Abdomen short, subconic, shiny black, intermediate segments usually pruinose on basal margin; hairs on entire upper surface longish and erect; one pair of median marginals on basal segments but weak on first; marginal row on last two segments, no differentiated discal row on last; genitalia small, blackish; forceps moderately long, united about as wide as thick, in profile tapering to a sharp forward bowed tip; accessory process slender, shorter than forceps, bearing several very minute stubby hairs on anterior side near apex; fifth sternite rather widely divided, lobes shiny blackish, with a few long slender hairs on inner margin.

Female. Front in profile not so prominent at antennal base, at vertex 0.28 of head width, gradually widening forward at facial angle; frontal vitta deep red, narrowed upward, over half parafrontal width at middle; two proclinate and two reclinate orbitals; outer verticals barely differentiated; two or three frontals below antennal base; abdomen ovate, hairs depressed on intermediate segments above and basal fourth to third of each segment silvery, the pollen thin but denser than in male; genitalia retracted, without piercer, fore tarsi moderately stout, with four apical segments short and slightly swollen.

Length, 5 mm.

Holotype male and *allotype* female, College Station, Texas, May 18, 1923 (H. J. Reinhard). *Paratypes*: 3 males and 4 females, same data, except dated April 24 to June 18, 1919-44.

STUDIES ON PARASITES OF THE SPRUCE BUDWORM, *ARCHIPS FUMIFERANA* (Clem.) *

1. Life History of *Apanteles fumiferanae* Viereck (Hymenoptera, Braconidae)

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ABSTRACT

This paper describes all stages of the spruce budworm parasite *Apanteles fumiferanae* Viereck, including the adult. Illustrations of all stages are presented. A short account of the life history of the host is included.

INTRODUCTION

The spruce budworm, *Archips fumiferana* (Clem.), is the most important forest insect in Canada at the present time and vast areas of forest are being ravaged as a result of its continued attack. Waves of budworm attack in the past have subsided, due in some cases to exhaustion of food supply, but in other cases they have died out in the midst of forests apparently suitable for the continuance of attack. The cause of the decline in the latter instances is not known.

Intensive investigations now in progress are designed to elucidate some of the factors involved in the epidemiology of the spruce budworm. Approximately sixty insect parasites of the spruce budworm have been identified in Eastern Canada; very little is known regarding their life histories or their effects on the populations of the host. The two papers in this series represent a contribution toward the study of the life history and identification of two of the important species of parasites of the spruce budworm.

After the essential features of the life history of *Apanteles fumiferanae* had been worked out, the existence of an unpublished manuscript on *Apanteles fumiferanae* by Dr. J. D. Tothill (4) was discovered. This manuscript was in the files of the Forest Insect Laboratory, Fredericton, N. B., and was made available through the courtesy of Mr. R. E. Balch, Officer-in-Charge of the laboratory.

*Contribution No. 2373, Division of Entomology, Science Service, Department of Agriculture, Ottawa.

LIFE HISTORY OF THE HOST

In order to demonstrate the synchronization of the host and parasite life histories, the seasonal development of the spruce budworm may be briefly described as follows:

The adult moths lay their eggs on balsam fir or spruce needles during the latter part of June and the first part of July. After one to two weeks the eggs hatch and the young, first-instar budworm larvae migrate along the branches of the tree seeking a sheltered place in which to spin a small silken hibernaculum. These first-instar larvae are less than one-eighth inch long and do not feed. The moult from first to second instar occurs, in the hibernaculum, from two to three weeks after hatching (personal communication, Dr. S. G. Smith, Forest Insect Laboratory, Sault Ste. Marie, Ontario). The following spring, just before the balsam fir and white spruce buds burst and begin to elongate, the second-instar larvae leave the hibernacula. These larvae at first mine the needles and later attack the succulent young growth of the new shoots. Here they remain until they exhaust the food contained in the bud; they then migrate to another young shoot and continue their feeding. When there are many larvae present, all the new foliage on the tree may be consumed; the larvae then attack the older foliage and may completely defoliate the tree. In the vicinity of Chalk River, Ontario, where most of the material for this paper was collected, the larvae are full-fed by about the first week in June. Pupation then occurs and the adults, as already noted, emerge in late June and early July.

LIFE HISTORY OF APANTELES FUMIFERANAE VIERECK

The following account of the life history of this parasite is based on work carried out by the writer. Where results and observations are at variance with those of Tothill (4) the latter's findings are also included. The general outline which follows is based on the study of the various stages as described in detail below.

Emergence of adult parasites coincides with the hatching of the budworm eggs. Parasite oviposition in the newly hatched budworm larvae occurs at this time. It has been demonstrated by dissection and by rearing of winter-collected larvae that the parasites overwinter in second-stage budworm larvae, in some cases at least as eggs. In the spring they develop in the budworm larvae and emerge as full-fed larvae from fourth- or fifth-stage budworms. Pupation follows and the adults emerge from five to sixteen days later.

MATERIAL AND METHODS

Material from two main sources was used in this study, viz., (a) overwintering larvae on white spruce foliage collected at Laniel, P. Q., during the winter of 1941-1942 and shipped to London, Ontario, (b) larvae on balsam fir foliage collected in early spring of 1942 near Chalk River, Ontario, and transferred to a screened insectary. Data on length of time spent in the cocoon near Searchmont, Ontario (1943), and Black Sturgeon Lake, north of Port Arthur, Ontario (1944), are also included.

The foliage from Laniel was placed in large emergence cages and the young budworm larvae coming from it were carefully reared in order to determine the general features of the parasite's life history in relation to that of its host.

The bulk of the material on which the descriptions are based was secured at Chalk River, Ontario. Budworm-infested foliage was kept under observation in an insectary and each day a number of budworms were removed from the foliage for rearing and others were preserved in alcohol. Numbers of *Apanteles fumiferanae* third-stage larvae issued from reared material and were allowed to develop to adults in order to ascertain the length of time spent in the later stages of development. The preserved host larvae were later dissected carefully and any parasites they contained were preserved. These parasite larvae were later separated into stages by means of gross microscopical examination and measurements. Measurements of each stage are presented in the accompanying table (Table 1). Typical larvae of each stage were drawn under the microscope.

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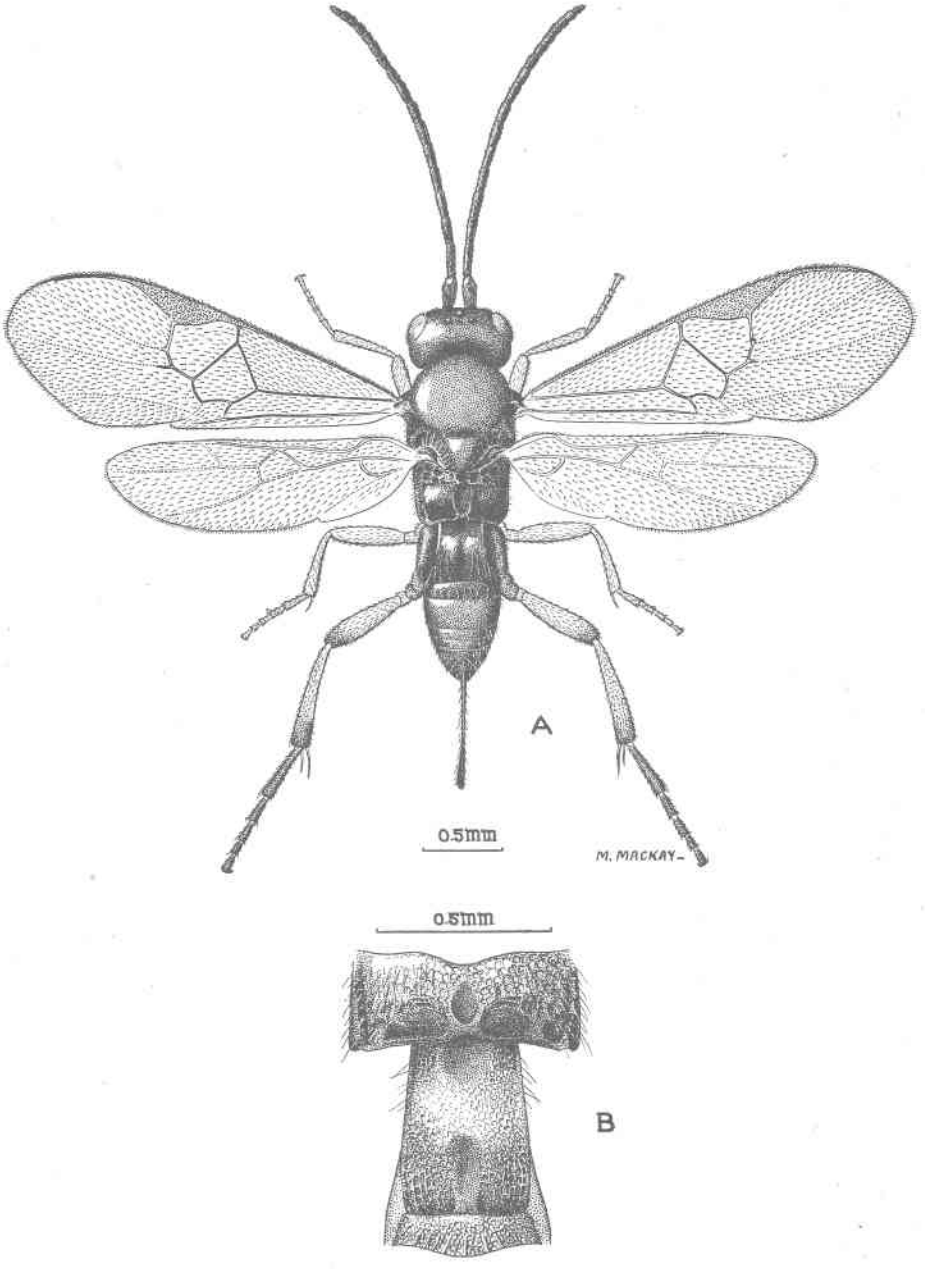
PLATE VIII.



APANTELES FUMIFERANAE VIER.

A. Adult of *Apanteles fumiferanae* Viereck, showing female from dorsal view.

B. Details of propodeum and first and second tergites from dorsal view.

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Table 1
Measurements of *Apanteles fumiferanae* Viereck (in mm.)

Larval stage	Length Range	Average	No. measured	Width Range	Average	No measured
1st	0.249-2.147	1.062	187	0.043-0.570	0.205	198
2nd	1.406-3.648	2.404	178	0.143-0.972	0.523	184
3rd	2.700-4.320	3.438	5	0.522-1.260	0.833	5

Th mouth-parts of first- and third-stage larvae were drawn from material cleared in potassium hydroxide and stained with safranin. The nomenclature of Vance and Smith (5) was adopted in the description of the mouth parts.

Description of the Stages of *Apanteles fumiferanae* Viereck

The Adult

The adult of *Apanteles fumiferanae* was described by Viereck (6) in 1912 from material reared from the spruce budworm. A dorsal view of the female and details of the propodeum and first and second tergites are illustrated in Plate VIII. As the original description of the species is very short and consists merely of a comparison of the species with *A. edwardsii* Riley (2), and as the species has not yet been adequately described, the author has redescribed this insect as follows:

Female. Length 3.5 mm. Length of ovipositor sheath 1.5 mm. Face narrowing very slightly below so that it is slightly narrower at base of clypeus than at the insertion of the antennae, slightly broader than long, with a slight median ridge, densely punctate. Clypeus distinctly separated from face. Vertex sparsely, temples and cheeks more densely punctate; head not rostriform. Disk of scutellum almost flat, about as long as broad at the base, sparsely punctate, rather shining; the posterior polished area on lateral face of scutellum small, extending forward to about the middle of the disk, semicircular in shape, the roughened striate area in front of it very large and conspicuous. Mesoscutum uniformly closely punctate, somewhat shining; mesopleura punctate dorsally and anteriorly, with a distinct groove, shining. Propodeum heavily punctate, with a large oval areola sharply margined, finely punctate within; costulae indistinct; sides of propodeum approximately parallel, the apical angles very prominent. Radius of forewing slightly longer than tranverse cubitus; nervellus curving strongly toward the base of the wing. Posterior coxae finely punctate, shining, lateral surface flattened. Inner spur of hind tibia noticeably longer than outer and about half as long as metatarsus. Abdomen slightly longer than thorax, about two and a half times as long as its extreme breadth. First tergite rectangular, slightly broader at apex than at base, with a rather distinct median longitudinal depression on apical half, twice as long as wide at base, punctate with the punctures somewhat erased in the basal portion, several irregular longitudinal rugulae present on the apical portion at either side of the median longitudinal depression. Second tergite short, transverse, approximately three times as broad at apex as median length, with the sides diverging posteriorly, rather uniformly punctate and with numerous fine irregular longitudinal rugulae. Remainder of the abdomen smooth and shining. Lateral membranous margins along apical half of first tergite, and along length of second tergite and basal half of the third tergite. Ovipositor sheath moderate in width and slightly over half the length of the abdomen.

Black; antennae entirely black; tegulate blackish; wings hyaline; stigma brown with darker anterior margin; thorax and abdomen black; hind coxae black, front and middle coxae dark brownish-black; first two pairs of legs reddish-stramineous; hind femora and tibiae reddish-testaceous with a varying amount of darker fuscous toward the apices; hind tarsi fuscous; ovipositor sheaths black.

Male. Length 2.5 mm. Posterior polished area on lateral face of scutellum slightly smaller than in female, making the roughened striate area in front relatively larger than in the female. Apex of propodeum narrower than base. Posterior coxae not flattened ventrally. Abdomen slightly shorter than thorax,

about three times as long as its extreme breadth. Second tergite about three times as broad as long, sides almost parallel. Remainder of abdomen narrower than in female, tapering to a sharp point; lateral membranous margins along whole of first and second tergites very prominent. Colour as in female.

Apanteles fumiferanae is species 43 in Muesebeck's key (1). *A. solenobiae* Walley (7) which also traces to *fumiferanae* in this key, can be distinguished from *fumiferanae* in having the stigma brown with a large pale spot at the base, the hind femora not fuscous at apices, the mesopleura only narrowly punctate in front with their remaining surface highly polished and impunctate, and the nervellus not strongly curved toward the base of the wing.

A. fumiferanae is very similar to *A. polychrosidis* Viereck but, according to Muesebeck (4, p. 517) the species are distinct, *polychrosidis* having the tegulae yellow, the legs usually darker, the mesoscutum indistinctly punctate and the disk of the scutellum smoother and more polished.

The Egg

The egg (Plate IX, Fig. 1), dissected out of preserved spruce budworm larvae, measures 0.292 mm. in length and 0.098 mm. in width at the widest point. The chorion is light brown in colour, semitransparent, and the developing embryo may be seen within. The egg is slightly curved, and widest near the cephalic end which is broadly rounded and narrows only slightly toward the caudal end. The surface is smooth.

The Larval Stages

First Stage. Just after hatching, the larva measures about 0.25 mm. in length (Plate IX, Fig. 2, A). The body is widest anteriorly and is somewhat wedge-shaped, tapering posteriorly. There is a short spine-like caudal appendage extending posteriorly from the ventral part of the last body segment. The larva is creamy-white in colour.

A later first-stage larva (Plate IX, Fig. 2, B) has, besides the head, twelve body segments and a caudal appendage or anal vesicle. The head appears to be composed of two divisions, the second being much broader than the first. The posterior part of this second head division is the widest part of the body. Behind the head there are twelve fairly regular annular segments and an anal vesicle. Either the tenth and eleventh, or the eleventh and twelfth, or all three of these segments appear to be partially fused. The twelfth, which is probably a composite segment, is slighty wider than the other abdominal segments but is not as wide as the second division of the head. The anal vesicle appears as a rounded projection of the eleventh segment. The spine-like process disappears as the larva grows, finally disappearing before the end of the stage.

The mouth-parts of this stage (Plate IX, Fig. 3) are on the anterior-ventral surface of the first segment of the head. This segment appears as a forward and slightly ventrally projecting lobe of the second segment. Although some of the mouth-parts are sclerotized, they are very lightly pigmented. The mandibles (md) are fairly long, pointed structures with curved blades. The base of the mandible is broad and sits in a shallow concavity laterad of the mouth opening. The mandibular articulations and the supporting head structures are very difficult to interpret. There is, however, a sclerotized ring (pl) around the base of the mandible which the writer takes to be homologous to the pleurostoma, possibly combined with the superior and inferior pleurostomal rami, of other hymenopterous parasites which have more clearly defined first-stage larval mouth-parts. The labiostipites (ls) are merely fleshy lobes bordering the mouth opening ventrally. On the labrum (lm) are two small protuberances, the labral processes, which project forward.

As also noted by Tothill, the mandibles of both forms described as first-instar larvae are the same size, indicating that there is no moult between the two

forms which are so different in appearance. Tothill states that the caudal appendage of the first- and second-stage larvae is a blood gill which is simliar in structure and function to the one which he described for *Apanteles hyphantriae* Riley (3).

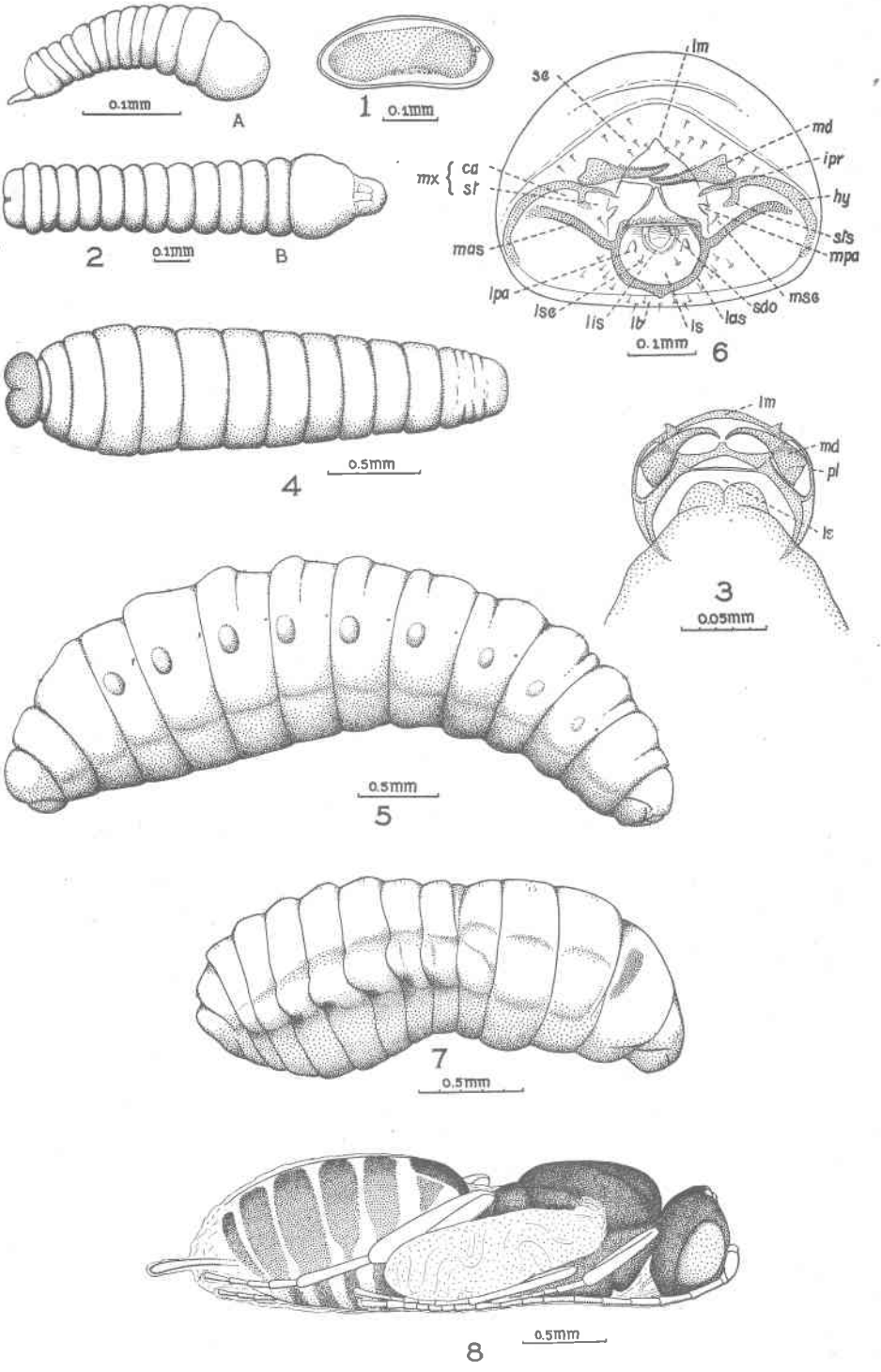
Second Stage. As in the previous stage, the head of the second-stage larva is divided into anterior and posterior portions. From a dorsal view it is somewhat wedge-shaped, tapering anteriorly to a rather blunt end. It is followed by twelve segments. The twelfth segment, which is narrow, bears a large, bilobed caudal appendage or anal vesicle which may become as wide as the body. The anterior half of the body is slightly narrower than the posterior half and the whole is more or less fusiform with blunt ends. (Plate IX, Fig. 4). The body is creamy-white in colour. Tothill notes the presence of visible leg and wing buds and of a well-defined facial plate and remarks that "as the larvae grow the silk glands become more convoluted and noticeable."

No definite sclerotization of the mouth-parts of this stage has been demonstrated and there is no pigmentation in this area. Various treatments failed to make the mouth-parts visible. Tothill states that mandibles are absent in this stage.

Third Stage. The third stage (Plate IX, Fig. 5) appears within the host larva and issues soon after the moult. Just after moulting, the caudal appendage or anal vesicle is still present, but this invaginates during the instar. This is a non-feeding, spinning stage. It is grub-like, curved, and widest at about the level of the seventh to ninth segments. A distinct separation between the dorsal and ventral surfaces is now clearly visible for the first time as a pleural membrane. The head no longer appears to be two-segmented and the head-capsule is roughly hemispherical from a lateral view. The body consists of thirteen segments, the last of which contains the anal opening. Eight pairs of spiracles are visible, occurring on segments two, four, five, six, seven, eight, nine and ten. They are close to the anterior margin of each segment. In the median-lateral line of segments two to ten there is a row of conspicuous round elevations, and on the mid-dorsal surface of segments one to eleven there is a row of short spines.

The mouth-parts of this stage (Plate IX, Fig. 6) are well sclerotized, although not all the structures are present which may occur in the parasitic Hymenoptera. The mandibles (md) are pointed and bear two rows of teeth on the dorsal edge of the blade. They are lightly pigmented. The ventral edge of the base of the mandible articulates with a narrow pigmented bar, the inferior pleurostomal ramus (ipr). No pleurostoma or superior pleurostomal ramus is visible, probably because they are not pigmented, hence the mandibles appear to articulate at only one point. The hypostoma (hy) extends laterally from the inferior pleurostomal ramus and, after a slight upward curve, makes a semicircle ventrally, when viewed anteriorly. A short, curved stipital sclerome (sts) projects ventrally from the point where the hypostoma first curves dorsally. A pigmented U-shaped labiostipital sclerome (las) borders the labiostipites (ls) laterally and ventrally. At the mid-ventral part, this sclerome is enlarged slightly. The dorsal part of the area enclosed by the labiostipital sclerome is wrinkled horizontally and a pigmented strip extends across the open end. Just ventral to this is located the horizontal silk duct opening (sdo). Below the opening lies the ligular sclerome (lis). This is U-shaped and lightly pigmented with the ventral border sometimes indistinct. The labiostipites project beyond the upper open end of the labiostipital sclerome, with the apex more or less pointed. On either side of the ligular sclerome is a labial palpus (lpa), a small conical projection from the labiostipites. Mesad and ventrad of the labial palpi is a pair of labial setae (lse). From the labiostipital sclerome a maxillary sclerome (mas) extends on either side laterally and dorsally into the area enclosed by the semicircular hypostoma, but does not reach as far as the hypostoma. The maxillae

PLATE IX.



APANTELES FUMIFERANAE VIER.

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(mx) are bounded dorsally and laterally by the hypostoma, ventrally by the maxillary sclerome. The stipital sclerome, projecting ventrally from the hypostoma, partially divides the maxilla into a cardo (ca) and a stipes (st). On the maxillary stipes is located the maxillary palpus (mpa). Laterad and ventrad of the maxillary palpus is a maxillary seta (mse). No epistoma is visible. A varying number of setae (se) are present on the labrum (lm) and the frontal area. On the head-capsule illustrated there were six pairs of setae dorsal to the mandibles and two pairs laterad of them. A varying number of setae are also present on the labiobase (lb), as shown in the drawing.

Tothill notes that spiracles do not appear to be present in this stage and that mandibles are not visible. These observations are at variance with the findings of the writer.

The Cocoon

The cocoon of *Apanteles fumiferanae* is spun on the tree and is attached to the needles or entangled in webbing and frass left by budworm larvae. It is white in colour and is very opaque. The cocoon measures about 4 mm. in length and 1.5 mm. in width.

The Prepupa

The eonymph very closely resembles the third-stage larva except in the loss of activity and the disappearance of the small median-lateral round elevations on segments two to ten.

The pronymph (Plate IX, Fig. 7), the commencement of which is marked by the first appearance of the imaginal eyes, is quite different in appearance from the eonymph. A slight constriction appears between larval segments one and two and a much deeper and more prominent constriction occurs between larval segments four and five. Thus the developing head, thorax and abdomen are clearly demarcated. The lateral areas of larval segments two to eleven are raised to form a continuous ridge which is especially prominent on segments four to eleven. The pronymph is considerably shorter than the third-stage larva and, like it, is curved. It is creamy-white in colour.

The Pupa

The exarate pupa of *Apanteles fumiferanae* (Plate IX, Fig. 8) at first is creamy-white in colour with conspicuous dark-brown eyes. Later the head, dorsum and venter of the thorax become blackish and finally the abdomen and legs assume the colour characteristic of the adult. The pupa measures about three millimetres in length.

LENGTH OF TIME SPENT IN THE COCOON

Data on this part of the life history of *Apanteles fumiferanae* are available from Chalk River (1942), Searchmont (1943) and Black Sturgeon Lake (1944). At Chalk River, 31 males spent an average of 12 days in the cocoon; 41 females averaged 12 days. At Searchmont the period was 8 days for 11 males and 12.5 days for 15 females. Twenty-six males spent an average of 12 days in the cocoon at Black Sturgeon Lake and 24 females from that locality spent an average of 11.5 days.

ACKNOWLEDGMENTS

The study of this parasite was initiated at the Universtiy of Western Ontario under the direction of Dr. J. D. Detwiler. Field studies were made at the Dominion Entomological Laboratory, Chalk River, Ontario (1942), and at field stations near Searchmont, Ontario (1943), and Black Sturgeon Lake, Thunder Bay District (1944). The writer is particularly indebted to Dr. J. D. Detwiler for his assistance, kindly suggestions, and criticisms of the work; to Dr. C. E. Atwood, formerly of the Forest Insect Unit, Division of Entomology, who arranged for the shipment of material to London and Chalk River and offered

many invaluable suggestions and criticisms; to Dr. M. L. Prebble, Officer-in-Charge of the Forest Insect Laboratory, Sault Ste. Marie, Ontario, who assisted in arranging the final form of the manuscript; and to Miss Margaret MacKay, of the Forest Insect Unit, who prepared the illustrations. Special acknowledgment is also due to Mr. D. E. Gray of the Forest Insect Unit for his many helpful suggestions; and to Mr. G. S. Walley of the Systematic Unit, Division of Entomology, for the identification of adult specimens of the parasite and for help in preparation of the redescriptions.

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EXPLANATION OF PLATE IX.

Immature Stages in Life History of *Apanteles fumiferanae* Viereck.

Figure 1. Egg, lateral view.
2. First-stage larva.
A. just after hatching, lateral view.
B. at end of instar, ventral view.
3. Cephalic skeleton of first-stage larva.
4. Second-stage larva, dorsal view.
5. Third-stage larva, lateral view.
6. Cephalic skeleton of third-stage larva.
7. Pronymph, lateral view.
8. Pupa, female, lateral view.

SYMBOLS USED IN THIS PAPER

ca — maxillary cardo
hy — hypostoma
ipr — inferior pleurostomal ramus
las — labiostipital sclerome
lb — labiobase
lis — ligular sclerome
lm — labrum
lpa — labial palpus
ls — labiostipites
lse — labial seta
mas — maxillary sclerome
md — mandible
mpa — maxillary palpus
mse — maxillary seta
mx — maxilla
pl — pleurostoma
sdo — silk duct opening
se — seta
spr — superior pleurostomal ramus
st — maxillary stipes
sts — stipital sclerome

BOOK NOTICES

A MONOGRAPH OF THE BEETLES ASSOCIATED WITH STORED PRODUCTS, Volume I, by H. E. Hinton, Assistant Keeper, Department of Entomology, British Museum (N. H.). VIII and 443 pages, 503 figures, 1945. British Museum (N. H.), London, England. Price 30 shillings.

The exigencies of the food situation in Britain in 1940 intensified interest in the pests of stored products. As "Beetles are by far the most important and most numerous order of insects attacking stored products", and "about six hundred species representing some thirty-four families have been found associated with stored products in various parts of the world", a comprehensive study and revision of coleopterous stored products pests was initiated.

In 1943 Dr. Hinton was lent to the Food Ministry by the Department of Entomology of the British Museum. Primarily he was responsible for insect iden-