1937

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NETTLETON - 1937

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by

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Submitted as a Thesis to the Faculty of the Graduate School
in Partial Fulfillment of the Requirement for the
Degree of Master of Science

Massachusetts State College

June 1937

C O N T E N T S

THE BIOLOGY OF THE PARASITE APANTELES CARPATUS SAY

INTRODUCTION

The purpose of this paper is to give an account of the biology of the solitary parasite, Apanteles carpatus Say, of the true clothes moths, with a brief discussion as to the possible economic importance of the parasite.

This parasite is a member of a very large genus of the family Braconidae. The estimated number of species in this genus is nearly 600 (Watanabe,1932). It has the typical features of many members of the genus, the family Braconidae, and the order Hymenoptera. Many members of this genus have the cocoons yellow or white, and are gregarious or solitary. The species in question has an isolated cocoon.

Apanteles carpatus Say is closely related to Apanteles ephestiae Baker, both structurally and biologically. The latter has hyaline wings rather than whitish, the veins of the forewings brown, the stigma longer and narrower, and the posterior femora darker (Muesebeck,1920). Mr. D. S. Wilkinson (1932) in his key to the Ethiopian species of this genus, includes A. carpatus Say in his group S which contains 77 other species, a few of which are listed from America, a few from Europe, and the rest from Ethiopia.

Apanteles carpatus Say, a native parasite, was first described by Thomas Say as Microgaster carpata. The type, which was lost, was collected at New Harmony, Indiana, and

its description was published in the Boston Journal of Natural History in 1836. In 1881, C. V. Riley made the generic change to Apanteles, but retained the feminine ending ata. Chittenden (1897) changed the feminine ending to the masculine, atus.

The synonymy of this species given by Muesebeck (1920) failed to include the generic change made by C. V. Riley. The suppression of Apanteles igae Watanabe to A. carpatus Say was made known to me in 1936 by C. F. W. Muesebeck. Apanteles clavatus Provancher has also been synonymized to A. carpatus Say (Muesebeck,1926). The original synonymy by Muesebeck (1920) has been revised as follows:

Microgaster carpata Say, Boston Jour.Nat.Hist.,vol.1, pt.3,1836,p.263; LeConte, Writ.of Th.Say, Entom., vol.2, 1859, p.714.

Apanteles carpata Riley, Trans.Acad.Sci. of St.Louis, IV, no.2, April, 1881, p.19.

Apanteles clavatus Prov., Addit.faune Canad.Hymen. 1888, p.338.

Apanteles carpatus Chittenden, U.S.Div.Ent.Bull.8, n.s., 1897, p.42.

Apanteles (Apanteles) carpatus Viereck, Bull.22, Conn.State Geol.and Nat.Hist.Survey, 1917 (1916), pp. 191, 200.

Apanteles igae Watanabe, Insecta Matsumurana, vol.7, nos. 1 and 2, 1932, p.97.

Very little is known of the biology and life history of this insect. Chittenden (1897) in a report on the meal snout moth (Pyralis farinalis L.) states: "This little braconid

was reared in numbers from refuse hay, meal, and other feed infested with Pyralis farinalis L., a large quantity of which was kindly brought me from Lakeland, Md. by Mr. F. C. Pratt of this division. A cocoon of this moth was noticed that was unusually firmly attached to the jar, a sufficient quantity of silk being used to completely conceal the inclosed chrysalis. This chrysalis was found to have been perforated near the head, the hole corresponding in size to that of a parasitic larva of the species in question. The parasites began issuing in August, being present in the largest numbers at the time of greatest abundance of their host, viz., during the hot weather toward the closing days of September and the first of October, and disappearing at the end of the latter month with the decrease of the moths. It reappeared in our rearing jars, together with its host, the following April."

Apanteles carpatus Say has been reared from four species of hosts: it was reared from Tinea pellionella L., Trichophaga tapetzella L. (Insect Life,1890-1891), and Chittenden reared it from Pyralis farinalis L. in 1897; Marlatt (1915) reared it from Tinea pellionella L., Trichophaga tapetzella L., and Tineola biselliella Hum. Mr. D. S. Wilkinson (1934) has reported its occurrence in Europe where it is parasitic on Tineola biselliella Hum. In the abstract of Wilkinson's paper, Tineola biselliella is mentioned as a new host. It has also been reared at Tokyo, Japan, by Mr. T. Isobe, from Tinea pellionella L. (Watanabe,1932).

In a letter received from Mr. C. F. W. Muesebeck (April 7, 1937), he states that because of the numerous collections of this parasite in regions other than those given in his paper on the genus Apanteles (1920), it can be definitely said that this parasite is widely distributed throughout the entire United States. It is also known to occur in Japan and Europe.

The last three instars of Tineola biselliella Hum. were used in the study of this parasite. Other host cultures, into which the parasite was introduced, included Tribolium, Acroia, Trogoderma, Plodia, and Sitophilus.

The host food was principally wool cloth from old suits of men's clothes. Brewer's yeast was tried as a means of hastening larval development of the host. However, fungous growth occurred in the early cultures containing brewer's yeast, and therefore it was discontinued.

The cages consisted of gallon battery jars with glass plates for covers, wide-mouth glass bottles 2 inches wide by 2.25 inches high, with cloth covers, and pint and quart friction-top, ice cream containers.

Hosts and parasites were maintained under controlled temperatures and moisture environments, and under laboratory conditions. All temperature recordings are in degrees Centigrade, and moisture is in percent of relative humidity. The humidity was maintained with saturated salt solutions containing an excess of the salt. The salts yielded humidities as follows:

Potassium sulfate	96 percent
Sodium chloride	75 "
Cobalt chloride ($6H_2O$)	63 "
Magnesium chloride	32 "
Calcium chloride	26 "

The moisture was controlled in the battery jars by placing salt solutions contained in wide mouth bottles (2" by 2.5") in each jar. The solution bottles were covered with fine gauze to prevent entrance of the insects. The moisture was controlled in the bottle cages by hanging them in glass top pint fruit jars, having the bottom covered with the solution. A soft string was tied around the neck of the cage, with one end extending out of the fruit jars. When the cover was placed on the fruit jar and clamped in position, the cage was held at the desired height in the jar by the string.

Stock cultures of the hosts, and hosts and parasites, were kept in the battery jars. These stock cages were kept at laboratory temperature, but the humidity was maintained at 75 percent. All experimental tests were made in the bottle cages. The food of the adult parasites was placed on the fine gauze cover of the cages. Host larvae with their food were placed in the experimental cages and the parasites were admitted when desired or when available. The cage was then put into the humidity jar, and the whole in the desired temperature chamber or laboratory. The experimental cages

were examined two or three times daily; generally from ten to eleven o'clock in the morning, five to six o'clock in the afternoon, and sometimes from nine to ten o'clock in the evening. The results were recorded at these different hours, and sometimes more often, as the situation required.

DESCRIPTION OF THE STAGES OF THE PARASITE

The adult parasite is a small, black braconid, 2.50 mm. to 2.75 mm. in length, with brown, flagellate antennae in the female, and either black or brown in the male. The thorax is without parapsidal furrows, the striate area in front of the scutellum is large, and the tegulae are yellowish or variable in color. The stigma of the forewing is large, triangular, light brown, the veins colorless, and the second cubital cell lacks an exterior nervure. The propodeum is black, distinctly areolated, and almost twice as wide as it is long; the posterior coxae are black and all the tarsi are dull yellow. The abdomen is about four times as long as its greatest width, compressed ventrally, its ovipositor sheaths almost as long as the abdomen (Say,1836; Muesebeck,1920).

When hatched, the first instar larva averages 0.4 mm. in length, increasing to 1.6 mm. in length by the end of the instar. The morphological features that are significant in this instar are: small, colorless, tusk-like, non-dentate mandibles (fig.8); a caudal horn very prominent in the early part of this instar (fig. 1)

which gradually shortens and finally disappears at the first moult, at which time the anal vesicle is evident (fig. 5); large labral processes; no visible tracheation; the body segmentation is distinct, with eight abdominal segments; and the alimentary tract is continuous, but closed at the posterior end.

The second instar larva (fig. 11) averages 1.8 mm. in length at the beginning and 3.1 mm. in length and 0.7 mm. in width by the end of the instar. The outstanding features in this instar are: caudal horn lacking; the anal vesicle is much more evident and developed than in the first instar; the mandibles are still soft, mono-dentate, but are now much larger and slightly S-shaped, (fig. 9) with slight pigmentation at their tips; the labral processes are now hardly noticeable (fig. 7); the alimentary tract has not changed, except in the latter part of the instar just before moulting (fig. 12); tracheation is now evident; and the body segmentation is the same as the first instar.

The third instar at the beginning has an average length of 3.3 mm. and an average width of 0.6 mm. When it is full-grown it is 4.5 mm. long (fig. 13). Several features, which were present in the first and second instars, have been lost and new features have appeared. These features are: the mandibles are now yellow-brown with twelve teeth (fig. 10), have an enlarged basal region, and are sclerotized; the anal vesicle is absent in the last half of the instar; the alimentary tract is distinctly marked off into areas but still closed at the posterior end; silk glands and fat granules are evident, both

being well developed; the labral processes are absent; and the body segmentation is distinct, having nine abdominal segments.

The mature pupa is of the typical exarate type, common to the order Hymenoptera, measuring 2.6 mm. to 3.0 mm. in length and 1.4 mm. in width. The prepupal stage demarks the period in which most of the external larval features are lost. The following features occur: the meso- and meta-thoraces are more evident; the compound eyes and ocelli appear quite early; and are colored dull brick red. At thirty-six hours from the time this stage began, the mesonotum and scutellum are well demarked and the mandibles of the last stage larva are still evident. At the end of forty-eight hours the last stage larval mandibles are still evident; the compound eyes and ocelli are darker red; the head and abdomen are not fully differentiated from the thorax; and the venter of the abdomen is evident. At the end of forty-eight hours the prepupal stage is over; voidance of larval excrement occurs, and it moults, as indicated by the loss of the larval mandibles and the appearance of all external appendages. The head and abdomen are now easily distinguishable from the thorax and are distinctly developed. At the end of three days, pigmentation becomes prominent. The body loses its glistening whiteness and gradually darkens, until the color of the adult is reached just before emergence. This occurs at three and one-half to four days from the time the prepupal stage begins.

The cocoon consists of glistening white, tightly woven, silken threads and generally lies within the cocoon of its host. It averages 4 mm. in length and 1.2 mm. in width, rounded at both ends, and elongate-oval in shape. It possesses the typical hinged cap of Apantales at the anterior end, through which the adult gnaws its way to the outside.

BIOLOGY

The average length of life of the adult is three to five days, this figure being obtained by dividing the total number of days by the total number of adults for all conditions. The average under different controlled conditions is also from three to five days. The optimum range of temperature at which the average length of life occurred, was from 21.1° to 32°, with a relative humidity of 75 percent. At 29°, and various percentages of relative humidity (26 percent to 96 percent), adults lived at most one-half day, except those at 75 percent. The minimum length of life was one-half day, and the maximum was sixteen days. The information obtained is presented in Table 1.

Table 1. Longevity of adults at different temperatures, different percentages of relative humidity, with different hosts.

Temp. °C.	Rel.Hum. Percent	Food	Host	Number Adults	Length of Life in Days Average	Range
23.1	75	----	Clothes Moth	13	3.80	0.5 - 9.0
27.0	75	----	" "	8	3.06	1.5 - 7.0
29.0	75	honey	" "	22	3.50	1.0 - 7.0
23.1 - 24.6	75	honey & yeast	" "	1	4.50	-----
"	75	honey	Granary Weevil	1	4.00	-----
"	75	honey & yeast	" "	3	2.00	-----
"	75	honey	Wax Moth	4	3.90	1.0 - 6.5
"	75	honey & yeast	" "	2	7.50	7.0 - 8.0
"	75	honey	Tribolium	10	6.05	1.0 - 16.0
"	75	honey	Dermestid	4	4.00	1.5 - 7.0
"	75	honey & yeast	"	3	2.66	2.0 - 3.5
29.0	26	honey	"	2	0.50	-----
"	32	"	"	2	0.50	-----
"	63	"	"	4	0.50	-----
"	75	"	"	1	2.50	-----
"	90 - 96	"	"	2	0.50	-----
32.0	26	"	"	1	0.50	-----
"	32	"	"	1	0.50	-----
"	75	"	Clothes Moth	1	5.50	-----

The adults of this parasite showed no particular preference for the kinds of food offered them. Two types were used, - honey, and honey and yeast mixed in equal parts. Adults without food lived just as long as those that were furnished with food (Table 1).

This species is apparently thelytokous, as no males were observed during the study. Several generations were reared without the coition of males. That no males are known to exist, has been confirmed by C. F. W. Muesebeck (by correspondence, April, 1937). Under the above conditions, the sex ratio is 1.0.

The adults of this parasite exhibit different characteristics of behavior. Freshly emerged adults, when exposed in cages containing from six to eight host larvae, and having honey for food, exhibit activity in seeking host larvae for oviposition. However, one of these was observed feeding before ovipositing. Another did not feed at all during the period of observation, which lasted about twenty minutes. Several other adults were allowed to escape from a battery jar in the presence of strong light. A few of these flew toward the light, but remained in the light for only a few minutes, flying eventually to a darker area in the laboratory. Other liberated individuals flew in the opposite direction, away from the light. These reactions to light apparently indicate no definite phototropic response. This same reaction has been observed with adults within the battery jars. The females often, when on the sides of the jar, showed no particular reaction to ordinary light. At other times no females were

seen on the sides of the jar and when the cloth within the jar was lifted, the females would likewise show no reaction to the admittance of light. Due to the fact that so many things are involved, or seem to be involved, in a discussion on geotropism and chemotropism, no effort has been made to determine whether these two tropisms do exist for this parasite.

Numerous host larvae, that had been exposed to parasites for several days, were dissected to determine the number of parasite larvae. The greatest number in any larva, recovered so far, is 21. One host larva contained 13 first instar parasite larvae and others contained from 3 to 4 parasite larvae. Newly emerged females have been dissected to determine the number of ova in the ovaries, but no counts have been made because of the difficulty in finding them. Apparently the female does not lay a great number of eggs.

The female is very active at the height of oviposition and moves about rapidly in search of a suitable host larva. When one is found, she quickly inserts her ovipositor. During this act, the wings are raised from a horizontal position to an angle of about 30 degrees and the hind legs are straightened, raising the abdomen upward. The abdomen is then curved slightly downward and the ovipositor is thrust perpendicularly into the host larva. This entire action requires only a few seconds. Upon completing the first insertion, the female usually seeks out another host larva for oviposition. However, females have been observed ovipositing, or in the position of oviposition, on the same larva

for four or five successive thrusts. Females were also observed cleansing themselves before proceeding to seek host larvae. In one case this cleansing process occurred between successive ovipositions. Usually the female will not oviposit unless there is cloth between her and the larva, or when the larva is enclosed in its case. Only one exception was observed when a female thrust her ovipositor into an exposed larva. A few females have been observed ovipositing or in the act of oviposition, but the attempt to recover eggs by dissection was unsuccessful in these cases.

The parasite attacks the third, fourth, and fifth instars of Tineola biselliella Hum., but the fourth and fifth are preferred over the third. This statement is based on the greater percentage of first instar parasite larvae recovered by dissection from the fourth and fifth instar host larvae, than from the third instar host larvae. Pupae enclosed in their cocoons were also offered to parasites. The ovipositor was inserted in a number of cases an presumably oviposition occurred. However, all of the host pupae produced normal host adults.

The egg requires from three to five days to develop before hatching. One egg that was recovered from a host larva showed partial embryonic development at the end of 2.50 days. No other eggs have been recovered.

There are three larval instars of the parasite, which can be distinguished as follows:

Instar	Caudal Horn	Mandibles	Anal Vesicle
First	Present	Mono-dentate, soft, lacking pigment, and tusk-like (fig. 8)	Present (more evident in the latter part of instar)(fig. 5)
Second	Absent	Mono-dentate, lightly pigmented at tips, and slightly S-shaped (fig. 9)	Present (figs. 11 and 12)
Third	Absent	Multi-dentate, yellowish-brown, sclerotized, and enlarged at base (fig. 10)	Absent in the latter half of instar (fig. 13)

The first instar lasts from six to nine days, the second from five to seven days, and the third from three to four days.

The first instar larvae of the parasite feed for the most part on the body fluids of the host without much apparent effect on the host larvae. The second and third instars feed upon the storage and fat tissues of the host larvae, consuming the greater part of the host reserve food material. The host larva continues to feed after deposition of the egg of the parasite and it completes the feeding period. When the host larva begins to spin its cocoon, the parasite larva is nearly full grown. Death of the host occurs shortly after issuance of the parasite larva. After issuance of the larva of the parasite, the host still shows signs of life, but its movements are very sluggish. The dead host larva is flat and flabby in appearance.

The last stage larva upon reaching full growth, leaves the host larva to pupate. Issuance occurs through the anterior end of the host larva, just behind the head capsule. It forces its

way out on the lateral side of the third segment behind the head of the host larva. When the parasite larva is about two-thirds emerged, it attaches a few threads of silk to nearby objects. After issuance, it spins a few strands posteriorly and laterally, laying a foundation about the lower half of the body. The parasite larva moves the anterior half of its body while spinning the silk-like strands. It is very agile in its movements, being able to move the anterior half of the body without disturbing the posterior half. Within three to five hours, a thin layer of these silken strands cover the entire parasite larva. This outer framework is made sufficiently large to permit movements within, and yet not crowd the parasite larva. In six to ten hours, the parasite is barely visible through the cocoon. At twenty to twenty-four hours, the cocoon has assumed its typical shape and possesses the anterior cap-like structure through which the adult emerges.

The average length of the pupal period is 4.4 days, having been computed for all conditions of temperature (20° to 32°) and humidity. At 29°, pupation will occur in from 3 to 3.5 days, at 75 percent relative humidity. At 21.1° to 23.8°, without controlled humidity, the pupal stage requires at least twenty-four hours more for completion. The following table shows a few results on the length of the pupal period:

Table 2. The length of the pupal period at 23.1° to 24.6°, 75 percent relative humidity, and clothes moth as the host.

Number of Individuals	Number of Days	Average Length in Days
3	4	4.4
2	5	

At a constant humidity of 75 percent, and at four different temperatures, the length of the developmental period from egg to adult ranged from 18 to 28 days (Table 3). The average length for the developmental period, under all conditions, is 23.38 days. The optimum range is apparently from 25 to 26 days. A greater number of individuals were reared at 27° than at 23.1°, 29°, and 32°. The length of the developmental period at 23.1° and 29.0° was approximately the same. I have been unable to find any tangible evidence that would indicate the reason for such similarity in the length of the developmental period at these two temperatures. At a constant humidity of 75 percent, the length of development from egg to adult at 27° was 2.5 to 5.5 days longer than at 29°. From the original culture, six consecutive periods of development from egg to adult, or six generations, were reared at room temperature and incubator temperature. Taking the average number of days, 23.38, as representative of the length of a developmental period from egg to adult, the number of generations per year under these experimental conditions would be fifteen.

Table 3. Length of the developmental period (egg to adult) at 75 percent relative humidity, and clothes moth as the host.

Temp. °C.	Number of Individuals	Length of Development in Days		
		Number	Average	Range
23.1	2	19		
	3	20		
	1	21	21.1	19 - 24
	1	22		
	2	23		
	1	24		
27.0	9	24		
	9	25		
	7	26	25.0	24 - 28
	1	28		
29.0	2	19 - 21		
	1	18 - 20		
	1	19 - 23		
	1	20 - 26	20.4 - 23.4	18 - 27
	1	21 - 22		
	1	21 - 24		
	1	21 - 27		
	2	23 - 25		
32.0	1	18	18.0	----

All of the experiments on the length of a developmental period had Tineola biselliella Hum. as the host, except in two cases, when two single individuals were reared on Acroia and Trogoderma. Due to the fact that the culture used for Trogoderma contained wheat that might have been infested with Plodia, I am not sure whether the individual in this instance was reared on Trogoderma or Plodia. Other attempts to rear this parasite on hosts besides clothes moths were unsuccessful. The results are shown in Table 4.

Table 4. The length of the developmental period of A. carpatus Say on hosts other than clothes moths.

Host	Temp. °C.	Days to Develop	Number Individuals
Acroia	24.6	19 - 27	1
Trogoderma	21.1	28 - 36	1
Tribolium	27.1	Unsuccessful	---
Plodia	23.1	Unsuccessful	--- (Uncontrolled humidity)
Sitophilus	23.1	Unsuccessful	---

Stock cultures, containing both hosts and parasites, have been maintained by Mr. N. Turner of the Connecticut Agricultural Experiment Station at New Haven, Ct. In every case complete parasitism occurred in these cultures, resulting in the eradication of the host. I know of no record where such a result occurs under natural conditions. Synchronization of the life cycles of both the host and parasite under laboratory conditions, so that suitable host larvae will be present at all

times, has been unsuccessful. This might indicate the impossibility of using this parasite as an effective means of control. When the parasite is introduced, it attacks only the last three instars of the host. In the meanwhile, the smaller of the host larvae do considerable damage, and if the parasites are not present, these smaller host larvae will eventually give rise to host adults. There seems to be no definite evidence that this parasite has any economic importance.

SUMMARY

Apanteles carpatus Say is a native, solitary, internal parasite of the true clothes moths. It is widespread throughout the entire United States and has been recorded from Europe and Japan. Several types of cages were used in rearing this parasite, but no innovations were made. Rearing occurred under different environmental conditions, as discussed in this paper. Studies were made of all stages of the parasite from the standpoint of behavior, length of life, relation to its hosts, and its biology. All of these have been presented. It was reared from two other hosts, *Acroia* and *Trogoderma*. The adults show no phototropic response. Many freshly parasitized larvae were dissected to recover the eggs of the parasite, but these dissections were unsuccessful, except in one case when a broken egg was obtained.

CONCLUSIONS

This parasite has not been recovered from Acroia and Trogoderma under natural conditions. It is thelytokous, the male never having been taken. The eggs hatch in from 3 to 5 days and the larva passes through two full instars and almost the entire third within its host. Under suitable conditions, adults will live from 3 to 5 days, on an average, with a range from 1/2 to 16 days. The developmental period from egg to adult averages from 22 to 25 days in length, with a minimum of 18 days and a maximum of 28 days. Adults show no particular preference for the kinds of food offered them. Females will not oviposit unless cloth is between the host and the parasite, or when the host larva is enclosed in its case. The adult attacks the last three instars of the host. The last stage larva issues from the host larva before pupating and the pupal period averages about 4.4 days in length. This parasite seems to have no possibilities of being economically important.

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ABBREVIATIONS

at - alimentary tract

av - anal vesicle

ch - caudal horn

h - head

lb - labium

lbr - labrum

lbrpr - labral process

md - mandible

EXPLANATION OF PLATE

Fig. 1. Lateral view of early first instar larva.

" 2. Dorsal view of early first instar larva.

" 3. Lateral view of middle first instar larva.

" 4. Dorsal view of late first instar larva.

" 5. Lateral view of late first instar larva.

(Figs. 1 to 5 show gradual shortening of the caudal horn in the first instar larva.)

Fig. 6. Ventral view of the head of first instar larva.

" 7. Ventral view of the head of second instar larva.

" 8. The mandible of third instar larva.

" 9. The mandible of second instar larva.

" 10. The mandible of first instar larva.

" 11. Lateral view of early second instar larva.

" 12. Dorsal view of late second instar larva.

" 13. Lateral view of full-grown third instar larva.

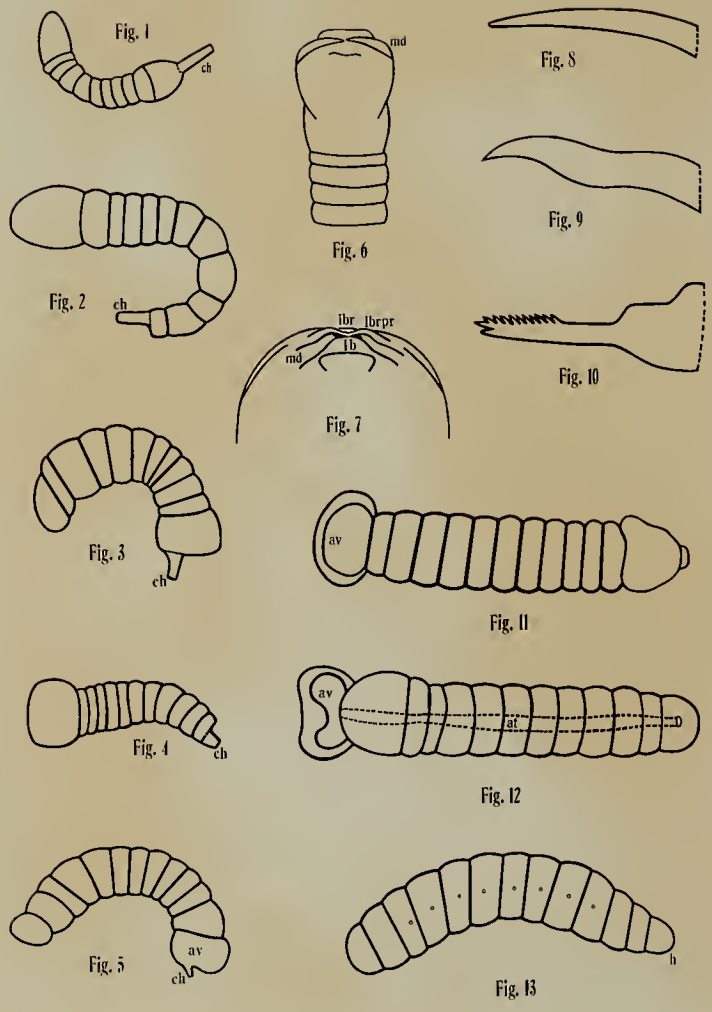
Fig. 1
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Plate 1

ACKNOWLEDGMENTS

The author wishes to express his very sincerest appreciation to Dr. Harvey L. Sweetman for his criticism, his aid in organization, his other helpful suggestions, and the innumerable hours and days devoted by him during the preparation of this paper.

The author also wishes to extend his gratitude to Mr. C. F. W. Muesebeck of the Bureau of Entomology, to Miss Grace Griswold of the University of Cornell, to Mr. Neely Turner of the Connecticut Agricultural Experiment Station, to Professor Bailey and to Professor Serex, the latter two being members of my thesis committee. All of these persons contributed in one way or another toward the completion of this paper.

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Date 5-21-37