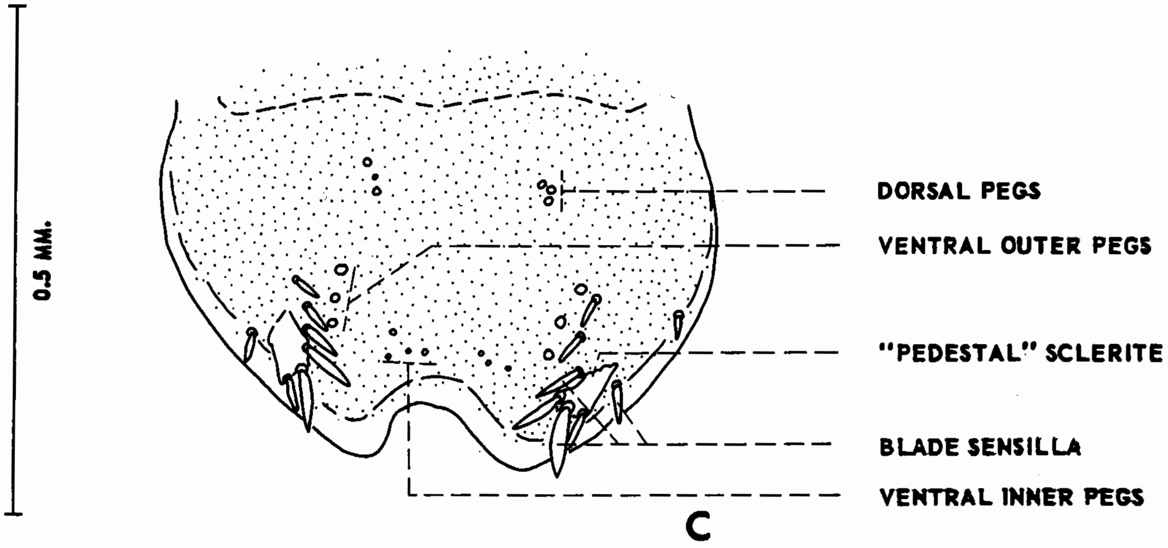

0.5 MM.
DORSAL PEGS
VENTRAL OUTER PEGS
"PEDESTAL" SCLERITE
BLADE SENSILLA
VENTRAL INNER PEGS
c

PLATE XI

a. Anterior aspect of hypopharynx.

b. Denticles on hypopharynx.

c. Sensillum on edge of labrum.

d. Ventral, outer, peg sensillum on labral palatum.

e. Sensillum on postmental area of labium.

f. Blunt seta on spinneret.

g. Pit sensillum on galea.

h. Sclerotized rod on apical membrane of fourth segment of the maxillary palpus.

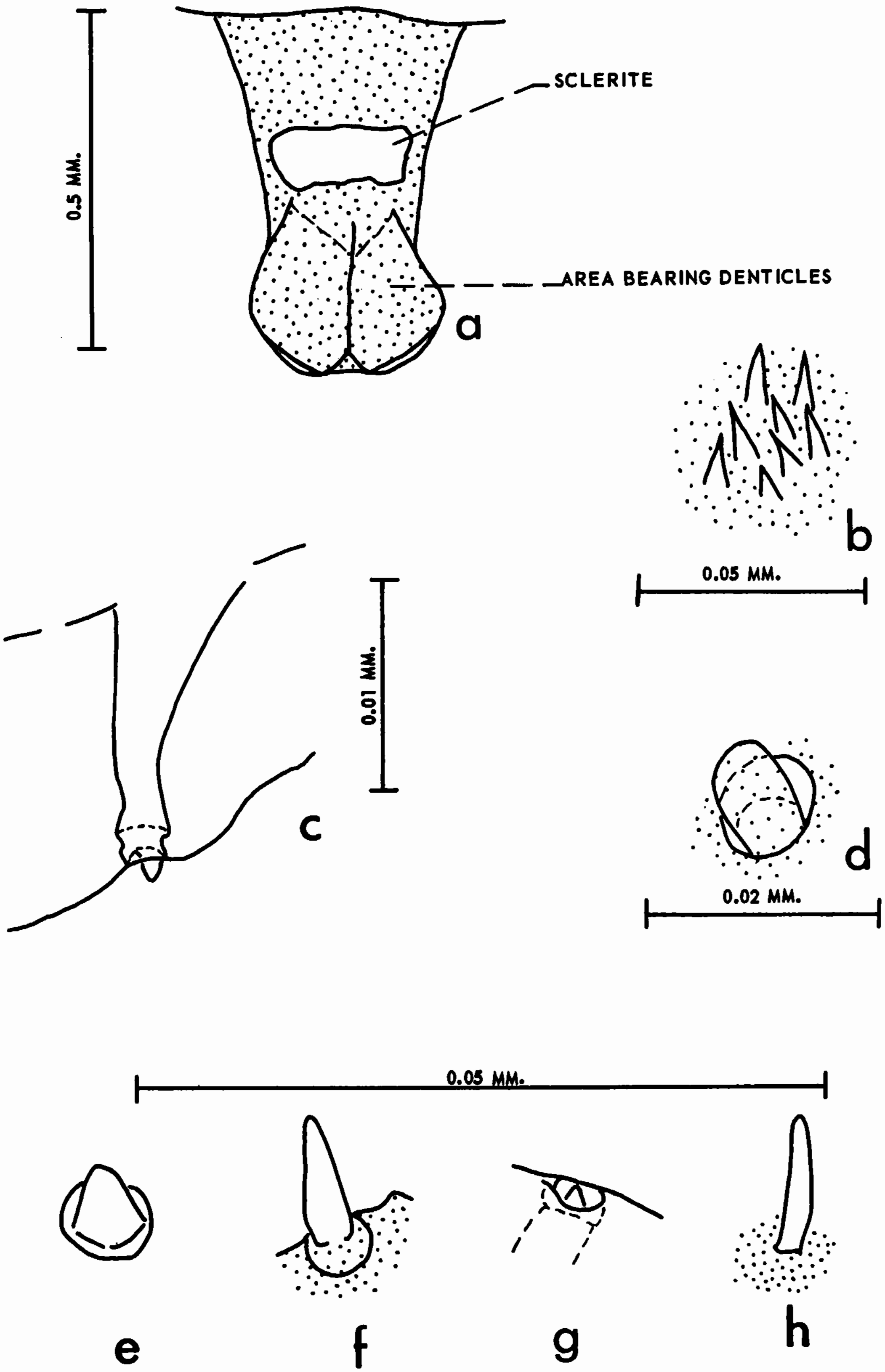

0.5 MM.
SCLERITE
AREA BEARING DENTICLES
a
b
0.05 MM.
0.01 MM.
c
d
0.02 MM.
0.05 MM.
e
f
g
h

PLATE XII

a. Anterior aspect of the prothorax, head removed.

b. Lateral aspect of the thorax.

c. Ventral aspect of the thorax.

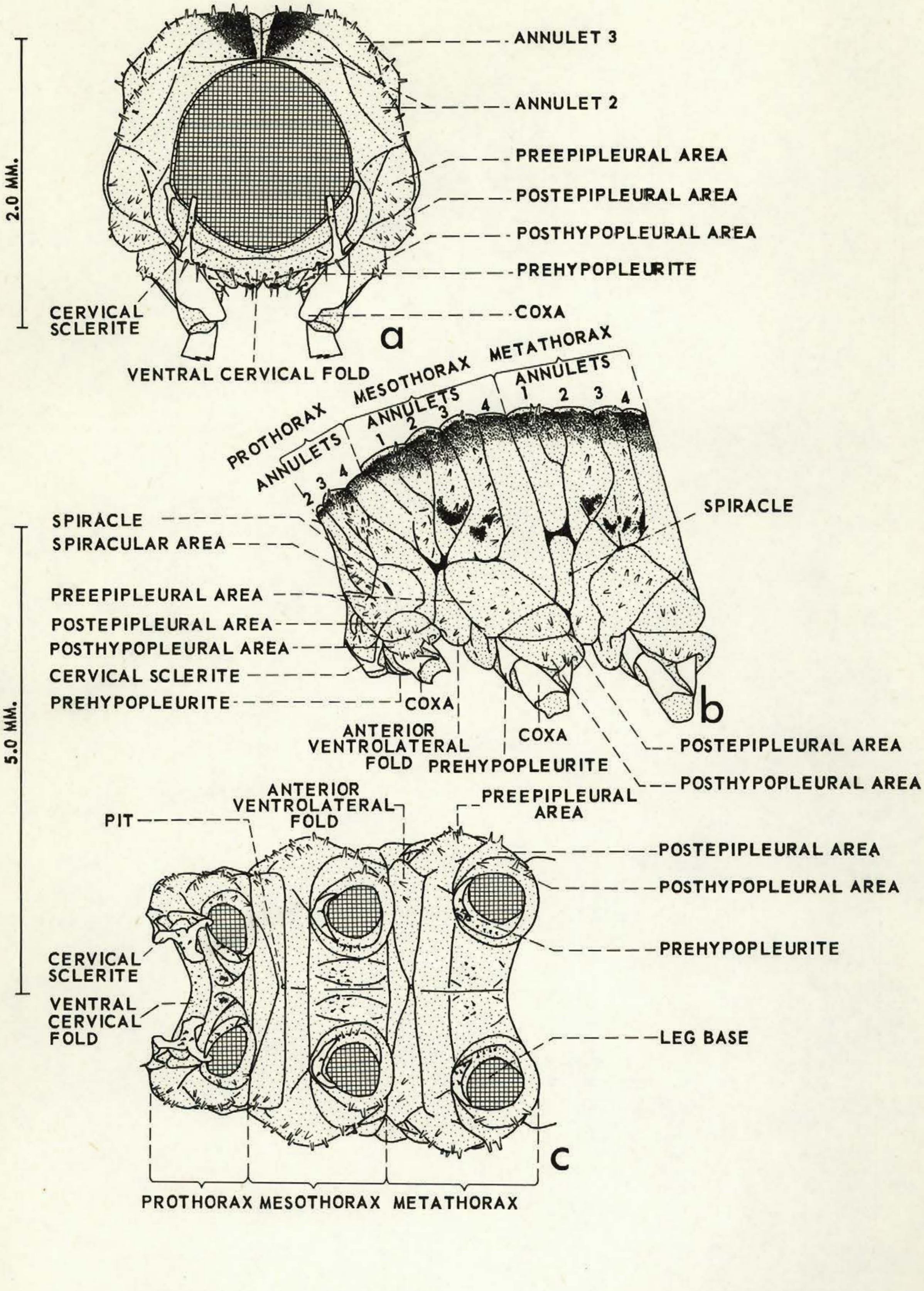

2.0 MM.
ANNULET 3
ANNULET 2
PREEPIPLEURAL AREA
POSTEPIPLEURAL AREA
POSTHYPOPLEURAL AREA
PREHYPOPLEURITE
COXA
CERVICAL SCLERITE
a
VENTRAL CERVICAL FOLD
PROTHORAX
MESOTHORAX
METATHORAX
ANNULETS
2 3 4
1 2 3 4
1 2 3 4
SPIRACLE
SPIRACULAR AREA
PREEPIPLEURAL AREA
POSTEPIPLEURAL AREA
POSTHYPOPLEURAL AREA
CERVICAL SCLERITE
PREHYPOPLEURITE
COXA
ANTERIOR VENTROLATERAL FOLD
COXA
PREHYPOPLEURITE
SPIRACLE
b
POSTEPIPLEURAL AREA
POSTHYPOPLEURAL AREA
5.0 MM.
PIT
ANTERIOR VENTROLATERAL FOLD
PREEPIPLEURAL AREA
POSTEPIPLEURAL AREA
POSTHYPOPLEURAL AREA
PREHYPOPLEURITE
CERVICAL SCLERITE
VENTRAL CERVICAL FOLD
LEG BASE
c
PROTHORAX MESOTHORAX METATHORAX

PLATE XIII

a. Ventral aspect of the prothorax.

b. Inner aspect of mesothoracic invagination for muscle attachment.

c. Anterior aspect of same.

d. Inner aspect of metathoracic invagination.

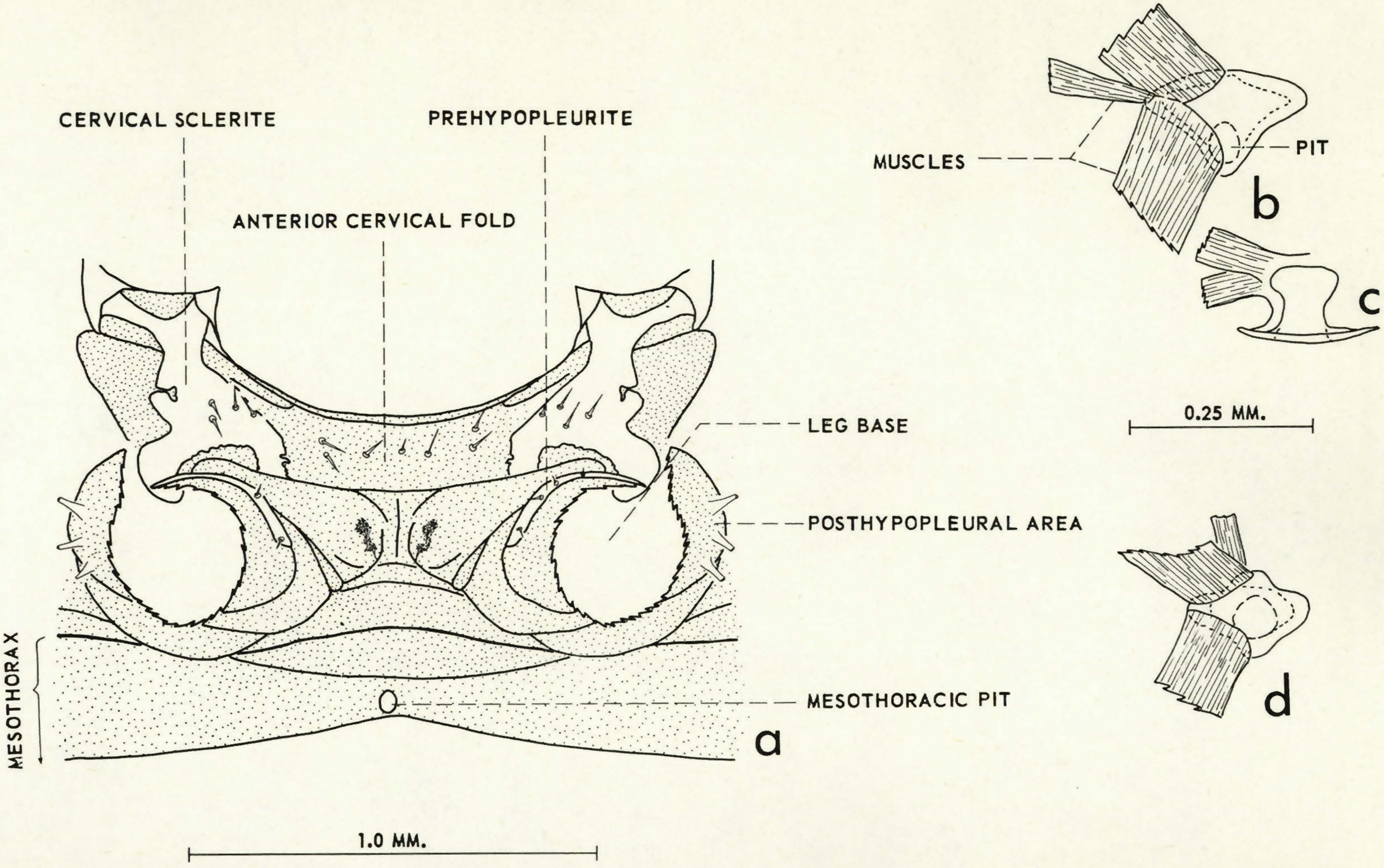

CERVICAL SCLERITE
PREHYPOPLEURITE
ANTERIOR CERVICAL FOLD
LEG BASE
POSTHYPOPLEURAL AREA
MESOTHORAX
MESOTHORACIC PIT
a
1.0 MM.
MUSCLES
PIT
b
c
0.25 MM.
d

PLATE XIV

a. Anterior aspect of metathoracic leg and prehypopleurite.

b. Posterior aspect of metathoracic leg.

c. Lateral aspect of same.

d. Mesal aspect of same.

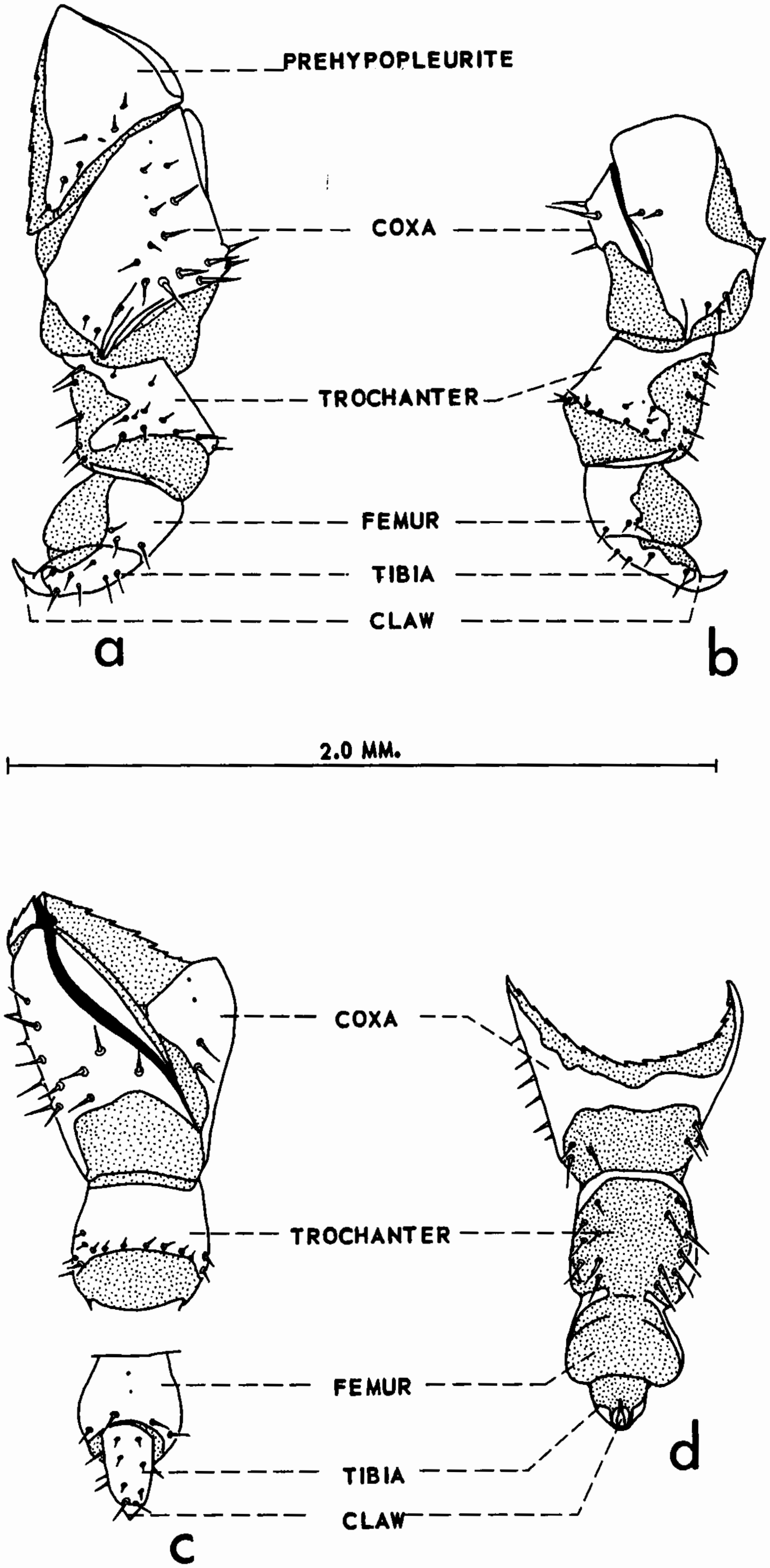

PREHYPOPLEURITE
COXA
TROCHANTER
FEMUR
TIBIA
CLAW
a
b
2.0 MM.
COXA
TROCHANTER
FEMUR
TIBIA
CLAW
c
d

PLATE XV

a. Cross section of second abdominal segment.

b. Lateral aspect of abdominal segments one and two.

c. Ventral aspect of abdominal segments one and two.

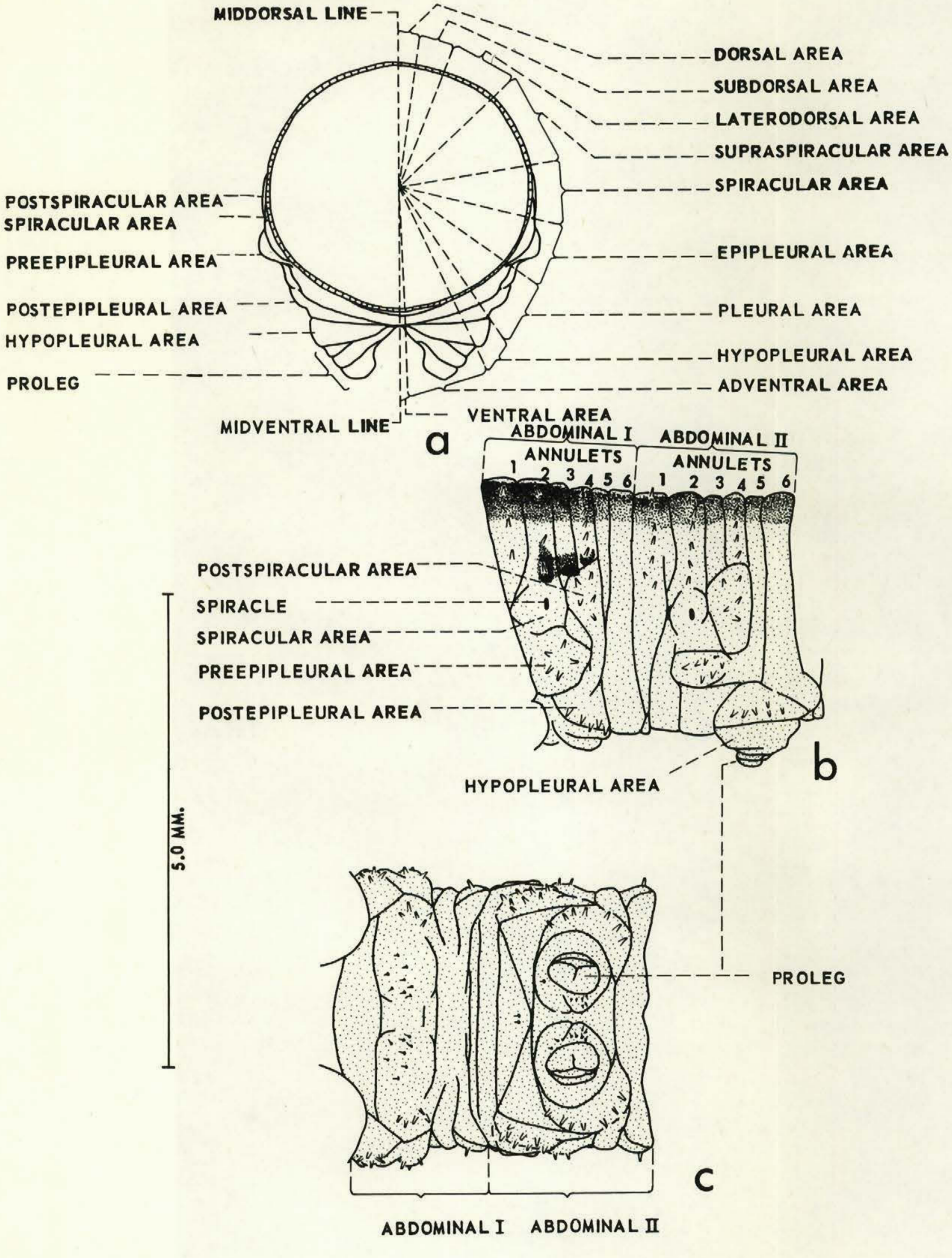

MIDDORSAL LINE
DORSAL AREA
SUBDORSAL AREA
LATERODORSAL AREA
SUPRASPIRACULAR AREA
SPIRACULAR AREA
POSTSPIRACULAR AREA
SPIRACULAR AREA
PREEPIPLEURAL AREA
EPIPLEURAL AREA
POSTEPIPLEURAL AREA
PLEURAL AREA
HYPOPLEURAL AREA
HYPOPLEURAL AREA
PROLEG
ADVENTRAL AREA
MIDVENTRAL LINE
VENTRAL AREA
a
ABDOMINAL I
ANNULETS
1 2 3 4 5 6
ABDOMINAL II
ANNULETS
1 2 3 4 5 6
POSTSPIRACULAR AREA
SPIRACLE
SPIRACULAR AREA
PREEPIPLEURAL AREA
POSTEPIPLEURAL AREA
HYPOPLEURAL AREA
b
5.0 MM.
PROLEG
c
ABDOMINAL I
ABDOMINAL II

PLATE XVI

a. Lateral aspect of abdominal segments nine and ten.

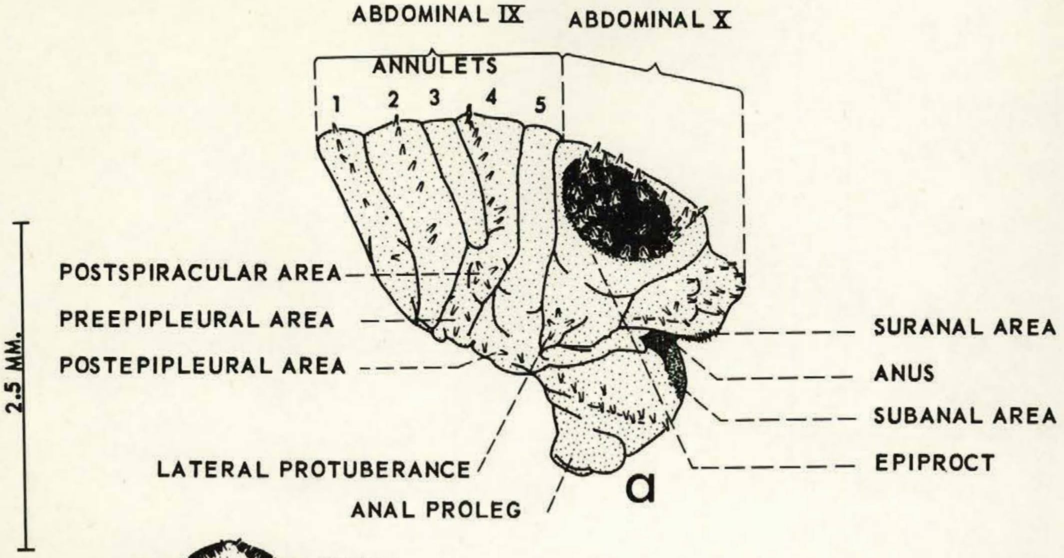
b. Anal aspect of abdominal segment ten.

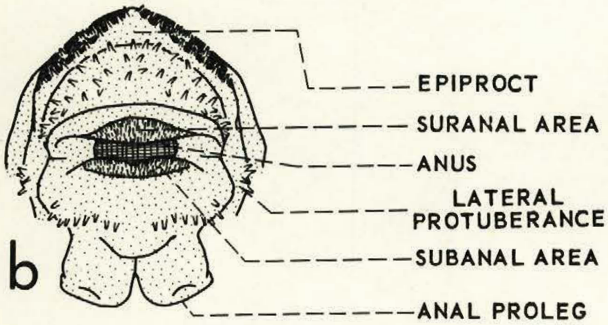
c. Epiproct, somewhat flattened.

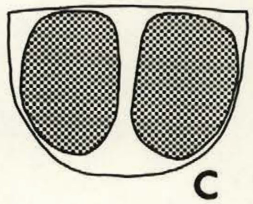
d. Sensillum styloconicum and spiniform denticles.

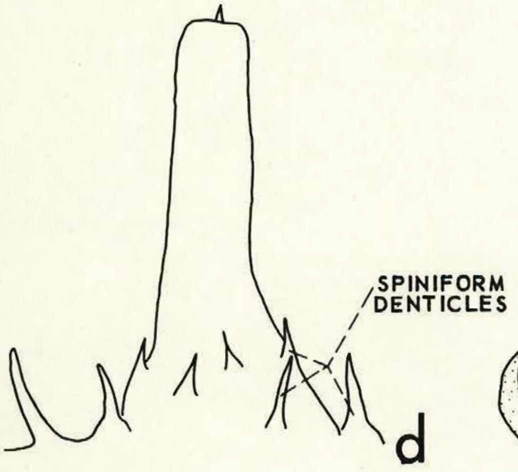
e. True seta.

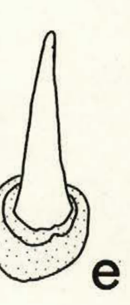
f. Spine on suranal area.

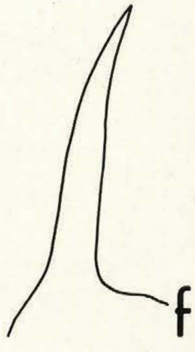

ABDOMINAL IX
ABDOMINAL X
ANNULETS
1
2
3
4
5
2.5 MM.
POSTSPIRACULAR AREA
PREEPIPLEURAL AREA
POSTEPIPLEURAL AREA
LATERAL PROTUBERANCE
ANAL PROLEG
SURANAL AREA
ANUS
SUBANAL AREA
EPIPROCT
a


EPIPROCT
SURANAL AREA
ANUS
LATERAL PROTUBERANCE
SUBANAL AREA
ANAL PROLEG
b


c


SPINIFORM DENTICLES
d


e


f

0.1 MM.

PLATE XVII

a. Surface features of a portion of the frons.

Bar = 0.2 mm.

b. Scale-like spinules on the postmental membrane.

Bar = 0.2 mm.

c. Markings on unsclerotized cuticula indicating internal muscle attachments.

Bar = 0.1 mm.

d. Right spiracle, abdominal segment three.

Bar = 0.2 mm.

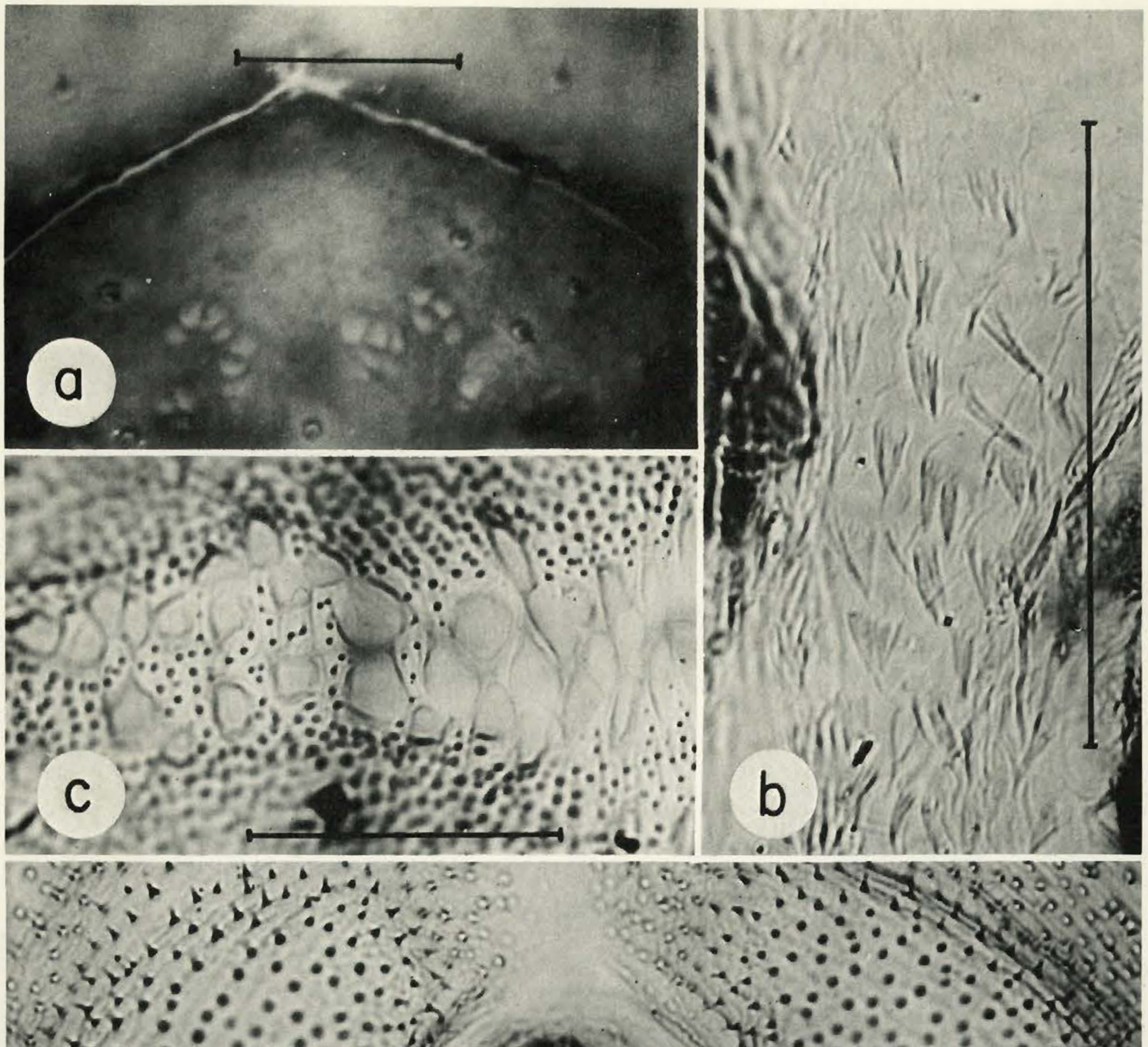

a
b
c
d

PLATE XVIII

a. Cross section of normal integument.

Bar = 50 microns.

b. Cross section of pigmented integument.

Bar = 50 microns.

c. Cuticular features on the dorsal and dorsolateral areas of the left side of the metathorax.

Bar = 0.4 mm.

d. Cuticular features on the dorsolateral area of the right side of annulet 5, abdominal segment five.

Bar = 0.2 mm.

e. Cuticular features on the dorsolateral area of the right side of annulet 4, abdominal segment four.

Bar = 0.2 mm.

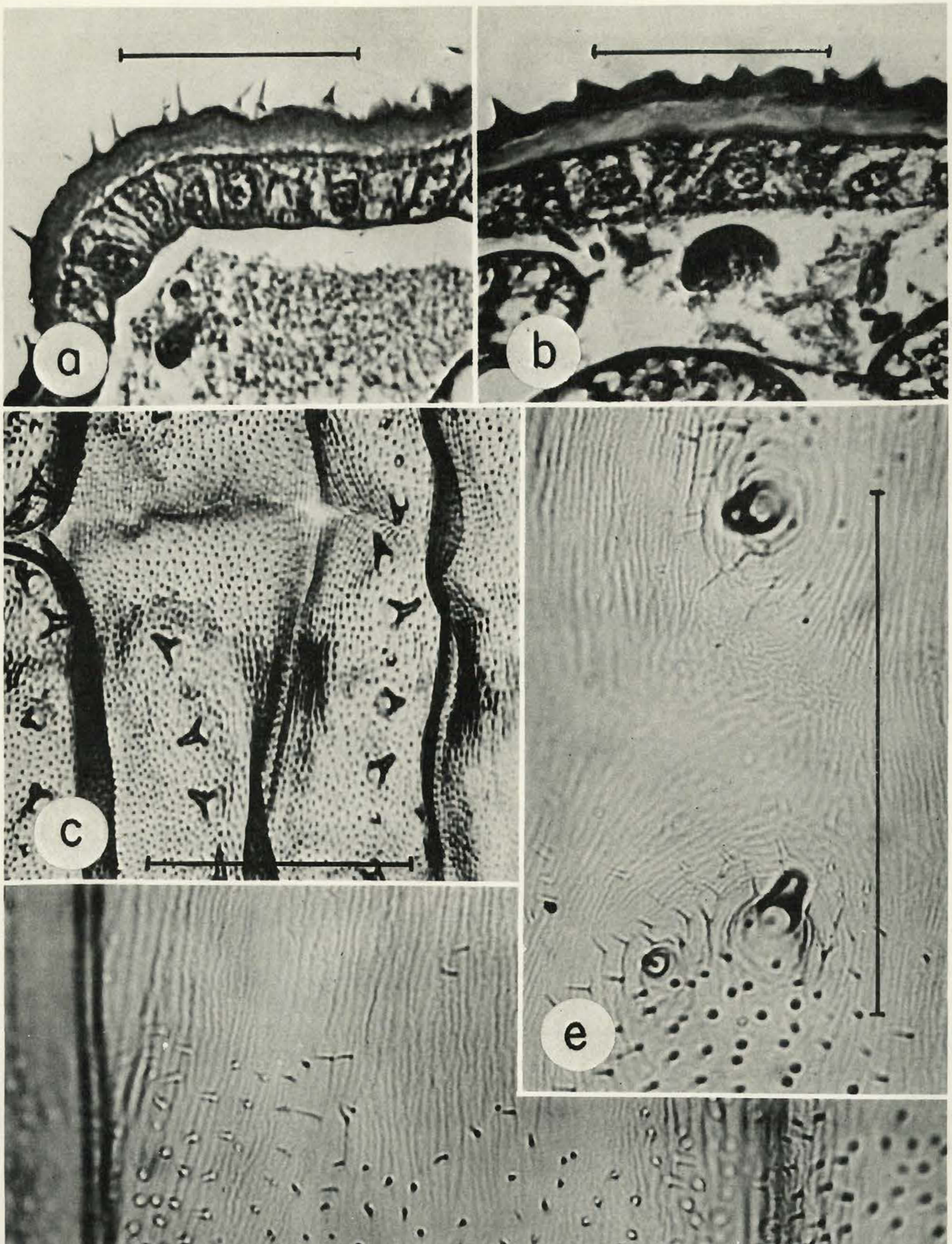

a
b
c
d
e

PLATE XIX

Serial cross sections of a sensillum styloconicum related to their approximate levels on a longitudinal section.

Bar = 50 microns.

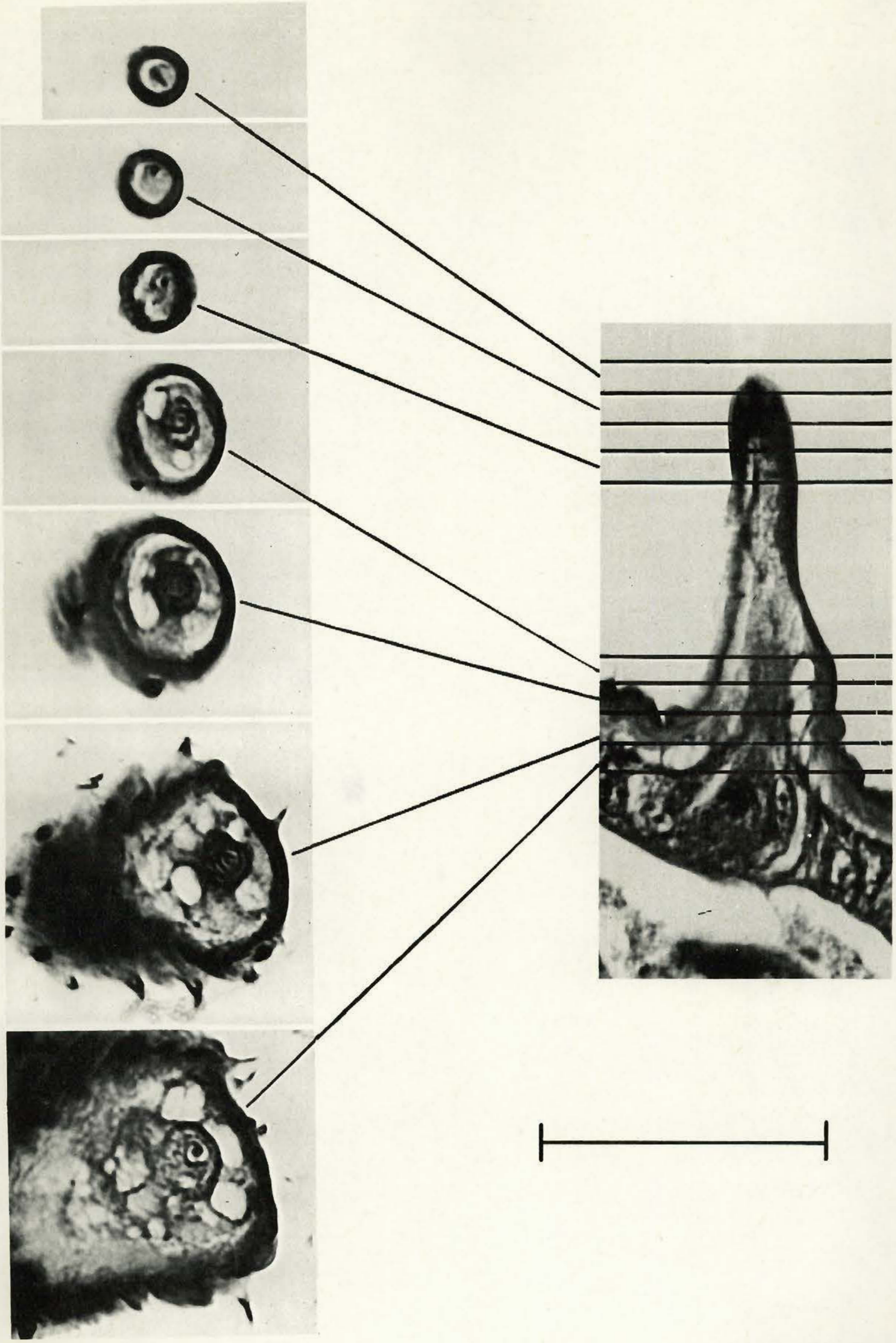
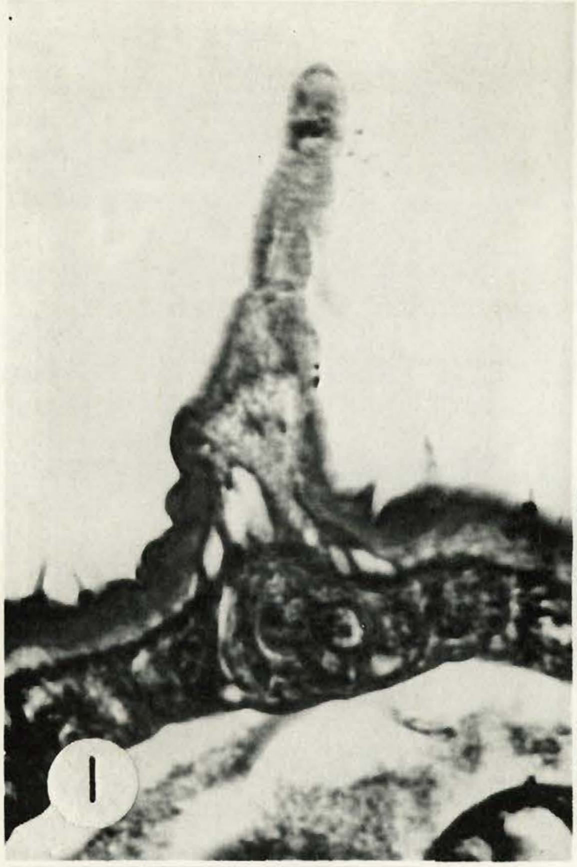


PLATE XX

Serial longitudinal sections of a sensillum stylo-
conicum.

Bar = 50 microns.


1


2


3


4

PLATE XXI

a. A group of mature, feeding larvae.

b. Facial aspect of the head of a mature, feeding larva.