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OF

The Entomological Society of America

VOLUME VII, 1914

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Volume VII. Number 1.

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PUBLISHED QUARTERLY BY THE SOCIETY
COLUMBUS, OHIO

Smithsonian Institution
APR 23 1914
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Entered as second class matter April 11, 1908, at the Post Office at Columbus, Ohio, under the Act of Congress of March 3, 1879.

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ANNALS

OF

The Entomological Society of America

Volume VII MARCH, 1914 Number 1

A STUDY OF DRYOPHANTA ERINACEI (MAYR) AND ITS GALL.*

C. J. TRIGGERSON.

Smithsonian Institution
APR 23 1914
National Museum

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INTRODUCTION.

The Cynipidae constitute, biologically, one of the most interesting families of the Hymenoptera. They have long attracted attention, not only from the systematic view-point, but also from the view-point of their life-history, the variety of the galls they produce or inhabit, their biology, and the cause of gall formation. The purpose of this paper is to present an intensive study of one gall-maker *Dryophanta erinacei* (Mayr), discussing its life-history, its parasites, its guests, and the cause of gall formation.

The Oak Hedgehog Gall is rounded or oblong, with the surface finely netted with fissures, and more or less densely covered with spines. It varies in length from 10-15mm., and occurs on both sides of the White Oak leaf. The point

*Contribution from the Entomological Laboratory of Cornell University.

of attachment is generally on the midrib (Fig. I, Pl. I), though it is often found on the lateral veins. When young it is yellowish green, but in autumn it becomes yellowish brown, much lighter in color than the tinting of the leaf. The gall first appears late in June, and reaches full development about the third week in August. It is widely distributed, having been reported from New England, North Carolina, Iowa, Illinois, Indiana, Kansas, Michigan, Ohio, Virginia, Canada, and probably Florida and Colorado.

A longitudinal section through the gall shows that it contains several chambers varying from two to eight in number. These I have named according to their location. First to be noted are the *central cavities*, (Fig. 2a, Pl. I), which measure 2mm. x 3mm. and are located in the central portion of the growth. These are occupied by Dryophanta erinacei and the parasites. Second, there are the *lateral cavities*, (Fig. 2b, Pl. I), situated at the side and base of the growth and measuring 1½mm. x 2mm. These are occupied by inquilines. Lastly, there are to be found the *peripheral cavities*, (Fig. 8a, Pl. II), located on the coriaceous portion of the gall, and covered with the basal layer of spines. These are 1mm. in size, and are likewise occupied by iniquilines.

The gall was first described by Walsh in 1864 under the name Cynips q. erinacei. When Mayr in 1881 established the genus Acraspis he included the insect causing this gall, which therefore was known as Acraspis erinacei. The first description of the insect appeared in a paper by Beutenmüller '09, entitled "Species of Biorhiza, Philonix, and their allied Genera, and their Galls," in which he places it in the genus Philonix. As will be shown later in this discussion, the insect belongs to the genus Dryophanta, and should be known therefore as Dryophanta erinacei (Mayr).

The Life-History of Dryophanta Erinacei.

The agamic form of Dryophanta erinacei emerges from the oak hedgehog gall about the fifth of November. It varies from 1.50 to 3mm. in length. The head is black, rufous on both sides of the face, finely punctate, with whitish pubescence; antennae black, fourteen jointed, with basal joints rufous; thorax rufous; plurae black with rufous mark anteriorly; all minutely punctate; parapsidal grooves distinct posteriorly,

obsolete anteriorly; scutellum rufous, punctate and pointed posteriorly; metathorax black; abdomen piceous; ventral spine and tip of abdomen hairy; legs yellowish rufous, tibia slightly darker; wings aborted.

The insect makes its way to the leaf and flower buds of the white oak, where oviposition takes place. On the tree where our observations were made, it continued to emerge and oviposit until the twenty-first of November. The insects are most active on cold days or early in the morning. During the warm weather they are inactive and sluggish, hiding at the base of the petioles, in the crotches of the young shoots, or in the crevices of the bark. They have been taken in this vicinity on rare occasions in early December, but usually they succumb to the first heavy frosts at the close of November.

Its method of oviposition does not differ much from that already described by Kieffer for other species of the Cynipidae which attack buds. The insect clasps the apical portion of the bud with the second pair of legs, (Fig. 3, Pl. I), and pressing alternately with the first and third pair produces a teetering motion which forces the ovipositor into the buds. The long ovipositor lifts the apical edge of the outer scale, and is gradually pressed down along the edge of succeeding scales, and finally thrust into the region of the young leaf and flower. Then there is a sudden jerk of the body which curves the distal end of the ovipositor, turning the openings against the concave face of the innermost scale. The insect now retains a motionless attitude for almost four minutes, during which the egg is deposited. The ovipositor is then withdrawn, the passage being filled with a waxy substance for the protection of the egg. This waxy secretion is doubtless from the accessory glands of the reproductive system, and is homologous with the secretions with which Corydalis cornuta, certain of the Lepidoptera, as the Apple Tent-Caterpillar, the Tussock-moths, and many other insects cover their eggs.

The egg, (Fig. 20, Pl. III), is an oval body 400μ. x 225μ. provided with a pedicel which is 1mm. in length. It is attached by this pedicel to the upper brown portion of the scale, falling either against the green portion of the scale (Fig. 6, Pl. II), or being held among the young leaves or flowers, in which position it remains during the winter. It is worthy of emphasis that this pedicel does not constitute the apical pole of the egg

since the larva emerges from the opposite pole, and as already indicated it serves as an appendage for attaching the egg to the bud scale.

As will be seen later the eggs of the Chalcids are flask-shaped, (Figs. 31, 32 and 37, Pl. IV), but here the elongate portion is in reality the cephalic portion of the egg. This is shown by the fact that the egg is oriented in the ovum in such a way that the elongate portion is cephalad, also that the larva always emerges at the base of the neck (Figs. 32 and 37, Pl. IV). This therefore, is exactly opposite to the condition found in Dryophanta erinacei.

Buds were examined on the eighth of May and the unhatched eggs found were very turgid, appearing slightly enlarged. On the twelfth of May a slight swelling, at the apex of which an empty egg shell was visible, appeared on the lower green portion of the scale, (Fig. 9, Pl. II). This proved to be a freshly formed gall, containing a young larva of Dryophanta erinacei. The gall at this stage was thin-walled, with a pebbled surface, greenish in color, and contained a watery fluid. The egg-shell remains attached to the apex of the gall until the latter has reached considerable size, when it dries up and disappears. These hypertrophies develop rapidly, as many as three appearing on one scale. The wall of the gall has by this time changed to a yellowish brown color, and soon becomes quite dry and brittle.

Galls also develop on the apical portion of the leaf and flower buds, (Fig. 10, Pl. II). These are red, being similar in color to the young leaf and flower. The wall is pebbled on the surface, and thin. The cavity contains a single larva bathed in a watery fluid, and similar in all respects to the one inhabiting the scale gall. The terminal galls are of the same size as those on the scales, varying in number from one to four, and when mature are reddish brown. Since only the agamic form of Dryophanta erinacei was found ovipositing on the leaf and flower buds, and since the eggs of this species and no other were found in the leaf and flower region, and since males and females similar in size and character emerge from the two galls, it is evident that they are produced by the same insect. The difference in color in the galls is due to the normal difference of the tissue of which they are formed.

Shoots were brought into the laboratory, placed in water and covered with bell jars. Here about noon on the twenty-first of May the first male and female emerged. They were quite vigorous, and about four-thirty in the afternoon the female was noticed actively moving along the midrib of the young leaf. Suddenly she stopped, and set up a rapid nodding motion which lasted thirty-five seconds, during which the ovipositor was thrust into the tissue. The insect remained motionless for a time, then withdrew the ovipositor, filling the passage with a yellow substance which, as in the agamic form, is probably a secretion poured forth by the accessory glands of the reproductive system. The process was repeated four times in succession without moving the body forward. Each time the ovipositor was inserted the body was curved slightly more than at the preceding puncture. The entire time occupied by the four ovipositions was from four-thirty-four to four-fifty, or sixteen minutes, thus allowing four minutes to each oviposition of which a little over two minutes and a half was occupied by the passage of the egg. Many other observations were made, and the time in all instances corresponded to the first recorded.

While the first observations of oviposition were made without having seen copulation occur, in all the following instances it was observed. The male strikes the female several times with the antennae, after which the latter rests quiet. The male then clasps her thorax latero-caudad of the second pair of wings with the second pair of legs, while the first pair rest on the dorso cephalic portion of the thorax, and the third pair extend slightly latero-cephalad of the abdomen; copulation takes place, lasting for a few minutes.

The egg of the sexual form, (Fig. 25, Pl. III), is oval, 160μ x 450μ. provided with a pedicel 750μ. in length, which is shorter than in the agamic form. It is always placed in the fibro-vascular bundles, and at an angle of about 80° to the axis of the leaf. The egg differs from that of the agamic form only in the elongate portion being shorter.

The larva is characteristic of the Cynipidae, having a slightly depressed head, fine needle-like mandibles, broad thorax, and reflexed pointed abdomen. During development the abdomen does not become as enlarged as in the agamic form. The thorax also continues prominent throughout all

larval stages, which is not the case with the agamic form. Fig. 27, Pl. III, represents a mature larva of the sexual form, and may be compared with Fig. 19, Pl. III, which represents a mature larva of the agamic form in the corresponding stage.

In the open the adults did not emerge until the twenty-ninth of May, and continued to oviposit from that time until the fifth of June. Oviposition here was as observed in the laboratory, the time occupied corresponding exactly to that already noted. Fig. 4, Pl. I, shows a female of the sexual form.

The sexual form which possesses the characteristics of the genus Dryophanta may be described as follows:

Female: Color. Head, thorax and abdomen shining black, nonpubescent; mandibles yellowish brown; mouthparts yellow; antennae first two joints yellowish, flagellum shading to black at the tip. In the male the entire antennæ are black. Length 2mm.

Head: Face opaque, surface irregular, rugose about the ocelli; compound eyes 200μ.x300μ. Distance between compound eyes and hind ocelli 75μ.; between hind ocelli 100μ.; between compound eyes and fore ocelli 500μ. Distance between compound eyes and antennæ 75μ.; between antennæ 75μ. Width of head at temples 1.50mm.; mandibles tridentate, mouth parts as in Figs. 21, 22, and 23, Pl. III. Antennæ fourteen jointed,(Figs. 28 and 29, Pl. III).

Thorax: Smooth, parapsidal furrows distinct posteriorly, obsolete anteriorly, pluræ smooth.

Scutellum: Rugose, becoming smooth in front, cross furrow reduced to a shallow depression (Fig. 26, Pl. III).

Appendages: Wings hyaline, fringed with setæ, veins yellowish brown, (Fig, 24, Pl. III); legs yellowish, coxæ of the third pair yellowish brown.

Abdomen: Smooth, deeper than long, first segment one-third the size of the abdomen, outline of the remaining segments as seen from the side serrate; ventral spine and tip of abdomen hairy.

Male: Color. Same as female, length 1½mm.

Head:	Distance of compound eyes to hind ocelli	50μ
	" between hind ocelli	150μ
	" of compound eyes to fore ocelli	600μ
	" of compound eyes to antennæ	50μ
	" between antennæ	50μ

Antennæ fifteen jointed.

Thorax: Mesonotum more gibbous than in female.

Abdomen: Petiolated, longer than deep as seen from the side; petiole cylindrical.

On the twenty-fifth of June the first evidences of gall-formation appeared on the leaf-veins, the hypertrophied tissue pushing through the slightly ruptured epidermis. The

embryoes obtained at this stage measured 125μ.–130μ. In galls gathered on the first and second of July, larva were found measuring 374μ. These were similar to the young larva which give rise to the sexual form, having a slightly depressed head, sharp pointed mandibles, broad, prominent thorax, and pointed, reflexed abdomen. During the summer, molts were observed after which the larva measured 500μ, 750μ., 1¼mm., 1¾mm., 2¼mm., respectively, thus showing five stages during the life-history. Fig. 19, Pl. III, shows a larva 1¾mm., obtained about the middle of August. From this time, the thorax does not show a great increase in size, but the abdomen loses its reflexed character, becomes globose, and increases in size until pupation. The first pupa was obtained on the fifth of September, but the adults did not emerge until the fifth of November. Fig. 5, Pl. I, shows a pupa of the agamic form.

Thus we have another illustration of dimorphism in the Cynipidae, the agamic form of Dryophanta erinacei developing in the oak hedgehog gall on the white oak leaves, emerging and ovipositing in the leaf and flower buds of the same tree, from which, in scale and terminal galls, the sexual form develop. These, emerging, oviposit on the veins of the white oak leaves, and their offspring cause the oak hedgehog gall.

The Parasitic and Inquiline Life in the Gall.

The oak hedgehog gall is not merely the abode of the maker, but also of several parasites and inquilines. In order to obtain a knowledge of these, their mode of life, their relationship to the maker, and to each other, we shall consider them under the following heads:

A. Parasitic and inquiline life as shown by breeding experiments.

B. Parasites in relation to Dryophanta erinacei and to each other during gall development.

C. Inquilines, their relation to Dryophanta erinacei, to the parasites, and to each other during gall development.

Parasitic and Inquiline Life as shown by Breeding Experiments.

The breeding experiments were of a twofold character. First, galls were placed in cages, and the species inhabiting them bred out. Second, larva were studied individually in order to obtain larval characters, and then bred out and thereby related to the adults.

I. Leaves bearing galls were gathered, separated from the grass and other leaves, then placed in cardboard boxes at one end of which a test-tube was inserted. In these tubes the insects gathered, and were easily collected. The galls were divided into two classes—those gathered when the leaves were falling from the tree, and those subjected to snow, frost, and general winter conditions for one and two months respectively. The leaves were moistened once a week in order to keep the galls from drying up, and thus preventing the adults from emerging. The parasites appeared first, but the inquilines did not emerge until the last of February.

The parasites, of which eight different species were obtained, belonged to the family Chalcididæ, and were all known to be parasites in the oak galls. The inquilines belonged to the Cynipidæ, genus Synergus. The following table will give the various species, and the number of each obtained.

TABLE I.

Decatoma flava (Ashmead)	600 specimens
" querci-lana-dorsalis (Fitch)	1 specimen
" varians (Walsh)	30 specimens
Eurytoma studiosa (Say)	75 "
" auriceps (Walsh)	30 "
Ormyrus ventricosus (Ashmead)	150 "
Syntomaspis sp.	15 "
Tetrastichus sp.	10 "
Synergus erinacei (Bass.)	70 "

II. The larvæ were removed from the galls, and studied, and the larval characters determined. These specimens were bred out in order to connect with the adult form. The method employed was to note and tabulate such characters as the form of the mandibles, the arrangement and size of the setæ, and the general larval form of a large number of specimens. Each individual was then placed separately in a four dram vial which was sealed and set in a dark place. Four species were bred through to the adult. Both from the study of the larva in the

cavities, and the result of the breeding experiments, it was evident that the parasites inhabited the central cavities, while the inquilines, though occasionally found in this region, were mostly confined to the lateral and peripheral cavities.

Owing to the small percentage of several of the parasites as shown in Table I, we were able to breed out only five species. The descriptions of the larval forms obtained are as follows:

Decatoma flava: The larval form of this Chalcid, (Fig. 34, Pl. IV), when mature measured 1¼mm. It possesses slender bidentate mandibles, (Fig. 33, Pl. IV). The setæ are short and spine-like, arising from distinct, prominent tubercles, and are located as in diagram, (Fig. 42, Pl. V), six on the head, ten on the prothorax, eight on the mesothorax, six on the metathorax, and four on each of the abdominal segments.

The egg, (Fig. 32, Pl. IV), is flask-shaped and measures 200μ.x50μ., neck 560μ., and pedicel 56μ. It is pigmented, and becomes brownish black on maturing. The long neck lies cephalad in the ovary of the adult, and the larva emerges from the egg at the base of the neck, (Fig. 32, Pl. IV). Thus the neck is not comparable to the long pedicel of the eggs of the Cynipidæ. The short, crooked pedicel at the opposite pole represents in atrophied form that found in the Cynipidæ.

Eurytoma studiosa and Eurytoma auriceps: The larval forms of Eurytoma studiosa and Eurytoma auriceps are so similar that it is impossible to determine specific characters. The one shown in Fig. 43, Pl. V, always bred out to Eurytoma studiosa during the winter, but during the summer larvæ corresponding in all respects to the diagram bred out to both Eurytoma studiosa and Eurytoma auriceps. Hence the general characters given here may be considered generic rather than specific. Fig. 35, Pl. IV, gives a general view of this larva.

The mature larva measures 1¼mm., having bidentate mandibles similar to that shown in Fig. 33, Pl. IV. The setæ are long, slender, with distinct tubercles, and give the body a very hairy appearance. The general distribution of these, (Fig. 43, Pl. V), is twelve on the head, ten on the prothorax, ten on the mesothorax, ten on the metathorax, six on the first abdominal segment, four on each of the second, third, and fourth segments, and six on each of the remaining segments. The larva can be readily distinguished from the larva of Decotama flava by the length of the setæ, those of the latter being short, spine-like, and fewer in number.

The egg is flask-shaped measuring 240μ.x144μ., neck 720μ., and pedicel 64μ. The neck lies cephalad in the ovary of the adult, and the embryo emerges from the egg just at the base, (Fig. 37, Pl. IV). The pedicel is short, curved, and aborted. The egg is pigmented and becomes black on maturity. It is quite similar in form to the egg of Decatoma flava, but is slightly larger, and deeper in color when mature.

The egg of Ormyrus ventricosus is flask-shaped measuring 200μ.x 120μ., (Fig. 31, Pl. IV). In this Chalcid egg the pedicel is absent.

Synergus erinacei: The larva of Synergus erinacei, (Fig. 38, Pl. IV) —summer brood—is fleshy, 1mm. in length, and possesses tridentate mandibles, the second tooth of which is pointed like an arrow-head. The setæ are very small, difficult to locate, and without distinct tubercles at the base. Their location, (Fig. 44, Pl. V), is fourteen on the head, fourteen on the prothorax, twelve on the mesothorax, six on the metathorax, four on each of the eight following abdominal segments, six on the ninth, and eight on the tenth segment.

The egg is white, the body being kidney-shaped, 240μ.x80μ., and is provided with a long neck 440μ., Fig. 39, Pl. IV, shows one of these.

The larva of Synergus erinacei (spring brood) is dark, fleshy, 700μ. long, (Fig. 40, Pl. IV). The mandibles are tridentate, the central tooth blunt. The setæ are minute, without distinct tubercles, and distributed as in Fig. 36, Pl. IV, eight on the head, sixteen on the prothorax, ten on each of the meso- and metathorax, eight on each of the first three abdominal segments, and six on each of the remaining segments.

The eggs, two of which are shown in Fig. 41, Pl. IV, are white. The body is kidney-shaped 125μ.x56μ., and provided with a neck 410μ. in length.

Parasites, their relation to Dryophanta erinacei, and to one another during the development of the gall.

The Chalcids, Decatoma flava, Eurytoma studiosa, and Eurytoma auriceps were observed ovipositing from June tenth to the fourteenth. The method in all cases was similar, but the time occupied during oviposition, and the number of eggs deposited differed.

Decatoma flava selected a spot on the midrib where Dryophanta erinacei had oviposited, thrust the long ovipositor down alongside the same channel, and deposited an egg in contact with that of the Cynipid. The ovipositor was then withdrawn, and the opening sealed. This required three minutes.

Eurytoma studiosa and Eurytoma auriceps each selected a spot about the region where Dryophanta erinacei had oviposited, and forcing the ovipositor into the fibro-vascular bundles placed from one to six eggs near, but not in contact, with the egg of the Cynipid. The eggs are usually laid in clusters, and appear black in the tissue of the leaf. The opening is sealed on the withdrawal of the ovipositor. The time consumed by these two species in oviposition was four minutes each.

When the larva of Dryophanta erinacei emerges from the egg, it proceeds at once to form a cavity which encloses the eggs surrounding it. In newly-forming galls the cavity is small, and the egg of the parasites is frequently found resting in

the abdominal angle of the larva of Dryophanta erinacei. Here it often hatches. The larva breaks the shell near the base of the neck, (Fig. 37, Pl. IV.), and emerges, proceeding to attack the host in the abdominal region. If the Cynipid larva has just molted it is destroyed at once. If on the other hand, it escapes the attacks of the parasites during this period, they will live together until the next molt occurs, when the host is almost invariably killed and eaten. Only on rare occasions have the host and parasite been found living together in the same cavity until both have reached 1mm. in length.

If two parasitic larvæ of the same or different species are found in one cavity in the early stages, the stronger alone survives, for I never have observed more than one adult emerge from a single cavity. Since no Chalcid eggs are found in the cavities inhabited by the inquilines, we may conclude that the Chalcids are parasitic primarily on Dryophanta erinacei, and secondarily on one another.

The larva of Eurytoma studiosa and Eurytoma auriceps develop rapidly, and from the twenty-fourth of July to the first of August adults emerge, thus giving a summer brood. No adults of Decatoma flava emerge in the summer or autumn. After the parasites have destroyed the host, it is questionable whether they feed on the plant tissue, since the lining of the cavity they inhabit turns brown, becoming hard and brittle much earlier than is the case with the cavities occupied by Dryophanta erinacei.

It is impossible to determine absolutely the extent of parasitism in these galls, yet we gain some idea from the following. During four weeks 1050 galls were examined, which showed sixty per cent of parasitism not including the internal parasites which had not emerged from the maker.

Inquilines, their relation to Dryophanta erinacei, to the parasites, and to each other during the development of the gall.

The relation of the inquilines of this gall both to the host and to the parasites is very interesting, since they are present not only as guests, but also as parasites. The parasitic character of certain species of Synergus has already been pointed out by Möller and Mann, but nowhere have I found any record of their singular action as observed in this gall. Synergus erinacei is not only parasitic on Dryophanta erinacei, and the parasites

in the central cavities, but it carries its parasitic habits to the extent of mining from cavity to cavity, and having a meal out of the occupants. Fig. 12, Pl. II shows where a larva of Synergus erinacei has mined from A-B, also one is already breaking down the wall at C. Fig. XI, Pl. II shows where a larva of Synergus erinacei has mined from a lateral to a central cavity. In all, over eighty instances of mining have been observed. On eighteen occasions we have fed Dryophanta erinacei and different Chalcid larva to the inquilines, but only once were we able to induce it to attack a larva of its own species. The average time required by Synergus erinacei to consume a larva was 1½ hours. Hence we see that the supposed guest is not only a plant feeder, but has shown itself to be a serious parasite among the occupants of the gall.

The Stimulus to Gall Production.

A. The Relation of the Malpighian Vessels to Gall Formation.

Investigators have generally agreed that galls cannot be produced apart from the presence of insects, but different theories have been presented as to the cause of the abnormal growth. Adler (1881) points out that in Neuroterus lævius-clus and Biorhiza aptera, the gall is first caused by the insect wounding the surrounding cells with its fine mandibles, and that the growth of the gall is in some way dependent on the presence of the larva. Cook (1903) in his publication "Galls and Insects Producing Them," states that the Cynipidæ stimulate the plant to excessive growth by biting, and it is his contention that gall formation is primarily the result of mechanical stimulation. Rössig (1904) in a paper entitled "Von Welchen Organen geht der Reiz zur Bildungder Pflanzengalle aus?" attributes a rôle to both oenocytes and the Malpighian vessels, and though regarding the latter as giving off an effective secretion, he attributes the primary source of this secretion to the oenocytes.

His studies of the Malpighian vessels are purely from the morphological standpoint, and are based on a limited and poorly selected variety of species. He places great emphasis on the size of the cells constituting the vessels, and on the size of the vessels as compared with that of the larva. Moreover he includes in his discussion species that do not produce galls by means of any product poured forth by the Malpighian

vessels, since the galls are produced before the eggs are hatched. Finally, he brings no evidence from a broad, comparative study of the Malpighian vessels of various gall-producing species to support his conclusion.

The condition found in the bud-gall from which the sexual form of Dryophanta erinacei emerges is as follows: The egg rests on the living portion of the scale. When the larva emerges a viscous mass is adhering to it, but outside of this is a clear fluid resembling the secretion of the Malpighian vessels both in color and in action on glass when exposed to the air. The young galls soon appear enclosing the larva. In this instance the secretion of the Malpighian vessels appears to provide the first stimulus to gall-formation. With the agamic form, where the egg is enclosed in the plant tissue, one cannot observe the process so easily.

On examining the galls of both the agamic and sexual forms of Dryophanta erinacei, it was noticed that the cavities were lined with growing tissue, abundantly supplied with chlorophyll, also that where the larva of Dryophanta erinacei rested, both it and the plant tissue were bathed at times with a colorless fluid. When the larva was placed on a glass slide it at once poured forth an abundance of this fluid, which always became opaque, milky white, on drying. By varying the position of the larva when placing it on a glass slide, this secretion was seen to pour forth from the anal region, while the head and thorax remained dry. About this time a study of sections of the larva revealed two tubules consisting of four cells each, which showed great activity. Longitudinal sections proved these to be cells of the Malpighian vessels, (Fig. 45, Pl. VI.).

The Malpighian vessels of the agamic form of Dryophanta erinacei consist of two long tubules containing fifty-six rounded cells, with large nuclei, and attached to the hind gut, just at its point of union with the mid-intestine, (Fig. 48, Pl. VI.). They are whitish in color, the cells varying in size according to the larval period. They reach their maximum in the fourth larval stage. These larval tubules do not give rise to the adult vessels, but, degenerating in the prepupal and pupal stages, give place to the adult tubules which arise as evaginations of the hind-intestine, just below the attachment of the larval vessels. They are the largest glands in the body, extending slightly ventrad along the mid-intestine, their cephalic ends

reaching beyond the point of union of the mid and fore-intestine in the region of the thorax, and are held in place by the fat tissue. In a longitudinal section they appear as in Fig. 47 Pl. VI

The individual cells consist of a homogeneous cytoplasm in which vacuoles are found in the outer portion and also near the nucleus. Secretions are sometimes seen in these. The nucleus is irregular, and often greatly branched, sending long arms into the cytoplasm. It is densely packed with chromatin granules.

The larva were mostly fixed in Dietrich's fluid, and stained with borax carmine and Lyons blue. This proved very satisfactory for general work, but the best results were obtained when the larvæ were fixed in hot Gilson's fluid.

The cells are very active in secreting a colorless fluid during the period of gall-formation, which continues from the end of June until the middle of August. At this latter time, the larva has reached the fourth stage, measuring 1¾mm. There is somewhat of an increase in the size of the cells up to this point, which may be in proportion to the demand upon them. After this there is a slight decrease to a constant size, which is retained until degeneration begins. The following table shows the increase.

TABLE II.

	LENGTH	SIZE OF CELLS	
Larva	500μ	64μ.x72μ.	molt.
"	750μ.	64μ.x80μ.	molt.
"	1mm.	72μ.x80μ.	
"	1¼mm.	72μ.x82μ.	molt.
"	1½mm.	72μ.x88μ.	
"	1¾mm.	112μ.x120μ.	molt.
"	2mm.	72μ.x96μ.	
"	2¼mm.	72μ.x88μ.	molt.
"	2½mm.	72μ.x88μ.	

As pointed out earlier in this paper, molts occur at 500μ, 750μ, 1¼mm., 1¾mm., and 2¼mm. It will be observed that the cells reach their maximum at the fourth stage, about which time the gall is rapidly maturing. From this time, less and less secretion is poured out, and the linings of the cavities begin to lose their green appearance, gradually becoming yellowish brown, dry, and hard. Further, the larval form rapidly changes. The abdomen increases in size, becoming globose, while the head and thorax show only small increase. This is in striking contrast to the early stages. A larva of the fifth stage, measuring 2¼mm., when placed on glass or any foreign substance excretes practically no fluid.

It was observed in all early stages that the excretion of the fluid was under the control of the larva, being poured forth freely when required. When a larva was found not feeding on plant tissue the body was dry. When a parasitic larva rested on the host both were bathed in a colorless fluid. If the larva of Dryophanta erinacei was placed on a glass slide or foreign substance, it immediately poured forth an abundance of fluid. It was evident that a reserve must be retained in the tubules. In a longitudinal section, (Fig. 45, Pl. VI.), it will be noticed that the small proximal cells (indicated by *V.*) on each side of the lumen are arranged so as to press closely against those opposite. This formation appears constant throughout the various stages, and we believe has a valvular function.

A number of tubules were dissected out from larva of the earlier stages in normal salt-solution. This solution was allowed to evaporate, and the salt crystals formed used in grinding up the dried tubules. To the powdered mass a few drops of normal saline were added, and when all was dissolved, the fluid was filtered. The filtrate was treated with 85% alcohol, and the action brought down a heavy, white, floculent precipitate, which suggested that something of an enzymic nature might be present. This phase of the investigation was not pursued further at this time.

Fresh material was again obtained, the Malpighian tubules dissected out as above, thoroughly dried, and ground with powdered carborundum, which reduced them to a finer powder than the salt-crystals. The powdered mass was dissolved in a few drops of normal salt-solution and filtered. The filtrate was injected with a hypodermic syringe into the midrib of the white oak leaves, one drop being used to each puncture. The operation was repeated three times on several leaves. Checks were made, normal saline being used in these. The solution containing the Malpighian tubule product penetrated from one-fourth to one-half an inch in the fibro-vascular bundles of the midrib. The tissue was turned yellowish brown, and cracking appeared similar to that seen in many young leaves where the gall formation has just started, but owing to the death of the larva, has ceased. While these experiments did not produce a gall, they give suggestions as to the work performed by the secretion of the tubules. Nothing of the above described appearance was to be seen in the checks.

From a further study of Table II, it will be seen that between the first and fourth larval stages there has been a considerable increase in the size of the cells which constitute the tubules. The greatest increase was between the third and fourth larval stages, which was coincident with the greatest growth of the gall, when it doubled in size. During this period the larva gives off the greatest amount of secretion from the Malpighian vessels. After this time, as already noted, the larval form changes, and the amount of secretion diminishes rapidly, so that a larva taken, say two weeks later, that is about the first of September, would not pour forth any secretion when placed on a foreign substance. The lining of the cavity is by this time quite dry, brittle, and deep yellowish brown in color.

Now, from the development of the Malpighian vessels, and the amount of secretion poured forth by them coincident with the gall development, also in view of the effect of this secretion when applied to the plant tissue in the experiments, it is evident that the Malpighian vessels have elaborated some product which when poured forth by the insect stimulates the surrounding plant tissue to rapid growth. In a few instances, we have found urate crystals in the lumen of the tubules, but urates are present in the Malpighian vessels of all insects, and, as Rössig has shown, chemically pure urates do not produce galls. Hence an additional factor is without doubt present in the secretion of the Malpighian tubules of Dryophanta erinacei, and this produces the effective stimulus.

The Malpighian Vessels of the Inquilines.

The Malpighian vessels of the inquilines were dissected out. They were white in color, and consisted of two slender tubules. These arise at the point of union of the mid and hind-intestine, having a broader attachment than that found in Dryophanta erinacei, (Fig. 60, Pl. VIII). The cells are smaller than those of D. erinacei, the nuclei more regular, and the lumen quite distinct. They show no evidence of great secreting activity, and in a longitudinal section appear as in Fig. 61, Pl. VIII. The larva when placed on a glass slide does not pour forth a secretion as does Dryophanta erinacei. Further, the species, though an inhabitant of a gall, does not emerge from the egg until the gall has attained considerable growth. Its eggs are

rarely found in the central cavities, but generally in the rapidly growing tissue of the gall, where, after emerging, it forms a cavity. Again the summer brood oviposit on the young galls in July, laying their eggs just beneath the soft outer layer. Here on hatching the larva forms a mere depression in the hard portion of the gall, the soft outer layer forming the other wall. It therefore gives rise to no gall formation. We have here, then, a species of the Cynipidæ, an inhabitant of a gall, appearing after the stimulus to abnormal growth has been given, and evidently not contributing to it. Its larval Malpighian tubules are less developed than those of Dryophanta erinacei.

The Malpighian Vessels of the Parasites Inhabiting the Gall.

The Malpighian vessels of a Eurytoma larva, as dissected out, are yellowish in color, larger than those of the inquiline, and four in number. There are two long, clavate tubules drawn to a point at their cephalic ends, and two short ones with blunt ends, (Fig. 62, Pl. VIII). These arise at the union of the mid and hind-intestine. The long tubules extend cephalad slightly ventrad of the mid-intestine beyond the point of union of the mid and fore-intestine in the thorax. The cells are smaller than those of Dryophanta erinacei, the nuclei more compact, and they do not give evidence of a high state of activity. Further, it must be remembered that the black eggs of these parasites are found only in the central cavities, and never in the tissue of the gall. Hence they are in a place where there is no demand for gall formation. Again, the galls are well developed, and the cavities of fair size before these emerge from the egg. Therefore they do not give rise to a chamber, as do both the maker and the inquilines. Moreover when placed on a glass slide or foreign substance they do not excrete a quantity of fluid, as do the larva of Dryophanta erinacei. Finally, when they have destroyed the host, the cavity lining loses its green, healthy appearance, passing from a yellowish brown to a deep brown color.

Now, considering the habits of the parasites—that they do not form a cavity, but occupy one already developed by Dryophanta erinacei, and feed upon this species—also that the cells of their Malpighian vessels do not give evidence of great activity, we must conclude that the size of the tubules provides no evidence that they produce a gall through their agency.

The larva of Decatoma flava also possesses four tubules. Two are long, clavate, and drawn to a point at their cephalic ends, and two are short with blunt ends, (Fig. 64, Pl. IX). They are more slender, the cells smaller, and the nuclei more regular than those of the Eurytoma larva. The general condition stated regarding the former also applies to Decatoma flava.

It is interesting to note that the galls that contain the highest percentage of parasites and inquilines, and those in which the larva of Dryophanta erinacei have been destroyed at an early stage never reach full development; also that the tissues become dry, hard, and brittle. It is largely from this type of gall that the summer brood of the inquilines, and of Eurytoma studiosa, and Eurytoma auriceps emerge.

The Malpighian Vessels of other Gall-Forming Cynipidæ.

In the agamic form of Holcaspis globulus (Fitch) the Malpighian vessels, as obtained from fresh material, are white in color. They consist of two long tubules with large, globose cells, and irregularly branched nuclei. They give evidence of a high state of activity, and on contact with a foreign substance pour forth a fluid as did Dryophanta erinacei. In the degeneration of the larval tubules and the development of those of the adult they are similar to Dryophanta erinacei, (Figs. 54, Pl. VII and 57, and 58, Pl. VIII).

The agamic form of Dryophanta polita (Bass.), which causes the polished oak gall, possesses two Malpighian vessels which as dissected out are white in color. They are smaller than those of Dryophanta erinacei and Holcaspis globulus. The cells are globose, nuclei irregular, and branched. Their general action is similar to those already discussed. In a longitudinal section they appear as in Figs. 55 and 56, Pl. VII. The process of degeneration of the larval tubules, and the development of the adult vessels correspond to that already described for Dryophanta erinacei. Fig. 55, Pl. VII, is a longitudinal section through a pupa of Dryophanta polita, which shows the degeneration of the larval tubules and the adult vessels forming.

The Malpighian Vessels of Gall-Producing Tenthredinidæ.

The larva of Nematus pomum (Walsh) which causes the willow-apple gall was secured. Longitudinal sections through the larva show cylindrical tubules arising at the union of the mid and hind-gut, and extending caudad, (Fig. 66, Pl. IX). A longitudinal section of the tubule is shown in Fig. 65, Pl. IX. The cells are numerous, small, and regular, the nuclei being symmetrical, and densely packed with chromatin. We have no evidence here of great activity, nor does the larva secrete any fluid when placed on a foreign substance.

Now it is known that the Tenthredinidæ do not produce galls in the same manner as the Cynipidæ, but the stimulus is given at the time of oviposition. Adler says "I have carefully observed Nematus vallisnierii. The fly cuts into the tender leaves of the end shoot of Salix amygdalina, and inserts her eggs in the wound, frequently placing several in one leaf. At the same time some glandular secretion from the insect flows into the wounded leaf. A few hours after this injury, the leaf surface presents an altered appearance, and new cell-formation begins, freely leading to the thickening of the surrounding leaf surface. After the elapse of about fourteen days the green and red, bean-shaped gall is fully grown. If it is now opened the egg will be seen lying in the cavity. Three weeks elapse before the larva emerges from the egg."

Thus it is evident that the Malpighian vessels of the Tenthredinid larva are not factors in gall production.

The Malpighian Vessels of the Gall-Producing Diptera.

The larva of *Trypeta solidaginis*, from the globular gall on the goldenrod, shows Malpighian vessels consisting of small, round cells containing spherical nuclei, (Fig. 68, Pl. IX). The cells show no evidence of exceptional activity, nor have we any reason to believe that the Malpighian tubules are here factors in gall formation.

The larva of *Cecidomyia strobiloides*, which causes the pine-cone willow gall, likewise shows Malpighian vessels of a normal type. The cells are small, very regular, and do not indicate any unusual state of activity, (Fig. 69, Pl. IX).

From a study of these two forms it seems probable that the galls which they form are not due to any product poured forth by the Malpighian vessels, for these neither secrete a fluid when in contact with a foreign substance, nor do the cells show any divergence from the normal type.

The Malpighian Vessels of Other Hymenoptera.

Since we have only considered species which form galls or are associated as parasites and inquilines with the gall-maker, it is necessary that we study related species that do not form galls, in order that this comparative study may be more complete. For this purpose we have selected species of Braconids and Ichneumons.

A Braconid larva was obtained from the fall-webworm. A longitudinal section of this larva is shown in Fig. 67, Pl. IX. The cells of the Malpighian vessels are medium in size, and the nuclei irregular. They are equal to those of the tubules of the Chalcids, and larger than those in the vessels of the inquilines.

The Ichneumon larva was secured from the red-humped apple-worm. Sections through the Malpighian tubules showed that the cells were small and regular, the nuclei round. Here we have a tubule the cells of which correspond in size to those found in the tubules of the inquilines.

The Degeneration of the Larval Malpighian Tubules.

The degeneration of the larval tubules, and the development of the adult vessels in the forms studied, are of such interest that, though in part discussed by Rössig, they may here be considered, and especially since the stages missed by Rössig can be supplied.

Degeneration of the larval Malpighian tubules commences in the prepupal stage. The cytoplasm shows huge vacuoles, appears in shreds, and clings to the cell wall. The nucleus becomes greatly elongate and branched, and chromatolysis sets in. About this time small evaginations appear in the hind-intestine, which develop into cylindrical tubules. Gradually the cells of the larval Malpighian vessels break down, and pass into the lumen of the hind-intestine, while the adult tubules with small cells, and regular nuclei elongate rapidly.

A series of the Malpighian vessels dissected out show this process (Figs. 48, 49, 52, and 53, Pls. VI, and VII).

The method of degeneration and the relation of the phagocytes to this process has been in question. In the process of degeneration as shown in Dryophanta erinacei, Holcaspis globulus, Dryophanta polita, and in the Eurytoma larva, it is clear that the phagocytes play no part whatever. The cells break down and pass into the alimentary tract. Fig. 50, Pl. VII is from a cross section of a larva of Dryophanta erinacei, and shows a fragment of a cell of a tubule found in the lumen of the intestine. Fig. 51, Pl. VII is from a longitudinal section of a similar larva, and shows the degenerating cell just breaking away into the lumen of the intestine. Figs. 54, and 57, Pls. VII, and VIII show the degenerating cells of Holocraspis globulus, also the adult vessels forming. Fig. 55, Pl. VII represents the same condition in Dryophanta polita.

The only instance where phagocytosis was found was in the larva of Trypeta solidaginis. Here as shown in Fig. 76, Pl. X, the phagocytes are present, but from a study of the slide it was evident that chromatolysis had already set in, and the phagocytes were only of secondary importance in the degeneration of the cell.

B. The Relation of the Oenocytes to Gall Formation.

We must now consider the relation of the oenocytes to the production of the gall. Rössig says "The oenocytes have a certain influence, in that they in some manner break up the blood fluid, and work it over in advance for the Malpighian vessels." This conclusion rests on the following: First, a mere comparison of the size of the oenocytes with that of the larva; second, "The general opinion that they are excretory organs destined to store up urates, especially, as Verson has shown in Bombyx, during the time when the Malpighian vessells do not carry out their function, during molting and pupation. Berlese is of the same opinion." Lastly, a possible correlation in the development between the Malpighian vessels and the oenocytes.

Rössig points out that the oenocytes of the various larva which he has studied reach an unusual size. This growth is attained within a short time, after which they shrink and

gradually degenerate. Their size, in comparison with that of the larva, is remarkable. From some of the larva investigated he gives the following:

	LENGTH	OENOCYTES	NUCLEI
Larva of Biohriza terminalis	470μ.	20μ.	
" " Andricus ostreus	375μ.	23μ.	
" " Andricus fecundatrix	450μ.	25μ.	
" " Dryophanta divisa (end of June)	460μ.	20–67μ.	25μ.
" " Dryophanta divisa (17th July)	600μ.	100μ	50μ
" " Dryophanta divisa (end of July)	785μ.	146–150μ.	59μ

From this, the author points out, first the unusual size of the oenocytes as compared with that of the larva, and second the three-fold increase in size of the oenocytes within one month. He also gives measurements of oenocytes found in the inquiline inhabiting the gall formed by Andricus globuli, Vespa crabro, Nematus vallisnierii, Hormomyis fagi, and Aphis mali. With one exception, the larva are all larger than those of the gall wasps, and their oenocytes smaller. Now by a comparison of the size of the oenocytes with that of the larva, and secondly these oenocytes and larva with those of the gall-forming Cynipidæ he endeavors to establish his theory.

In discussing the first point the author says "In no other instance have such large oenocytes been found in so small a larva." Throughout his treatment of the oenocytes this fact is kept continually in the foreground. Mention is made of Kochevnikov's discovery of a remarkable oenocyte 176μ. in a pupa of a honey-bee 15mm.–16mm. in length, but the author points out that, since the oenocytes in Dryophanta divisa are so large as compared with the larva, and the latter so small as compared with the pupa of the honey-bee, (that is, 785μ. as compared with 16mm.), great importance must be attached to the oenocytes of the gall wasps.

Now does the size of the cell in comparison with that of the body determine its importance? It is very doubtful if such evidence can be used to support his conjecture regarding the function of the oenocytes.

In the second place we must discuss the three-fold increase of the oenocytes. This appears to be tabulated from one set of larva in a single species, but is not shown to be constant throughout that species. Now before a general conclusion can be drawn, this triple increase would have to be shown to be constant not only for a large number of larva of Dryophanta

divisa, but also in many species of the gall-forming Cynipidæ. In the following table it will be seen that in Dryophanta erinacei the oenocytes show no remarkable increase in size, and that they reach their maximum long after the Malpighian vessels have passed their period of greatest activity.

TABLE III.

D. ERINACEI.	LENGTH	OENOCYTES	NUCLEI
pupa		56μ.x64μ.	26μ.x32μ.
		64μ.x64μ.	32μ.x32μ.
		48μ.x48μ.	24μ.x24μ.
larva	2½mm.	80μ.x120μ.	32μ.x40μ.
		64μ.x 72μ.	32μ.x32μ.
		48μ.x 64μ.	32μ.x32μ.
"	2¼mm.	64μ.x 56μ.	32μ.x32μ.
		56μ.x 56μ.	24μ.x24μ.
		56μ.x 48μ.	24μ.x24μ.
"	2mm.	72μ.x 76μ.	32μ.x32μ.
		56μ.x 56μ.	24μ.x24μ.
		48μ.x 48μ.	24μ.x24μ.
"	1¾mm.	48μ.x 48μ.	32μ.x32μ.
		40μ.x 40μ.	24μ.x24μ.
"	1½mm.	56μ.x 56μ.	28μ.x28μ.
		48μ.x 48μ.	24μ.x24μ.
"	1¼mm.	48μ.x 52μ.	24μ.x24μ.
		48μ.x 48μ.	24μ.x24μ.
		40μ.x 40μ.	24μ.x24μ.
"	750μ.	40μ.x 48μ.	24μ.x24μ.
		40μ.x 40μ.	24μ.x24μ.
"	500μ.	40μ.x 40μ.	24μ.x24μ.
Eurytoma pupa		88μ.x 88μ.	40μ.x48μ.
		90μ.x 96μ.	48μ.x48μ.
		80μ.x 80μ.	40μ.x40μ.
Eurytoma larva	1¾mm.	88μ.x 80μ.	40μ.x36μ.
		64μ.x 64μ.	40μ.x40μ.
Synergus erinacei larva	1¾mm.	88μ.x 72μ.	32μ.x32μ.
		56μ.x 64μ.	24μ.x24μ.
Internal parasite, larva	750μ.	48μ.x 42μ.	24μ.x24μ.
		40μ.x 40μ.	24μ.x24μ.
Nematus pomum larva		56μ.x 40μ.	24μ.x24μ.
		40μ.x 44μ.	24μ.x24μ.
Trypeta solidaginis larva		72μ.x 80μ.	32μ.x32μ.
		60μ.x 62μ.	32μ.x32μ.

In Table III, the measurements given are constant in a large number of individuals for each species, and from the study of these it will be seen:

1. In Dryophanta erinacei the oenocytes reach their maximum size when the larva measures 2½mm. Fig. 93, Pl. XI shows such an oenocyte.

2. No oenocyte shows a threefold increase during the larval development. The average of the largest oenocytes was 64μ.x40μ., nucleus 32μ. while the smallest was 40μ.x40μ. nucleus 24μ.

3. The oenocytes of the second larval stage are as large as those of the fourth stage.

4. Among the inhabitants of the gall the largest oenocytes, (Figs. 83 and 84, Pl. X). were found in a Chalcid pupa, of the genus Eurytoma, while in a larva 1½mm. long of the same genus the oenocytes were larger than those of a similar sized larva of Dryophanta erinacei. Figs. 85 and 86, Pl. X, show such an oenocyte. It is important to note that these occur in a parasite, which, as pointed out earlier in this paper, does not produce a gall.

5. A 1¾mm. larva of Synergus erinacei possesses oenocytes, (Fig. 87, Pl. X), larger than those of a similar sized larva of Dryophanta erinacei, yet Synergus erinacei is only an inquiline.

6. In an internal parasite of Dryophanta erinacei measuring 750μ. the oenocytes are as large as those of a similar sized host. The parasite does not emerge from Dryophanta erinacei until after the gall has attained full growth, and hence has no part in the production of the gall.

7. The Tenthredinid, Nematus pomum, which develops in a gall not produced by any product poured forth by the Malpighian vessels possesses oenocytes of considerable size, while the Malpighian vessels are normal, (Figs. 80 and 81, Pl. X).

8. The same is true of Trypeta solidaginis, an oenocyte of which is shown in Fig. 82, Pl. X.

Now since the largest oenocytes are not found in Dryophanta erinacei, but in a Chalcid parasite which is not a gall-maker, since there in no triple increase in the oenocytes of Dryophanta erinacei, and further, since there is a distinct limit within the range of which the varying oenocytes of all species really fall, it is clear that the conclusion of Rössig is not substantiated by the present investigation.

"The general opinion that they are excretory organs destined to store up urates, especially, as shown by Verson in Bombyx, during the time when the Malpighian vessels do not carry out their function, during molting and pupation."

In general, students of oenocytes have considered them secreting organs, but as Perez has pointed out in "Contributions à l' Étude de Metamorphosis" we do not know what their secretion is.

It is true that Verson considered the cells secretors of urates in Bombyx, and Koschevnikov discusses the urate-laden

oenocytes of the honey-bee, speaking of them as permanent reservoirs which could not free themselves of their products, and had ceased activity. Berlese also describes oenocytes containing urates in many of the species he has studied. Perez, however, has pointed out that these workers have confounded urate cells with oenocytes, and it is significant to note that Berlese in his recent work "Gli Insetti" does not speak of oenocytes bearing urates, but limits that function to urate cells.

The urate-bearing oenocytes that Rössig describes in Andricus Malpighi have the distinct marks of urate cells, and are probably such. Further, he has shown that the injection of chemically pure urates into the plant tissue gives negative results, and therefore urates are not considered factors in gall production. Suppose that we concede to the oenocytes the function of secreting urates, have we gained anything?

According to the above quotation, the urate-secreting function of the oenocytes is performed particularly during the molting and pupating periods when the Malpighian vessels are not functional. It has been shown that the oenocytes do not secrete urates. In all the species we have studied, urate crystals or urate globules have never appeared in the oenocytes. In Dryophanta erinacei we have never observed any unusual activity in these cells during the periods when the Malpighian vessels are not active, and the same can be stated of Holcaspis globulus, Dryophanta polita, Synergus erinacei, and the Eurytoma larva. Moreoever we do not know the chemical constitution of the secretion seen in the vacuoles of the oenocytes. Therefore we have no reason for assigning to the oenocytes the function of secreting urates.

A Possible Correlation in the Development of the Malpighian Vessels and the Oenocytes.

In discussing this phase of the problem, Rössig states that he cannot speak with certainty, but thinks that at least in Dryophanta divisa a correlation exists between the development of the Malpighian vessels and the oenocytes. He presents the following tabulation:

		MALPIGHIAN VESSELS		OENOCYTES	
	LENGTH	CELLS	NUCLEUS	CELLS	NUCLEUS
D. divisa	460μ.	50μ.	36μ.	50μ.	25μ.
" "	600μ.	73μ.	50μ.	100μ.	50μ.
" "	714μ.	115μ.	56μ.	150μ.	59μ.

From this he concludes that the cells of the Malpighian vessels are doubled in size while those of the oenocytes increase threefold.

Now in comparing Table II and Table III, it will be seen that in Dryophanta erinacei there is no indication of any correlation existing between the oenocytes and the Malpighian vessels. The oenocytes have reached their maximum when the larva is in the prepupal stage, and the Malpighian vessels are largest when the larva measures 1¾mm.—approximately the middle of August. As far as our investigation has gone we have found nothing to support the idea of any correlation in the development of the oenocytes and the Malpighian vessels.

CONCLUSION.

The conclusions drawn from the foregoing study of Dryophanta erinacei are as follows:

1. From a study of the life-history of Dryophanta erinacei we have another illustration of dimorphism in the Cynipidæ.

A. The agamic form of Dryophanta erinacei produces the oak hedgehog gall on the veins of the white oak leaves, passes through five larval stages extending over a period from the last of June to the first of September. Pupation occurs on the first week in September, and the adults emerge about the fifth of November.

B. The adults oviposit on the leaf and flower buds of the same tree.

C. The following spring the eggs hatch, and the larvae produce galls on the leaf scale or the terminal growing points of the buds, from which within two weeks the sexual form of Dryophanta erinacei emerges.

D. These oviposit on the midrib and lateral veins of the young leaves of the white oak. From the eggs deposited emerge the young larvæ which produce the summer gall.

E. The sexual form belongs to the genus Dryophanta, and will therefore be known as the sexual form of Dryophanta erinacei, of which the insect, formerly known as Acraspis erinacei is the agamic form.

2. The study of the parasitic and guest life shows that the following insects inhabit the gall: Decatoma flava (Ashmead); Decatoma querci-lana-dorsalis (Fitch); Decatoma varians

(Walsh); Eurytoma studiosa (Say); Eurytoma auriceps (Walsh) Ormyrus ventricosus (Ashmead); Syntomaspis sp.; Tetrastichus sp.; Synergus erinacei (Bass.)

A. The Chalcids are primarily parasitic on Dryophanta erinacei, and secondarily on each other.

B. The inquiline, Synergus erinacei, is parasitic on the entire life of the gall, mining from cavity to cavity and devouring the larvæ they contain.

C. Eurytoma studiosa and Eurytoma auriceps, and Synergus erinacei have two broods. The spring brood appearing June tenth to fourteenth, and the summer brood appearing from July twenty-fourth to August first.

D. The percentage of parasites, not including the internal parasites, is at least sixty per cent.

3. The Malpighian vessels of Dryophanta erinacei secrete a fluid which stimulates the plant to produce the gall. This is shown by the following:

A. The character of the Malpighian vessels of the sexual and agamic forms of Dryophanta erinacei—their size, cellular structure, and exceptional glandular activity.

B. The character and effect of the secretion poured forth by the Malpighian vessels during gall formation.

C. The ultimate decline and ceasing of marked activity of the tubules when the gall has matured.

D. The increase in the size of the cells of the Malpighian vessels coincident with the development of the gall, and their decrease in size when the demand upon them is withdrawn.

E. A comparison of the Malpighian vessels of Dryophanta erinacei with those of the parasites and the inquilines found in the gall, and particularly the lack of any abnormal secreting activity in the latter.

F. A study of the Malpighian vessels of Holcaspis globulus, and Dryophanta polita, both of which correspond in their action, development, and degeneration to those of Dryophanta erinacei.

G. A comparative study of the Malpighian vessels of Dryophanta erinacei with those of Nematus pomum, Trypeta solidaginis, and Cecidomyia strobiloides shows that all the latter, though gall producers, possess tubules of normal type, which do not pour forth an abundant secretion during gall development, nor when in contact with foreign substances.

H. The study of the Malpighian vessels of species of Braconids and Ichneumons, shows tubules with cells not larger than those of the Chalcids and inquilines. The mode of degeneration however, appears similar to that found in Dryophanta erinacei.

4. The theory of the relation of the oenocytes to gall production as urged by Rössig is not confirmed by this study.

A. His argument is without support from the data furnished by Dryophanta erinacei, Dryophanta polita, and Holocraspis globulus. The oenocytes of the Eurytoma pupa and the larva, Synergus erinacei, are relatively larger than those found in a larva of similar size of Dryophanta erinacei, while the oenocytes of Nematus pomum and Trypeta solidaginis were equal to those found in Dryophanta erinacei.

B. The oenocytes do not secrete urates. Perez has shown this to be true in the ants, and Berlese appears to have now accepted this view. In the oenocytes of the various species studied, we have found no urate crystals or globules.

C. Since we do not know the chemical character of the secretion in the oenocytes, and since there appears to be no unusual activity in these cells during the molting and pupating periods of these species under consideration, we are not convinced that they take the place of the Malpighian tubules during these periods.

Until we know the chemical character of the secretion produced by the oenocytes, we shall only deal in speculation as to the rôle of these cells in insect life.

In conclusion I wish to thank Professor Comstock and Dr. W. A. Riley for the direction, and criticism so freely given, and especially Dr. Riley, at whose suggestion the work was undertaken, and whose assistance was invaluable throughout the entire study.

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EXPLANATION OF PLATES.

Plate I.

Fig. 1. Oak Hedgehog Gall attached to the midrib of a White Oak leaf.
Fig. 2. Longitudinal section through a Gall. A. Central cavities; B. Lateral Cavities.
Fig. 3. Agamic form of D. erinacei ovipositing on the bud of White Oak.
Fig. 4. Female, sexual form of D. erinacei.
Fig. 5. Pupa of agamic form of D. erinacei.

Plate II.

Fig. 6. Bud scale with eggs of agamic form attached.
Fig. 7. Bud scale with enlarged gall, egg-shell still attached.
Fig. 8. Longitudinal section through Oak Hedgehog Gall showing Peripheral Cavity.
Fig. 9. Bud scale on which young gall is forming with empty egg-shell attached.
Fig. 10. Terminal Galls.
Fig. 11. Oblique section through Oak Hedgehog Gall showing where S. erinacei has mined from A – B.
Fig. 12. Longitudinal section through Oak Hedgehog Gall showing where S. erinacei has mined from A – B, and is breaking down the wall at C.

Plate III.

Fig. 13. Mandible of Agamic form of D. erinacei.
Fig. 14. Maxilla of Agamic form of D. erinacei. A. Cardo; B. Stipes; C. Palpus; D. Galea.
Fig. 15. Labium of Agamic form of D. erinacei. A. Palpus; B. Glossa; C. Paraglossa.
Fig. 16. Antenna of Agamic form of D. erinacei.
Fig. 17. Two distal segments of antenna showing sensory pits.
Fig. 18. Aborted wings of agamic form of D. erinacei.
Fig. 19. Larva of agamic form of D. erinacei.
Fig. 20. Egg of agamic form of D. erinacei.
Fig. 21. Mandible of sexual form of D. erinacei.
Fig. 22. Maxilla of sexual form of D. erinacei. A. Cardo; B. Stipes; C. Palpus; D. Galea.
Fig. 23. Labium of sexual form of D. erinacei. A. Palpus; B. Glossa; C. Paraglossa.
Fig. 24. Wings of sexual form of D. erinacei.
Fig. 25. Egg of sexual form of D. erinacei.
Fig. 26. Scutellum of sexual form of D. erinacei.
Fig. 27. Larva of sexual form of D. erinacei.
Fig. 28. Antenna of sexual form of D. erinacei.
Fig. 29. Distal segments of antenna showing sensory pits.

Plate IV.

Fig. 30. Larva of internal parasite from agamic form of D. erinacei.
Fig. 31. Egg of Ormyrus ventricosus.
Fig. 32. Egg of Decatoma flava containing embryo.
Fig. 33. Mandible of Eurytoma larva.
Fig. 34. Larva of Decatoma flava.
Fig. 35. Larva of Eurytoma sp.
Fig. 36. Diagram showing location of setæ on segments of larva of S. erinacei (spring brood).
Fig. 37. Eurytoma egg with larva emerging.
Fig. 38. Larva of S. erinacei (summer brood).
Fig. 39. Egg of S. erinacei (summer brood).
Fig. 40. Larva of S. erinacei (spring brood).
Fig. 41. Egg of S. erinacei (spring brood).

PLATE V.

Fig. 42. Diagram showing location of setæ on segments of larva of Decatoma flava.
Fig. 43. Diagram showing location of setæ on segments of Eurytoma larva.
Fig. 44. Diagram showing location of setæ on segments of larva of S. erinacei (summer brood).

PLATE VI.

Fig. 45. Longitudinal section through larva of agamic form D. erinacei showing Larval Malpighian tubule, Valve, mid-intestine hind-intestine.
Fig. 46. Longitudinal section through larva of agamic from of D. erinacei showing larval Malpighian vessel, mid-intestine, hind-intestine, and hypodermis.
Fig. 47. Longitudinal section showing larval Malpighian vessel extending the length of the mid-intestine.
Fig. 48. Larval Malpighian tubules as dissected out from D. erinacei, agamic form.
Fig. 49. Degenerating larval Malpighian tubules, and adult vessels forming, as dissected out from D. erinacei, agamic form.

PLATE VII.

Fig. 50. Cross section from D. erinacei, agamic form, showing cell of larval Malpighian tubule in the lumen of the intestine, and adult vessel forming.
Fig. 51. Longitudinal section from larva of D. erinacei, agamic form, showing cell just breaking away into the lumen of the intestine.
Fig. 52. Larval Malpighian tubules of D. erinacei greatly reduced, and adult vessels nearing maturity.
Fig. 53. Larval Malpighian tubules of D. erinacei reduced to a few cells, adult vessels well developed.
Fig. 54. Longitudinal section of degenerating larval Malpighian vessel, with adult tubules forming from H. globulus, agamic form.
Fig. 55. A portion from a longitudinal section of a larva of D. polita, agamic form. showing degenerating larval tubules, and adult vessels forming.
Fig. 56. Longitudinal section through cells of degenerating larval Malpighian vessels of H. globulus.

PLATE VIII.

Fig. 57. Larval and adult Malpighian vessels of H. globulus as dissected out.
Fig. 58. Portion of longitudinal section of larval Malpighian vessel of H. globulus.
Fig. 59. Longitudinal section through degenerating cells of Malpighian vessel of H. globulus.
Fig. 60. Larval Malpighian vessels of S. ernacei as dissected out.
Fig. 61. Longitudinal section through cells of larval Malpighian vessel of S. erinacei.
Fig. 62. Larval Malpighian vessels of Eurytoma larva as dissected out.
Fig. 63. Longitudinal section through cells of Malpighian vessel of a Eurytoma larva.

PLATE IX.

Fig. 64. Larval Malpighian vessel of D. flava as dissected out.
Fig. 65. Longitudinal section through cells of Malpighian vessel from Nematus pomum.
Fig. 66. Longitudinal section showing attachment of larval Malpighian tubules to alimentary tract of N. pomum.
Fig. 67. Section showing larval Malpighian vessels, and adult tubule just appearing.
Fig. 68. Longitudinal section through a portion of a larval Malpighian tubule of T. solidaginis.
Fig. 69. Longitudinal section through a portion of a larval Malpighian tubule of C. strobiloides.

Fig. 70. Longitudinal section through a portion of a larval Malpighian tubule of D. erinacei, sexual form.
Fig. 71. Longitudinal section through a portion of a larval Malpighian vessel of an Ichneumon.
Fig. 72. A cross section of a larval Malpighian tubule of D. erinacei, agamic form.

PLATE X.

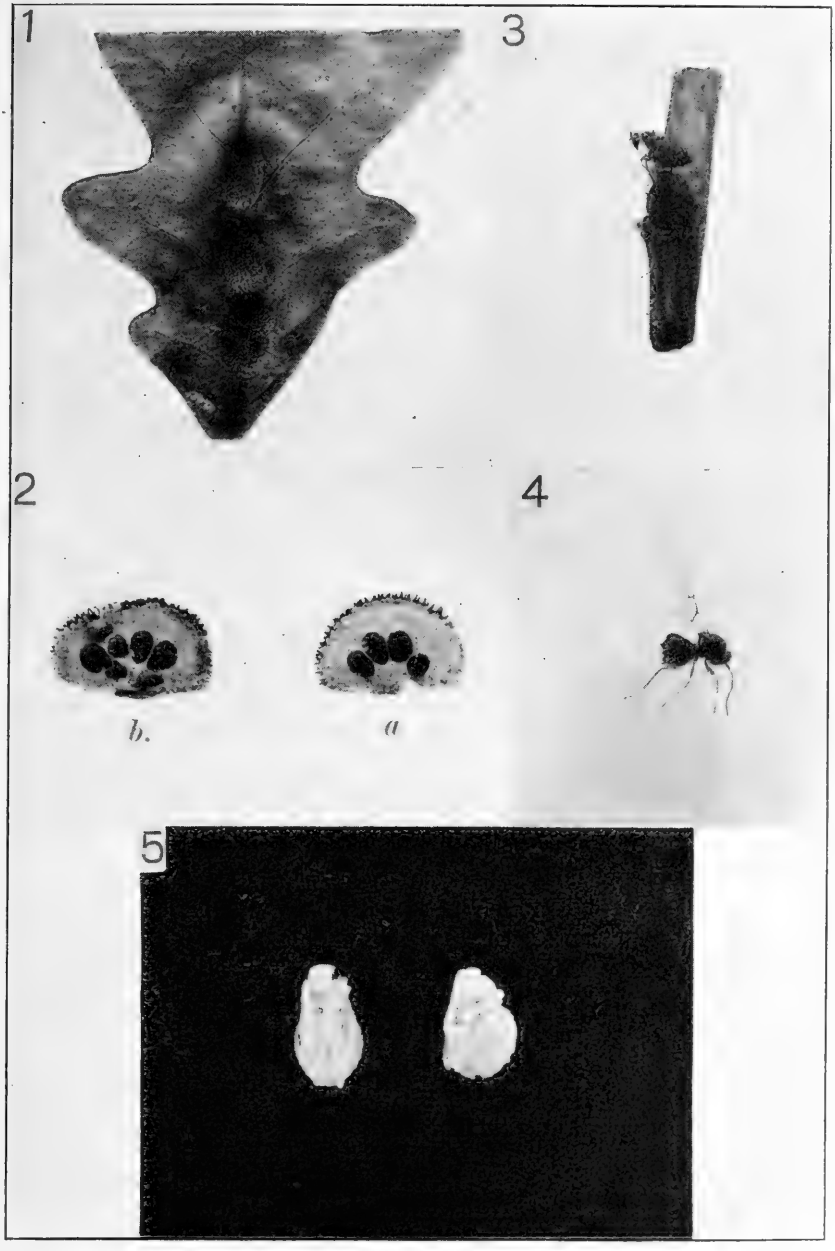
Fig. 73. A cross section of a larval Malpighian vessel of the same species showing degenerating cells.
Fig. 74. Cross section of an adult Malpighian tubule of D. erinacei.
Fig. 75. Cross section of larval Malpighian tubule of N. pomum.
Fig. 76. Cross section of larval Malpighian tubule of T. solidaginis showing phagocytes.
Fig. 77. Cross section of a larval Malpighian vessel of C. strobiloides.
Fig. 78 and 79. Oenocytes from larva of N. pomum.
Fig. 80 and 81. Oenocytes from larva of internal parasite in D. erinacei.
Fig. 82. Oenocyte from larva of T. solidaginis showing vacuoles.
Fig. 83. Oenocyte from thorax of Eurytoma pupa.
Fig. 84. Oenocyte from the abdomen of a Eurytoma pupa.
Fig. 85. Oenocyte from the thorax of a Eurytoma larva 1¾mm.
Fig. 86. Oenocyte from the abdomen of a Eurytoma larva 1¾mm.
Fig. 87. Oenocyte from S. erinacei containing vacuoles.

PLATE XI.

Fig. 88. Oenocytes from the abdomen of a larva of D. erinacei 1½mm.
Fig. 89. Oenocytes from the abdomen of a larval of D. erinacei 2¼mm.
Fig. 90. Oenocytes from the abdomen of a larva of S. erinacei.
Fig. 91. Oenocytes from the thorax of a larva of H. globulus.
Fig. 92. Oenocytes from the abdomen of a larva of H. globulus.
Fig. 93. Oenocyte from the thorax of a larva of D. erinacei 2½ mm.
Fig. 94. Oenocyte from the abdomen of a larva of D. erinacei 2½mm.
Fig. 95 and 96. Oenocyte from a larva of D. erinacei 2mm.
Fig. 97. Oenocyte from a larva of D. erinacei 1¼mm.
Fig. 98. Oenocyte from a larva of D. erinacei 1mm.

ABBREVIATIONS.

c. l. m. t. ..... Cell of larval Malpighian tubule
e. ..... Egg
h. int. ..... hind-intestine
hyp. ..... hypodermis
i. m. t. ..... Imaginal Malpighian tubule
md. ..... Mandibles
mx. ..... maxilla
m. d. ..... mid-dorsal
m. v. ..... mid-ventral
m. int. ..... mid-intestine
la. ..... labium
l. ..... lateral
l. ..... lumen
l. m. t. ..... Larval Malpighian tubules
oe. ..... oenocytes
ph. ..... phagocytes
s. g. ..... scale galls
s. p. ..... sensory pits
s. ..... setæ
t. g. ..... terminal galls
vac. ..... vacuoles



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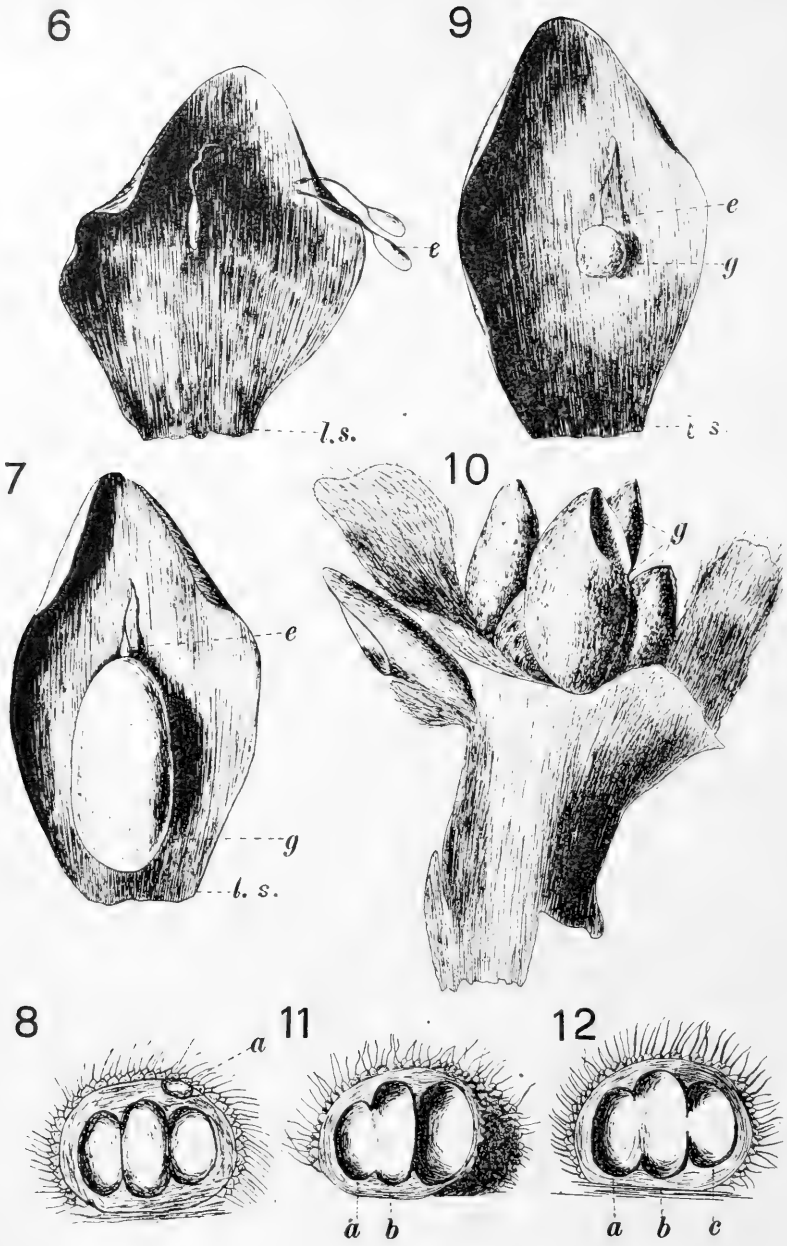

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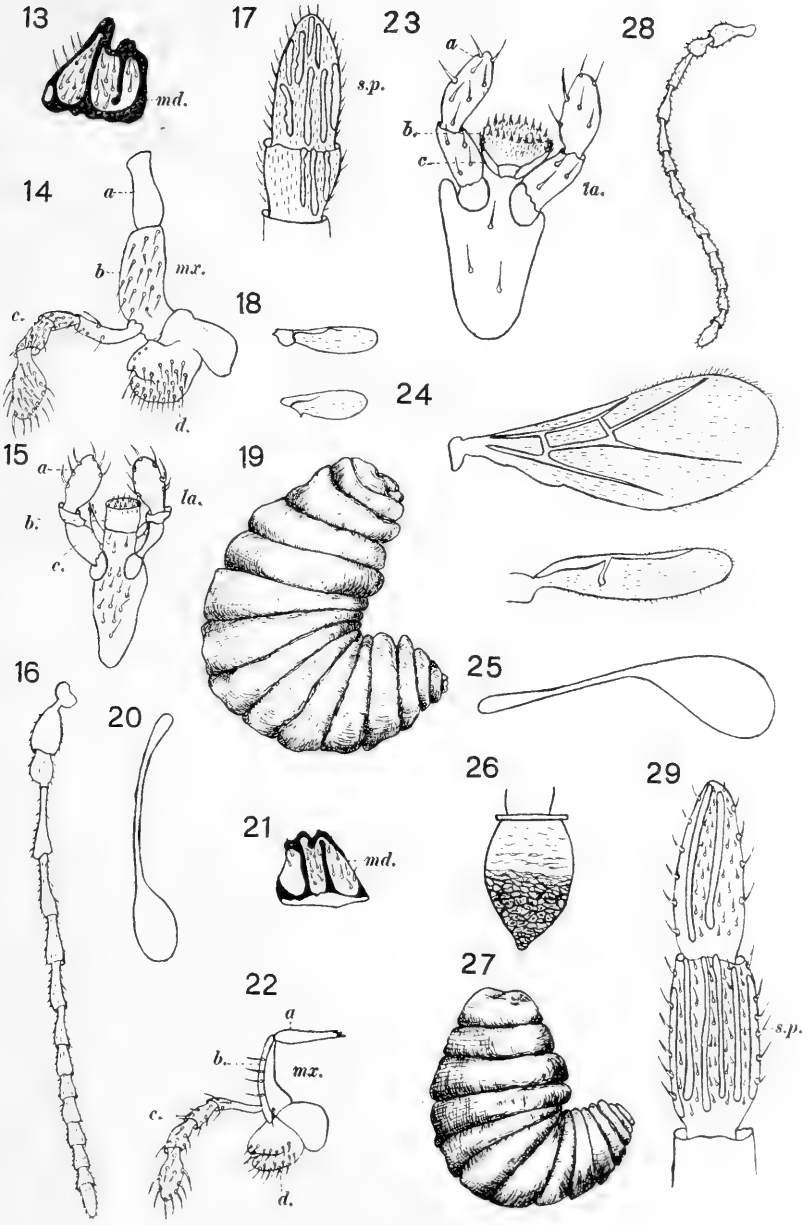

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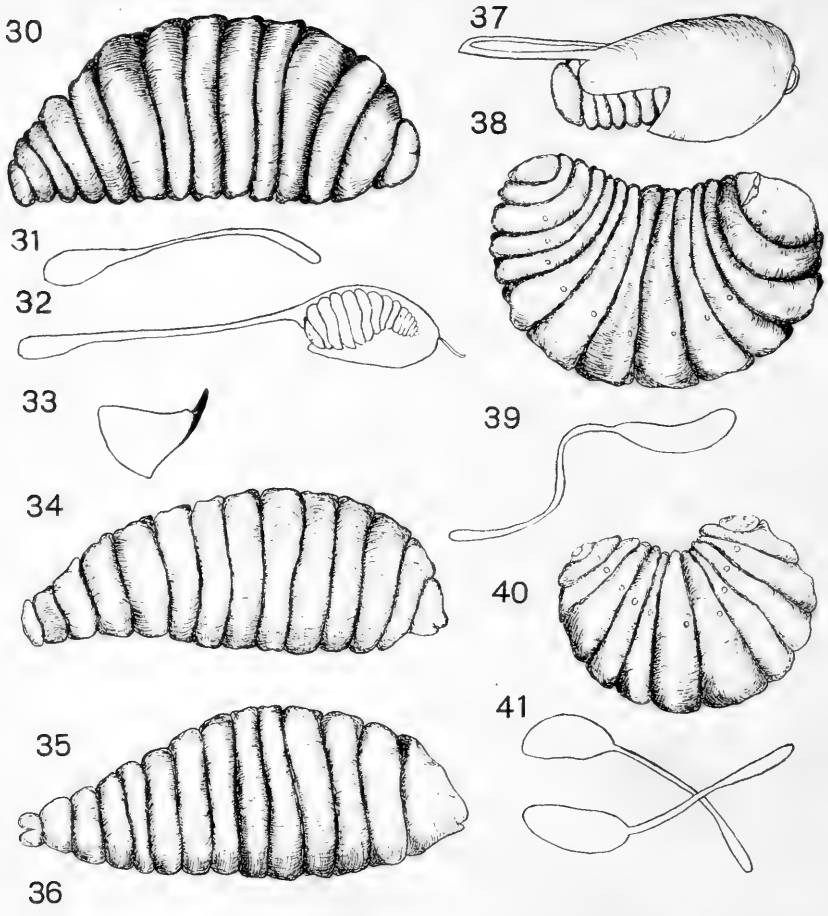

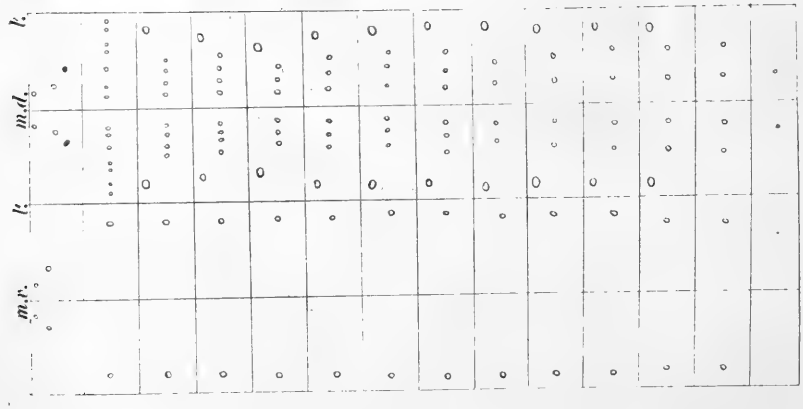

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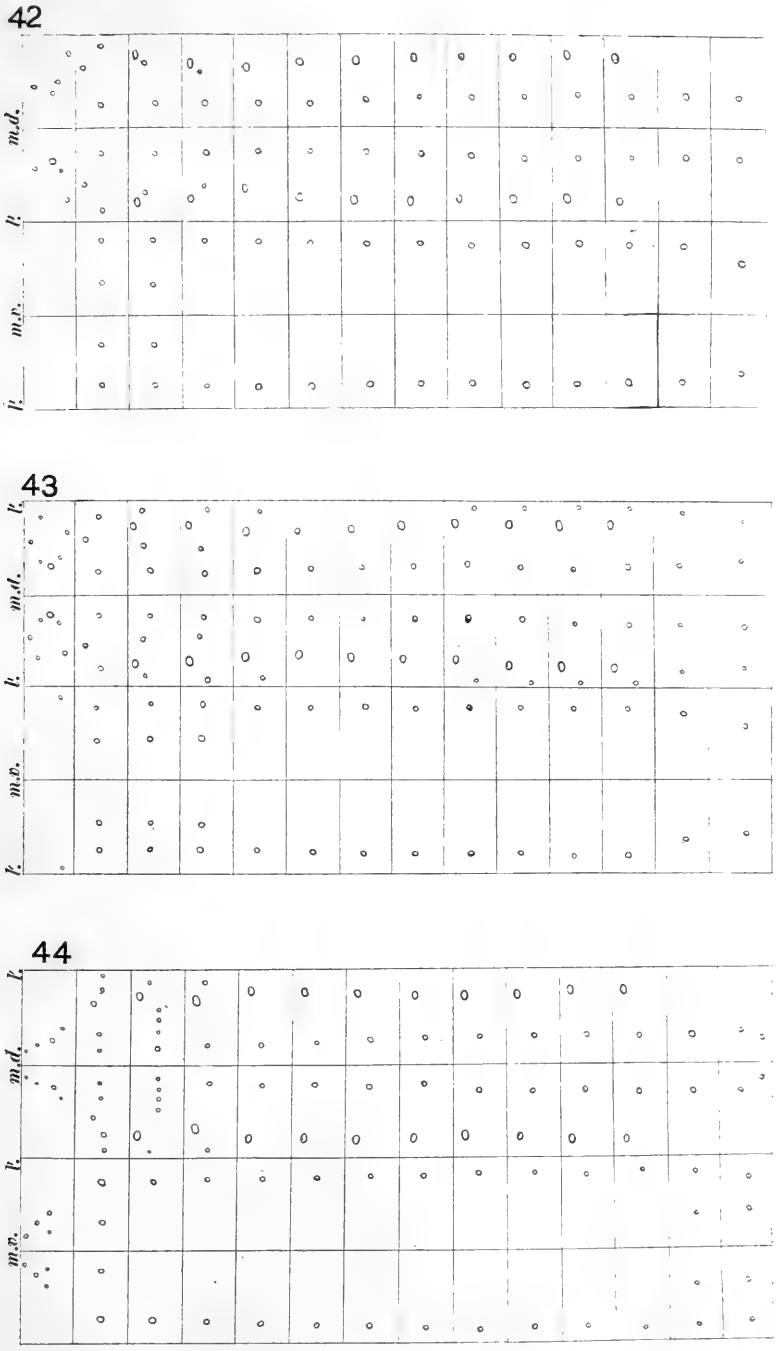

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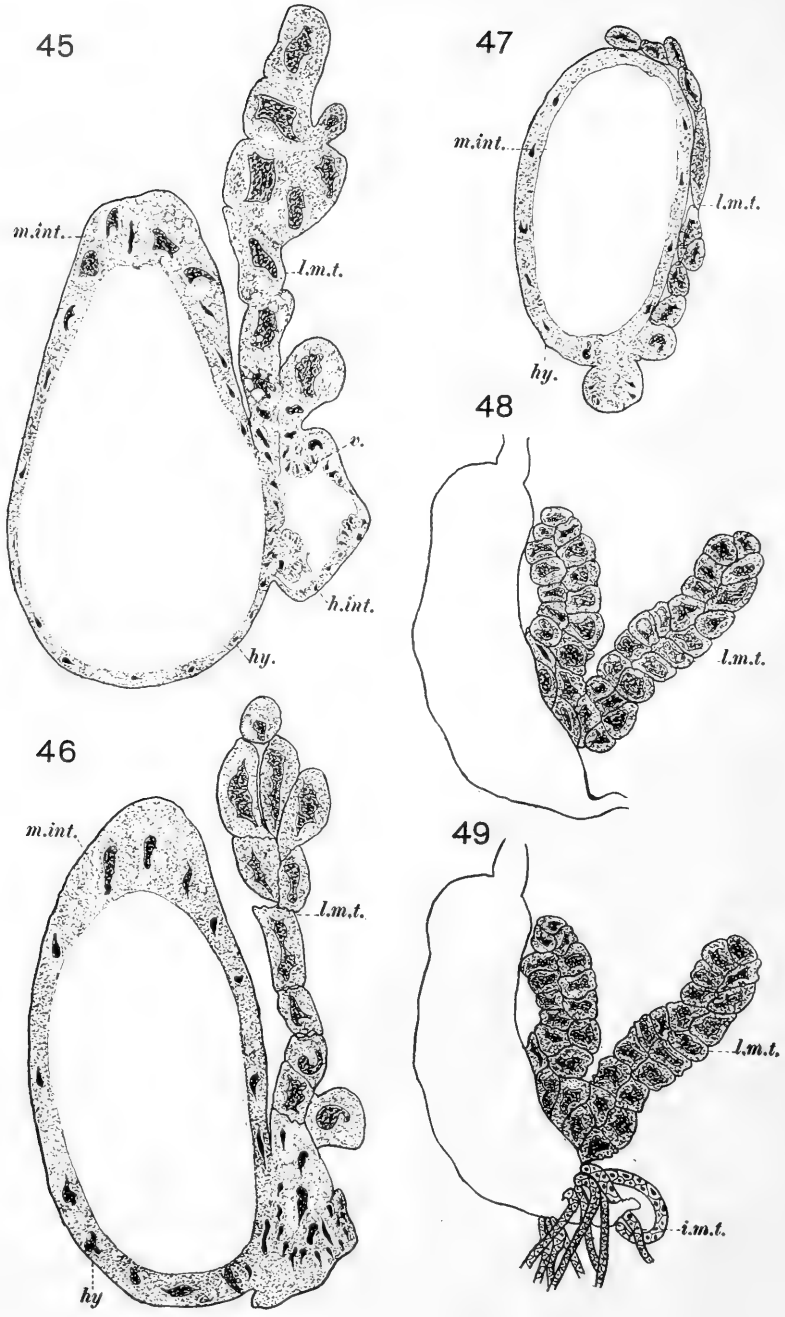

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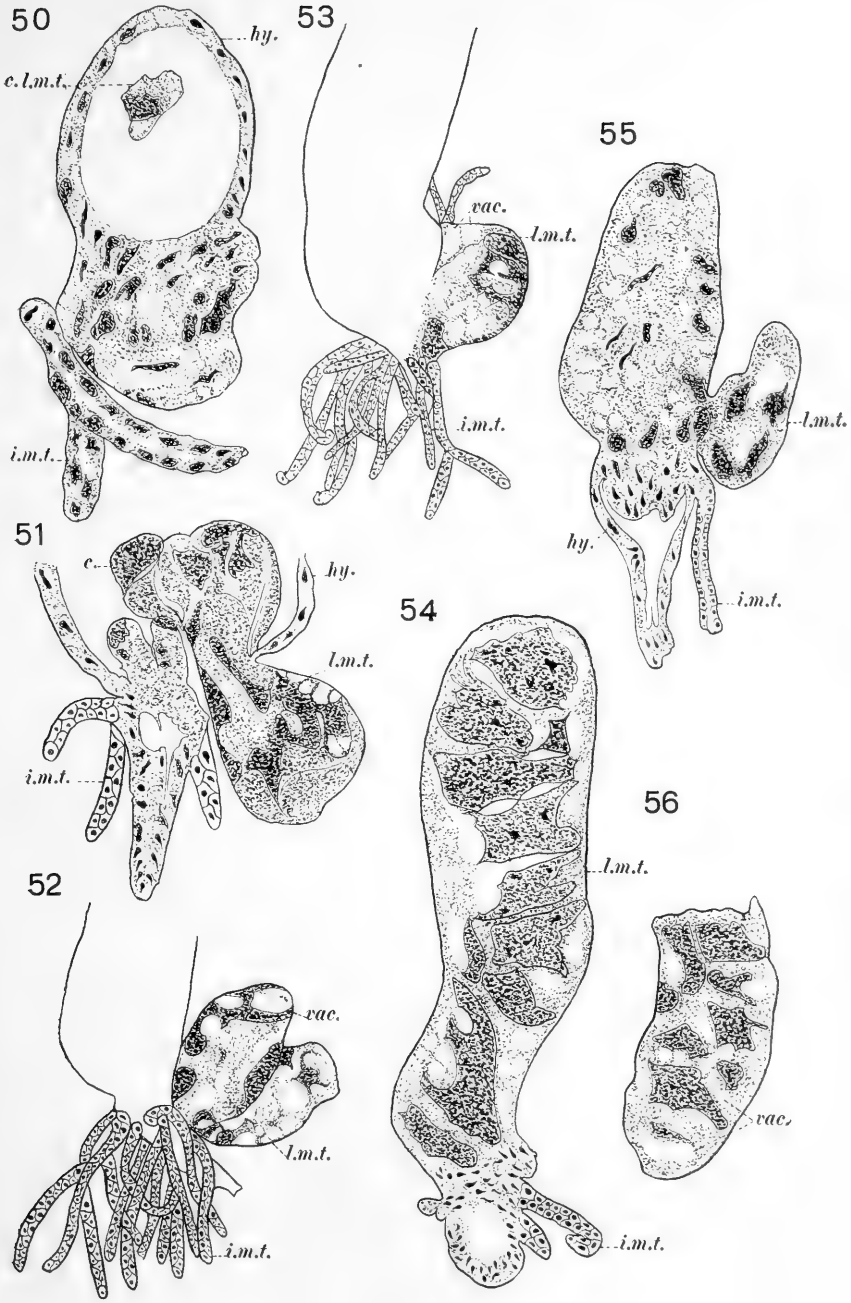

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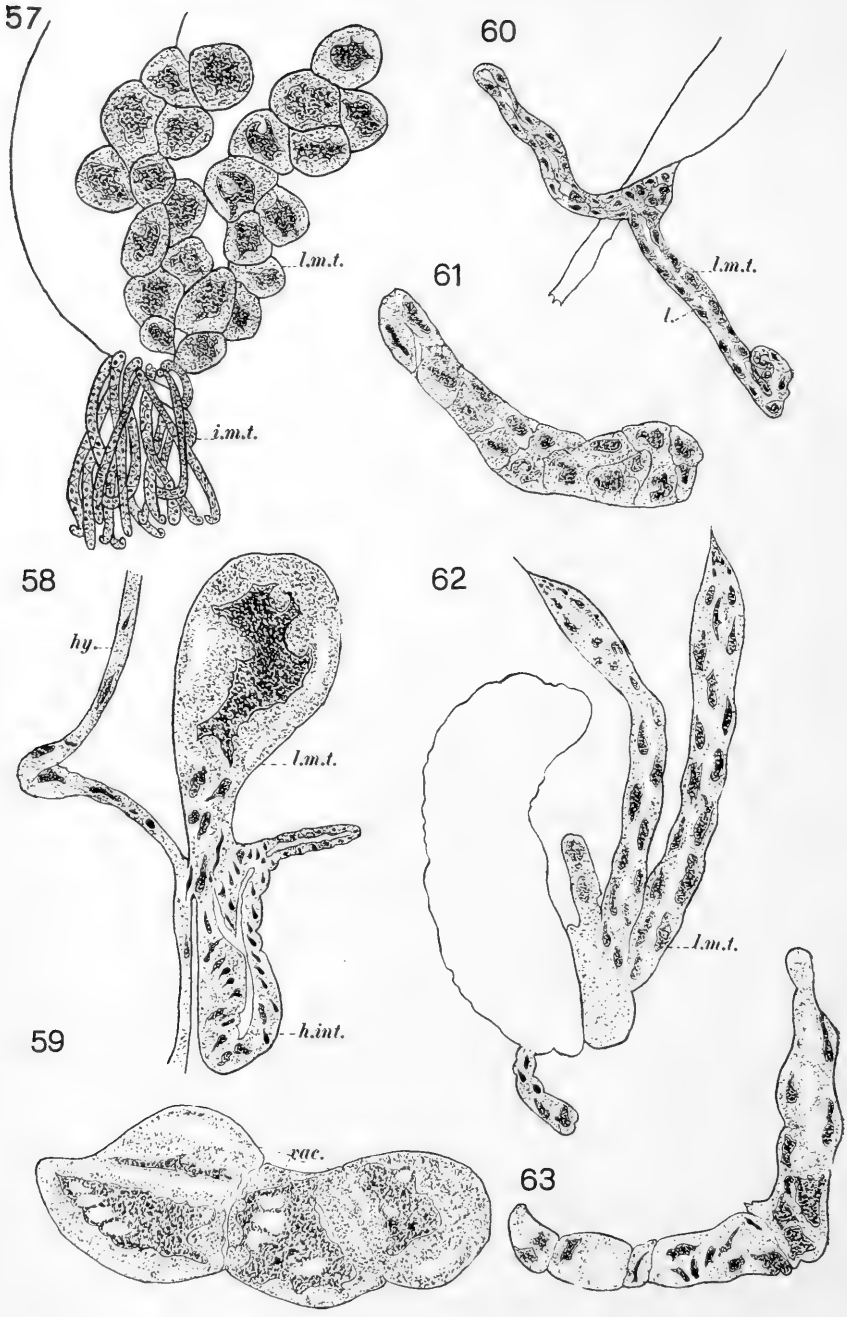

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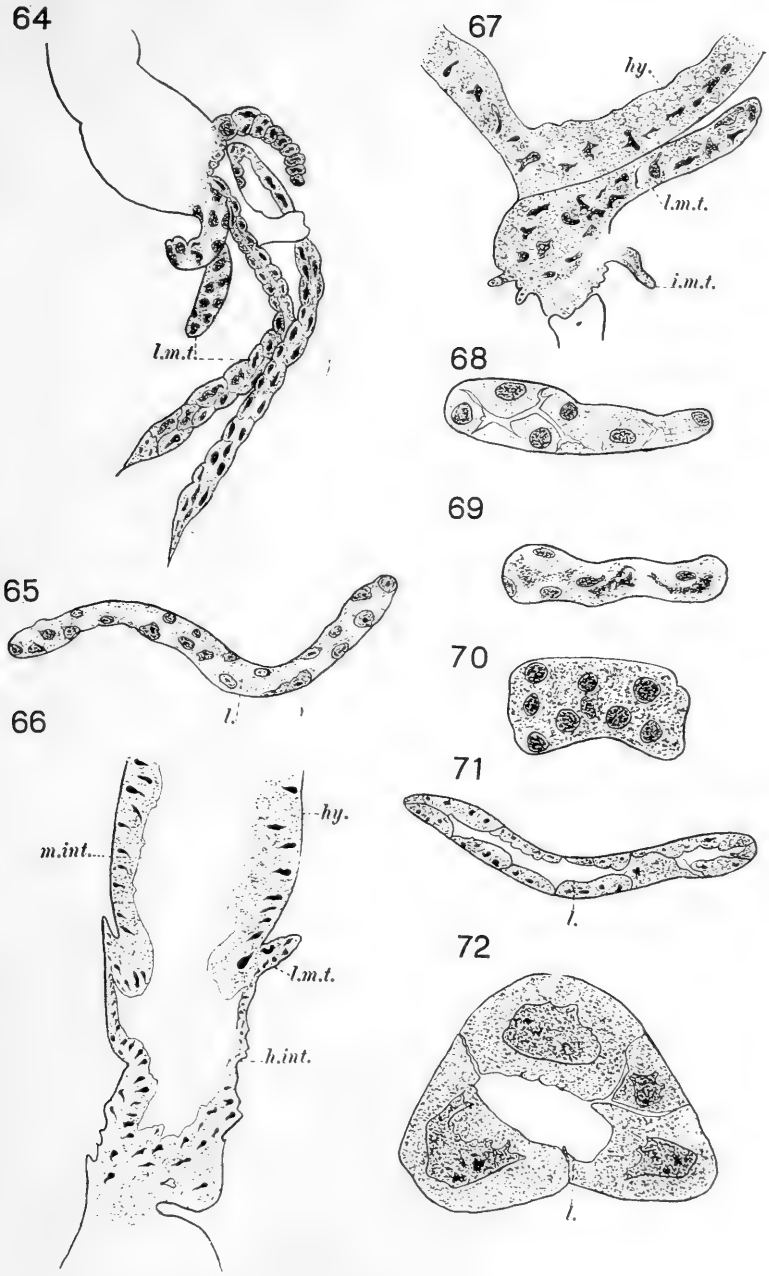

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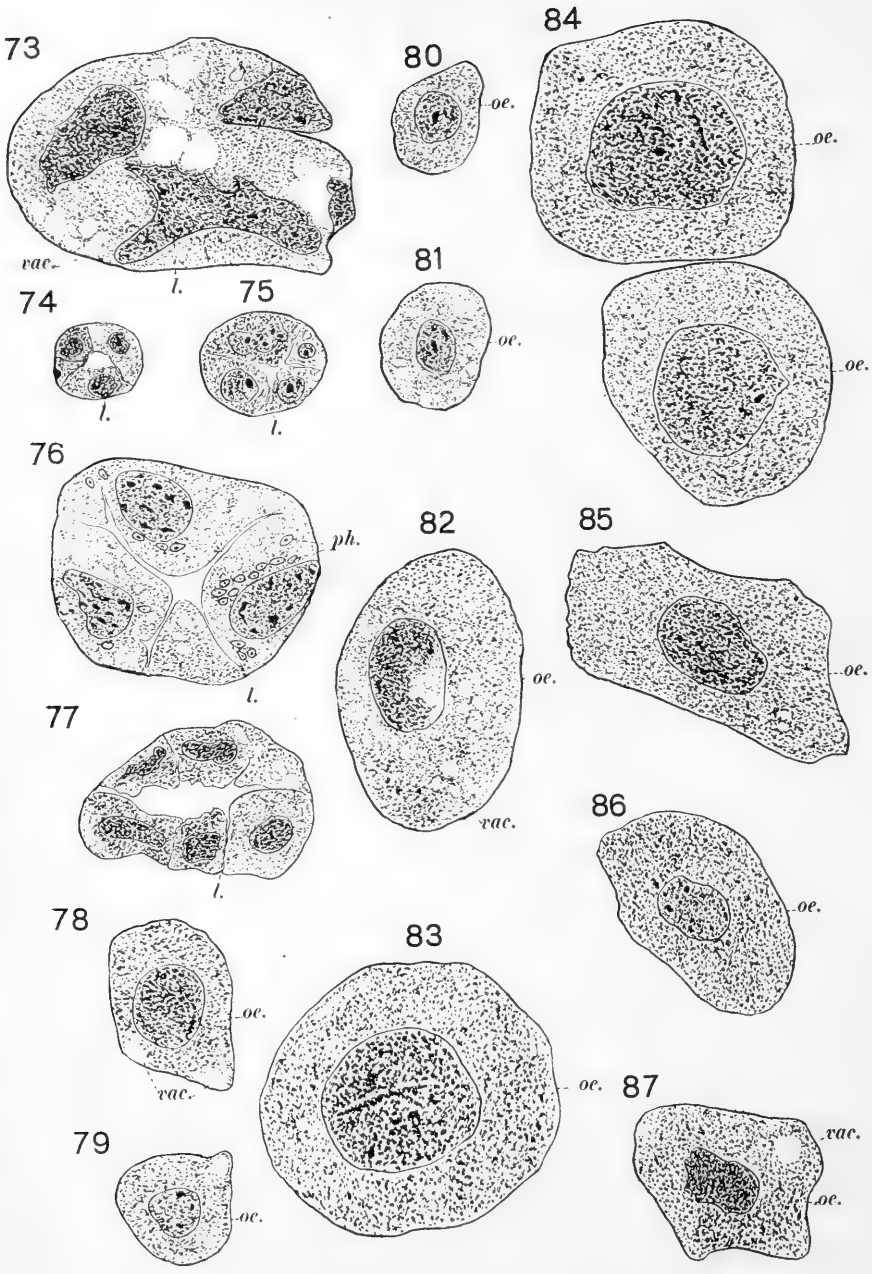

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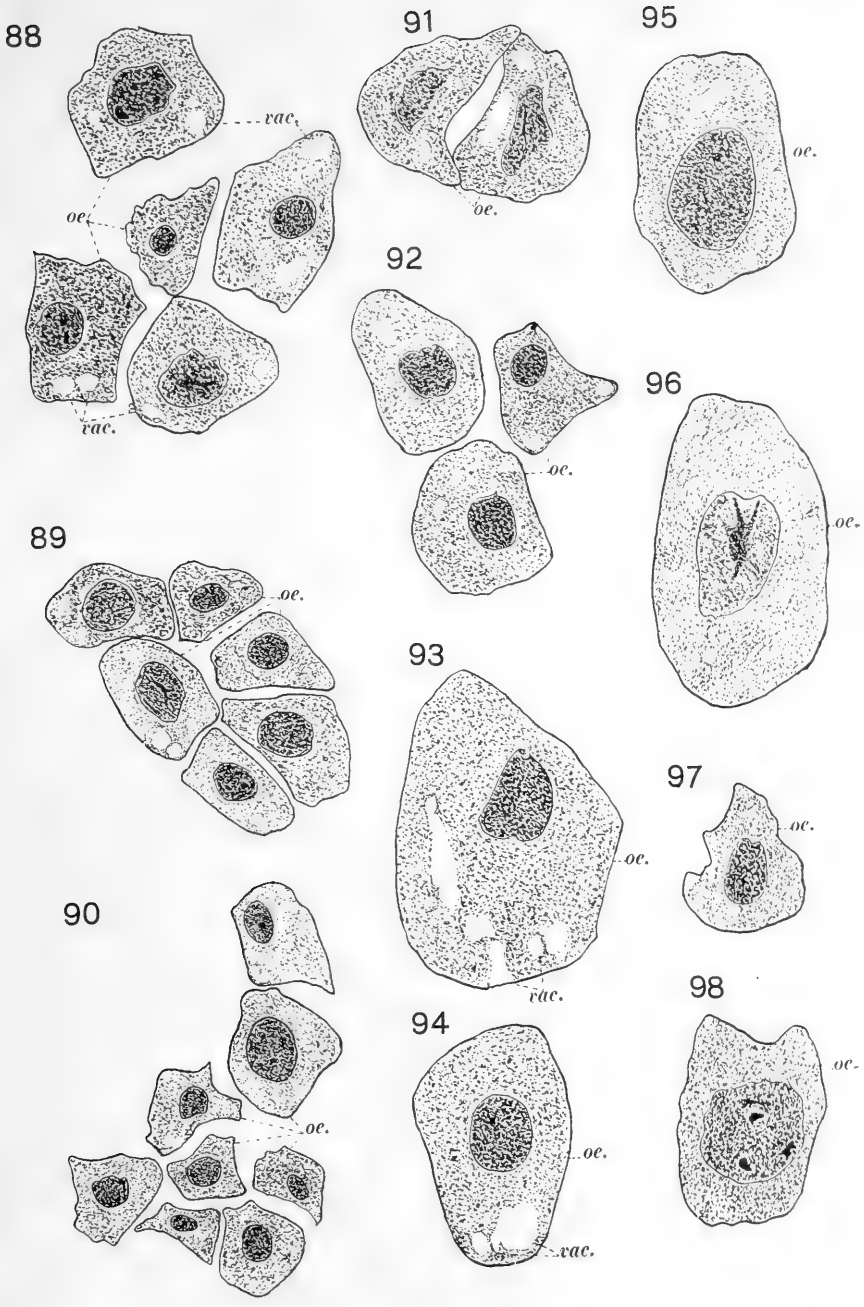


C. J. Triggerson.

THE ANATOMY OF THE DIASPININE SCALE INSECT EPIDIASPIS PIRICOLA (DEL GUER.).

By Leroy Childs, Stanford University, California.

The anatomy of several species of scale insects (Coccidæ) has been studied in the entomological laboratories of Stanford University, these species representing several different genera, such as Physokermes, Ceroputo and Icerya. All these, however, are of more or less generalized type and show but little marked divergence from a common form. Comparatively little work has been done in this laboratory or elsewhere on the anatomy of the more specialized Coccidæ, the Diaspinæ.

It is the purpose of this paper to describe the more important anatomical characteristics that are representative of the sub-family Diaspinæ as a whole. A knowledge of the facts of the make-up and functions of the parts should add to the interest of any study of the sub-family, whether the student have the viewpoint of an economic or systematic entomologist. In taking a particular member of the sub-family for this study, I have chosen the species familiarly known as the Italian pear scale *Epidiaspis piricola* (Del Guer). It is one commonly found about the University and in the whole Santa Clara Valley.

In studying the anatomy of such a small and well chitinized insect a number of difficulties of technic present themselves. The first thing that must be considered is the method of killing. Embedding and cutting were also features that demanded considerable experimentation before desirable results were obtained.

Three killing fluids were experimented with in particular; Towers' formula No. 2, Gilson's, and hot water. The latter proved to be the most useful. A fourth, Carnoy's mixture of six parts of absolute alcohol, three parts of chloroform and one part of glacial acetic acid, was also used somewhat for killing. It brought out the nervous system admirably, but the other tissues were badly distorted or destroyed by the action of this powerful agent.

The orienting of the material in the paraffine, ready for sectioning, was a little problem in itself, on account of the minuteness of the insect. The best results were obtained by

the following means: A small paper receptacle was half filled with melted 55% paraffine and allowed to cool considerably. The insect was then taken up in melted paraffine in a warm pipette, and dropped into the receptacle, which was then filled. The specimen was then moved into desired position with a warmed needle. After following this method of embedding, little trouble was experienced in trimming up the block, and the cutting could be done with accuracy in the plane wished.

Necessary care must, of course, be taken in seeing that all material is thoroughly embedded or the sections are very liable to tear when the knife comes in contact with the tough, chitinous covering of the insect. This chitin was found to be extremely impenetrable, and all attempts at staining *in toto* proved futile, though specimens were allowed to stay in the staining fluid for days.

This paper was prepared in the Entomological Laboratory of Stanford University, under the direction of Professor V. L. Kellogg. I am indebted also to Professor Harold Heath for suggestions during the work.

NERVOUS SYSTEM.

The nervous system (Plate XII, Fig. 4) of the Coccidæ seems to vary little in structural characteristics in the many widely differing groups of the family. The central system consists of a fused, bi-lobed cephalic ganglion forming the brain, and a prominent compressed thoracic ganglion from which four pairs of lateral nerves are given off. The posterior pair curve out towards the lateral margins of the insect and then curve back again apparently fusing or at least giving off a great number of smaller nerves which form a delicate fan-shaped nerve center in the pygidium. The circum-oesophageal connectives, (Plate XII, Fig. 4-a) are exceptionally long in Epidiaspis and, together with this lesser nerve center just mentioned, represent the chief differences of the Diaspinæ from the other forms studied. This pushing forward of the brain and the lengthening of the oesophageal commissures is undoubtedly a result of specialization arising from the development of the mouth-parts. The extremely well developed muscles that govern the sucking apparatus are found just below the brain, and it is undoubtedly their growth that has pushed forward

the more or less functional brain. However, a nerve can be seen arising from either side of the lobes reaching out towards the antennal rudiments.

Experiments were undertaken to ascertain the insect's sensitiveness to touch, which show that there is a decided lack of visible response to any sort of stimulus. The only movement that could be noted was that of the drawing in, or telescoping, of the posterior region when touched with a needle. This shortening takes place through the contraction of the segments. No other movement of the body was observed in response to other stimulants such as light, heat and water.

DIGESTIVE SYSTEM.

The Diaspinæ present an extraordinary arrangement of the digestive system, diverging in this respect considerably from the other sub-families. Dr. A. Berlese, the well known Italian biologist, seems to be about the only man who has done any considerable amount of work on this group, and he reports a very novel condition of the system. He describes elaborately in his studies, the arrangement of the organs of digestion and assimilation, and finds that the stomach is entirely disconnected from the intestine and the rectum. This condition seems to be almost unbelievable. It is a condition met with usually only in certain animal forms where there occurs a regurgitation of undigestible foods. Such an action is highly improbable among the Diaspinæ. Certainly no one has ever observed this phenomenon among them and the removal of wastes can probably be explained in another way.

The digestive epithelium of the stomach of Epidiaspis is made up of very large cells (Plate XIII, Fig. 9-a) with correspondingly large nuclei. The action of the digestive secretions on the ingested plant juices is such that it reduces them to a condition where they can be taken up by the blood-plasma and used for food, reaching this medium by osmosis through the walls of the blind sac or stomach. With the food also passes that which is of no use to the insect and which is taken care of by the exceedingly well developed Malpighian tubules, of which there is a single very large pair, (Plate XIII, Fig. 9-b). These excretory organs are fused, and at the very point of fusion a short duct leads into the rectum to which the

Malpighian tubes are attached by a filament (Plate XIII, Fig. 9-e) a short distance above the anal aperture. The proportionately large size of these tubules indicates that their function is not of ordinary or small proportions. They are made up of exceedingly large granular cells, with distinct nuclei, surrounding a thread-like lumen leading forward to the fusion of the two tubules, from which there is a connection into the tube leading into the rectum. These organs must be considered primarily as organs of excretion and capable of taking from the body cavity not only that material taken in with the food, but removing from the system the waste products of metabolism.

Dr. Berlese declares that there is absolutely no continuous connection from mouth to intestine. However, the writer finds some sections in his series that show what can hardly be denied to be direct connections, (Plate XIII, Fig. 9-c). Berlese's theory of digestion and assimilation is quite plausible and there is a good argument for its probability, for this connection, at best, is very small. The greater number of the sections that have been made—and I have sectioned several score of specimens—show the condition as Dr. Berlese describes. But it seemed possible that the result might be due to an imperfect technic, so that to find a united alimentary canal was the cause for cutting so much material. The results seem to point to this accomplishment. I think that it is in the killing that the trouble lies. We have to do with an insect with a rigid, chitinous exterior with the anal aperture and esophagus attached to chitin. The intermediate system possesses two large bodies, the stomach and the Malpighian tubules, joined by a very delicate intestine, which, unable to withstand the sudden shock of certain killing fluids, is ruptured, with the natural result that many, if not most, of the insects, show a disconnected digestive system.

This condition might possibly vary in the different Diaspinine genera, yet this is not probable. More work is still to be done on the group as a whole, and should this finding be true it will be a point of morphological importance at least, though perhaps not altering the present accepted theory in regard to the manner in which this system carries on its digestive and secretive functions.

REPRODUCTIVE SYSTEM.

The female reproductive system of Epidiaspis (Plate XIV, Figs. 14 and 15), is found to be characteristic of the usual insect type, consisting of a pair of ovaries joined to the vagina to form a figure much the shape of a capital Y. The vagina is a rather long, thick duct, lined with prominent gland cells with prominent nuclei, which undoubtedly secrete a tough, shell-like material during the passing of the eggs. The vagina opens on the ventral surface opposite the anal aperture. At the junction of the two branches of the vagina is found the minute opening of the seminal receptacle (Plate XIV, Fig. 14-b). This sperm sac is a long blind tube (Plate XIV, Fig. 16), and at the time observations were made was filled with an exceedingly large quantity of sperm cells, which could often be seen in the semi-cleared specimens under the microscope.

From the branches of the ovaries, masses of ovariole buds are given off, varying in size from a mere evagination of the egg tube to that in which the eggs are well developed (Plate XIV, Fig. 14-a). Each of these ovarioles is capable of producing a single egg, which, upon reaching maturity, passes down the slender connective into the vagina (Plate XIV, Fig. 15-c), and thence to the exterior. It is quite evident that all of these buds do not develop, and I have noted that the female apparently stops feeding to any great extent after egg laying begins. Consequently after a certain number of eggs have been deposited, she probably does not possess the vitality to bring all the others to maturity.

CIRCUMGENITAL GLANDS, OR SPINNERETS.

The study of the grouped glands or spinnerets (Plate XIV, Fig. 17 to 21), and their histology and function, offered an especial opportunity for some needed observations, and proved to be very interesting. The histology and actual function of these spinnerets have been subjects of much conjecture, although little real work seems to have been done on them. The reason for this is undoubtedly the fact that the glands (Plate XIV, Fig. 17-a) are functional for a very short period of time, and unless sections are made at this particular time, no glands can be found in connection with the grouped orifices. Sections made before the egg-laying period begins, cutting

squarely through these grouped spinnerets, often show a heavily nucleated invagination of the hypoderm, but aside from this no inkling as to the function can be ascertained. Just before the insect commences egg-laying, however, a white powdery substance can be found issuing from the openings, and sections made from the material killed at this time brought out the gland cells in their minutest detail. A slender duct (Plate XIV, Fig. 17-c) is found to connect each of the circular openings with the wax secreting glands. These units vary in number of cells from one or two to six or seven, each division possessing a prominent nucleus and uniting with the main duct by a slender, thread-like lumen. Between these ducts are numerous elongate supporting cells (Plate XIV, Fig. 17-b) which have no relation with the functions of secretion, except that they may aid in keeping the passageway open.

The spinnerets are circular, rather lens-shaped, and made of chitin, through which a minute pore is found connecting the cell and duct to the exterior. This opening seems always to be uniform in its makeup—a rosette with five small parts.

Prof. E. E. Green is the author of a general rule which can be applied to Coccids possessing these glands, that they are for the most part ovo-viviparous, or egg-laying, while those that do not possess these spinnerets are viviparous. I have made observations on a number of the local species and find the rule to hold true. I have also noted that the embryo reaches a greater state of development before the egg is deposited in the cases of those species in which there are very few spinnerets, than in those that possess a large number of grouped glands. In *Aspidiotus uvae* the circumgenital glands are found in very small numbers, two or three in a group, and the species is reported to be viviparous. The opportunity of studying a large series of these insects might reveal some very interesting facts. One can easily make a mistake in examining material for this phenomenon by using adult females which have died containing well developed eggs. The eggs are not destroyed by the death of the mother, but from them hatch young, around which is the shriveled skin of the mother, and through which there is no means of escape for the newly hatched insects. Such material when mounted impresses one as being of a viviparous form. Circumstances of this nature may be the explanation of some of the seeming exceptions to the rule.

Upon the arrival of the egg-depositing season the female assumes a different posture than is its earlier position, shortening itself to a considerable extent and appearing much more rounded (Plate XIV, Fig. 21). On the insect's taking this shape the vulva opens directly back instead of on the ventral aspect. With this change comes also a shifting of the normal position of the spinnerets (Plate XIV, Fig. 19) to the position shown in Fig. 20. In Epidiaspis the spinnerets consist of five groups, three anterior and two posterior, all about equidistant from the genital aperture. This shifting from the normal, together with an enlargement and infolding of the vulva, draws the glands to a position immediately surrounding and lining the opening. The eggs passing through this opening must necessarily pass over the glands, and in this passing the moist egg picks up a quantity of the powdery secretion that has exuded, more or less covering the newly deposited eggs (Plate XIII, Fig. 21). This powdery substance not only acts as a protection to the eggs, but also aids in keeping them from drying and sticking together and thus blocking up the limited space in which the insect has to store her ova.

THE MOUTH PARTS.

The mouthparts of the Diaspinæ are, as with the other subfamilies of the Coccidæ, hard to homologize with those of other insects. They are too minute to dissect and are always flattened out of shape when mounted, thus making a detailed description of the size and shape of the various parts a difficult thing to do with accuracy. For the most part this box-like framework of the Diaspinine mouth structure can be homologized with that for other Coccidæ, as described by Putnam, Mark, Moulton and others.

This framework is a very important structure in that it serves as a means of attachment for the powerful muscles that govern the sucking and swallowing apparatus. In the main, there are two arches (Plate XIII, Fig. 11) arcus superior (*a*), and arcus inferior, (*b*), which fuse to make a very rigid structure. Just below this box-like structure is a rostrum or mentum, conical in shape and attached at the base. This conical structure is covered with a chitinous layer and inside of this are a few short muscles, which are undoubtedly used

in the manipulation of the long buccal setæ, the four apparently modified mandibles and maxillæ, which are, in the case of this group of insects, extended into a long piercing beak. These four chitinous rods are arranged so that the plant juices pass up through the tube formed by their union. Attached behind the rostrum and lying free in the body cavity, is the setal pouch, extending well back towards the posterior end of the thoracic ganglion, into which the setæ are pulled when they are not in use.

At the base of the arcus inferior (Plate XIII, Fig. 11-b) is found a very interesting apparatus made particularly striking by its close resemblance to a piston valve, with all of its attachments, chamber, rod and head (Plate XIII, Fig. 12). Figure 13 shows a diagramatic cross section of this valve, showing inlet, 13-i, from salivary glands (Plate XIII, Fig. 11-d) and outlet into oesophagus 13-o.

Here again, in the impossibility of actual observation of the functioning, the interpretation of the actual function of the organ has to be based upon its structural make-up and the work that it apparently has to perform. Dr. Berlese is of the opinion that this pump is used for drawing the saliva from the large paired glands (Plate XIII, Fig. 11-e), and the arrangement of the ducts and the openings into the cylinder would seem to indicate this. Yet the rule for most insects with comparable organs is that these glands, as a result of an internal pressure caused by a continual secretion of the cells from within, or from muscular action, force the juices out. In the case of this insect no muscles are to be found that could perform this function, and, from the make-up of the glands themselves, they seem to the writer to be admirably adapted to operate through a pressure formed from within. Again, from the make-up of the long, slender, four-pieced proboscis, it would seem to be impossible to pump saliva into the plant tissues, for pressure from the inside would disrupt the tube. Necessarily, therefore, if there is a passage of fluid down this setal arrangement it would have to be done with little or no pressure. The presence of stained plant tissue at the point of puncture possibly indicates that some fluid does pass, as exemplified by the familiar reddish staining occasioned by the presence of the San Jose scale (*Aspidiotus perniciosus* Comst.)

on various fruit trees. This possibly might be explained as being the result of a mechanical stimulus and the disrupting of the cellular make-up of the plant, for the long chitinous rods that compose the mouthparts pierce and destroy a great many cells. This theory seems to be at fault however, in that all scale insects do not cause this phenomenon; for example, on the apple *A. perniciosus* causes a very distinct reddening while *E. piricola* does not.

The real function of the saliva is undoubtedly not to aid in the taking up of the plant juices, but to act upon these food properties after they have entered the insect's body. The relationship of the opening of the salivary glands to the oesophagus would seem to point to this. The food is poured into a common chamber at the base of the proboscis (Plate XIII, Fig. 12-c) passing on through the slender oesophagus (12-e) into the stomach.

The posterior part of the pharynx is a decidedly chitinized structure, apparently valvular, to which a number of powerful muscles (Fig. 12-f) are attached, and whose function it is to help force the food forward, through expansion and contraction of the walls of the oesophagus. These muscles are attached to the ventral wall of the insect, and undoubtedly act in conjunction with the large retractor muscles found directly above the pump-like cylinder of the mouthparts (Plate XIII, Fig. 12-b).

In the main the long, slender oesophagus resembles a capital letter U running forward from the chitinized pharynx parallel to the ventral wall (Plate XIII, Fig. 12-e) of the insect to about that point corresponding to the cephalic region of the chitinous box-like framework of the mouth-parts. At this point it turns toward the dorsal surface, passing between the two circum-oesophageal commissures close to the base of the brain. Here the tube turns parallel to the center, emptying into the stomach at a point just posterior to a vertical line that would run through the mentum (Plate XIII, Fig. 8). This tube is cylindrical in outline and it may be distinguished in sections from the surrounding tissue by the minute, circular cells, of which it is composed.

RESPIRATORY SYSTEM.

The Coccids possess a respiratory system that seems to be nearly uniform through the entire group, and that found in this species varies little from that of the larger representatives of the family. It consists, in Epidiaspis, of two pairs of stigmatic openings or spiracles, well guarded by hairs and spinneret-like glands which excrete a powdery wax over the exterior opening. These apertures (Plate XII, Fig. 6) possess rosettes (6-b) that make them indistinguishable from those that surround the vulva. A short tube leads from the stigma, opening into a chamber from which numerous tracheoles radiate, always, however, in a definite way so that all the individual insects of that species show the same characteristics and design (Plate VII, Fig. 2). For the most part these tubes are confined to the ventral surface, but can often be traced into the body cavity, surrounding the different groups of organs. The degree of diffusion of this system and its limit of ramification could not be determined, as only those tubes that possess a chitinization can be positively identified in the sections. In the larger, less specialized forms of Coccids, taenidial rings, the familiar characteristic of tracheal tissue are found, but in this species no such rings were noted, though a careful search for them was made. The characteristic trunk connectives joining the spiracles are very small and as a rule are unbranched. In some Coccidæ these have been found to be wanting, undoubtedly the result of degeneration.

THE CIRCULATORY SYSTEM.

The scale insects as a whole seem to be lacking in anything that may be called a definite circulatory system. No trace of a dorsal vessel can be found and no movement or pulsation of the body was noted that would indicate the presence of any such system.

EXPLANATION OF FIGURES.

Plate XII.

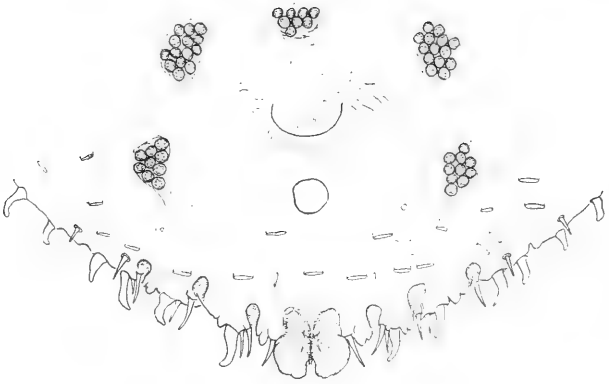
Fig. 1. Pygidium of adult female, dorsal surface with circumgenital orifice and glands showing through.
Fig. 2. Respiratory system of female insect, showing two pairs of spiracles.
Fig. 3. Glandular spine, used in spinning the shell. (cross section shown in Fig. 18-e).
Fig. 4. Nervous system. a. Circumoesophageal commissures; b. brain; c. thoracic ganglion.
Fig. 5. Cross section of segments. a. chitin; b. muscle; c. muscle attachment.
Fig. 6. Spiracle. a. opening; b. wax producing spinnerets; c. tracheal tubes.

Plate XIII.

Fig. 8. Sagittal-longitudinal section of adult female. a. stomach; b. malpighian tubules; c. rectum; d. vagina; e. ovarioles; f. thoracic ganglion; g. cephalic ganglion; h. salivary glands; i. setæ (rostral); j. setal pouch.
Fig. 9. Digestive tract. a. stomach; b. malpighian tubules; c. intestine; d. rectum; e. attachment filaments.
Fig. 10. Characteristic muscle structure found under chitinous covering.
Fig. 11. Mouth-parts and accessories. a. arcus superior; b. arcus inferior; d. valvular pump; e. salivary gland; g. costa inferior; h. costa superior; i. oesophagus (i. oesophagus drawn to one side); j. salivary ducts; k. setæ; m. muscle.
Fig. 12. Longitudinal cross section of mouth-parts. a. setæ; b. muscle; c. common chamber at base of setæ; the union point of oesophagus and duct leading from pump; d. salivary duct; e. oesophagus; f. muscles attached to base of oesophagus and to the body wall.
Fig. 13. Diagrammatic cross section of pump showing inlet and outlet. i. inlet; o. outlet.

Plate XIV.

Fig. 14. Ovaries, dorsal view. a. ovarioles; b. seminal receptacle; c. vagina; d. vulva.
Fig. 15. Ovaries, lateral view. (lettering the same as Fig. 14).
Fig. 16. Seminal receptacle. a. sperm cells.
Fig. 17. Sagittal section of gravid female cutting through caudo and cephalo-lateral circumgenital glands. a. wax glands with neuclei; b. supporting cells with neuclei; c. gland ducts; d. grouped gland orifices.
Fig. 18. Cross section of spinning glands that form the shell. d. dorsal spinneret with characteristic silk gland; e. spine-like marginal spinneret; f. silk gland; g. gland found in connection with the silk gland and supposed to secrete a cement-like fluid.
Fig. 19. Normal position of the vulva and circumgenital glands of adult female. a. vulva; b. anus.
Fig. 20. Shift in position of the circumgenital glands of the adult female during egg laying.
Fig. 21. Position of adult female during egg laying. a. normal position indicated by dotted line; b. position during the depositing of the eggs.



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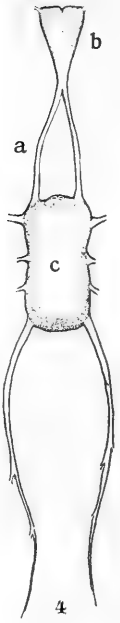

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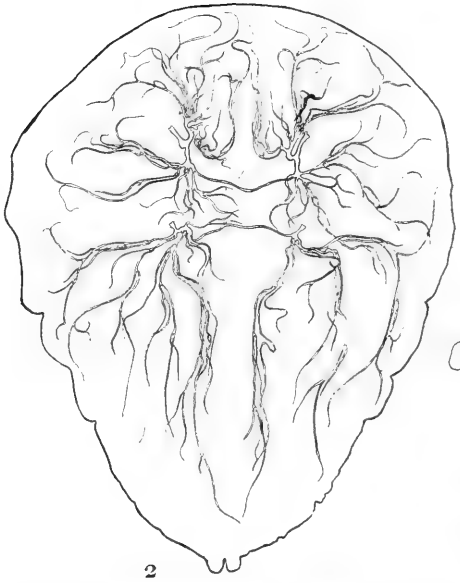

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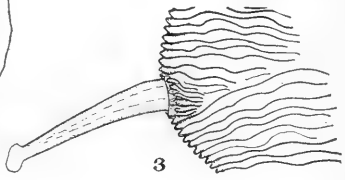

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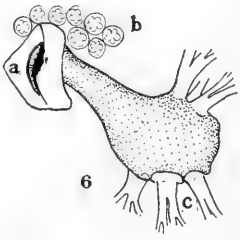

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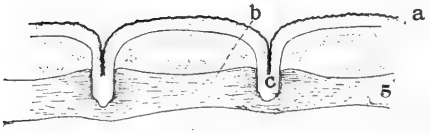

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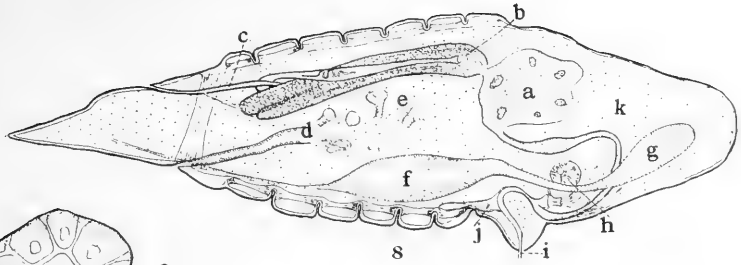
Leroy Childs.



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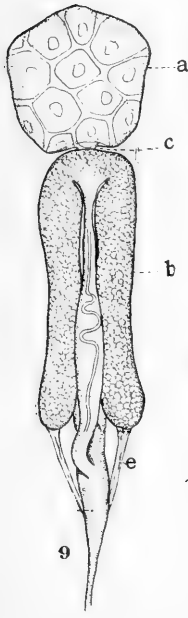

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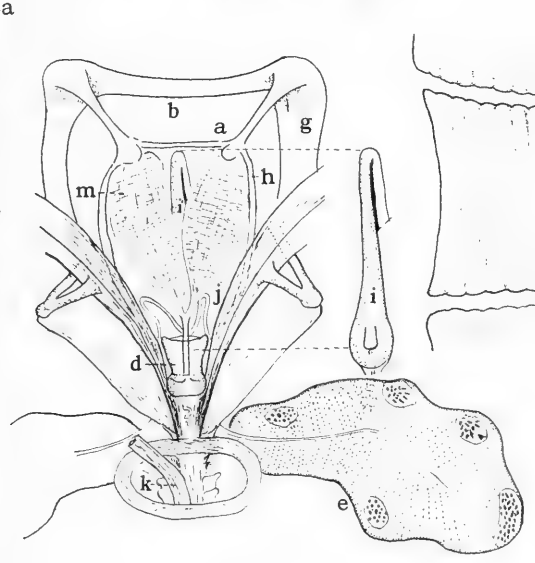

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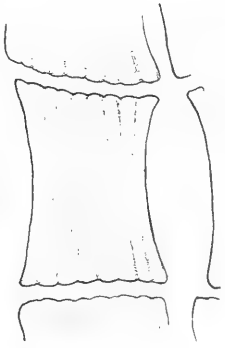

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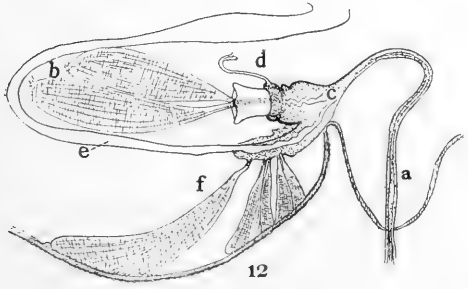

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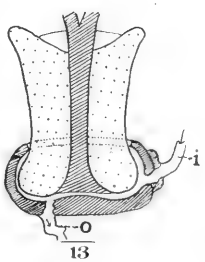

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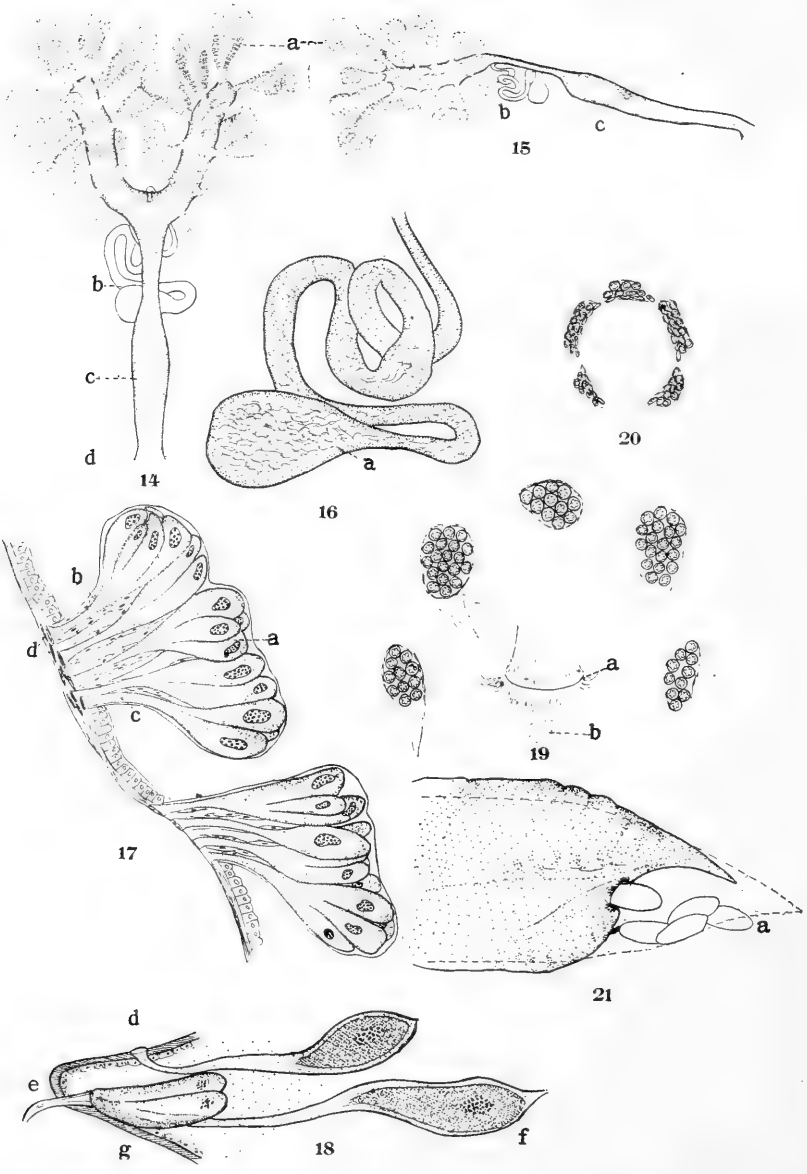
Leroy Childs.



Leroy Childs.

SOME PEMPHIGINAE ATTACKING SPECIES OF POPULUS IN COLORADO.

(Concluded from Vol VI, p. 493.)

By C. P. GILLETTE.

Thecabius populiconduplifolius Cowen, Plate XV, Figures 1 to 9.

Pemphigus populiconduplifolius, Cowen, Hemiptera of Colorado, Bull. 31, Colo. Exp. Sta., p. 115, 1895. Hunter, Aphididæ of North America, p. 79, 1901. Gillette,* Jour. Economic Ent. p. 355, 1909. Jackson, Cols. Hort. Soc. Vol. 22, p. 217, 1908. Contributions No. 29, Dep. Zool. and Ent., O. S. U., p. 217, 1908.

Pemphigus ranunculi n. sp., Davidson, Jour. Economic Ent. p. 372, 1910.

Pemphigus populiconduplifolius, Davidson, Jour. Economic Ent. p. 374, 1910.

Pemphigus californicus, Davidson, Jour. of Economic Ent. p. 414, 1911.

Pemphigus populiconduplifolius, Essig, Pom. Jour. Ent. p. 699, 1912.

Pemphigus californicus, Essig, Pom. Jour. Ent. pp. 699, and 700, 1912. Essig, Pom. Jour. Ent. p. 827, 1912.

Pemphigus populiconduplifolius, Patch,* Bull. 213, Maine Exp. Sta. p. 76, 1913.

The above literature may be briefly summarized as follows:

The original description by Mr. Cowen dealt with the alate fundatrigenia in the folded leaves of the cottonwoods with the mere mention of yellow apterous individuals, all from Colorado.

Hunter lists this species only.

The writer, in 1909, recorded the species from Massachusetts.

Davidson, 1910, described the alate and apterous forms taken in California from the buttercup (*Ranunculus Californicus*) to which he gave the name *ranunculi*, but which is probably *populiconduplifolius*, as Mr. Bragg and Mr. Asa C. Maxson have repeatedly traced this species to the buttercup in Colorado, where it seems to be perfectly at home. On page 374 of the same paper Davidson records *populiconduplifolius* in the folded leaves of *Populus trichocarpa* and mentions seeing the stem mother.

*These can hardly be *populiconduplifolius*, as the stem females were reported in both cases as being present in the colonies of developing lice, a condition which we have never found in Colorado where the types of the species were taken. Furthermore, I have a stem female from Massachusetts that was taken by Mr. L. C. Bragg, and it is readily distinguishable from any of the stem females that I have seen from Colorado by having remarkably thickened femora for all legs. The femora are very nearly twice as great in diameter as they are in the Colorado form and are of about the same length. Four winged migrants taken from *Populus balsamifera* (Acc. No. 47–10) in Maine by Dr. Edith M. Patch are before me, mounted in balsam. These seem to differ from Colorado examples principally by having weaker sensoria, which are also fewer in number, on the sixth joint of the antennæ. I will suggest that this eastern form be known as *Thecabius patchii*, though it does not have the typical habit of most known examples of this genus of having the stem mother in a gall by herself.

Jackson merely quotes Cowen's original description.

Davidson, finding the name *ranunculi* preoccupied, suggests *californicus* instead.

Essig lists this species both as *populiconduplifolius* and *californicus*.

Dr. Patch records several captures of this species in Maine on the leaves of *Populus balsamifera* and gives a figure showing the distribution of the wax glands of what she took to be the stem mother, and also an excellent figure of the antenna of the alate fundatrigenia, or summer migrant.

This is a rather common but not abundant species in northern Colorado and the writer has also taken it at Wheatland, Wyoming, upon a broad-leaved cottonwood.

Fundatrix, Figures 1-4.

The general color of the fundatrix is yellowish olive green, lightest over the middle area of the abdomen, more or less covered with a white powdery secretion and a few wax threads about the lateral margins and posterior portions of the body; head, eyes, antennæ and legs, including coxæ, black or blackish; in general form, broad oval; eyes small but very prominent; length 3.75 to 4.50, and width 2.50 to 3.00; hind tibia, .60; length of antenna about .70; 5-jointed; joints I, II and IV subequal in length, the fourth being a trifle the shortest; joint III barely as long as IV and V together with the spur; spur about half as long as joint IV; only permanent sensoria present and they are bordered with cilia. The arrangement of the wax plates upon the head and thorax is shown in figure 3, and is about as follows:

Head with a pair of large circular plates on the vertex between the antennæ; on the occiput a similar pair, not quite so large but somewhat wider apart, and midway between these a smaller pair, rather close together; on the prothorax four large plates in a transverse row, and two small ones in front of the middle pair; meso- and meta-thorax and joints 1-6 of the abdomen, each with a transverse row of 6 plates; joint VII with 4 plates; joint VIII with 2, and none on joint IX. It is not uncommon for two of these plates next each other to coalesce and so reduce the number.

The fundatrix is never found in the leaves folded along the midrib in which the other lice occur, but is always found in a narrow fold on the margin of one of the first leaves to open and upon the under side, see figures 1 and 5a. The second generation, almost as soon as born, leave the pseudo-gall of the fundatrix and travel to the tenderest little opening leaves at the tip of the twig, where they locate, several to a leaf, upon the lower or ventral surfaces where they begin to feed, causing the

leaves to fold along the midrib as shown at figure 5, b. Mr. Maxson in a letter makes the following statement in regard to his observations upon the early occurrence of the second brood:

"The first larvæ of the second generation were observed June 18th. These were traced to the young leaves at the tips of the branches where they located on the underside. These leaves began to fold along the midrib and in a few days typical *P. conduplifolius* galls were formed."

This second brood all acquire wings and leave the cottonwoods and go to the buttercups, *Ranunculus* sp., so far as our observations go. At the present writing, December 24th, there are several thrifty colonies in the laboratory on buttercups where they have been since the migrants were put upon the plants in July. They attack, not the roots, but the crown and leaves and stems near the ground. The buttercup seems to be a permanent food plant for this species, upon which it seems to be able to live continuously throughout the year.

COLLECTION DATA FOR FUNDATRIX.

Specimens in the collection have been taken as follows:

Ft. Collins, Colo., 6- 2-13, L. C. Bragg, *Populus occidentalis*
" " " 6-12-13, L. C. Bragg, " "
" " " 6-16-13, L. C. Bragg, " "
" " " 6-20-13, L. C. Bragg, " "
Denver, Colo., 6-25-13, L. C. Bragg, " "

Fundatrigenia.

The winged fundatrigenia taken from the folded poplar leaves is the form described by Mr. J. H. Cowen in Bulletin 31 of the Colorado Experiment Station, page 115, as follows:

"Length 1.8 to 2.2 mm. Alar expanse 6.85 mm. Nearly black, pruinose. The abdomen is deep green when the glaucus matter is removed by placing the insect in alcohol. Antenna 1.00 mm. long, joints slender, 5th and 6th with about six or seven annulations each; stigma short and broad; ungues usually with a constricted neck. Similar to *ramulorum* but larger and the antennal joint not nearly so strongly annulated."

In addition it might be said that the transverse sensoria (Figure 7) are not complete rings, many of them extending but a short distance, and especially is this true on joint III; on joint IV the number commonly varies between five and eight, and the same is true of joint V, while the number on joint VI is usually six besides the terminal or permanent one; spur, finger-like and about .05 in length, or about one-half as long as joint II; joints I and II equal in length, the former cylindrical, the

latter larger at distal end, each measuring .07; near the proximal end of joint III on the front side is a short tooth or spine; wings (Figure 6) clear, veins slender, stigma rather small. Described from seven types on one slide taken at Boulder, Colorado, June 23, 1910, by Mr. L. C. Bragg, along with a large number of co-types.

COLLECTION DATA FOR FUNDATRIGENIA.

Ft. Collins, Colo.,			7–11–12,	L. C. Bragg,	*Populus* sp.
"	"	"	8– 7–12,	L. C. Bragg,	" "
"	"	"	8– 6–12,	C. P. Gillette,	" "
"	"	"	7–12–13,	C. P. Gillette,	" "
Wheatland, Wyo.,			7–15–13,	C. P. Gillette,	" "
Boulder, Colo.,			6–23–10,	L. C. Bragg,	" "
Boulder, Colo.,			7– 4–11,	L. C. Bragg,	" "
Newcastle, Colo.,			7–23–93,	C. P. Gillette,	" "
Greeley, Colo.,			7–21–09,	C. P. Gillette,	" "
Lynn, Mass.,			6–27–09,	L. C. Bragg,	" "
La Salle, Colo.,			7–20–09,	C. P. Gillette,	" "
Eckert, Colo.,			6–26–10,	C. P. Gillette,	" "
Windsor, Colo.,			7–29–93,	C. P. Gillette,	" "
Niwot, Colo.,			7–15–08,	C. P. Gillette,	" "
Grand Jct., Colo.,			7–21–93,	C. P. Gillette,	" "
Veazie, Maine,			7– 5–10,	E. M. Patch,	" "
Delta, Colo.,			7–20–93,	C. P. Gillette,	" "
Niwot, Colo.,			7–15–08,	C. P. Gillette,	" "
Paonia, Colo.,			6–23–10,	C. P. Gillette,	" "

Mr. Maxson has given me the following statement in regard to the early appearance of the stem mother gall:

"The earliest date on which the galls were found was May 20th. On this date the lice were very small and appeared to be in the first stage after the egg, since no shed skins were to be found in the galls."

Alate Sexupara.

This form differs from the fundatrigenia by having joint II of the antenna (Figure 8) decidedly longer in proportion to its diameter; joint VI without transverse sensoria; joint V often without sensoria except the permanent one, but sometimes with one, two, or even three sensoria present; joint IV with but four or five sensoria, and joint V as long as joint VI with the spur.

This form has been taken at Fort Collins on several different dates during September on *Ranunculus* by Mr. Bragg, and about Longmont, Colorado, by Mr. Asa C. Maxson.*

*I am indebted to Mr. Maxson for the privilege of using the data that he has accumulated during the past two years from his studies of this insect. Mr. Maxson has also independently traced this insect to the *Ranunculus* from the cottonwood leaves.

Young larvæ.

The rather young larvæ of this species taken on *Ranunculus* are pale green in color and are heavily covered, especially over the abdomen, with fluffy wax threads. For full descriptions see Davidson's paper in Journal of Economic Entomology, 1910.

Pupæ on *Ranunculus*, pale yellow in color and very heavily covered with wax threads, especially over the abdomen.

Compared with Affinis.

This species is very close to *affinis* Kalt. of Europe, but seems to be distinct, and especially because of what seem to be rather marked differences in the antennæ. I have but a single European example of the alate fall migrant, sent me by Mr. J. J. Davis, from Dr. Tulgren, of Sweden.

I have found only six wax plates on the vertex of the fundatrix in twelve examples examined, while Tulgren gives eight for affinis; joint IV of the antenna is somewhat shorter in proportion to the other joints as compared with affinis in Tulgren's* figures, and joint V in the fall migrant commonly has two or three sensoria, while affinis is represented as having none.

Sexupara of affinis.

We have a good example of affinis from Europe, sent by Dr. P. van der Goot. Joints V of the antennæ have each one good transverse sensorium near the middle and one very small sensorium besides; joint IV has four well developed transverse sensoria on each antenna and is decidedly club shaped, being much heavier at the distal end. The same form of *condupli-folius* has joint IV more nearly cylindrical and usually with four well developed transverse sensoria, joint V usually with none but sometimes with one or two small sensoria, and joint VI with none.

The antenna of the virgogenia seems to agree with that of *affinis* as figured by Tulgren.

Asiphum sacculi n. sp., Plate XV, Figures 10 to 14.

I first saw the gall of this louse about eighteen years ago when on a mountain trip some twenty miles or more northwest of Fort Collins. I did not meet with it again until the present summer, when, on July 13th, I found two of the leaf pockets characteristic of this species in Estes Park on twigs of *Populus tremuloides* about six miles apart and at an altitude of about

*Aphidologische Studinen for Zoologi, 1905, Band 5, No. 14.

7500 feet. On August 9th, four more of the galls were taken near the Half-way House on Pike's Peak, at an altitude of about 9000 feet. In two of these galls there were no living lice. In each of the occupied galls taken (four), there was one large stem-female present, with a large number of her offspring in all stages of development up to the adult alate lice. There were no adult apterous lice and all that were half grown or more gave evidence that they were to get wings. In the breeding cages the alate lice began at once to deposit young with long beaks. In every case the lice were accompanied by a species of large black ant.

The Gall. An infested leaf becomes very much enlarged, and somewhat thickened with the edges turned in so as to make a heart shaped pocket, and the apex of the leaf is extended and turned back as shown in Plate XV, Figure 10. The color of the infested leaf is yellowish green, and lighter than the healthy foliage surrounding it.

Fundatrix. Figures 11 and 13.

A very large, oval, slatey gray louse, lightly covered with a fine white powder, and set everywhere with delicate gray hairs above and below; length of body about 4.50; width 4.00; antenna, .75; joint III longest and almost as long as joints IV and V together; permanent sensoria ciliated, joints I, II, and III with numerous delicate hairs; beak barely attaining third coxæ; hind femur .80; hind tibia .80.

Pupa. Figure 12.

The pupæ are quite dark in color, the abdomen being very dark olive green and the head and thorax a rather blue slated gray; the tarsi, eyes and terminal joints of the antennæ black. A conspicuous marking of the larvæ and pupæ consists of a row of five tufts of white waxy secretion along either lateral margin of the abdomen.

Fundatrigenia.

All the young of the fundatrix, the second generation, become winged and leave the galls. General appearance, that of a black louse; abdomen olive green; thorax, head, and antennæ blackish, or dusky; legs yellowish; tarsi dusky; wings a trifle smoky; the veins slender with a narrow dusky line on either side; stigma narrow, lanceolate, dusky, fork rising about midway on the cubital vein; length of body 3.50; wing 4.50; antenna (Figure 14) 1.00; joint III with 7 to 9 oval sensoria and a well developed spur near the base; joint IV, with two similar sensoria near the distal end; joints V and VI with the usual permanent sensoria only which are ciliated about the margins; joint III longest, fully as long as joint VI with the spur; joint V slightly longer than joint IV; cauda a broadly rounded lobe.

Habits for the remainder of the year unknown.

Mordwilkoja vagabunda Walsh.,* Plate I, Figures 15 to 20.

Byrsocrypta vagabunda Walsh, Proc. Ent. Soc. Pha., V. I, p. 306, 1862.

Pemphigus vagabundus, Walsh and Riley, Am. Ent. V. I, pp. 57 and 107, 1869; Riley, V. I, Mo. Rep. p. 120, 1869; Packard, Guide to Study of Insects, p. 524, 2nd. Ed. 1870; Thomas, Ent. Rep. Ill., V. I, p. 153, 1880; Oestlund, Aphids Minn. p. 22, 1887; Packard, Forest Insects, p. 434, 1890; Osborn, Cat. Hemip. Ia. p. 130, 1892; Cowen, Bull. 31, Colo. Exp..Sta. p. 116, 1895; Hunter, Aphid. of N. A., p. 79, 1901; Cook, O. Nat. V. IV, p. 118, 1904.

Pemphigus oestlundi n. sp., Cockerell, Ent. News, p. 34, 1906.

Pemphigus vagabundus, Jackson, Genus Pemphigus, Cols. Hort. Soc. XXII, p. 200, 1908.

Mordwilkoja oestlundi, Davis, William's Aphididæ of Neb. p. 4, 1911; Patch, Bull. 213, Me. Exp. Sta. p. 100, 1913.

The galls of this louse at the terminal buds of cottonwood twigs have occurred in greater or less abundance in at least one limited locality near Fort Collins, Colorado, for the past fifteen or more years. The section referred to is mostly rather low, moist land, along the course of an irrigating ditch and near the river. It seems strange that the galls should not have become more generally distributed unless the alternate host is largely limited to the area mentioned. I am assuming that there is an alternate host for the reason that the lice all become winged and leave the galls rather early in the summer. Most of them are gone by August 1st here.

The Galls, Figures 18, 19 and 20.

When growing, the galls are as green in color as the cottonwood leaves, and are, in fact, a transformed leaf in each case. On the inside of the green gall the main veins of the leaf are very prominent. Apparently these galls differ from others produced by Aphids by not having any opening to the exterior during their growth, but Mr. L. C. Bragg has discovered a small brown scale (Figure 18 A, and 20, b) at the base of the gall, which seems to be the apex of a folded leaf, beneath which is an opening to the interior and through which the blade of a penknife may be passed without cutting any tissue. This opening is so narrow that the lice do not escape by it. About the time that fully matured winged lice are developed in a gall (about July 10th to 15th,

*Professor Oestlund, in his Aphididæ of Minnesota, p. 22, states that Walsh's *vagabundus* is evidently something different from the louse that has since been known to be associated with the coxcomb gall. To be sure, September is late to take the migrants from these galls, and the measurements given by Walsh are too large for this species. But he evidently had a louse belonging to the Genus *Pemphigus*, as then understood, and in the Walsh-Riley paper published in Vol. I, of American Etomologist, page 107, the vagabond gall was figured, and both the winged lice and the apterous stem mothers from the galls mentioned. As Walsh at that time considered the winged lice from these galls the same as what he had described as *B. vagabunda*, it seems to me best to abide by his identification of his own species, and especially as we do not know any other species to which to refer his original description, which is quite inadequate for its identification anyway. I am therefore retaining the name *vagabunda*.

at Fort Collins), little star-shaped mouths (Figures 18 and 19, o) appear at the apices of the more prominent lobes thru which the alate lice escape. Many of them appear on a single gall as shown in Figure 18. The galls nearly always are from terminal buds, and whether one or more of the leaves form a single gall I have no certain knowledge, but apparently it is one in each case. Large galls measure as much as 80 to 95 mm. in greatest diameter, and about 50 to 60 in the greatest thickness.

The Fundatrix. Figures 15 and 16.

One fundatrix was found in every gall opened. General color of body yellowish green, the yellow tinge seeming to come from a large number of small embryos within; nearly unicolorous throughout, but a little darker along the lateral margins; legs and antennæ yellowish, the antenna blackish at tip; both antennæ and legs very short; joints of antenna 4; joint III about one-half the entire antenna in length; spur two-thirds as long as joint IV; permanent sensoria ciliated.

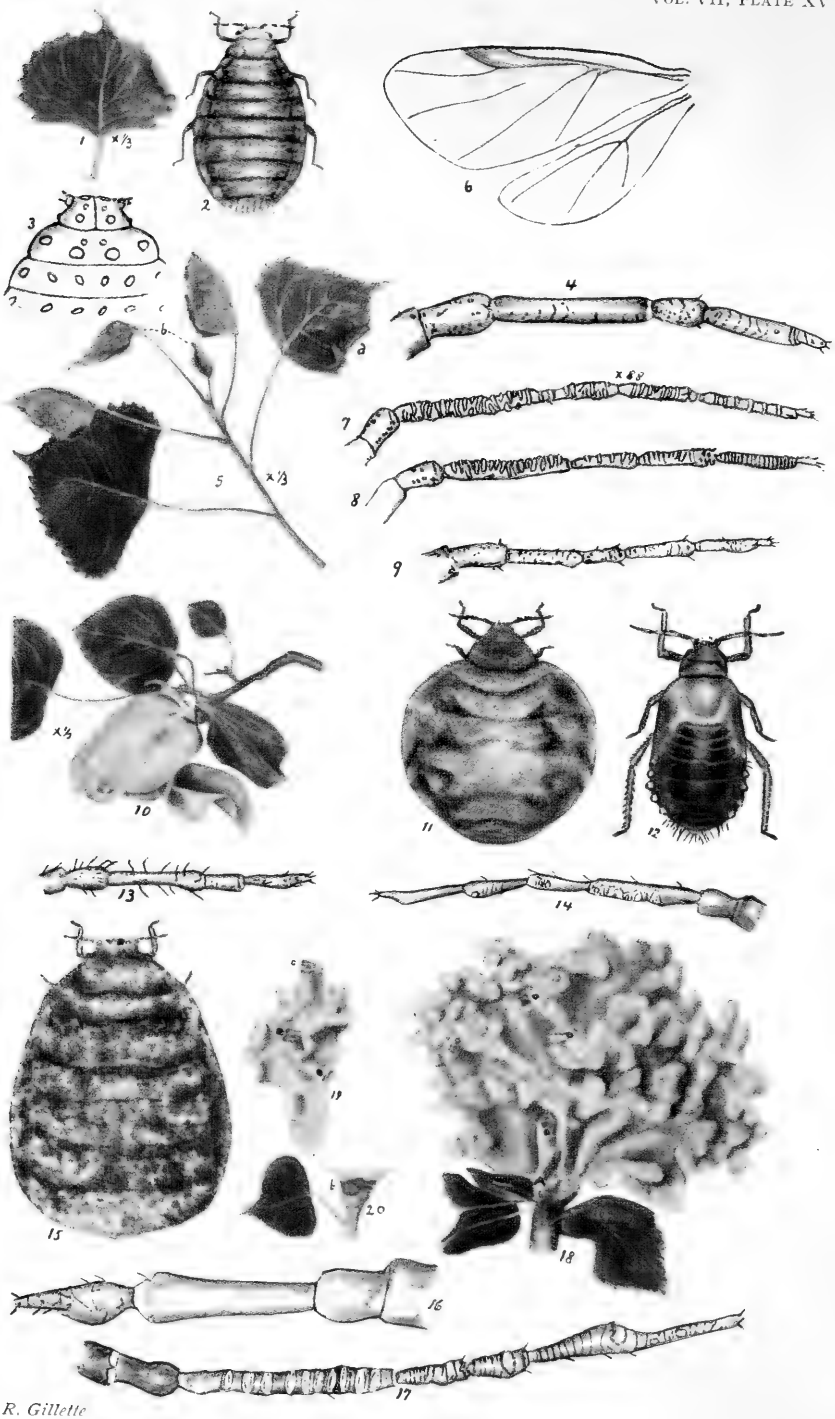
Length of body 5; width 3.70; constricted a little at base of abodmen. In general, stout, pear-shaped, the small end being at the head; covered everywhere with a light covering of white powder.

Young lice and pupæ in the galls are very pale yellowish and much powdered. There are a great number, possibly a thousand in all, in a gall and apparently the stem females were just in their prime and packed full of embryos on July 11. All of the offspring get wings when adult.

Fundatrigenia, Figure 17.

All alate lice with black head thorax and antennæ, and dark green abdomens, and the thorax and abdomen are heavily pruinose with more or less cottony threads towards tip of abdomen, making a tuft. Length of body 2.50 to 3.00 mm.; antenna .85; joint III as long as joints IV, V and VI to base of spur; joints IV and V sub-equal; spur about equal to joints IV and V together; a distinct spur near the base of joint III; sensoria on transverse ridges, but not surrounding the joints; joint III with nine to eleven sensoria; joint IV, two; joints V and VI with permanent sensoria, only; spur with two or three sensoria, usually three, scattered along its length; cauda very small, rounded.

Described from lice escaping from the galls July 11, 1913.



C. R. Gillette

Explanation of Plate XV.

(C. P. Gillette).

Plate XV. Figures 1 to 9, *Thecabius populiconduplifolius* Cowen: 1, stem mother gall on margin of leaf; 2, young adult stem mother; 3, showing wax plates on head and thorax of stem mother; 4, antenna of stem mother; 5, cottonwood twig showing the folded terminal leaves where the young from the stem mother gall have settled at b, and a stem mother gall at a; 7, antenna of fundatrigenia, or second generation lice; 8 antenna of alate sexupara or pre-sexual form; 9 antenna of apterous form found on *Ranunculus* during the summer and fall.

Figures 10 to 14, *Asiphum sacculi*, n. sp.; 10, pocket-like gall from Aspen; 11, fundatrix or stem mother; 12, pupa; 13, antenna of the fundatrix; 14, antenna of the fundatrigenia.

Figures 15 to 20, *Mordwilkoja vagabundus* Walsh: 15, fundatrix; 16, antenna of fundatrix; 17 antenna of fundatrigenia; 18, the vagabond gall containing fundatrix and young; 18, a, brown scale beneath which there is an opening into the interior of the gall; 19, a section of the gall showing oscula (o) that open for the escape of the mature lice; 20 (b) the closed mouth, also shown at 18, a.

Drawings by Miss Caroline M. Preston, except Figures 1 and 2, which are by Miss M. A. Palmer. Original.

DISPERSAL OF MUSCA DOMESTICA LINNE.

JAMES ZETEK, Ancon, C. Z.

The latter part of May, 1913, unusual numbers of flies appeared at the Isthmian Canal Commission hotels and commissary at Balboa, Canal Zone. An inspection revealed a pile of cow manure, etc., about 800 square feet in area, located at one corner of Ancon Cemetery, 2,500 feet distant in direct line from the hotel. This place is indicated by the letter "B" on the accompanying map. This manure was heavily infested with maggots, principally of *Musca domestica*, *Hermetia illucens*, *Volucella obesa*, and *Paralucilia macellaria*. Puparia were very abundant and adults in countless numbers. This was the only manure pile found away from the incinerators.

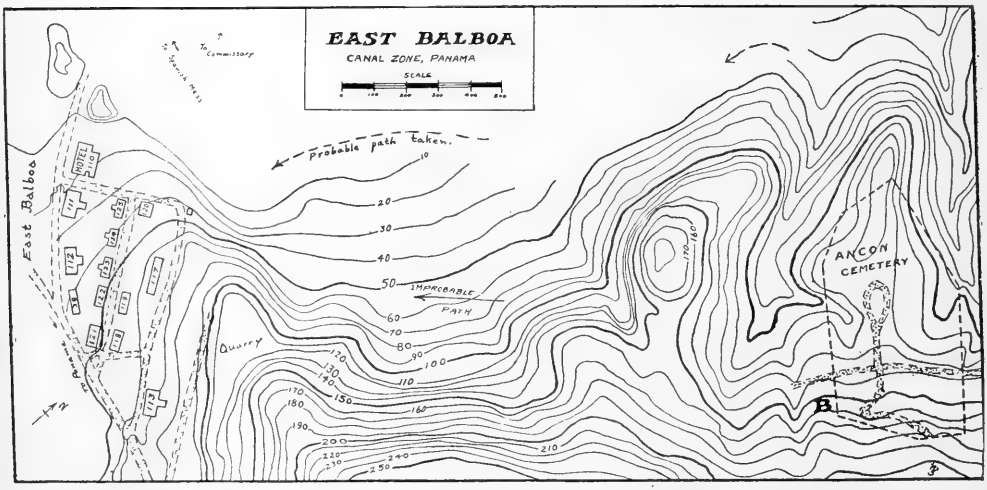


FIG. 1. Map of the region.

A pit was dug, into which was placed a small quantity of the infested manure. A cover of earth one foot deep was added as a protection from heat rays. Over this was placed a screened cage. On June 6th the cage contained about five thousand adult flies, most of them the common typhoid-fly. At 9:00 a. m. these were sprayed with an aquaeous solution of gentian-

violet, to which a small amount of gum tragacanth had been added. (See Annals Ento. Soc. Am. Vol. VI, No. 1, pp. 5–21). These marked flies were liberated at 9:30 a. m. at the same place.

At the hotels, commissary and a few private houses, tanglefoot paper was used freely, and this was afterwards collected by the writer and examined for the presence of any marked flies. The method used was to wet each fly with a solution of alcohol and glycerine. The marked fly became known by the resolution of the tiny crusts of anilin dye adhering to its body. Seventeen marked flies were thus recovered, viz:

East Balboa Hotel, 4 ♂ *Musca domestica* from paper exposed for 32 hours after the sprayed flies had been liberated at the cemetery.

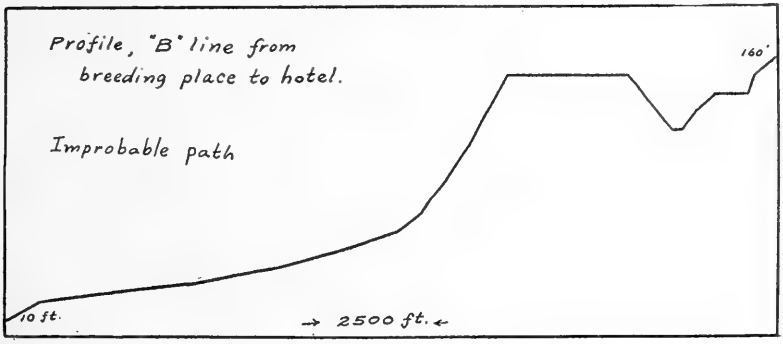


FIG. 2. Profile in direct line.

Spanish Mess, 9 (7 ♂, 2 ♀) typhoid flies from paper exposed 32 hours.

Commissary, 3 ♂ typhoid flies, from paper exposed 32 hours.

Spanish Mess, 1 ♂ typhoid fly, from paper exposed 75 hours (in reality 43 hours after last batch of paper was collected.)

No attempt was made to catch flies outside of these screened buildings, hence the 17 recovered adults represent only such as had gained entrance through holes in the screening or while the doors were opened and closed. The species found on the fly paper were mainly *Musca domestica* and *Hermetia illucens*, both of which breed freely in pit closets as well as in manure, and which were very plentiful upon cooked and uncooked food.

The probable path taken by the flies in this particular case was down the East and West gully along the cemetery, then along the lowlands to the Commissary and Hotels. The profile figured is made in a direct line from the breeding place to the hotel, but it seems hardly probable that this was the path actually taken. The former is the more likely one.

Thus it has been clearly shown that a mass of manure 2,500 feet from the hotels and 150 feet above them, was a menace to these places. The experimental results were augmented shortly after when this manure heap was completely destroyed. The flies at the Commissary and hotel quickly diminished in numbers.

CONWENTZIA HAGENI BANKS.

Life History Notes and Variations in Wing Venation.

By J. S. Houser, Ohio Experiment Station.

The species under consideration was first called to the attention of the Department of Entomology, of the Ohio Experiment Station, in November, 1912, by Mr. J. M. Keck, of Cleveland, who submitted the overwintering cocoons for determination. Dr. MacGillivray, to whom specimens were referred, pronounced them as belonging to the neuropterous family Coniopterygidæ. A little later, reared adults were sent to Mr. Nathan Banks, who gave the specific determination as *Conwentzia hageni* Banks.

At the time the material was taken the insect was in the larval stage, neatly encased in the double cocoon so well described by Quayle (Bul. 234, California Experiment Station). The gross appearance of the cocoon so closely resembles the compactly woven webs of some of the smaller spiders that it would be very easy to confuse the two, but as soon as a dissection is made, the double silk formation of the former very quickly separates them.

The cocoons were found most abundantly on a cherry tree some ten feet in height, the greater portion occurring in masses on the trunk. A considerable number, however, were to be found on the upper portions of the tree, where the crotches of the twigs seemed to be a favorite spot for their construction. Larvæ only were to be found, hence, it is safe to say the winter is passed in this stage. The three specimens upon which I was able to get exact records, changed from the larval to the adult stage in 16 days after being transferred to a temperature of 70° to 75°.

Since quantities of the overwintering eggs of the clover mite, *Bryobia pratensis* Garman, were found upon the tree which bore the Coniopterygid hibernacula, it is altogether likely that this pest supplies one of the principal sources of food for the insect. Quayle reports *Conwentzia hageni* Banks, feeding abundantly upon the citrus red spider, *Tetranychus mytilaspidis* Riley. Two visits were made last summer to Cleveland with the hope of learning something definite regarding the feeding habits of the larvæ; an additional visit was

made this winter in the hope of securing more of the hibernating material, but at no time were any of the insects to be found. The colony seemed to have disappeared entirely.

So much for general notes. The chief reason for directing your attention to the subject at this time is to point out some variations of wing venation which the writer observed, and in

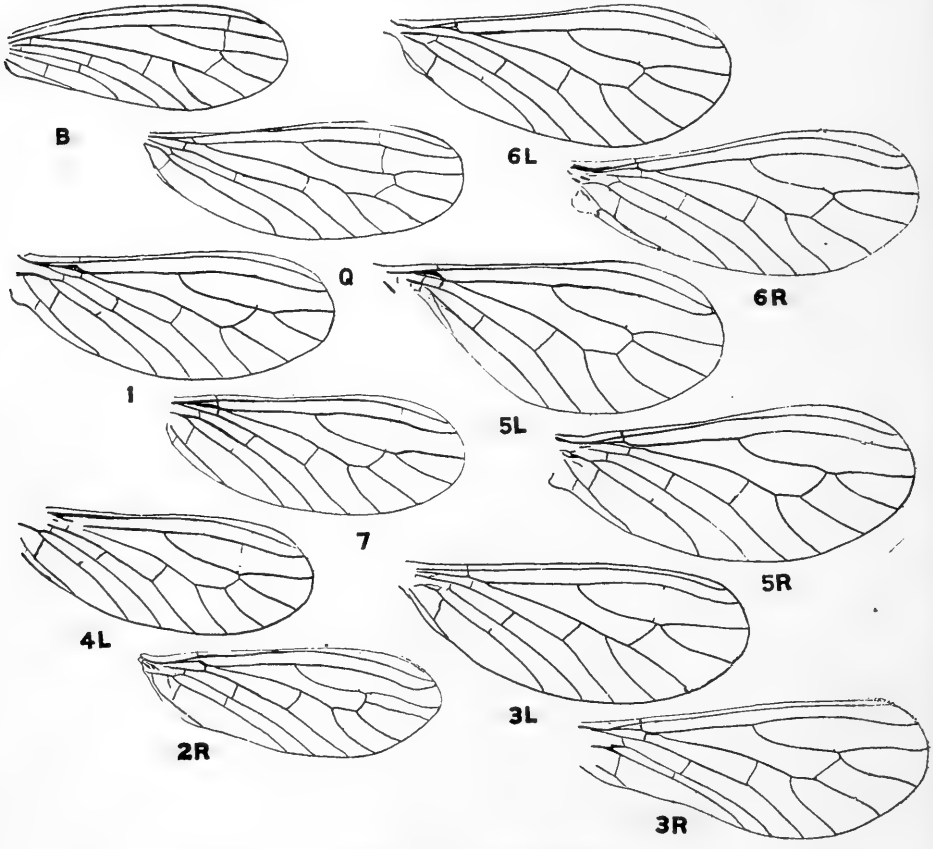


Fig. 1. *Forewings of Conwentzia hageni* Banks.

B. From Banks Proc. Ent. Soc. Wash., Vol. VIII; Q. From Quayle Univ. Cal. Publications, Bul. 234.

1, 7, 4L, 2R. One wing from each of four individuals in the author's collection.

6L and 6R, 5L and 5R, 3L and 5R. Left and right wings of three individuals in the author's collection.

so doing he does not wish to be misunderstood to be attempting to break down the validity of the specific determination, but wishes merely to record the variations from the standpoint of scientific interest. In the accompanying illustrations, B and

Q are copied from Banks, Proc. Ent. Soc. Wash., Vol. VIII, and Quayle, Univ. Cal. Publications, Bul. 234, respectively, while the remainder are from retraced photo-micrographic prints. Illustrations 1, 7, 4L, and 2R, are all from different insects. 6L and 6R; 5L and 5R; 3L and 3R, are three pairs of wings. All of my specimens were bred from the same lot of material and illustration No. 1 is made from a mounted slide used by Banks in making the determination.

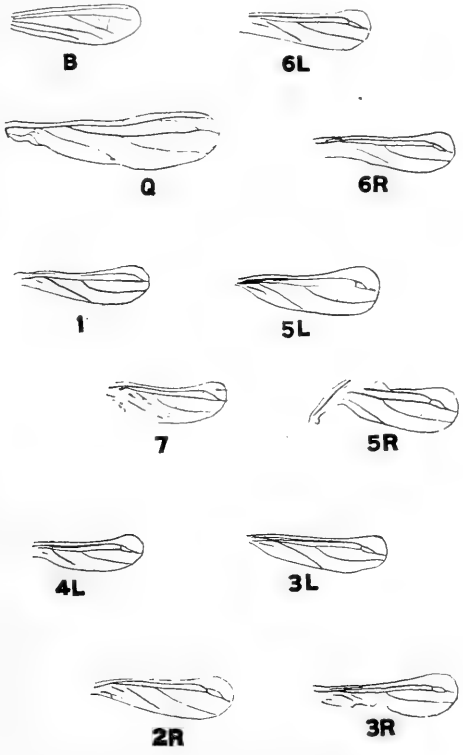


Fig. 2. *Hindwings of Conwentzia hageni* Banks.
The corresponding hindwings of the series of forewings shown in Fig. 1.

Banks refers to the variation in the placing of the cross-vein* from Sc to R1 and the one from the radial sector to $M1_{+2}$. The illustrations of the fore wing by Banks and Quayle do not differ materially, excepting that the cross vein between

* Whether this is a cross vein or SC_2 is an unsolved point. It is possible that an examination of pupal wing parts would decide the matter.

Cu2 and the first anal vein is not shown by Quayle. In all of my specimens the cross vein from Sc to R1 is either exceedingly faint, or wanting entirely; sometimes being indicated by a thickening of R1 at the point where it might be expected to occur. Cross vein from R1 to radial sector is usually indicated by a sharply defined stub, extending about one-seventh of the distance upward from the radial sector, and is sometimes indicated above by a less sharply defined stub extending downward. The position of the cross vein from the radial sector to M1+2 is exceedingly variable, sometimes joining above to R2+3+4+5, and sometimes to R4+5. In some cases, such a difference occurs between the wings of the same insect as in the case of 5L and 5R; 3L and 3R. In the majority of cases the cross vein between Cu2 and the 1st A is represented by a short stub only, which arises from 1st A.

The variations in the venation of the hind wings are even more striking than in the fore wings, especially regarding the types illustrated by Banks and Quayle, when compared with my photographs. Banks illustrates a cross vein between R1 and the radial sector; Quayle shows a long oblique cross vein between Sc and R1; while in all my specimens Sc bends sharply downward towards the distal end and joins R1. Some wings have a short cross vein joining Sc and R1 near the point where the former joins the latter, forming a very peculiar little cell.

None of the longitudinal veins of the hind wing are shown by Banks as joining the outer margin which agrees with Enderlein's generic description of *Conwentzia*. Quayle shows radius and its branch; media and cubitus joining the margin. In my specimens Cu R1, if not joining the margin, approaches perilously near to it, while the radial sector unquestionably joins the margin and cubitus joins in some instances.

An additional and final comparison may be drawn between the comparative size of the fore and hind wings as represented by the drawings of Banks and Quayle and my photographic series. In the entire set of reproductions, the size ratio between the fore and hind wings is truthfully maintained, hence, by collating wings B, Q and 1, of the fore and hind series, it will be seen that no very great difference obtains regarding the size of the forewings, whereas the hind wing of Quayle's specimen is markedly larger than either of the others.

A COMPARISON OF NATURAL CONTROL OF TOXOPTERA GRAMINUM IN SOUTH AFRICA AND THE UNITED STATES.

By William Moore,
Asst. Prof. of Entomology, University of Minnesota.

During the past year, the author, while engaged as Lecturer in Entomology at the Potchefstroon School of Agriculture, spent considerable time in studying Toxoptera graminum in South Africa and its control there by natural enemies. As the results obtained have been somewhat different from those obtained in the United States, it is thought that a comparison of the conditions and the results would be of interest to Entomologists.

Toxoptera graminum is found over certain large areas in South Africa but attracts the greatest amount of attention in the Orange Free State, Basutoland, and the western portion of the Transvaal. It seems to have been present, at least in the Free State, for many years, since the older farmers can remember the pest as long as they have been farming in the eastern portion of the Free State, known as the Conquered Territory. The earliest definite record was 1896, which year is distinctly remembered by a farmer who lost his entire wheat crop in that year. In the higher portions of South Africa, i. e., an elevation of more than 5000 feet, Toxoptera is either not present or is not present in numbers sufficient to attract the attention of the farmer. In the lower coastal regions, it also appears to be absent as, for example, along the coastal region of Natal. It is probable that the increased importance of Toxoptera during later years has been due to the destruction of the locusts which formerly swarmed over South Africa. There is little doubt but that the locusts destroying the grain and incidentally destroying Toxoptera were responsible for the prevention of what might have been a serious attack during that year. Since the locusts have been destroyed, Toxoptera has had a better opportunity of showing the injury of which it is capable.

In South Africa, there seem to be two forms of Toxoptera under normal conditions, namely, the winged migratory females and the apterous, viviparous females, the males and the

oviparous females apparently being absent. As these forms are too well known to entomologists to require a description, only a few notes concerning their migration and food plants will be given.

Toxoptera, during the summer time, from about the middle of November until March, live upon various grasses and volunteer grain plants. The most important grasses in this connection are Johnson's Grass (Sorghum halepense), Goose Grass (Eleusione indica), Sweet Grass (Panicum laevifolium), Teff, Millet, Indian Corn, and Kaffir Corn (Sorghum Sp.). The Blue Grass, upon which it is found so frequently in the Free State, is not Andropogon hirtus, as reported by C. B. Van der Merve and mentioned by F. M. Webster, but is the Sweet Grass Panicum laevifolium, which is usually called Blue Grass in the Free State and Sweet Grass in the Transvaal. There are a number of grasses in South Africa known as Blue Grass, without a distinctive common name. From March until June or July, Toxoptera is found upon green forage crops such as barley, rye, and oats. These give it an opportunity to exist from the time that the grass becomes too old for it, or is killed by the frost, until the main grain crop of the year is up, about June or July. It is also very abundant during the winter time upon Rescue Grass (Bromus willdenowii).

It exists on the winter grain until about September or October when it changes to its summer host plants. The severe attack usually occurs either in March on the green forage crops or in July, August, or September, on the main grain crops. The most critical time of the year for Toxoptera in South Africa is in October or November, when it becomes necessary to change from the grain field to its summer grasses. The winters in South Africa are dry and, if rains do not occur before October or November, the summer grasses do not come up, while, on the other hand, the grain rapidly ripens, becoming unfavorable for Toxoptera. At such a time, no doubt, large numbers of Toxoptera are lost in making this change. Some of these are always saved by their ability to live upon the roots and underground shoots of Johnson's Grass where they are attended by a common, grayish-brown ant, *Plagiolepsis dustodiens*. This is interesting, inasmuch as H. Maxwell-Lefroy, Government Entomologist of British India, reports Toxoptera

graminum seeking shelter in the depths of the grass roots. They were found in this situation in South Africa in many cases all through the summer, probably thus obtaining some protection from the hot rays of the sun. The forms on the roots were quite white but when such were removed to wheat plants in the Insectary, either they or their off-spring assumed their natural color and it was found that the colonies on the roots tended by the ants consisted of both Toxoptera graminum and also Aphis maidis. These two species were also frequently found associated upon the summer grasses, especially Panicum laevifolium, Indian Corn, and Kaffir Corn.

As to the rate of reproduction of Toxoptera in South Africa, it might be stated that it is about the same as it is in the United States. In South Africa, migrations over large areas as reported in the United States, are not so apt to occur. Similar migrations on a smaller scale, however, do occur. Usually, it is from the dryer portions to the wetter portions of the country, inasmuch as Toxoptera will kill the grain sooner, under dry conditions. There have been no reports of extensive migrations in the Transvaal but they are known in the eastern districts of the Orange Free State. Farmers about Ficksburg, O. F. S., state that the swarms occur coming from the west late in September or October. As the natives of Basutoland do not raise grain for green forage crops, and as the grass is always dead long before the winter grain comes up, most of the Toxoptera injuring the grain in Basutoland must come by migrations from the Orange Free State. It is difficult to get any definite data on this point from the natives but they seem to know that something of the sort occurs.

In South Africa, two internal parasites have been found which are capable of breeding in Toxoptera. The first (Aphidius phorodontis (?) is commonly bred from Toxoptera in the field. Another species is Diaeretus rapæ and has been bred in the field from both the Cabbage Aphis (Aphis brassicæ) and the Green Peach Aphis (Myzus persicæ), both occurring upon cabbages but in the Insectary this species was also bred into Toxoptera. It is doubtful, however, whether this species would normally be found breeding in the field upon Toxoptera unless the grain field was quite close to a cabbage patch. Aphidius phorodontis has been bred from the Green Peach Aphis

(Myzus persicæ), the Black Peach Aphis (Aphis persicæ-niger), the Corn Leaf Aphis (Aphis maidis), Yellow Aphis on Milkweed (Aphis nerii), a reed Aphis (Hyalopterus arundinis) and the Black Bean Aphis (Aphis rumicis).

Aphidius phorodontis, however, seems to be capable of destroying just as many individuals of Toxoptera as is Aphidius testaceipes. The average period of development from egg to adult seems to be about ten to twenty days. The maximum number developed from one female was 286 which is only 15 below the maximum obtained by Mr. Parks in the United States Department of Agriculture. It is safe to assume that in "stinging" so many that it must often occur that two or more eggs are laid in one individual Toxoptera so that it is safe to assume that Aphidius phorodontis lays 300 or 400 eggs. There seem to be about 70 per cent. of the parasites females if the mother Aphidius has been fertilized. It was also shown that one male would fertilize more than one female but time did not permit of finding how many females might be fertilized by one male. If the female was not fertilized, she would lay eggs and the proportion of the parthenogenetic off-spring were about 70 per cent. males.

When an infested grain field is examined, even though species of Aphidius are present, one never finds a large number of parasitized forms of Toxoptera upon a weak plant such as is shown to be the case in the United States. Probably one wheat plant would, at the most, not have more than ten parasitized forms upon it. Besides this species of Aphidius, there are three different species of ladybirds which play an important part in controlling Toxoptera in South Africa. The first and most important is the Black Spotted Ladybird (Adalia flavomaculata), the Red Spotted Ladybird (Chilomenes lunatus), and the Black Ladybird (Exochomus nigromaculatus). These ladybirds are a most important factor in controlling Toxoptera. It is seldom that one finds a field badly infested in which ladybirds are not present and rapidly destroying Toxoptera. The life history of Adalia flavomaculata was worked out rather completely.

Under favorable climatic conditions, the eggs hatched in from five to seven days from the time they were laid. The larvæ feed for a short time upon the eggshells but soon begin feeding

upon the Aphids. The larval stage lasts from about ten to thirteen days during which time they eat, on an average, 320 Toxoptera per larva,—that being about 26 to 28 Toxoptera per day. The pupal stage lasts six to 10 days and about 30 to 35 days elapses from the time that they emerge until they lay eggs. During this time, they eat about 825 Toxoptera per ladybird, making an average of about twenty-five per day to each ladybird.

In this species, all the eggs seemed to be laid during one period which lasted for about a week to ten days, during which time they laid about 100 to 150 eggs. After having completed the egg-laying, they live for some time before they die. The Adalia seems to live about three to four months,—the males dying first. In one experiment, the larvæ were hatched from eggs laid on the 10th of October, 1912, the last ladybird died on the 24th of February, 1913, and the average number of Toxoptera destroyed was 2844 per ladybird. In this experiment, the ladybirds were given as many Aphids as they could eat. When the Aphids were scarce, the ladybirds would not pass as rapidly through the different stages and the number of eggs laid by the adults had a direct bearing upon the quantity of food present. When the food supply runs short, the eggs which have already been laid will be eaten while even the larva will eat each other and the adults will eat the larvæ.

In the case of the Red Spotted Ladybird, we have a larger species, being about 3-10 inches in length and nearly as wide,—hemispherical in shape. The adult ladybird of this species will lay from 150 to 250 eggs during her life. The egg-laying period seems to be divided into several different stages. In feeding experiments with the larvæ of this ladybird, it was found that during the ten days of its larval existence, each larva eats about 440 Aphids. Another interesting point is that the normal life of the Red Spotted Ladybird is much longer than that of the Black Spotted,—being about four to six months.

Both of these ladybirds were found to be parasitized by a species of Dinocampus. The parasite laid its eggs in the larva and in some cases, probably, in the pupa. The cocoon of the parasite is formed underneath the adult ladybird and it seems that the ladybird always reaches the adult stage before the larva of the parasite emerges from the ladybird's body to form

its cocoon. This species of Dinocampus seems to consist entirely of females, as no males were found, even though individuals were bred from females in the Insectary.

The third species of ladybird is much smaller than either of the other two but has a life-cycle similar to the others. No exact records were obtained as to the number of Aphids eaten but it was found that the average life, from the egg until the adult dies is about five to six months. One peculiarity noted was that the eggs were not laid on end as is generally the case with ladybirds, but rested on their sides on the leaf in little heaps. This little ladybird is very severely parasitized by a Chalcid belonging to the genus Homalotylus. The parasite is usually bred from the larva collected in the field. In the month of October, about 25% of the larvæ seemed to be parasitized. From three to seven eggs are laid by the parasite in one larva and the ladybird larva usually hangs itself up as though about to pupate before dying. The larva of the parasite pupates in the dead body of the ladybird larva.

This Chalcid will also breed in captivity in both the other species of ladybird, but has not been bred from either of them in the field.

The little Black Ladybird is most beneficial during the spring and autumn when the cold affects the parasite more than it does the ladybird. During the summertime the ladybird becomes more or less rare, no doubt due to the parasite effectively controlling it.

The ladybirds seem to be of greater value in controlling Toxoptera in South Africa than in the case with the ladybirds which feed upon Toxoptera in the United States. The fact that Aphidius does not immediately destroy Toxoptera but allows it to live for a few days, during which time, if the Toxoptera is an adult, it will produce young, detracts from the value of Aphidius, when compared with the ladybirds. An example will show better what is meant. Take a plant with 200 Aphids, 50 adults and 150 young, under control conditions and introduce a female parasite. There is then a possible chance that all the Aphids on this plant will have an egg laid in them but this will not always happen, inasmuch as two or more eggs would be laid in one Toxoptera while others would escape the parasite. Granting, however, that all of them contained eggs and would

die in about seven days, it is found that the fifty adults would have produced about 500 young during the first two or three days after the egg of the parasite had been laid in their bodies. These young would have a very small chance of being destroyed by the parasite and would reach maturity after the death of their mothers or about three or four days before the offspring of the Aphidius which had "stung" the 200 Aphids, had emerged. During these three or four days, they would be producing young, so that when the Aphidius emerged, there would be between 2000 and 2500 Toxoptera on the plant.

When the offspring of this female parasite emerged, however, the chances are that all the Toxoptera would be destroyed. From the above, it will be seen that starting with one Aphidius and 200 Toxoptera on one plant, there would be at the end of about fourteen days, 2000 or 2500 Toxoptera, while the plant would not be entirely clean of Toxoptera until about twenty days had elapsed. On the other hand, if an adult ladybird had been introduced with the 200 Toxoptera, every individual would have been cleaned away from the plant in ten days at the most, while it probably would have been within five or six days. When the ladybirds are present in the field with Aphidius, another fact must be remembered, namely, that if Aphidius has "stung" a number of Toxoptera and a ladybird later ate these parasitized Toxoptera, the ladybird is also destroying the parasites as well as the Toxoptera. This is even carried further by the ladybirds, inasmuch as they will eat the parasitized forms even when the Toxoptera is dead, and the parasite is in the pupal stage. It is no doubt due to this reason that one does not find wheat plants covered with parasitized forms in the field in South Africa, as one does in the United States. When a number of infested wheat plants were enclosed with wire netting so that Aphidius could gain entrance, but a larger insect, as a ladybird could not, it was soon found that the wheat plants were crowded with parasitized forms similar to those described by Webster as occurring in the United States. There seems to be but little doubt that in South Africa, the ladybirds are of more value in combating Toxoptera than Aphidius. This is of particular interest inasmuch as an attempt is now being made to introduce *Aphidius testaceipes* into British East Africa where Toxoptera is found near Njora.

If *Adalia flavomaculata* and *Chilomenes lunatus* are found there, it is very doubtful whether the value of *Aphidius testaceipes* will be as great as it is in the United States.

The Little Black Ladybird, *Exochomus nigro-fasciatus*, is reported from the Soudan and it, no doubt, occurs in British East Africa. Several Aphid-eating Ladybirds have also been reported from the Soudan as being particularly beneficial in controlling an Aphid on Kaffir Corn.

Another point in favor of the ladybirds is that they will breed and will control Toxoptera at a lower temperature than Aphidius. All the stages are greatly retarded, however, by cold and the adults do not seem to lay eggs. It seems from experiments carried out that more Aphids are required per ladybird in their lives when it is cold than is the case at a warmer temperature. Larvæ of Adalia lived for about thirty-five days at a mean daily temperature of from 45 to 55 degrees and ate during that time 416 Aphids per larva, as compared with 319 in the summer time in a period of thirteen days. At a lower temperature, therefore, the larva eats only about half the number of Aphids per day, but feeds for about $2\frac{3}{4}$ times as many days.

Besides the ladybirds, one finds a Syrphid Fly (*Xanthogramma scutellare*) does considerable good in controlling Toxoptera. The Syrphid also incidentally destroys Aphidius by destroying Toxoptera which contain the eggs or larvæ of Aphidius. In no case, however, were they found destroying the parasitized forms of Toxoptera. A leaf which has been cleaned by Syrphid Fly larva will be found to have a few parasitized forms of Toxoptera remaining on it. This, however, would not be the case if the leaf had been cleaned by a ladybird or a ladybird's larva.

This Syrphid Fly is also retarded in its good work by a parasite Bassus laetatorius. This parasite very effectively controls the Syrphid Fly when the latter becomes very abundant in the field. The most beneficial work of this Syrphid was found to be in fields which were just becoming infested with Toxoptera migrating from some other place. This Syrphid seems to be the first to find the Aphids in their new home and commence the work of destruction, but as soon as the

Syrphids become overly abundant in the field, the parasites find them and they so reduce their number that they are of very little value.

In conclusion, it might be stated that the cause of a bad outbreak of Toxoptera in South Africa is due to the same causes as a bad outbreak in the United States. If the early winter months are abnormally cold, while the middle months of the winter are warmer than the average, followed again by a cold spring, there is a long period of from five to six months during which time Toxoptera breeds more rapidly than the ladybirds or Aphidius, the result being a bad outbreak of Toxoptera.

Another factor which sometimes tends to cause bad outbreaks is long periods of drought since, under such conditions, plants are not able to withstand the number of Toxoptera which normally they could carry without showing any ill effects, thus dying, not entirely from injury by Toxoptera, but, with drought as a secondary factor. If such land be irrigated, the plants are enabled to survive the attack.

REPORT ON PARASITES.

Dr. L. O. Howard.

The work on parasites and predatory enemies of the gipsy moth and brown-tail moth has continued along the same lines as during the previous year, except that no attempt has been made to import additional parasites this season. The material imported from Europe last year has been colonized and an effort has been made to determine the extent to which the species secured have established themselves in the field.

Owing to the fact that one of the imported egg-parasites of the gipsy-moth, *Anastatus bifasciatus*, breeds very slowly, extensive collections were made during last winter of parasitized gipsy moth egg-clusters from colonies that were planted in previous years. From this material it has been possible to liberate 1,500,000 parasites of this species, and these have been placed in 1,500 colonies in sections where the insect had not become established. Eight hundred colonies were planted in towns along the western border of infestation, and the balance were liberated in a number of towns in the northern part of Massachusetts. During November of this year collections were made in New Hampshire in the colonies of Anastatus that were planted a year ago, and examination showed that these plantings were practically all successful although the spread has been slow. From these collections about 100,000 parasitized eggs were secured and will be used for colonization in New Hampshire next spring.

Investigations have shown that another egg-parasite of the gipsy moth, namely *Schedius kuvanæ* has become perfectly established in several colonies where it has previously been planted. During the past year there has been a decided increase in the abundance of this parasite, and in some cases it has spread nearly a mile and a half from the limits of its last year's spread. The parasites attacking the caterpillars of the gipsy moth have been found more abundantly than during the previous year.

Compsilura concinnata, a species of Tachinid fly, was very abundant during the summer of 1912, especially in the territory which was longest infested by the gipsy moth, and

continued to spread during the past summer. It has not been so abundant in the oldest infested territories as in some of the outlying colonies. Collections of more than eleven hundred gipsy moth caterpillars made in four towns in central Massachusetts show a parasitism by this species of over 40 per cent, while similar collections in the central infested area have indicated an average parasitism of about 5 per cent. It is probable that the decrease in parasitism in the old infested area, as far as this species is concerned, is due to the fact that gipsy moth caterpillars are not nearly as abundant as they were during the previous year, and also because of the enormous numbers of the American tent and forest caterpillars which were present in this region and which are also attacked by this parasite.

Limnerium disparidis and *Apanteles* species were received from Europe for the first time in 1911 and were planted in several badly infested gipsy moth colonies. Both species were recovered during the summer of 1912, which indicated that it is possible for the insects to withstand our cold winters. In the case of the latter species, as high as 7 per cent of parasitism of gipsy moth larvæ was found. The present summer the Limnerium was recovered from a single locality where the species was liberated in 1911. Although it has evidently become established, it has not thus far shown marked ability to increase in the gipsy moth infested area in New England.

Another species of Apanteles, namely *A. lacteicolor*, an important parasite of the brown-tail moth caterpillars, has been recovered in large numbers and has been found to attack gipsy moth caterpillars in widely separated regions. This species seems to be multiplying more rapidly than any of the other Hymenopterous parasites of the gipsy moth. In order to colonize this species over as wide an area as possible, an arrangement was made with the State Entomologist in New Hampshire and the Superintendent of Moth Work in Maine to liberate as many colonies as possible along the outskirts of the area infested by the brown-tail moth in those states. Small collections of gipsy moth larvæ were made at Melrose, and in some cases ten per cent of the larvæ were killed by this species. In several localities in New Hampshire the past summer cocoons of this parasite were very abundant, and

several hundred were easily collected for experimental work. They were taken for the most part on the foliage of trees and attached to dead caterpillars.

The Calosoma beetle (*Calosoma sycophanta*) has been observed in large numbers in towns where bad colonies of the gipsy moth were present. It has not been possible to obtain definite records of the amount of benefit derived from this species or of its abundance, except in cases where trees were burlapped, as these bands furnish favorable hiding places for the caterpillars and are favorite locations for the beetles and larvæ to obtain food. In such cases, where caterpillars were abundant, twenty or more of the Calosoma larvæ have frequently been found under a single burlap band on an average sized tree. As they feed upon the pupæ as well as upon the caterpillars, the amount of benefit derived is very great, although it is difficult to figure the percentage of larvæ killed.

From collections made during the winter of 1912-13 it was determined that *Monodontomerus aereus* has spread over practically the entire territory now known to be infested by the brown-tail moth. It was not found in as large numbers as during the previous year. *Pteromalus egregius* has been found widely scattered over the area infested by the brown-tail moth, and its numbers are slowly increasing, judging from the records that have been secured from sample collections.

There is thus no doubt that a number of the imported species are thoroughly established and that they are increasing each year, and further that many hundreds of thousands of caterpillars were killed by them during the past summer.

NOTES ON SOME OLD EUROPEAN COLLECTIONS.

By H. T. Fernald, Amherst, Mass.

There seems to be little on record in this country about the older European collections of insects. Possibly the facts are more or less common knowledge, but if so, a rather careful search has failed to produce much of value. Yet in these days when types are coming into such prominence as the "court of last resort" in our attempts to finally establish specific identities, the location of these collections, their state of preservation and any facts which may enable workers to find the specimens they desire to examine, should be on record. The following notes are therefore offered in the hope that they may be of some use at least, to those who expect to study abroad.

The collection of Linné as including the first insects to which the binary nomenclature was applied, is of much interest.

This collection appears to be now in part at Upsala and in part at London. The material at Upsala was for many years at the royal castle Drottningholm, but in 1803 what remained was sent to the Academy of Science at Upsala by Gustav Adolph IV, where it was arranged and labelled by Linnaeus' student, Thunberg. This was probably the portion which constituted the collection belonging to the Queen of Sweden, and of which Clerck illustrated the Lepidoptera in his Icones Insectorum, and to judge from this, and such statements as are available, consisted only of Lepidoptera.

In the zoological museum of the University of Upsala are two wooden cases of Linnaean Hymenoptera which have recently been examined by Schulz (Berl. Ent. Zeits., LVII, 55, 1912), and reported upon.

Linné's private collection was sold by his wife after the death of her son in 1783, to Dr. James E. Smith, of England, for one thousand guineas. It consisted of his books, correspondence, insects and plants, and reached London in 1784.

In 1788, due largely to the influence of Smith, the Linnaean Society was established, and this material is now in charge of this society which is located at Burlington House, Piccadilly,

London. It is kept in the original case, in which are drawers containing the insects, while others contain the plants and books. Smith long retained the collection and being a collector, received many specimens from friends. These it would seem, he placed in the drawers with the Linnaean specimens, so that as it now stands, the collection contains many specimens not properly belonging with the Linnaean material. This unfortunate condition is liable to cause confusion in any examination, as the Linnaean specimens can only be distinguished by the handwriting on the labels.

The work of Fabricius can be found in a number of collections in Europe. His personal collection is in the Zoological Museum of the Univeristy of Kiel, but he made numerous visits to different museums, naming the insects where he went, and many of these are still in existence.

At Kiel his collection is in glass-topped trays, the tops being loose in many cases. The trays are in two large cases, one occupied almost entirely by beetles, while the Hymenoptera and some other orders fill the other.

The two groups named, at least, are in fair condition, and the Hymenoptera are arranged to correspond with the Systema Piezatorum. Each genus has a special label, bearing besides the name, the number of the genus, as given in the Systema, and each species is preceded by a similar label giving the name and number of the species. In some cases the insect itself is missing though the label is present, and some numbers are also absent, probably because the book enumerated species he had seen and described, but which he himself did not have.

Probably the next largest collection of Fabrician material is now in the British Museum of Natural History in London, and is known as the Banksian Collection. This material was obtained by Mr. (afterwards Sir Joseph) Banks and Dr. Solander, who accompanied the celebrated Captain Cook in his voyage to the South Sea Islands and around the world, from 1768 to 1771. It was studied by Fabricius between 1772 and 1775 and the new species were published by him in 1775 in his Systema Entomologiæ and are indicated by the words "*Mus. Bankianum,*" or in his later writings by the words "Mus. Dom. Banks." This collection was for years in the hands of the Linnaean Society, but is now in the British Museum

where most fortunately it is preserved as a separate collection bearing the original Fabrician labels, thus giving us Fabricius' ideas of the old species even where they are not his types.

They have been worked over somewhat since, not always fortunately, and some care must be exercised to be sure of all the labels. Thus Frederick Smith in his Catalogue of the Hymenopterous Insects in the British Museum records *Sphex pensylvanicus* L. as being in this collection. An examination of the specimen shows the unquestionable Fabrician label "*pennsylvanica*" and above it a much more recent label, "Pennsylvania" written by Smith, to judge from the hand writing. So close to the underside of the body as to be easily overlooked, is a third and very old label reading "Nov. Holl." Now as Captain Cook on the voyage during which these insects were collected, did not touch at any point in North America, it is evident that Fabricius named the insect entirely from its appearance, without reference to the locality where it was captured, and Smith, probably failing to notice the upper label, added a locality label of his own preparation to agree with the name. An interesting feature of the case is that Fabricius wrongly identified the specimen, which is not *pensylvanica* at all, but *fumipennis* of Smith, described by the latter from other material, in the same book in which he records this insect in the Banksian collection, evidently failing to recognize the identity of the two. An occasional case like this indicates that care in the study of this collection is indispensable.

The National Museum at Paris also contains some specimens named by Fabricius. What remains of the Bosc collection is there, and Fabricius frequently records species from the "Mus. Dom. Bosc." which apparently came into the hands of the National Museum at the death of Bosc in 1828. This material is much scattered, however, and can only be recognized by labels in the hand of Fabricius and the others which read "Museum Paris Coll Bosc 1828" printed on green paper and which were undoubtedly added when the collection became the property of the Museum.

The collection of Klug is in the Zoological Institute of the University of Berlin. It is not kept separate but has been worked into the general collections and can now be recognized only by the labels. These are on green paper and bear the

specific name, beneath which is a capital N and at the bottom the locality, all enclosed by a black line. Frequently the middle of the left side of the label has a slit cut in, so that it might slip around the pin instead of being penetrated by it. In some cases the label has been closely trimmed, but comparison of the writing with that on the entire ones, is sufficient to establish its identity.

Klug seems to have been more liberal with names on museum specimens than with published descriptions of these species, at least in the Hymenoptera. Apparently later workers in some cases found the names Klug had given to the specimens and published them, adopting names which would otherwise have no standing. Erichson seems to have done this in one case at least, and Dahlbom in several.

Though the collection of Dahlbom is at the University of Lund, his work is to some degree in evidence at Berlin where he studied for a time with Klug, and specimens named by him are frequently met with there. His own collection at Lund is kept by itself in the condition in which he left it and for the most part in a good state of preservation.

In the Paris Museum a few specimens which seem to have been labeled by Latreille are still preserved. These labels have double red line borders and the names which are hand-printed are, first the French name, and beneath this the Latin one, the two being bracketed together on the right, beyond which is the abbreviation "Latr." In some cases at least, these names do not appear to have been published and therefore have no standing.

A few boxes of Hymenoptera in this collection are marked "Brullé Collection" on the outside, so that some of Brullé's species at least, are still in existence.

The Lepelletier collection is in much the same condition and some boxes bear the label "Lepelletier Collection." In these the material named by him is probably indicated by names written in red ink between parallel red lines on the labels. Unfortunately many of his species are missing, and in the case of the *Sphecidæ* none of his American species can be found. Whether they have been accidentally destroyed, or, most of them being from Serville, were returned and later were lost, cannot now be determined.

Though not one of the old collections, that of Achille Costa may be mentioned. This is now at the University of Naples, where it is kept in a room by itself. There is no entomologist at the University and the collection is in charge of the Professor of Parasitology, but it is in excellent condition and apparently well cared for.

Many other old collections may be found in different parts of Europe, but not having paid particular attention to them they are not touched upon here. It is noticeable nearly everywhere that these collections are for the most part kept in trays so open that in this country a single year would probably see their complete destruction by museum pests. These nuisances do not appear to be very important abroad or the priceless collections of Linne, Fabricius and others would long ago have become mere heaps of dust at the bases of the pins.

Discussion.

Dr. Howard said in discussion that there is so much of value in information of the character of that contained in Dr. Fernald's paper, that he was emboldened to add two statements: First, that the bulk of the collection of A. H. Haliday, the brilliant Irish entomologist, is now carefully preserved by Prof. G. H. Carpenter in the College of Agriculture, in Dublin; Second, that the Ratzeburg types are preserved like religious relics by Dr. Eckstein at the forest school at Ebersiwalde bei Berlin.

THE ENTOMOLOGICAL SOCIETY OF AMERICA.

Organized 1906.

Officers for 1914.

President.

Philip P. Calvert.....University of Pennsylvania, Philadelphia, Pa.

First Vice-President.

James G. Needham.....Cornell University, Ithaca, N. Y.

Second Vice-President.

C. Gordon Hewitt.....Dominion Entomologist, Ottawa, Canada.

Secretary-Treasurer.

Alex. D. MacGillivray.....University of Illinois, Urbana, Ill.

Additional members of executive committee.

Herbert Osborn, Ohio State University, Columbus, O., *ex officio.*
Willaim M. Wheeler, Harvard University, Cambridge, Mass.
Vernon L. Kellogg, Leland Stanford Jr. Univ., Stanford Univ., Calif.
Nathan Banks, United States National Museum, Washington, D. C.
E. P. Felt, State Entomologist, Albany, N. Y.
J. M. Aldrich, U. S. Bureau of Entomology, Lafayette, Ind.

Committee on nomenclature.

H. T. Fernald, Massachusetts Agric. College, Amherst, Mass., 1914.
E. P. Felt, State Entomologist, Albany, N. Y., 1915.
T. D. A. Cockerell, University of Colorado, Boulder, Col., 1916.

Councilors for the American Association for the Advancement of Science.

Philip P. Calvert, University of Pennsylvania, Philadelphia, Pa.
Charles J. S. Bethune, Ontario Agric. College, Guelph, Ontario.

Editorial board of Annals.

Herbert Osborn, Managing Editor, Ohio State Univ., Columbus, O.
J. H. Comstock, Cornell University, Ithaca, N. Y., 1914.
Charles J. S. Bethune, Ontario Agric., College, Guelph, Ontario, 1914.
C. W. Johnson, Boston Society of Natural History, Boston, Mass.,1914.
Vernon L. Kellogg, Leland Stanford, Jr., Univ., Stanford Univ., Cal., 1914.
L. O. Howard, Chief, Bureau of Entomology, Washington, D. C., 1914.
W. M. Wheeler, Harvard University, Cambridge, Mass., 1914.
Philip P. Calvert, University of Penn., Philadelphia, Penn., 1914.
J. W. Folsom, University of Illinois, Urbana, Ill., 1914.

RESOLUTIONS.

On the Death of Philip Reese Uhler.

Dr. Philip Reese Uhler, L. L. D., Provost of the Peabody Institute, Baltimore, Maryland, died October, 21, 1913.

Dr. Uhler was an honorary fellow of the Entomological Society of America, one of the first to be distinguished by such election and was recognized as one of the most eminent entomologists of the country. His contributions, especially to our knowledge of the Hemiptera, were of great extent and form the basis for the study of this group in America and have had no small influence upon the development of the subject in the world at large. They will stand as an enduring monument to his industry, skill and keen insight as a systematist.

Along with the high qualities of his scientific work he had a most engaging personality and his memory will be cherished by all who had the good fortune to secure his friendship.

He was a man of true scientific spirit and enthusiasm, a lover of the fields and woods, an expert collector, and most generous in his aid to his fellow workers.

Recognizing the permanent value of his contributions to entomology and also the high character and worth of the individual, the members of the Entomological Society of America desire to place on record in an enduring manner its sense of appreciation for the man and his work and it is hereby resolved that this testimonial be spread upon the minutes of the Society and printed in the Annals.

Committee Herbert Osborn
Philip P. Calvert,
J. H. Comstock.

PHILIP REESE UHLER, LL. D.

PROCEEDINGS OF THE ENTOMOLOGICAL SOCIETY OF AMERICA.

Atlanta Meeting.

The Eighth Annual Meeting of the Entomological Society of America was called to order by Dr. Philip P. Calvert in the absence of the President, Rev. Charles J. S. Bethune, at 10:00 A. M., Tuesday, December 30th, in the rooms of the Physiological Department of the Atlanta Medical College. In calling the meeting to order Dr. Calvert conveyed to the Society Dr. Bethune's deep regret at being unable to be present and his hearty good wishes for its success. The meetings were all well attended, the number was surprising considering Atlanta's isolation from great educational centers. The following committee, appointed by President Bethune, was named:

Committee to draft resolutions on the death of Dr. Philip Reese Uhler.—Herbert Osborn, J. H. Comstock, and Philip P. Calvert.

The chair was directed by motion to appoint the following committees: Committee on Resolutions; Committee on Nominations; Auditing Committee.

The following papers were then read, but through the action of the Executive Committee that all abstracts should be omitted from the proceedings, only titles are given:—

J. T. Lloyd, Cornell University—The structure of the hind intestine of *Corydalis*.

Paul S. Welch, Kansas Agricultural College—Observations on the habits and life-history of *Hydomyza confluens* Loew. Read by title.

Stanley B. Fracker, University of Illinois—New characters in the classification of microlepidopterous larvæ.

Cornelia F. Kephart, Cornell University—The poison glands of *Euproctis chrysorrhoea* Linn. Presented by W. A. Riley.

N. L. Partridge, University of Illinois—The tracheation of the anal area of the wings of the Lepidoptera and the homology of the veins. Read by title.

Herbert Osborn, Ohio State University—The box-elder bug in Ohio.

V. E. Shelford, University of Chicago—The elytral tracheation of the subfamilies and genera of Cicindelidæ.

Edna Mosher, University of Illinois—Some interesting structures in the pupæ of Lepidoptera.

W. A. Riley, Cornell University—Some sources of error in the interpretation of insect tissue.

J. S. Houser, Ohio Agricultural Experiment Station—*Conwentzia hageni* Banks, life-history notes and variations in wing venation.

Alvah Peterson, University of Illinois—Notes on the head-structures of Thysanoptera. Read by title.

Philip P. Calvert, University of Pennsylvania—The desirability of a biographical dictionary of entomologists.

The President announced the following Committees:—

Committee on Resolutions—F. L. Washburn, Henry Skinner, and J. G. Sanders.

Committee on Nominations—W. A. Riley, P. J. Parrott, and G. M. Bentley.

Auditing Committee—T. J. Headlee, H. T. Fernald, and R. H. Pettit.

The Society then adjourned to meet at 2:00 P. M. The afternoon was devoted to a joint meeting of Section F of the American Association for the Advancement of Science and of the Entomological Society of America at which the following papers were presented:—

L. O. Howard, United States Entomologist—Note on the present status of the Gipsy Moth parasites in New England.

E. L. Worsham, State Entomologist of Georgia—Some notes regarding the natural history of the mole cricket.

H. T. Fernald, Massachusetts Agricultural College—Notes on some old European collections.

P. J. Parrott, W. O. Gloyer and B. B. Fulton, New York Agricultural Experiment Station—Studies on the Snowy Tree-cricket, *Oecanthus niveus*, with reference to apple bark diseases. Presented by P. J. Parrott.

J. Chester Bradley, Cornell University—Collecting insects in the Okefenoke swamp. Presented by J. G. Needham.

Herbert Osborn, Ohio State University—Studies on the geographical distribution of leaf-hoppers, especially of Maine.

Philip P. Calvert, University of Pennsylvania—The fauna of the epiphytic bromeliads in Costa Rica.

The Society adjourned at 4:45 P. M., to meet Wednesday, December 31st, at 9:30 A. M.

The annual business meeting of the Society was held upon reconvening and the following reports were presented:—

The committee appointed to draft resolutions on the death of Dr. Philip Reese Uhler presented its report. It was ordered accepted and printed.

The Secretary presented the following report for the Executive Committee, which met at the Hotel Ansley, Tuesday evening. Dr. W. M. Wheeler and Dr. Henry Skinner were named as additional members of the committee. Dr. Skinner sat with the committee.

REPORT OF THE EXECUTIVE COMMITTEE.

The following matters were considered in the interim since the last Annual Meeting:—

The appointment of Dr. E. P. Felt to give the Annual Public Address at the Atlanta meeting.

A request from the Secretary that the President be given permission to call for the election of a sufficient number of persons to make a quorum of the Executive Committee at the Atlanta meeting in case there were not four members in attendance.

Mr. Nathan Banks presented a request from the International Committee on Nomenclature of the Second International Congress of Entomology, that this society should name two members to serve on the American National Committee. President Bethune named as representatives, Dr. E. P. Felt and Dr. H. T. Fernald.

Mr. A. W. Baker, Secretary of the Entomological Society of Ontario, presented a request that the Entomological Society of America should send a delegate to its Jubilee meeting, the fiftieth annual meeting, to be held at the Ontario Agricultural College, Guelph, Wednesday, Thursday, and Friday, August 27 to 29. The President named the Secretary as the representative of the Society. Your Secretary had the pleasure of attending these meetings. He had the most delightful time, intellectually and socially, of any scientific meeting that he has attended. There were delegates present from England, Scotland, United States, and Canada.

The following new members were elected June 1, 1913:

W. C. Allee.	David Gunn.
Frank M. Gibson.	H. A. Horton.

The following members have died during the year:

D. F. Berrenger.	Charles W. Hooker.
A. G. Hammar.	J. M. Shaffer.

P. R. Uhler.

The following resignations were presented and accepted:

Otto Bucholz.
Fred Johnson.
C. A. Shull.
P. E. Smith.
R. I. Smith.
Anna C. Stryke.
A. G. Vestal.

The names of thirteen members were dropped from the rolls for non-payment of dues.

The following new members were elected by the Executive Committee at its meeting last evening:—

L. C. Barber.
G. T. Bethune-Baker.
S. W. Bilsing.
M. W. Blackman.
Josef Bruner.
R. E. Campbell.
Leroy Child.
E. S. Cogan.
W. M. Davidson.
G. A. Dean.
H. F. Dietz.
W. D. Edmonston.
W. O. Ellis.
J. B. Gill.
J. E. Graf.
T. E. Holloway.
J. R. Horton.
H. L. Johnson.
Cornelia F. Kephart.
R. J. Kewley.
F. H. Lathrop.
Philip Luginbill.
F. L. McDonough.
R. S. McDougall.
J. R. Malloch.
W. M. Mann.
E. A. McGregor.
Ximena McGlashan.
J. D. Mitchell.
L. J. Nickels.
F. B. Paddock.
Phil. Rau.
E. A. Richmond.
L. P. Rockwood.
James Sinclair.
M. P. Somes.
Dayton Stoner.
D. T. Stevens.
T. J. Talbert.
J. D. Tothill.
C. T. Vorhies.
Otis Wade.
J. R. Watron.
H. B. Weiss.
G. M. Wendelken.
F. X. Williams.
T. S. Wilson.
H. P. Wood.
W. C. Woods.
M. A. Yothers.

The total membership of the Society as reported at the Seventh Annual meeting was 410, deducting the names of the persons who have died during the year, resigned, or dropped by the Secretary and adding the names of the new members elected in June and at this meeting, the membership is now 439.

The Secretary was instructed to prepare a small booklet describing the origin of the Society and its aims, as an aid in further extending the membership.

The first suggestion of a national entomological society was presented at the last Philadelphia meeting in 1904, of the American Association for the Advancement of Science. Dr. Henry Skinner was asked by the Executive Committee to prepare a history of the Entomological Society of America to be read at the Eighth Annual Meeting.

TREASURER'S REPORT.

RECEIPTS.

Cash on deposit in the First National Bank of Champaign, Illinois, December 9, 1912	$ 40.87
Life Membership Fees deposited with the Cleveland Trust Company, Cleveland, Ohio, September 18, 1912	100.00
Life Membership Fee of W. T. M. Forbes deposited with the Cleveland Trust Company, of Cleveland, Ohio, September 18, 1913	50.00
Interest on Fees of Life Members, July 1, 1913	4.37
Cash received from Herbert Osborn, Managing Editor of the Annals	252.86
Cash collected as dues	726.09
	$1,144.19

BALANCE.

Bills paid:		
Annals and separates for December, 1912	$377.47	
Annals and separates for March, 1913	332.25	
Engraving bills paid by the Treasurer	66.09	
Stamps and Stamped envelopes	27.62	
Printing for the Secretary-Treasurer's office	28.03	
Stenographer	20.25	
One-half guarantee on Cleveland smoker	3.67	
Check refused by bank	2.00	
		$857.38
Life Membership Fees deposited with the Cleveland Trust Company, Cleveland, Ohio, December 8, 1913		150.00
Interest on Fees of Life Members deposited with Cleveland Trust Company, Cleveland, Ohio, December 8, 1913		4.37
Cash on deposit in the First National Bank of Champaign, Illinois, December 8, 1913		132.44
		$1,144.19

Dr. C. Gordon Hewitt, Provincial Entomologist of Canada and Dr. William Barnes, Lepidopterist of Decatur, Illinois, were elected Fellows of the Society.

It was voted, that in the future no abstracts of the papers presented at the Annual Meeting should be included in the printed proceedings of the meeting.

The following amendment to Article IV, Section 2 of the Constitution was recommended, which reads:

Article IV, Section 2. The business of the Society not otherwise provided for shall be in the hands of an Executive Committee, consisting of the officers named in Section 1, and of six additional members, five of whom shall be elected from the Fellows by the Society, and the sixth shall be *ex officio* the Managing Editor. Four members of the Committee shall constitute a quorum.

To be amended to read:

Article IV, Section 2. Executive Committee.—The business of the Society not otherwise provided for shall be in the hands of an Executive Committee, consisting of the officers named in Section 1, and of six additional members, five of whom shall be elected from the Fellows by the Society, and the sixth shall be *ex officio* the Managing Editor.

There shall be a meeting of the Executive Committee at each Annual Meeting. Four members shall constitute a quorum and in the case of the non-attendance of this number at any Annual Meeting, the Society shall elect a sufficient number from among the Fellows in attendance to complete the quorum.

On motion the report of the Executive Committee was adopted.

REPORT OF THE MANAGING EDITOR OF THE ANNALS.

The Editor begs leave to report for the past year the following items:

RECEIPTS.

Subscriptions	$170.60
Back Numbers	81.91
Authors Reprints	70.00
	$323.11

EXPENDITURES.

Engravings	$52.80
Postage	9.65
Stenographic Help	7.80
Paid Treasurer	252.86
	$323.11

The volume for the year, which includes about five hundred pages and fifty-nine plates, will I believe maintain the quality of preceding volumes and it has been necessary to postpone or refuse other papers of excellent quality because of the lack of funds for further publication. It is hoped that the income for the coming year will permit the handling of a number of these papers but the Editor believes that the amount printed should be kept within the margin of receipts and if possible no deficit be created. The sale of a few sets of back volumes would assist much in the publication of additional matter and any assistance in placing such sets will be very much appreciated.

The Editor desires to express his appreciation of the aid rendered by the members of the Editorial Board, and to the Secretary for his untiring efforts in attending to the details of the business falling to his office.

Respectfully submitted,

HERBERT OSBORN,
Managing Editor.

REPORT OF THE AUDITING COMMITTEE.

Your Auditing Committee presents herewith its report. We have examined the books of the Treasurer for the year ending December 8, 1913, and find them to be correct. We have also examined the accounts of the Managing Editor of the Annals and find them to be correct.

Signed, THOMAS J. HEADLEE,
H. T. FERNALD,
R. H. PETTIT.

REPORT OF THE COMMITTEE ON NOMINATIONS.

Your committee begs leave to report the following names as nominees for the respective offices for 1914:—

OFFICERS.

President: Philip P. Calvert, University of Pennsylvania, Philadelphia, Pa.

First Vice-President: James G. Needham, Cornell University, Ithaca, N. Y.

Second Vice-President: C. Gordon Hewitt, Provincial Entomologist, Ottawa, Canada.

Secretary-Treasurer: Alex. D. MacGillivray, University of Illinois, Urbana, Ill.

ADDITIONAL MEMBERS OF EXECUTIVE COMMITTEE.

Herbert Osborn, Ohio State University, Columbus, Ohio, *ex officio.*

William M. Wheeler, Harvard University, Cambridge, Mass.

Vernon L. Kellogg, Leland Stanford Jr., University, Stanford University, Cal.

Nathan Banks, United States National Museum, Washington, D.C.

E. P. Felt, State Entomologist, Albany, N. Y.

J. M. Aldrich, United States Bureau of Entomology, Lafayette, Ind.

MEMBER OF COMMITTEE ON NOMENCLATURE.

T. D. A. Cockerell, University of Colorado, Boulder, Colorado.

Signed, W. A. Riley,
P. J. Parrott,
G. M. Bentley.

On motion, the Secretary was instructed to cast a ballot for the officers named and they were declared elected.

REPORT OF THE COMMITTEE ON RESOLUTIONS.

The Committee on Resolutions beg leave to submit the following:—

Resolved, That the Entomological Society of America hereby express their appreciation of the various courtesies extended to them at this meeting by the city of Atlanta, by Governor and Mrs. Slaton, by the University and Capital City clubs, by the Atlanta Medical College, and by the local Press.

Resolved, That its thanks are also due the Atlanta Chamber of Commerce for its hearty co-operation with the University Club and the Atlanta Convention Bureau through whose efforts the meeting at Atlanta was made possible; and further

Resolved, That our thanks are especially due and are hereby extended to the local Executive Committee and Mr. E. L. Worsham for their painstaking and effective efforts in behalf of the convention.

Signed, F. L. Washburn,
Henry Skinner,
J. G. Sanders.

The Committee on Nomenclature presented an informal report which was ordered accepted.

REPORT OF THE COMMITTEE ON ENTOMOLOGICAL TYPES.

One of us (Cockerell) examined the collections of the U. S. National Museum and the Carnegie Museum during the year. The types, so far as seen, were found in excellent condition, but not all in systematic order or available for study and comparison without some searching. We know of no museum in which the entomological staff is really adequate. At the Carnegie Museum one is amazed at the richness and value of the collections, including materials which have been described in many important memoirs, and enormous numbers of specimens not yet worked over, but evidently including much of interest. The entomological curator has succeeded in keeping everything in good condition, but it would take a considerable staff of workers to put the collections all in order and keep the accessions worked up. At the U. S. National Museum one finds a large staff of well-known entomologists, many of whom work over time and on holidays in the effort to keep the collections in order and work up the accessions. However, the appearance of an adequate entomological staff is illusory, since nearly all of the men belong to the Bureau of Entomology of the Department of Agriculture, and have to give their attention to economic problems and routine work of various kinds. Judging by the large amount of published work issued from the Museum, one might suppose the number of workers to be sufficient, but this idea is soon dispelled on examining the very large and important collections remaining unstudied and noting the continued stream of accessions. The scientific staff of the National Museum is inadequate in almost all departments, but especially in Entomology, a subject which covers a much greater and more important field than the public imagines. The type problem becomes part of the general problem of securing adequate and competent curatorial assistance; not only for the proper care and availability of the types already owned by the Museum, but also and especially in regard to obtaining other types. The study and description of the new species now in the Museum would add thousands of types to the collection; while many private workers would give or leave their types to the institution, were entomology treated by Congress and the authorities as it deserves.

We think, therefore, that all entomologists should make a point of urging, whenever possible, the claims of their science to a larger share of support in important Museums. In doing this, they may properly point out the astonishing revelations of recent years in regard to the importance of various insects to man, showing that a knowledge of entomology is of prime importance for the progress of civilization. They may also point out that in the case of large public museums, all the major expenses have been met, and it is only necessary to add a comparatively small amount to greatly increase the scientific output.

Several workers in the National Museum recently agreed with the suggestion that 5% of the total expenditure on the Museum, added to the cost of maintaining the scientific departments, would double the scientific out put.

Signed, T. D. A. Cockerell,
L. O. Howard,
Henry Skinner.

On motion, the report was ordered accepted and printed and the Committee continued for another year.

REPORT OF THE SPECIAL COMMITTEE ON HOLDING A SUMMER MEETING ON THE PACIFIC COAST IN 1915.

Your committee desires to report that there seems to be a strong sentiment in favor of holding a summer meeting on the Pacific coast in 1915.

It finds the officers of the Panama-Pacific International Exposition willing to co-operate in every reasonable manner, and it is informed that the meeting can be held on the exposition grounds or at either Stanford University or at the University of California. One member of the Committee suggests the desirabliity of a group of entomologists traveling together and arranging to have a field meeting at some Rocky Mountain point. There would probably be no difficulty in arranging for the necessary stop over privileges.

The western entomologists will be enthusiastic supporters of such a gathering and it should be attended by a number of eastern men. We feel it highly desirable to have such a meeting and therefore recommend that arrangements be consumated. We respectfully suggest including in the nominations for 1915, at least one vice-president who would be in position to serve as chairman of the meeting in case a president was unable to attend.

Signed, E. P. Felt, W. M. Wheeler,
V. L. Kellogg, T. D. A. Cockerell,
A. J. Cook.

On motion, the report was ordered accepted and printed and the committee was ordered continued as a Committee on Arrangements with the addition of Dr. E. C. Van Dyke of the University of California.

The following amendments to the Constitution submitted at the Cleveland meeting of the Executive Committee were read:—

Article IV, Section 3. The President shall represent the Society upon the Council of the American Association for the Advancement of Science until such time as the Society shall be qualified for representation by two councilors, in which case the second councillor shall be elected from the Fellows by the Executive Committee.

To be amended to read as follows:

Article IV, Section 3. Councillors to the American Association. The President and the preceding Past-President shall represent the Society upon the Council of the American Association for the Advancement of Science. In case of the death or resignation of either or both councillors, the vacancy shall be filled by the Executive Committee.

Article V, Section 3. Election of Officers. All officers shall be elected by ballot at the Annual Meeting for the term of one year and shall be eligible for re-election. The term of their office shall commence with the first of June following their election.

To be amended to read as follows.

Article V, Section 3. Election of Officers. All officers shall be elected by ballot at the Annual Meeting for the term of one year and shall be eligible for reelection.

On motion, the amendments were adopted.

The Executive Committee at the Cleveland meeting submitted the following addition to the Constitution:

ARTICLE VII.

Section 1. Publication.—The official publication of the Society shall be known as the Annals of the Entomological Society of America. Each volume shall consist of four fascicles and the first fascicle of each volume shall contain the proceedings of the Annual Meeting.

Section 2. Editorial Board.—The publication shall be under the charge of an Editorial Board consisting of ten members, one of whom shall be the Managing Editor. The Managing Editor and his associates shall be responsible for the selection of the material to be published.

Section 3. Election of Editorial Board.—The members of the Editorial Board shall be elected by the Executive Committee. Each member of this board, excepting the Managing Editor, shall serve for three years or until his successor has been elected, three members retiring annually.

Section 4. Report Managing Editor.—The Managing Editor shall present a report at each Annual Meeting to the Executive Committee and the accounts of his office shall be reported upon by the Auditing Committee.

On motion, this additional article to the Constitution was adopted.

Mr. H. H. Lyman read a letter from President Bethune expressing his regret at being unable to be present at the meeting.

On motion, the Secretary was instructed to send a Night Letter to President C. J. S. Bethune, extending greetings from the Society, their pleasure on the recovery of his sight, and their regret at his inability to attend the meetings.

The following communication submitted to the Secretary by Mr. Nathan Banks was read:—

Inasmuch as there is no independant society in this country able to publish large works on Entomology, and since there are even now manuscripts awaiting printing, and with time there will be more, I suggest that the Entomological Society of America found such a society. This Society to be known as "The Thomas Say Society." Its object to publish catalogues, revisions, and monographs of North American insects. That it be authorized to solicit and collect money for a permanent fund, the interest on which shall be used for the printing of said works. That the Society shall be controlled by a board of five entomologists, chosen by the Executive Committee of the Entomological Society of America. Each member to serve five years, the first board to have one member for one, two, three, four, and five years, thereafter one selected each year. That all money received for sale of publications be added to the permanent fund. That said board of control shall select whatever officers they deem necessary and have authority for accepting articles for printing and disbursement of funds.

On motion, the President was directed to appoint a committee of three to consider ways and means for the establishment of such a society. The President appointed the following committee:—Nathan Banks, Chairman, H. H. Lyman, and Morgan Hebard.

The following papers were then read:—

James Zetek, Panama Canal Zone—The dispersal of *Musca domestica*.

William Moore, University of Minnesota—A comparison of the enemies of *Toxoptera graminum* in South Africa and the United States. Presented by F. L. Washburn.

Robert Matheson, Cornell University—Life-history notes on *Psephenus lecontei* and *Hydroporus septentrionalis*. Read by title.

V. E. Shelford, University of Chicago—The sequence of color changes during ontogeny in *Cicindela*.

R. W. Leiby, Cornell University—Notes on the external anatomy of some Pentatomidæ.

L. S. Barber, Florida State College for Women—The biology of *Gelechia gallæsolidaginis* with some reference to some of its parasites.

A. F. Conradi, Clemson College—A little known wireworm, *Horistonotus uhleri.*

Leonard Haseman, University of Missouri—The life-history of a species of Psychodiæ. Read by title.

A. D. MacGillivray, University of Illinois—The Structure of the thorax in generalized insects.

James Zetek, Panama Canal Zone—Behavior of *Anopheles tarsimaculata* Goldi. Read by title.

J. T. Lloyd, Cornell University—Life-history of *Elophila magnificalis,* an aquatic lepidopteron. Read by title.

The following exhibits were shown:—

J. S. Houser, Ohio Agricultural Experiment Station—*Conwentzia hageni* Banks, a coniopterygid.

E. L. Worsham and J. Chester Bradley, Office State Entomologist of Georgia—Collections of Coleoptera and Odonata from Georgia belonging to Georgia State Board of Entomology.

J. Chester Bradley, Cornell University—Photographs of the Okefenoke swamp.

S. B. Fracker, University of Illinois—Setæ of microlepidopterous larvæ.

James Zetek, Panama Canal Zone—Blue-print upon which was shown the more important data obtained in the study of the behavior of *Anopheles tarsimaculata* Goldi.

The Annual Public Address of the Society was given on Wednesday evening, December 31st, at the Atlanta Medical College by Dr. Ephraim Porter Felt, State Entomologist of New York, on the Subject of Gall Insects.

A smoker for the entomologists and zoologists in attendance at the meetings was held at the University Club on Thursday evening January 1st, Mr. E. L. Worsham and the staff of the State Entomologists office acting as hosts.

On motion, the Society adjourned to meet in one year with the American Association for the Advancement of Science, at Philadelphia, Pennsylvania.

ALEX. D. MACGILLIVRAY,
Secretary.

NOTICE TO MEMBERS AND CONTRIBUTORS.

The Annals of the Entomological Society of America, published by the Society quarterly, includes the Proceedings of the Annual meetings and such papers as may be selected by the Editorial Board.

Papers may be submitted to any member of the Editorial Board and should be as nearly as possible in the form desired as final, preferably typewritten, and illustrations must be finished complete ready for reproduction. Plates must not exceed 5x7 inches unless intended to fold. In general, papers to be accepted must be original, complete and previously unpublished and, except in connection with the proceedings, it will not be the policy to publish preliminary announcements or notes. Authors will be allowed fifty reprints gratis and additional copies at cost to the Society.

The Managing Editor is provided with the most recent address of all members on record in the Secretary's office for mailing the numbers of the Annals and hereafter members complaining of the non-receipt of numbers must present their complaint to the Secretary within four months from the date of the mailing of the issue. After that time the numbers will be furnished only at the regular published rate.

Requests for information as to membership and the annual subscription and dues of members may be sent to the Secretary-Treasurer, A. D. MacGillivray, 603 Michigan Ave., Urbana, Ill.

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The regular annual subscription price for the ANNALS is in the United States, Cuba, Porto Rico, Hawaii and Mexico, $3.00; Canada, $3.50; other countries, $4.00. Checks, drafts or money orders should be drawn payable to ANNALS ENTOMOLOGICAL SOCIETY OF AMERICA, and addressed to Biological Building, State Univ., Columbus, Ohio, U. S. A.

Volume VII. Number 2.

ANNALS

OF

The Entomological Society of America

JUNE, 1914

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PUBLISHED QUARTERLY BY THE SOCIETY
COLUMBUS, OHIO

Entered as second class matter April 11, 1908, at the Post Office at Columbus, Ohio, under the Act of Congress of March 3, 1879.

The Entomological Society of America.

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A STRUCTURAL STUDY OF THE CATERPILLARS: III, THE SOMATIC MUSCLES.

Wm. T. M. Forbes, Ph. D., Worcester, Mass.

In consideration of the very few dissections of the muscular system of Lepidoptera which have been published, and their radically different interpretation, it has seemed advisable to study a few more forms and trace if possible the points of disagreement.

PREPARATION.

A serious matter in such a research is the preparation of material. The muscles are small and slender, quite difficult to trace without a good microscope and plenty of light, easily broken in dissection in hardened material, and almost perfectly transparent when fresh. Besides this they do not differ in color from the fat with which they are intermingled, and when preserved in formalin hardly differ in consistency. The most satisfactory material was opened out after killing with cyanide, and pinned out on a piece of cork; then treated with strong corrosive sublimate (bichloride of mercury) and dissected while immersed in a dilute solution of the sublimate. This makes the muscles intensely white, distinguishable from the fat by their silky luster; but the mercury attacks dissecting instruments badly and so most of the work was done with material preserved in formalin (4 per cent., that is, 10 per cent. of the commercial solution). Alcohol was also tried, and was nearly as good; the muscles being darkened

Smithsonian Institution
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a good deal in some cases, which made them more difficult to see in a dim light, but brought them out in contrast with the fat. For the work with the thorax it is important to open up the caterpillar and pin it out before hardening, as otherwise many of the muscles will be broken. If specimens are to be preserved whole for dissection purposes they should be killed in hot water, or injected with a stronger solution of preservative to prevent decay. The prothorax and last segment are particularly hard to get in a satisfactory condition, because of their peculiar shape, and the close connection of the former to the head, which should be split vertically when opening the caterpillar. It is most convenient to open the caterpillar near, but not quite on the middorsal line.

The viscera and loose fat of the body cavity are removed as a preliminary, as well as the wings of the heart, leaving the heart, trunk trachea and nervous system as long as possible for landmarks. The dissection can follow the order given by Lyonet, to advantage, but it is often unnecessary to open any specimens by the venter, as the dorsal musculature is comparatively simple, and is often uninjured on one side. Plate XIX follows this order fairly closely in its six stages, but in other plates less stages are shown for economy.

It soon appeared that the muscles represented by Lyonet, for the Goat moth caterpillar, could be found in such widely divergent forms as a Sphinx, a Noctuid and a Lasiocampid, so his lettering is used in the figures. Lubbock's dissection was hardly as perfect, while Berlese's figures are wholly diagrammatic and useless for the study of homologies; in fact several of his comparisons with the muscles of other insects are invalid. We will only be able to come to a true knowledge of the homologies when the nerve-muscle relations are fully worked out; and in the Lepidoptera the matter is much confused by the anastomoses between all three pairs of nerves, and even between successive segments.

THORAX.

To go on to details; I have not made any satisfactory dissection of the *prothorax*. Evidently however, Lyonet represents the state of affairs much more accurately than Berlese. The dissection figured on Plates 1 and 2 may be taken as accurate so

far as it goes, but is incomplete. The following comparisons may be made between Lyonet's, Lubbock's and Berlese's lettering:

LYONET.	LUBBOCK.	BERLESE.
C^+	82	CXXXIXa
D, E	1, 4, 5	139–140
A	6, 7	140b
α	22	CXXXIX
G, H, I, L	61, 62	CXXXIV
β, γ, δ, etc.	35, 76, 80, 81	CXLI
a, b	16, 17, 21	CXXXII
ζ	19, 20, 26	CXXXIIa
c	18.	CXXXIIb
r, etc.	77	129
i, l, etc.	70, 71, etc.	147
u, v	57, 58	XL

The whole arrangement is complex and only in a general way comparable to that of the other segments. C^+ is interesting as extending well beyond the segment line, and in Cossus the length of two whole segments—being the longest muscle in the caterpillar. It also crosses the middle line in Cossus, but not in Noctua, where it is shorter. If Lyonet is correct there are no longitudinal muscles within the nerves, (except perhaps the aberrant A and C^+ which presumably represent the great longitudinal muscles of the following segments); and some of the muscles are innervated from the subœsophageal ganglion, evidently belonging to the cervical system. The spiracle is supplied by the "bride epiniere" or so called sympathetic fibre, derived from the same segment, but it runs largely in the following one and seem to supply also some of its muscles, besides anastomosing with its first nerve. This indicates strongly that the spiracle originally lay on the incisure, as the rudimentary second one actually does, and that it has moved forward. For the same reason we see that the other spiracles have moved back, being supplied by the nerve of the preceding segment; and all the spiracles are accounted for.

The *meso-* and *metathorax* are perfect counterparts of each other, and strongly contrasted with the other segments in structure. The few points of difference between them noted by Lyonet, are further reduced by the correction of a couple of misinterpretations, and particularly by treating the three bellies of his α as separate muscles. In discussing these, and the remaining segments we may use Berlese's division of the

segments into four annulets, illustrated on Plate IX, Figs. 1 and 2. These are the acro-, pro-, meso- and meta-tergites and sternites, separated by the antecosta, precosta and inter-costa. The tergopleural suture is indicated only by the position of the rudimentary wing, while the pleurosternal one is the strongly marked subventral fold, to which several muscles are attached. In the abdomen these boundaries are less distinct, but the pleurosternal suture can be traced in a general way, and the tergopleural must be placed at least a little higher, as indicated by the spiracle, which should lie within the pleuron. Of the true legs we have a well marked coxa, which is mostly membranous in the Sphinx, a strong femur, to which only one or two small somatic muscles are attached, and the rudiment of a trochanter, which bears the insertion of r. The insertion of the various muscles of the leg is beautifully shown by Lyonet, in Plate VIII, Fig. 7. In Cossus where the coxa is wholly chitinized k, n, p, s, t, u, v, x, ϵ, ϑ, κ, λ, μ, ν and ξ run to it. The body muscles may be divided as to their origin in the embryo into the dorsal and ventral longitudinal systems, and the lateral and ventral transverse ones; the last is not represented in the caterpillar by a developed muscle, but its rudiment may exist associated with the fork of the sympathetic nerve and the ventral diaphragm. This would be 4 of Berlese. The lateral transverse muscles are again divided into two sets, between which lies couple of longitudinal fibres (E of the abdomen) and the trunk trachea, but as the trunk trachea is not well developed in the thorax, and replaced by collaterals in the body cavity, the muscles must there be treated as a single unit. If we consider C, E and G as homologues of E, etc., of the abdomen θ will be the only fibre of the deep set in the thorax, as it is in the abdomen. It should be noted that the spiracles can migrate without disturbing these fibres, while the deep transverse fibres would have to be swept before them. The muscles also differ from each other in their normal or oblique direction, their length and their insertion. The table annexed classifies them, and gives the relations between meso- and metathorax, and between the various nomenclatures, omitting those muscles which puzzle me.

	LYONET		LUBBOCK	BERLESE	
	Meso-.	Meta-.		Meso-.	Meta-.
LONGITUDINAL DORSAL.					
Rectus (1)	A	A	1	70	37
	B	B	1	70	37
Oblique segmental	C	C	8	70b	37b
	E	E	8′		37c
	D	D	5	70a	37a
	F	F	5	70a	37a
	G, H	H	4		
	α (1st belly)	G	6, 7		
Shorter segmental	I	I			
To intercosta	K	K	61		
From precosta	L, M,	L,	9-11		
To precosta	S	S	62		
	T	T	63		
From intercosta	Q	Q	12, 13		
	R	R	14, 15		
To antecosta	λ (part)	λ (part)	64, 65 (part)		
INTRANEURAL (2)	c	c	18	+	
LONGITUDINAL VENTRAL, SUPRANEURAL					
Segmental	a	a	21	LXXII	XXX
	b	b	17	"	"
	–	d	(16)	"	"
	e, f	e	22	+	
	d	f	20	LXXII	XXX
	g	g	16 (19)	"	"
	h	h	23	"	"
To mid-ventral line behind coxæ	1	1	26	+	
LONGITUDINAL VENTRAL, SUBNEURAL					
To mid-line in front of coxæ	i	i		IVb (3)	
Crossed to front of coxa	k	k	24	IVa (3)	
Short anterior transverse (4)	z	z	25	+ (3)	
From mesosternite at mid-ventral line	n	n	28	+	
From precosta	m	α (3rd belly)	77		
Short fibres from leg	q	q	79		
	u	u	57	V=Iα	
	v	v	58	V=Iα	
TRANSVERSE; TO PLEUROSTERNAL LINE					
Antecosta to prosternite	β	β	49		
Precosta to precosta, superficial	δ	δ	49		
Precosta to prosternite, deep	ν	ν			
Precosta to mesosternite	μ	μ	72	XVIIIa (3)	
Antecosta to posterior incisure	ϵ	γ	66	XXXIVa	
Antecosta to mesosternite	λ	λ	70	XVII (3)	
	(posterior bellies)		65 (part)		
Intercosta to mesosternite	κ, ξ	κ, ξ	50	XVIIIa (3)	
Anterior incisure to precosta	γ	α (2d belly)	76		
To anterior incisure	η	η	40		XXXVIb
	w	w	41, 42		

	LYONET		LUBBOCK	BERLESE	
	Meso-.	Meta-.		Meso-.	Meta-.
ACROSS PLEUROSTERNAL LINE					
Intercostal region to leg	ζ, ϑ	$\epsilon, \zeta, \vartheta$	46, 51	5α (3)	5
Posterior incisure to leg	t	t	55	XVIIβ (3)	
Superficial on incisure	θ	θ	35	XXXVI	XVIIa
Deep on incisure	x	x	34, 38	XXXVIa	XVIIIa
BELOW PLEUROSTERNAL LINE					
To leg	s	s	78	IIα, 6a	
To near midventral line	p	p	73-75		
SPIRACULAR (rudiment)		π			

NOTES: (1) *Muscles droits* of Lyonet.
(2) Passing between the two longitudinal connectives.
(3) Fig. 478.
(4) Certainly derived from longitudinal muscles like k. In the mesothorax it tends to cross the middle line.
\+ Indicates that the muscle is represented but not named.

The wing is shown in the deepest layer of the dissection on Plate XVIII, in its normal position. The only fibres closely associated with it seem to belong to w and λ, practically all the pleural muscles being inserted far above it. Evidently the pleurites are very slightly developed in the caterpillar stage.

The *mesothorax* seems to differ from the metathorax as figured only in having a fibre or two more or less in the case of such homologous muscles as a, b, (d); β; Q. R. S and T. The union between thorax and abdomen is made with only a single disturbance of the musculature, aside from the fact that the ante- and precosta of the first segment of the abdomen are undeveloped; and that is that one head each of E and F have moved forward a short distance beyond the incisure, carrying with them a couple of fibres of θ, and attaching themselves to the insertions of G and t respectively.

MIDDLE SEGMENTS OF ABDOMEN.

One of the middle segments may be taken as typical of the abdomen. Examples of three families are figured on Plates XX, XXI and XXII. As compared with the thorax the most striking difference is the weak development of the oblique lateral muscles, and the absence of muscles that cross the median line; both conditions correlated with the simpler movements of this part of the body. Here also there are no such confusing cases as α of the thorax, where several morphologically widely separated muscles form a single functional unit. There is no

fibre piercing the nervous system, and no short dorsal anterior muscles, though it was probably such a muscle ventrally, that gave rise to p′, which is wholly independent of p and x, though not well marked in Cossus and Malacosoma. In the abdomen the principal nerve divides the ventral muscles quite centrally, forming the most satisfactory distinguishing character between the fibres f and g, and forming the most fundamental distinction between a and the other recti; the relation of the dorsal muscles is more obscure, as the nerve divides up, but A, B and C evidently lie above, and E, F and H below it. The transverse muscles are divided into two groups as already noted in the case of the thorax. The following classification of the muscles gives their designation by Lyonet, Lubbock and Berlese.

	LYONET	LUBBOCK	BERLESE
LONGITUDINAL DORSAL			
Rectus	A	1	VII
	B	3	"
	C	2	"
Segmental	D	4	"
	G	5	"
From antecosta, oblique	F(4)	8	X
	H	7	"
From antecosta to antecosta	E	6	IX
From precosta	I	9	XI
	L	10, 11	"
From intercosta	Q, R	12, 15	XVI
LONGITUDINAL VENTRAL, SUPRANEURAL.			
Rectus	c	18	2
	b	17	"
	d(3)	16	"
Antecostal, oblique	f′ (in Malacosoma only)		
Longitudinal segmental	e	20	2
	ff	19	"
To antecosta of following segment	f	25	IV
From antecosta, oblique	h	+	
LONGITUDINAL VENTRAL, SUBNEURAL.			
Antecosta to antecosta, longitudinal	a	21	III
	i	22	"
To antecosta of following segment, oblique	g	24	IV
Segmental, oblique	g′	25	2
From front of leg	k	27	1 aα
From near midventral line, between legs	p	28-30	1a
From posterior side of leg	t	57	V
From leg toward mid-ventral line	x	56, 58	1aβ (1)
From near mid-ventral line to leg	(p′)	46(part)	1aβ
SPIRACULAR	M	45	
TRANSVERSE SUPRATRACHEAL.			
Acrosternal	θ	35	XVII
At precosta	θ(2)	36	"

	LYONET	LUBBOCK	BERLESE
TRANSVERSE SUBTRACHEAL, *Above subventral fold.*			
From near incisure to precosta	α	37, 38	XVIII
Mesotergite to mesosternite	δ, ϵ	51, 52	XVIIIa
Crossing the pleurosternal line.			
Spiracle to precosta	1	39	5b
Propleurite to precosta	m(sometimes)	42	5b
	q(rarely)	40, 41	
Mesotergite to parts of leg	β, γ	46–50	5α, 5β
Short posterior muscles	ζ, y	33–34	XVIII
Below the pleurosternal line.			
Behind precosta	q, m	40,41(42)	5bα
Across leg in front	n	43	6α
Across leg behind (from ψ)	r	53–54	6β
From fold or ψ to leg	γ(part)		6aα
From fold or ψ to anterior edge of following segment	ζ(part)	31–32	
	z	55	XVIIIβ?

NOTES: (1) 1aβ in most forms, not distinct from V in *Cossus*, I on legless segments
(2) The fibre of θ which runs between the precostae is marked 4 on the plates; it is not well defined in *Cossus or Sphecodina*. Fibres of θ proper spread fan-like from the acrosternite to various points in the acro- and protergites.
(3) To antecosta of following segment in *Phœocyma*.
(4) From acrosternite in *Phœocyma*.

The muscles which attach to the ends of the segments are sharply divided into two groups, in the first, comprised of A, B, C, E, a, b, c, d, the muscles of successive segments are united, forming a single polygastric muscle, the remainder are so inserted to leave a distinct space between muscles of successive segments. In the case of D and i, the distinction is striking, as compared with A and a respectively.

NERVES.

There are three pair of nerves from each abdominal ganglion. The principal or anterior one runs almost directly out from the anterior half of the ganglion, passing over all the muscles near the midventral line, but soon plunging in (between a and c) and running between the layers up to the subdorsal region, where it ends in a longitudinal fibre, perhaps the chordotonal organ. It supplies but little of the skin, but sends off numerous branches to the muscles, especially the larger segmental ones. The second or posterior pair of nerves runs obliquely downward under i, passes between k and p, often forming the only distinction between these two muscles, and then ramifies in the crowd of short muscles connected with the proleg, and on the skin. The third runs directly back as a single nerve from the posterior end of the ganglion under the fused connectives,

until they separate, then forks, in the substance of the very slightly developed ventral diaphragm and runs out, often along the incisure, to the spiracle and from there to the tip of the wing of the heart; no muscles overlie its main stem, but it sends down branches to anastomose with the second nerve, and connects with the anterior one in the neighborhood of the spiracle. It certainly supplies the spiracle and probably some muscles, but on account of the anastomoses it is impossible to be sure. Sometimes the fusion of the connectives is complete, as in Sphecodina (Plate 5) and this nerve seems to arise from the anterior end of the ganglion after the one to which it belongs. In the thorax its connections are always perfectly clear, because of the wide separation of the connectives.

On the third to sixth segments the structure is identical, as described, except for purely individual variation, but the others show various stages of reduction.

OTHER SEGMENTS OF THE ABDOMEN.

The *second segment* differs only in the reduction of the muscles of the proleg, and the loss of a couple of fibres, but they do not change their points of insertion. x is insignificant or absent; k and p are usually unchanged, but may appear as short parallel oblique fibres evidently homologous to I and L dorsally. This condition appeared in an odd specimen of Malacosoma disstria. γ, m, n, q and r are reduced in strength, but not notably changed in points of insertion.

In the *first segment* the proleg is so reduced as to be unrecognizeable, in a stage corresponding to Berlese's Fig. 477 D, which was evidently prepared from the seventh segment. The fat pad, which causes the proleg of the second segment to keep nearly its normal relations, is unimportant here, and the transverse fibres (of the l, q group) are shortened. β, (representing γ) is merely a couple of fine fibres which barely cross the fold. The antecosta dorsally and precosta ventrally are also not developed and the muscles which normally end in them are continued to the front of the segment; these are a, i, E and f′ when present. As the trunk trachea disappears at the first spiracle α is not distinguished from θ, whose fibres are crossed as a result of the moving forward of E and F. H, however, may remain unchanged, and the spiracle is only

a little in front of its usual position. The innermost fibres of c nearly meet in the middle line, covering the origin of a.

Toward the posterior end reduction is progressive to the last segment, and becomes extreme in the ninth, which however, is unmistakably a true segment. The fibres gradually go over to the rectus type, becoming simple and longitudinal, and gradually decrease in number, till in the ninth segment only five ventral ones are left.

The ganglia are fused in the *seventh segment* more or less completely, but always the true seventh ganglion is recognizable with its usual nerves,—,the sympathetic nerves from the last spiracle run back united with the nerve for the eighth, as far as the incisure, then run normally to the spiracle and last wings of the heart. All the principal muscles are present, but a, f, g, h, i and E do not extend beyond the eighth acrosternite, because of the disappearance of the pre and ante-costa of the eighth segment. The deep muscles are reduced, p and x appear clearly as longitudinal (oblique) muscles similar in character to I, L and Q, R of the dorsal region. ζ also appears longitudinal, a suggestive fact, as in general it resembles more closely the fanlike transverse muscles, but z is evidently transverse. α is normal, m and q are undifferentiated, and clearly pleurosternal; d is normal, n and r extraordinarily shortened, while β (representing γ) and δ are also nearly simple—evidently the proleg is merely the small area enclosed by n and r.

The *eighth segment* has the two normal nerves running back from its ganglion in the preceding segment. The first runs outside c, which apparently represents part of a of other segments; it passes between f and g, defining them as usual. Muscles a to i and the corresponding dorsal ones are all reduced to the simple segmental type, M and l, being connected with the spiracle, remain normal, but θ is simplified in front and its homologue behind is much reduced. The lateral muscles are perfectly simple, and the longitudinal ventral ones are reduced to a single set of sort fibres (p).

In the *ninth segment* with the disappearance of heart and spiracle the sympathetic is also gone, but the two principal nerves are easily found, (sometimes with the first arising behind the second). The first runs between a and b, which latter has to serve for b, c, d, e, f, ff, and h of normal segments;

e probably represents normal g, while d would be a transverse fibre. The odd fibre e' may be the last trace of the proleg. The posterior nerve, with the disappearance of the proleg, runs mainly to the skin.

The *last segment* is specialized to such an extent that an embryological study would be necessary to straighten it out. It doubtless is a fusion of at least two. Its one large nerve runs mainly to the proleg and on its way serves as a stalk for the nerves of the preceding joint.

COMPARATIVE ANATOMY.

Including this paper I can find only five widely separated families represented by dissections of the muscular system, namely:

COSSIDÆ; *Cossus cossus* by Lyonet.

NOTODONTIDÆ; *Pygæra bucephala* by Lubbock.

LASIOCAMPIDÆ; *Malacosoma americana* and *disstria* in this paper.

NOCTUDIDÆ; Two species, probably of *Noctua* and *Nephelodes*, both trifidæ and a *Phœocyma* (quadrifidæ) in this paper.

SPHINGIDÆ; *Delilephila lineata*, briefly by Berlese; and *Sphecodina abbotii* in this paper.

These few species indicate, however, that the characters of the muscles are likely to be as well marked as of any other part; the following points stand out most strikingly:

In the *Sphingidæ* the muscles, especially the large ones, tend to be broken up secondarily into a considerable number of fibres. This shows strikingly in the recti. Q and R show a variety of lengths and tend to run to at least two secondary annulets; x and p cross the middle line and interlace with each other. Well marked resemblances to Cossus appear in the broad convergent and overlapping e and ff, in the filling of the body cavity with tracheæ, and the slight differentiation of 4. The thoracic muscles are particularly massive; the longitudinal connectives are fused unusually far in the thorax, and completely in the abdomen, throwing the apparent origin of the sympathetic fibres back to the ganglion of the next segment.

The *Cossidæ* show their primitive character in the well separated ganglia in the seventh segment, the slight differentiation of 4, the fact that x is nearly longitudinal and hardly distinct from t, even in the segments with prolegs, and the well developed ninth segment of the abdomen.

The *Lasiocampidæ*, like the Sphingidæ, show a tendency to increase of muscles, but it is slight. The deeper transverse fibres alone become numerous and unstable; they are weak and altogether much as one would expect in a form which had passed through a lappet-bearing stage and was degenerating. It is not unlikely that such a larva as Epicnaptera will show a strong and highly specialized lateral system. The differences between the two species is slight, in the first segment *disstria* has only three, *americana* usually five ventral rectus muscles; the lappets are much distincter in *disstria*, but not really functional, so that the difference is not noticeably reflected in the muscles. As a whole the genus is characterized by the massive upper fibre of ζ, a suggestive character in a lappet-bearing family, and the frequent presence of the aberrant fibre f' (as figured) in both species. In the eighth segment there is a large tracheal tuft, which may serve as a sort of lung to aerate the blood where it first enters the heart.

The *Noctuidæ* are marked by their simple and normal condition, without the primitive points of Cossus or the specializations of the others, and are closely similar to each other. p and x meet on the middle line, but do not cross, as in Cossus. In general they are much like Cossus, but possess 4, and p'. The tracheæ are reduced and inconspicuous. Of the two species the Noctua had slenderer lighter muscles. The insertion of p along the midventral line is a little different in character, and as it leaves its trace on the skin may prove a help in identifying in this difficult group.

A Catocaline caterpillar, apparently a *Phœocyma*, shows a number of interesting specializations, apparently connected with its extraordinary jumping power. The thorax (Plates XVII and XVIII) is normal in general plan, but with various oblique muscles joined end for end into long sets; four pair of these, namely, E, α_1, α_2, and α_3; C^+, L and G; α, C, S and L; and c, f and C extend the whole length of the thorax and there are several other shorter sets, while only the α system of the meso- and metathorax was recognized by Lyonet in *Cossus*. The peculiar breaking up of S in the metathorax at least, caused apparently by the attachment of I through it, does not even occur in other Noctuids, about the mesothorax I am uncertain, as that part of my specimen was damaged in dissection. The principal peculiarities of the abdomen, aside

from those resulting directly from the slender body, are the setension of F to the acrosternite, under α and ζ, the extension of d well into the following segment outside the other ventral muscles and the simplified leg-muscles of A3, correlated with the much reduced proleg; the most noticeable point in this is that while not forming a longitudinal series of transverse fibres as they do in the seventh segment, muscles m and q are represented by a series of several evidently homologous fibres. The nervous system also shows the highest specialization I have seen in a caterpillar; as the first abdominal ganglion is moved forward well into the thorax (Pl. 1, Fig. 1) and the fused last ganglia have also moved forward into the preceding segment and nearly fused with the sixth abdominal. Their nerves, however, are normal, except for the oblique direction.

Lubbock has notes on a few other species in his paper, among them a Pieris.

SUMMARY.

1. Corrosive sublimate produces the most perfect material for dissection of the muscles; four per cent. formalin is more generally satisfactory.

2. The caterpillars should be opened out before hardening.

3. Lyonet's work has proved fully satisfactory, and Lubbock's sufficiently so for almost perfect correlation of the two.

4. The meso- and metathorax are alike, the first eight segments of the abdomen much alike, and capable of general correlation with the thorax.

5. The ninth abdominal segment is much reduced, but an unquestionable segment. It is less reduced in the most generalized form.

6. The first and last segments are of a different type, and probably compound in nature.

7. The first spiracle has moved forward, the second has become rudimentary in situ and the other eight have moved back, but the first rather less than the others. All have the same innervation, in the abdomen largely from the preceding segment.

8. The meso- and metathorax alone have muscles traversing the nerve-cord.

9. The anterior nerve trunk divides the longitudinal muscles into superficial and deep sets, and the longitudinal trachea similarly divides the transverse ones.

10. The antecosta and ventral precosta arise as specializations of the acrosternal insertions of the muscles and exist only in specialized segments. The muscles may exist in their absence.

11. Characteristics are pointed out of members of five families and characteristic figures are published of a Noctuid, a Lasiocampid and a Sphingid.

12. The following muscles are differently lettered by Lyonet in the meso- and metathorax.

MESOTHORAX	METATHORAX	MESOTHORAX	METATHORAX
G, H	H only	m	3d belly of α
1st belly of α	G	γ	2nd belly of α
e, f	e only	ϵ	γ
d	f	ζ, φ	ϵ, ζ, φ

It is suggested that his lettering of the metathorax be adopted in general, but that m be used for the posterior of the three muscles he confused as α.

13. The muscle marked E by Lyonet, and IX by Berlese is only a segment in length, both terminations being on the antecosta.

14. Cases occur of wide shifts in the origin and insertion of muscles, both relative and absolute, notably in the primitively longitudinal ones p, p', and x, near the midventral line and in d and F of Phaeocyma; they should therefore be used with a good deal of caution in identifying sclerites or parts of the body, at least where as in the caterpillars the sclerites are obsolescent.

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A complete monograph of caterpillar structure based on *Cossus cossus*, (family *Cossidæ*) with numerous engraved plates, illustrating, among other things, the entire muscular system and its nerve-supply.

LUBBOCK, J.: Arrangement of cutaneous muscles of the larvæ of *Pygaera bucephala*. London, 1858.
Family Notodontidæ.

BERLESE, ANTONIO: Gli Insetti; Milano, 1909.
A long chapter on insect muscles and their homologies, with figures of *Deilephila* (*Sphingidæ*) and numerous non-Lepidopterous insects.

EXPLANATION OF FIGURES.

Plates XVII and XVIII—Dissection of the thoracic muscles of *Phaeocyma* sp., following Lyonet's lettering, and nearly following his order of dissection. The muscles not hatched, which appear in the various layers are those which appear more distinctly in succeeding ones. The dorsum of the mesothorax, and the prothorax, especially in front are incomplete.

oes. suboesophageal ganglion.
gang. T^1. First thoracic ganglion.
gang. T^2. Second thoracic ganglion.
gang. A^1. First abdominal ganglion. The ganglion of the metathorax lies near the letter c of that segment, under the muscles c.
tr. Functional trunk-trachea of the thorax.
sp. A^1. First abdominal spiracle.
D, A, B and E at the lower edge of Fig. 1, and E on Fig. 2, belong to abdominal muscles, the latter extending forward well into the thorax.
Rudimentary crossed muscles are shown in Fig. 1, overlying the prothoracic ganglion.
In Fig. 6 the stippled areas represent the position of the wings; they underlie all the muscles except the long fibres of T and w.
sp. in Fig. 6 is the rudimentary second thoracic spiracle, in Figs. 4 and 5 π indicates its trachea.

In this and most of the other figures the musculature is shown as it appears when the caterpillar is opened and spread out, the muscles nearest the body cavity appearing superficial, and the last layer of dissection representing the ones close to the skin. In this figure the head was cut in several pieces to enable the prothorax to be spread out flat, and the broken lines represent the mid-dorsal and midventral lines, marked by the position of the dorsal vessel and nerve cord. The small muscles of the legs are not shown.

Plate XIX.—Metathorax of *Noctua baja* (?), dissected in six stages, following approximately Lyonet's directions and using his lettering.

gang. Ganglion.
sy. Fork of sympathetic nerve.
π. Rudiment of middle thoracic spiracle and its trachea.
im. Rudiment of an imaginal muscle.
The wing is shown in the deepest dissection and coarsely dotted.

Plate XX—The middle abdominal segments of *Nephelodes minians* (?) similarly dissected in six stages, in the following order:

1, 2,
4, 3,
5, 6.

Plate XXI—Middle segments of *Sphecodina abbotii*, dissected in the same order, in four layers.

tr. Trachea.

Plate XXII—Middle segments of *Malacosoma americana* dissected in four layers in the following order:

2, 1,
3, 4.

d. v. Dorsal vessel or heart.
w. h. wings of the heart.
sp. Spiracle.
tr. trachea.
gang. Ganglion.
sy. Fork of sympathetic nerve (belonging to preceding segment).
The position of the hooks of the proleg is indicated by a series of bars.
5 is a small muscle in the planta.

Plate XXIII—First two layers of muscles of the first two segments of the abdomen of *Malacosoma americana*, the first layer on the right.

In all the preceding dissections the caterpillar is represented as if opened on the dorsal line and spread out flat, so that the mid-dorsum is divided between the two edges and the midventral line lies in the middle.

Plate XXIV—Ventral musclature of the posterior segments of *Sphecodina abbotii*. The left side is shown as seen from the inner side. 1, as seen when opened and spread out; 2, after removing the muscles hatched in Fig. 1; and 3, similarly after removing those hatched in Fig. 2. The principal nerves are shown as wavy black lines; the segments are numbered and their boundaries indicated in Fig. 1 by arrows.

Plate XXV—Diagrams of segment.

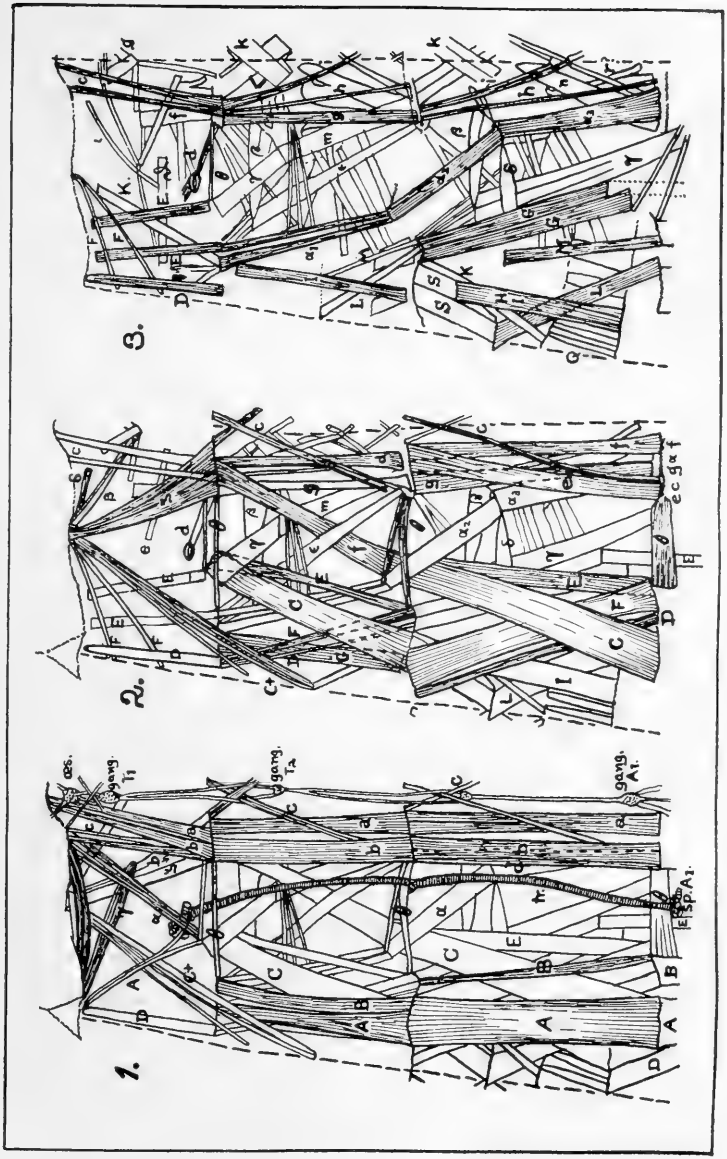
Fig. 1. An abdominal segment (left half) spread out and with the principal annulets and regions labelled, modified after Berlese.

ACRO. acrotergite.
PRO. protergite.
MESO. mesotergite.
META. metatergite.
The four sternites are similarly placed.
sp. spiracle.
ap. tergostern. tergosternal apodeme, pleurosternal suture, or subventral fold.
ante. antecosta (ventral end).
pre. precosta.
inter- intercosta.
pl. planta of proleg.
φ, ψ. Minor apodemes.
ω. ringlike folds, considered by Berlese to mark rudimentary segments of the leg.

Fig. 2. A similar diagram of the metathorax, as developed, e. g. in Sphecodina.
w. Wing-bud, marking the upper boundary of the pleurites.
pleur. pleurite, its boundaries indicated by arrowheads.
m. cx. membranous part of coxa.
ch. cx. chitinized part of coxa.
ACRO, PRO, MESO. and META., as in Fig. 1.

Fig. 3. A superposition diagram of the muscles of the metathorax as seen from within. Each muscle is represented by a double line, interrupted where it passes under another, and the insertions are shown as heavy black bars or dots. The diagram is meant to show the relative position, insertion and direction of action of the muscles, but not their size or form, and is supplementary to Pl. XIX. The rudimentary spiracle and trachea is indicated to the right of the letter θ. Middorsum at left edge, mid-venter at right. c and k, which cross far beyond the middle line, are only partly shown.

Fig. 4. A similar diagram of a middle abdominal segment, serving as an index to Plates 4-6. Dorsally the precosta and intercosta are shown, laterally the antecosta, and ventrally the precosta, pleurosternal suture, apodeme φ (running to the left of the letter ζ) and the oval indicating the boundary of the proleg. The ganglion is dotted, and the anterior nerve indicated as a waved line.



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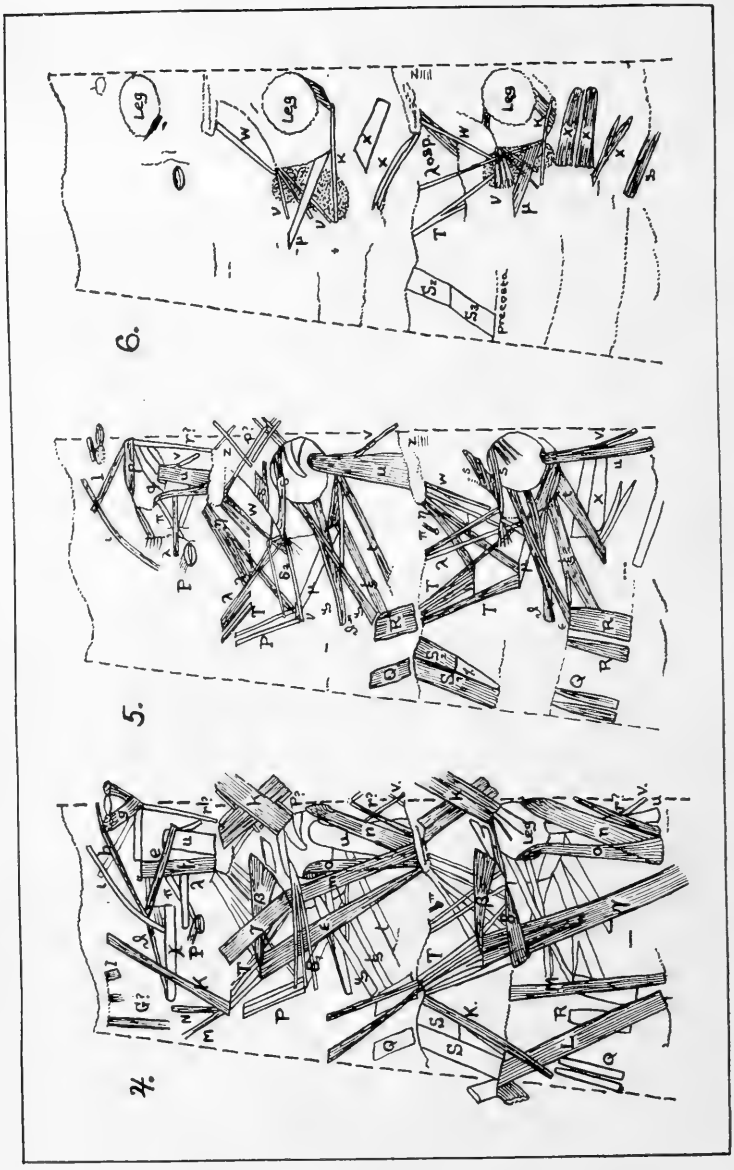

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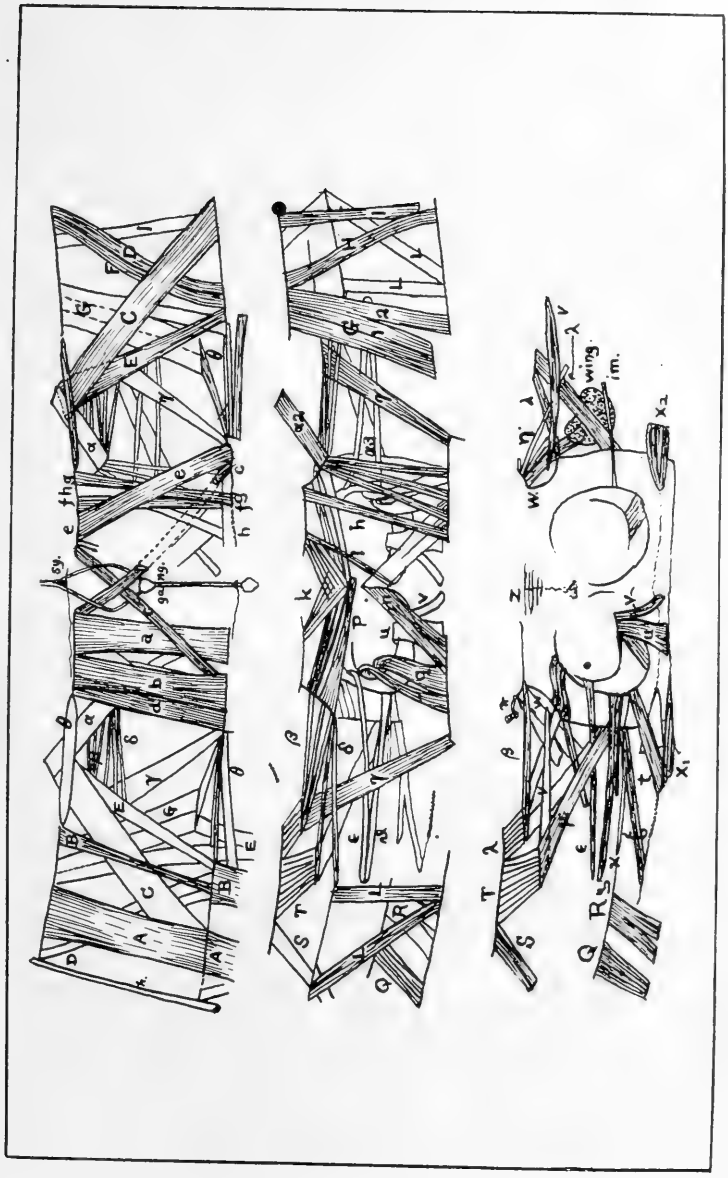

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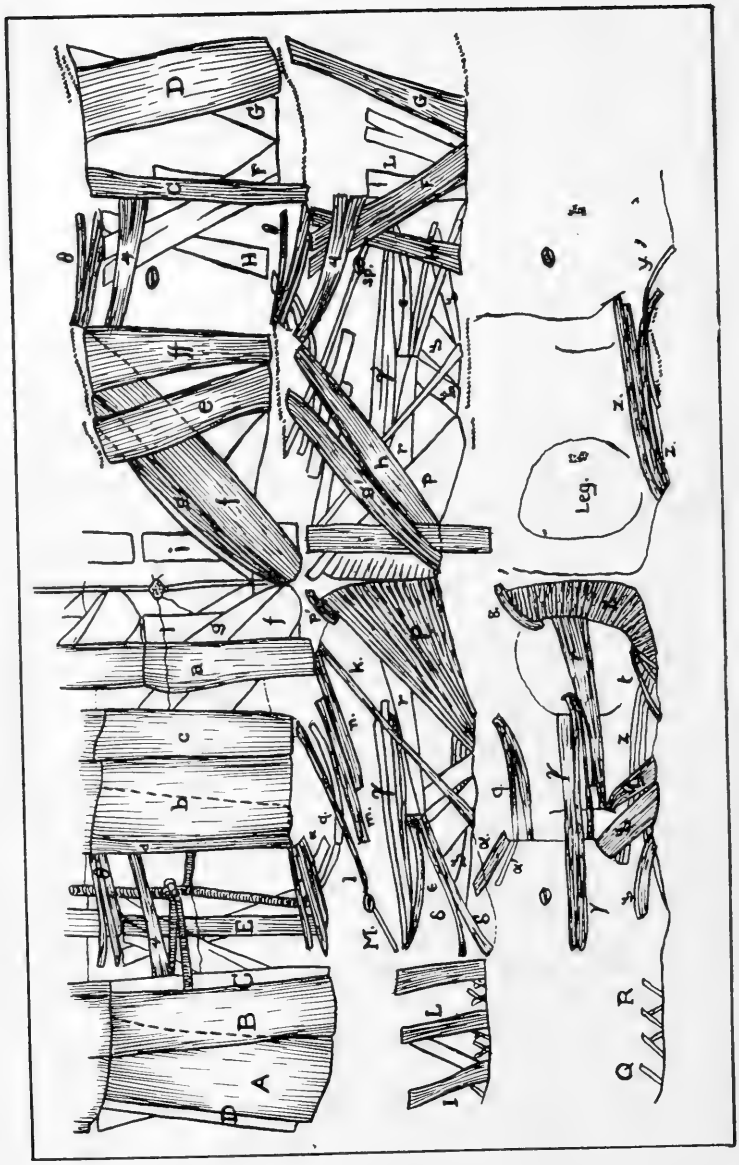

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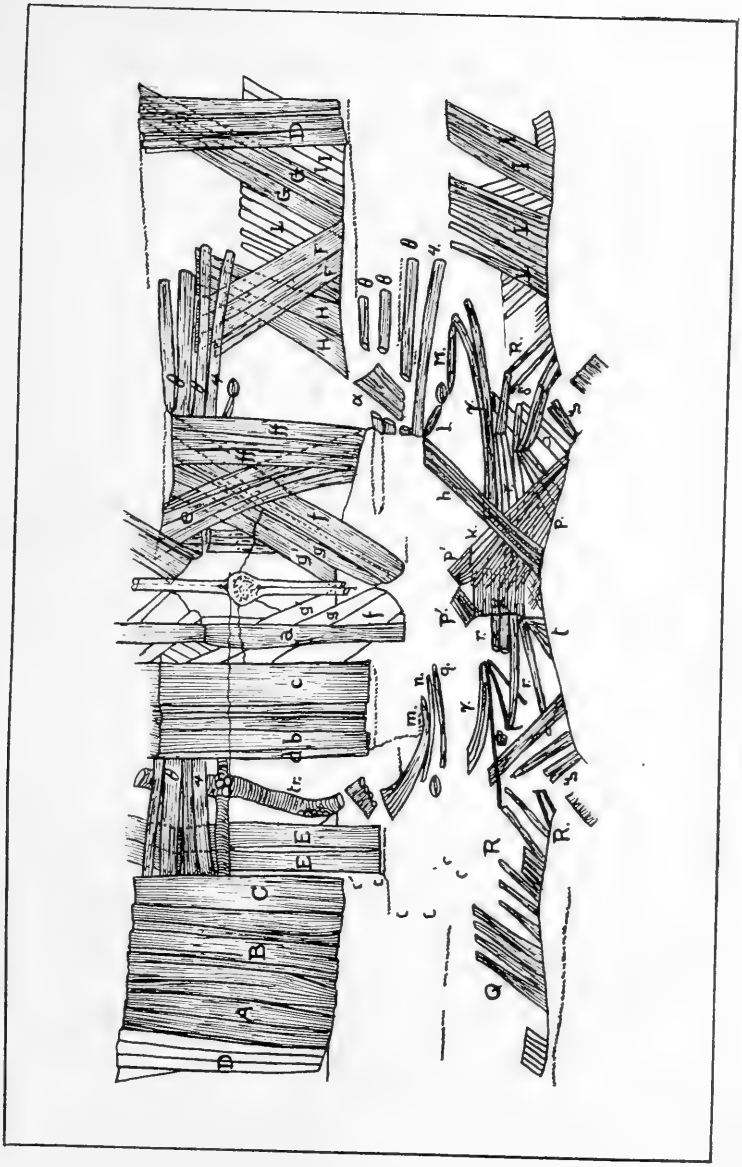

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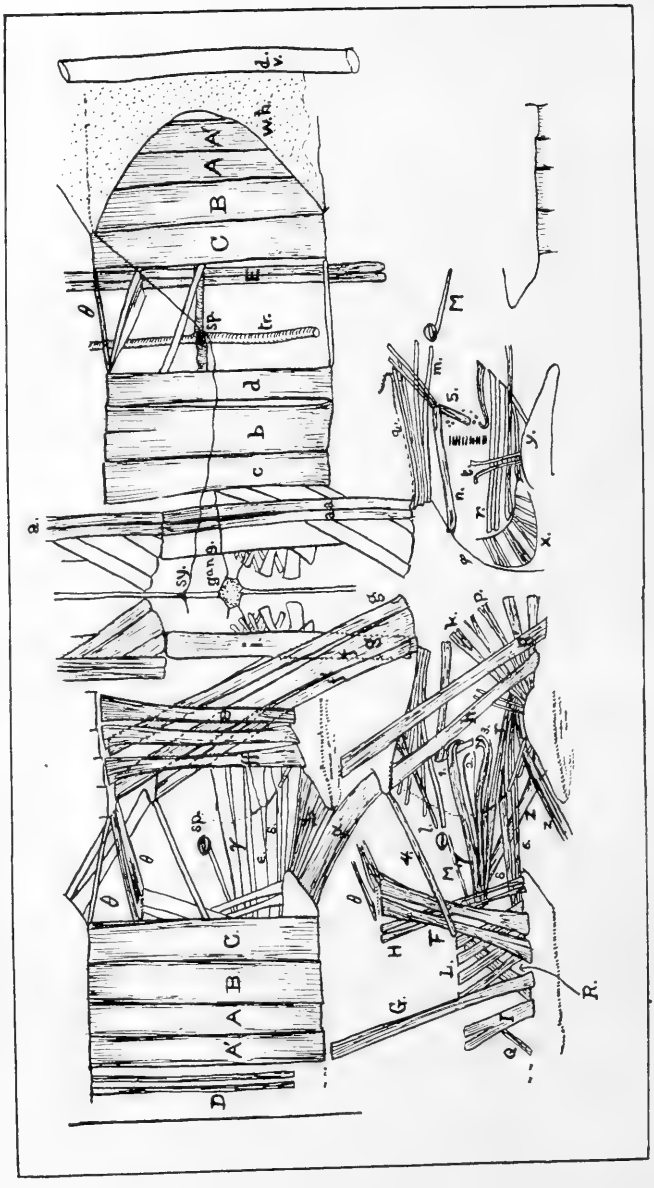

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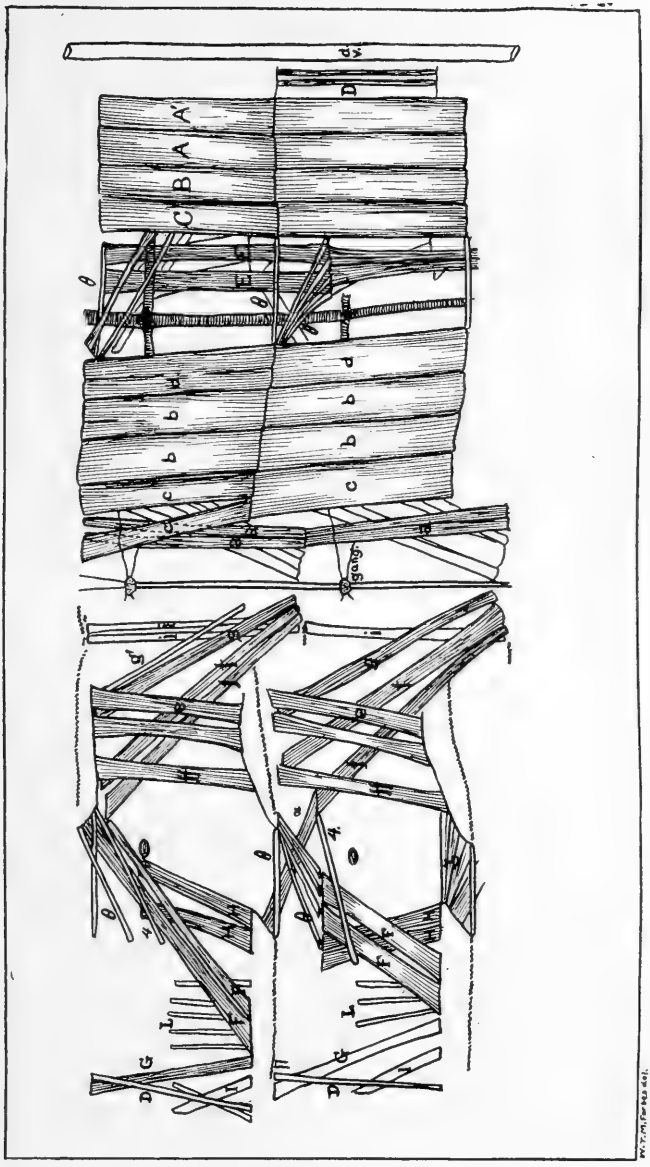

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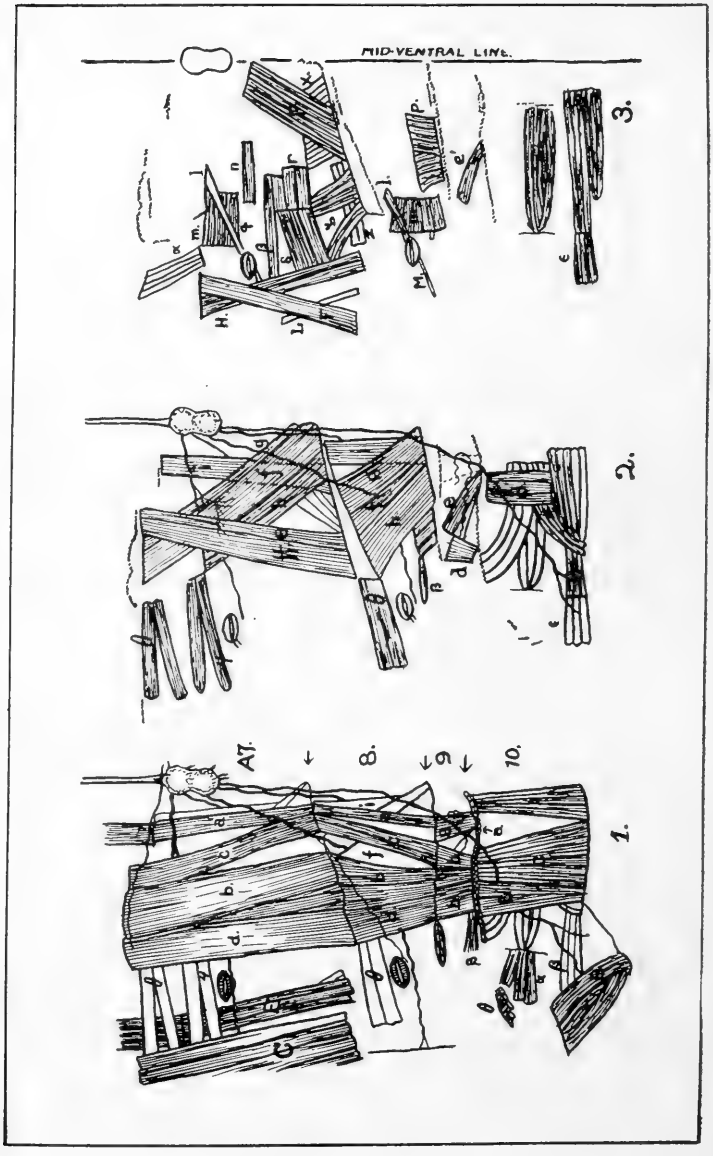

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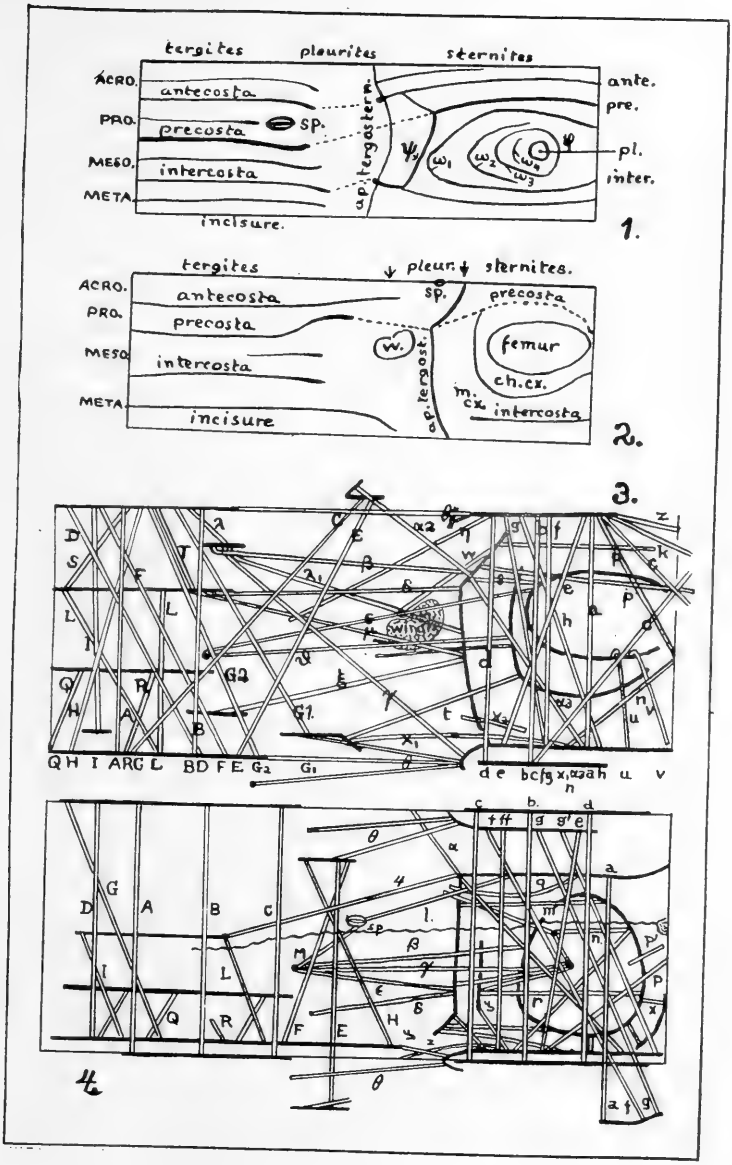
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intercosta
ap. tergost.
2.
3.
Q H I ARC L BD F E G2 G1
d e bcfg x1 α2 a h n u v
4.

Wm. T. M. Forbes

OBSERVATIONS ON THE LIFE HISTORY AND HABITS OF HYDROMYZA CONFLUENS LOEW., (DIPTERA).*

By Paul S. Welch.

During the past three summers the writer carried on some biological investigations in the vicinity of Douglas Lake, Mich., in the extreme northern end of the southern peninsula of that state. The work was done in connection with the University of Michigan Biological Station, the facilities of which aided materially in securing the data which form the basis of this paper.

Hydromyza, one of the several small genera belonging to the *Cordyluridæ*, has only one species (*H. confluens* Loew) reported for North America. This species is northern in its distribution and seems to have been reported only from New Jersey (Johnson, '04, p. 162) and Michigan (Needham, '08, p. 270). Needham reported it from Walnut Lake, in southeastern Michigan, and predicted that it would probably be found common about *Nymphaea* beds in the United States. In looking over the literature relating to this insect the writer was surprised to discover how little has been written about it. Aside from a brief, two-page paper by Needham ('08, pp 270-271), nothing seems to have been written on the habits or life history of this very interesting insect. It occurred in sufficient numbers to make possible the accumulation of a number of interesting facts relating to this species. The data presented in Needham's brief paper were tested and found to agree with the observations of the writer in almost every respect. Data merely mentioned by Needham have been worked out in more detail and a number of new observations were made. Unfortunately the writer has been unable to observe the method of oviposition and the younger larval stages have not been studied.

THE LARVA.

Food Plant.—Hydromyza confluens was found in connection with the yellow waterlily, *Nymphaea americana*, (Provancher) Miller & Standley. This is the form which has until recently been included under the name *N. advena* or *N.*

* Contribution from the University of Michigan Biological Station, No. 21.

advena variegata, but Miller and Standley ('12, p. 78), have shown that the boreal species has several distinct characters which separate it from the true *advena*, and they have raised Provancher's name, *americana*, to indicate this northern species. *N. americana* occurs in some abundance in the protected bays, in the beach pools, in the mouths of some of the streams, and in sphagnum bogs of the Douglas Lake region and the insects under consideration were correspondingly abundant. Needham ('08, p 270), reported this insect in connection with *Nymphaea advena*, but judging from his description and figures it seems very probable that the species in Walnut Lake was *N. americana*, rather than the true *advena*.

A careful examination of all the aquatic plants occurring in the immediate vicinity of the *Nymphaea* beds was made with the view of determining whether or not other plants were used as food. In no case did the larva occur on plants other than *N. americana*. The white waterlilies (*Castalia odorata*) were entirely exempt in spite of the fact that white and yellow waterlilies mingled in the same beds. In every case the evidence pointed to the conclusion that this insect is restricted to *N. americana* in the region studied.

The Gall.—The immature stages of this insect were found in the long, constantly submerged petioles of the yellow waterlily. A large number of plants were examined and in no case did they occur on any part of the plant other than the petiole. Furthermore they were confined exclusively to certain petioles, namely, those of the floating leaves. Special effort was made to determine whether or not larvæ ever occurred on the peduncles or on the petioles of the submerged leaves. Both were found to be entirely free from infestation. Although the writer has no data on the method of oviposition, the reason for this distribution on the plant seems apparent. Needham ('08, p. 270) suggested that "Probably the attack of the gall maker begins when the first leaves reach the surface in late spring; then they have their first opportunity to reach the proper place of oviposition by crawling down the stalk." The writer regards this as the most feasible explanation since it will be shown later in this paper that it is possible for the adult insect to pass under water by crawling on a supporting surface and that it actually does so of its own volition. The short and wholly submerged leaves of *N. americana* do not at any time

reach the surface and since this is true there would be no opportunity for the female to deposit the eggs, hence the constant freedom from infestation. Furthermore, in the region of Douglas Lake, the flowers do not reach the surface of the water until in late July and in August, a date which is much later than the time of oviposition, and as a consequence they are exempt from the attacks of the insect.

The gall first becomes perceptible on the petiole as a slight, ovoid enlargement and can be detected by pulling the petiole between the fingers. Each gall is produced by one larva only and in no case is more than one larva found in a single gall. It is very probable that in the early stages the presence of the larva is not perceptible since this enlargement really occurs at a time when the larva is well toward maturity. As the time of pupation approaches the gall begins to turn brown, ultimately assuming a deep brown color, thus making it easy to detect. The shape of the exterior of the mature gall varies somewhat, usually appearing as an ovoid swelling, although it should be noted here that many of the galls do not increase the diameter of the petiole. The galls also vary in size to some extent, the length of those containing pupæ ranging from 6 to 9 mm. They are always longer than broad, the long dimension being in the direction of the long axis of the petiole.

The number of galls per petiole varies rather widely. Sometimes only one gall occurs on a petiole, but usually the number is greater. In a large series of observations the maximum number on a single petiole was found to be 14 and many of the petioles contained as high as 13. In one of the series of counts in which 45 infested petioles were examined, 7 was found to be the average number of galls per petiole. No relation was found to exist between the length of the petiole and the number of galls. It might be assumed that the longer petioles contain the larger number of galls, but this was not always true. Numerous instances were observed in which a petiole, six feet in length contained only two or three galls, while a neighboring petiole, three feet in length, contained 10–12.

Galls occur irregularly along the petiole and may be situated near the bottom, even in those almost six feet long. They may be distributed along the entire length of the petiole and well

separated from each other, or they may be distributed in such a way that some are widely separated and others so closely placed that two or three may appear to be continuous.

The interior of galls containing pupæ, or half to full-grown larvæ, can be easily examined by removing the infested petiole from the water and holding it between the eye and the light. The cavities are not at all uniform in shape. Each has a slightly elongated central chamber and one or more side channels which are usually just large enough to contain the larva. The total space in the gall of a full grown larva is commonly three or four times as large as the larva itself. The size of the cavity represents the bulk of the food which the larva has consumed during its growth and since there is no connection with the exterior all of the excrement is deposited within the gall. The consumed matter, as indicated by the amount of excrement, does not seem to decrease much in bulk so that near the time of pupation the greater part of the gall is filled with a brown excreta which almost surrounds the insect. This brown excrement has much to do with the brown exterior which characterises these excrescences and renders them conspicuous.

The full-grown Larva.—The morphological details of the full-grown larva will be included in a future paper which is in preparation. Needham's paper contains a very brief description of the larva and presents some of the more important anatomical details.

Variation in Maturity.—An examination of the galls on a given petiole often showed differences in the degree of maturity and when the larvæ on such a petiole were extracted and examined it was found that they too were not all exactly of the same degree of maturity. In some cases part of the number had pupated while others on the same petiole were still in the active larval stage. It thus appears that some of the larvæ lag behind the others in development and the question arises as to how this fact is to be interpreted. It is conceivable that this might result from the deposition of eggs at different times by different females, but the writer, after examining a large number of such cases, is skeptical of such a possible interpretation and believes that in the majority of cases at least, all of the galls of a given petiole are the result of eggs laid at one time since, (1) although some of the larvæ lagged

behind others in development, the differences did not seem to be sufficiently marked to warrant the conclusion that the eggs were deposited at different times, and (2) in some cases those lagging behind occurred in the middle of the petiole, while those towards the upper and lower extremities of the petiole developed at the same time, a condition which would not be likely to happen in case the eggs were laid by different females. The above evidence is not entirely conclusive but it seems to support the more feasible explanation, namely, that the eggs on a petiole are all laid at one time, and that the variation in the degree of development is possibly due to internal or external factors, probably the former since the external conditions seem perfectly uniform for all those deposited on a given petiole.

Activity.—Like many other dipterous larvæ, this gall maker is very sluggish. Specimens, removed from galls, showed only slow, squirming movements which were very ineffective so far as locomotion was concerned. The activities of these larvæ could be observed to some extent by holding an infested petiole between the eye and the source of light. The feeding activities appeared to be very deliberate.

Effect on the food plant.—As mentioned above, the first evidence of infestation is the presence of a slight, ovoid swelling at various places along the petiole. Later these swellings begin to develop a brownish color, ultimately becoming a deep brown. About this time or a little later the entire petiole loses its green color, takes on a yellow appearance, and shortly afterwards the entire leaf begins to turn yellow, showing signs of deterioration. During the last week in July and the first week in August of 1913 one could readily pick out the infested lilies by the yellowish leaves. This work of the larvæ leads to the decay of both leaf and petiole. The nature of the injury is simple. The larvæ affect the plant in two different ways: (1) The larva, as it eats out the internal cavity of the gall, severs the vessels which connect the leaf with the root-stalk, this alone being sufficient cause for the decay of the leaves. It was found that the heavily infested petioles deteriorated no more rapidly than did the slightly infested ones and that one larva is just as efficient as several in causing the death of the leaf. (2) These galls produce weak spots in the petioles so that wave action breaks them at the points of

infestation. Leaves with broken petioles were found floating about early in the season before the galls had begun to turn yellow, but the greatest havoc from this cause was produced during the first week of August of the past year when the larvæ were pupating. At this time in one of the badly infested lily beds approximately 40% of the leaves were broken off and were floating about in a semi-decayed condition.

The possibility of other insects playing a part in causing this deterioration of the petioles and the change in the color of the leaves was taken into account and, while other enemies were present, it was possible to observe many leaves and petioles which were infested only by the larva of *H. confluens* and which showed the same effects as those which happened to be affected by more than one enemy.

All of the lily beds in the immediate vicinity of Douglas Lake were examined and the degree of infestation observed. There was considerable variation in this respect since some were only slightly infested while in others the percentage of infestation was as high as 50 or 60. None were entirely exempt. It was found that the heaviest infestation occurred in a lily bed which was located at the end of a point which formed one side of a protected bay and was thus exposed to the wind and wave action to a greater extent than any of the other lily beds. In this particular case the infestation was almost twice as great in this exposed lily bed as in another in the protected bay only about one hundred feet away. The infestation in the lily beds in the beach pools and the sphagum bogs, which are protected from the action of the wind and waves, was very slight. The writer is not prepared at the present time to account for this distribution, but merely gives the facts for this particular region, realizing that the distribution just described may not agree with that of other regions.

It thus appears that the larva of *Hydromyza confluens* is a serious enemy to *Nymphaea americana* since every petiole which contains even one larva is doomed. Three summers of work on insects infesting waterlilies in the Douglas Lake region has convinced the writer that, although there is a rather large number of species which attack this plant, yet *Hydromyza confluens* has only one rival for first place as the greatest enemy namely, the larvæ of *Bellura melanopyga*, one of the *Noctuidæ*, which also plays havoc in the lily beds.

THE PUPA.

The detailed description of this stage is reserved for another paper which is in preparation.

Position.—The position of the pupa in the gall is variable, the only constant feature being the fact that its long axis always lies almost or quite parallel to the long axis of the petiole. However, the position of the head and the caudal end is not at all constant since in some cases the head is up (towards the surface) and in others it is down (towards the root-stalk). In galls which are well advanced in development and contain pupæ this point can easily be determined from the exterior without breaking into the gall by noting the position of the *window*, a feature to be described later. When the window occurs at the lower end of the gall it is positive proof that the head of the full-grown larva or the head of the pupa is down; if the window is at the upper part of the gall, the head of the larva or pupa is up. In a series of observations in which 242 pupæ were examined it was found that 130 occupied a position in which the head of each was up and 112 in which the head of each was down. Other statistics of the same kind showed a similar result, namely, that the majority of the pupæ lie in the galls with the head towards the surface of the water.

The Window.—The window mentioned in the preceding paragraph is a very interesting and unique provision for the emergence of the adult and, as stated by Needham, is constructed by the larva immediately before pupation. It is circular in outline and only large enough to allow the passage of the emerging adult. In constructing this window the full-grown larva works towards the exterior of the petiole until it reaches the epidermis. Here it removes all of the surrounding tissue (exclusive of the epidermis) from a circular area which is destined to be the window so that the latter is composed only of epidermis. A circular incision, which extends around approximately two thirds of the circumference, is made along the periphery of this area. The remaining one-third is left intact and thus a circular lid, attached at one side, is produced. The attached portion always has a definite relation to the position of the pupa, namely, it is constantly on the side of

the circumference nearest the caudal end of the pupa. The larva evidently constructs this circular incision by rotating the head through about 240 degrees, cutting the epidermis with the mandibles as it goes. Needham ('08, p. 270) in discussing this matter makes the following statement: "Just before transformation to the pupal stage the larva eats a hole out to the epidermis and returns to the center of the cavity; this hole is a passage of exit for the adult, which then has only to break through the transparent epidermal window to gain its liberty." One would infer from this statement that the window is opened at the time of the emergence of the adult by the rupture of the epidermis, but this is not the case. Also no mention is made of the fact that the epidermis is cut in any way. The evidence is conclusive that the operation of opening the window is not a mere rupture of the epidermal tissue since: (1) Very careful examination shows that a circular incision is actually made and that the translucent window is merely pushed open at emergence, (2) it is an easy matter to open one of these windows on a gall from which the adult has not emerged by either carefully inserting the point of a needle between the edges of the incision, or by splitting the gall and applying very slight pressure against the inside of the window, which in either case opens as a hinged shutter with the attachment constant in position, and (3) an examination of a large number of petioles from which the adults had emerged showed that in every case the window opened as a hinged shutter, the attachment of which always had the above described, definite relation to the body of the gall and to the pupa. If the opening of the window was a matter of rupturing the epidermis there would be no possibility of this constancy in the form of the opened window. It should be mentioned in this connection that the incision is not an absolutely continuous one, since a few minute portions of the tissue are left uncut and serve to hold the window closed up to the time of emergence. It is therefore possible, under average conditions, to determine from the exterior whether or not the adult has emerged. If the window is not loose around the edges the insect is still within the gall, but if the window is loose and gapes slightly it is very strong evidence that the adult has emerged. An exception to this rule may occur in a petiole

which has been subjected to side to side strains such, as are produced by wave action, and the window has thus been broken open.

According to the observations of the writer, pupation occurs shortly after the window is completed and the pupa lies with the cephalic end in close proximity to the window. In some cases the pupa lay so close to the window that the movements of the adult in escaping from the puparium would have been sufficient to open it.

One of the characteristics of *Nymphaea americana* is the shape of the petiole. It is conspicuously flattened so that approximately one-third of the circumference is quite flat while the remaining two-thirds are very convex. For convenience in discussion these surfaces will be designated as the plane surface and the convex surface. On the former there is a median, longitudinal ridge. Needham's paper indicates nothing as to constancy or variation in the position of the window with reference to the two above-mentioned surfaces although he figures a gall with the window on the convex surface. The position of this window is variable, sometimes occurring on the plane surface and sometimes on the convex, but not in equal numbers and the writer was lead to make some observations on this point. Of 226 galls examined at random the window in 137 occurred on the convex side and in the remaining 51 cases on the plane surface. Various other counts not recorded in the above numbers showed similar results. Available data does not seem to offer an explanation for the predominance of the windows on the convex surface.

THE ADULT.

Broods.—Although the writer has no positive evidence as to the number of broods per summer, there seems to be the possibility of at least two. A few adults were observed about the *Nymphaea* beds during the first part of July, at least three weeks before the larvæ in the petioles were grown. The maximum appearance of the adults in 1913 occurred between August 1st and 6th. During the period, July 10–25, adults were very rare and it may be that this represents the interval between two successive appearances of the adults. Very few of these insects remained in the pupal stage after August

6th. Adults were very abundant during August 1–6, and it was a common thing to find numbers of them copulating.

Local distribution.—In spite of the fact that these insects have well developed powers of flight they are not found at any great distance from the waterlilies. They occurred ordinarily on the leaves and flowers of these plants and when disturbed made only short flights, seldom taking to open water or to shore. Only in rare instances were flies found resting on plants other than *N. americana.* When undisturbed they assembled in the open flowers or ran restlessly about over the lily leaves, making short flights where leaves were not contiguous.

Relation to water.—These flies are related to the water in several interesting ways. Although the emergence of the adult has not been observed in the field it seems safe to assume that when the adult emerges from the pupal stage it must of necessity push the window open and pass up through the water to the surface, either by crawling up the petiole, or by independent passage through the water, presumably the former. It was found that the flies emerged and came to the surface when the infested petioles of *N. americana* were brought into the laboratory and completely submerged in water. In many cases individuals which develop near the base of the longer petioles must, in emerging, come up through about five feet of water before reaching the surface.

It seems almost certain that the female deposits the eggs by going into the water and crawling down the petiole to the place where the eggs are deposited. Careful watch was kept on adults for periods of an hour or more at a time and none were observed to go beneath the surface in open water. If perchance an individual did alight on the surface it immediately took to wing again. Adults which fell on the surface of the water did not sink, but appeared to be supported mainly by the surface film. The fact that they may and do voluntarily pass under water was demonstrated when the writer observed a few individuals walk over the edge of the lily leaf, go under water, and travel on the lower surface of the leaf for short distances. None were seen to go down the petiole.

Experiments in which adults were submerged showed that under such conditions the flies apparently have a specific gravity less than water, and consequently they rise to the

surface if opportunity affords. They stay below only by clinging to some submerged object. While under water a goodly supply of air clings to them in the form of a dense, silvery coating. When allowed to come to the surface they immediately lose the silvery coating and are apparently as dry as if they had never been in contact with water. Experiments, in which adults were subjected to forced submergence for varying lengths of time, showed that they can remain under water for several minutes without apparent detriment to themselves, due without doubt to the generous coating of air which surrounds them. Submerged individuals usually appeared uneasy and made vigorous effort as if seeking release. The ease with which they apparently resist wetting and the quantity of air which they take below with them make possible the mode of emergence and oviposition suggested above.

Relation to the Yellow Waterlily.—The adults as well as the immature stages have a definite and interesting relation to the yellow waterlilies. This relation will be discussed under two heads, (1) food relation, and (2) possible agents in pollination. Although each of these relations will be treated independently, it will be understood that such separation is purely artificial and also that both are operative at the same time.

(*1*). *Food relation.*—The time of maximum abundance of the adults coincided closely with the opening of the majority of the flowers and it was very evident that the flies were deriving food products from them. Flies swarmed in the newly opened flowers in great numbers, congregating between the petals and the stamens to the extent that often the interior of the flower was black with them. In the case of flowers which had been open only a short time the anthers were crowded in a compact mass under the edge of the expanded stigma or were just beginning to spread out in a radial fashion, while the petals had spread out widely, thus forming a cup-shaped flower and producing a space between the petals and anthers into which the flies crowded. Flowers frequently contained as many as fifty adults. They regularly disposed themselves as described above with the heads in close proximity to the base of the anthers. It often required a distinct shake of the flower stalk to disturb them and this proved to be an easy way to collect adults since one of these flowers could be cautiously thrust into a bottle and the inmates dislodged. This

habit resembles a similar one described by Fulton ('11, p. 300) for certain *Diptera*, the adults of which also congregate in the flowers of a yellow waterlily. Later when the anthers became spread out the flies found better concealment beneath them.

The conspicuous assembling of flies in the flowers is indicative of some rather strong attraction which the latter have for the former and it seems safe to assume that the flies profit therefrom. Nectar is said (Lovell, '02, p. 205) (Robertson, '89, p. 122) to be secreted on the outer faces of the petals in *Nymphaea advena* and it is also probably true of *Nymphaea americana*. Therefore it is possible that the visits of the flies are induced in part by the presence of nectar which forms a source of food supply. Flies were observed in the flowers from the time of opening to the time when the flowering parts began to disappear.

(*2*). *Possible agents in pollination.*—The information that insects are found in connection with yellow waterlilies is not new since species representing several orders have been reported as occurring on these plants by Robertson ('89, pp. 122-123), Lovell ('98, pp. 60-65), Bembower ('11, p. 379) and others. Furthermore Elliot ('96, pp. 117-118) and others claim that flower haunting *Diptera* are of considerable importance in the fertilization of many of the flowers which are visited. It is claimed that *N. advena* may be self- or cross-pollinated (Bembower, '11, p. 379) and this is probably true also of *N. americana*. There is good evidence in support of the view that the insect visitors of yellow waterlilies (*N. advena* and others) may transfer pollen from one flower to another, or from one part to another on the same flower. The writer had occasion to examine large numbers of the adults of *Hydromyza confluens* and it was discovered that many were carrying the pollen of *N. americana*. Swarms of adults taken from flowers in which they had congregated showed that the great majority, and often all, of the insects were dusted with pollen. Very frequently pollen occurred so thickly over the body that the insect was distinctly yellow in appearance. Adults collected August 5–22, showed that pollen was being carried during this entire period. While it was not demonstrated absolutely that these flies carry pollen from one plant to another, the circumstantial evidence seems to point definitely to these insects as being at least one of the factors in the cross-pollination

(and possibly the self-pollination) of *N. americana* and may be summed up as follows: (1) The coincidence of the blooming period of *N. americana* with the maximum appearance of the adults of *Hydromyza confluens;* (2) The large numbers of flies limited in distribution to the immediate vicinity of the lily beds; (3) The assembling of the flies in large numbers within the flowers when the latter have opened sufficiently to admit them; (4) The heavy loads of pollen which are carried by many of the flies and the almost universal presence of varying quantities of pollen on all individuals; (5) The continuous blooming of *N. americana* throughout the greater part of August, so that at any given time there were flowers in all degrees of maturity, a fact which eliminates a difficulty due to the possibility that a given flower is proterogenous; and (6) The behavior of the adults in preferring to pass from place to place by crawling and by very short flights (usually the former when possible) rather than by extended flights, which means a maxium of contact of the insect with the various parts of the supporting plant.

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SOME SPECIES OF THE BEE GENUS COELIOXYS.

By J. C. Crawford.

This paper discusses only species occurring in America north of Mexico and no table to separate the males has been included since Prof. T. D. A. Cockerell published a table for this sex in the Canadian Entomologist for June, 1912, pp. 167–170. The key to the females includes all the species for the region under consideration in which the female sex has been described. In the table here presented the characters used for separating *rufitarsis* Sm. from *comstockii* Cress. and *lucrosa* Cress. from *moesta* Cress. are the characters used by Prof. Cockerell in a table to separate the types of the Cressonian species and some non-Cressonian species which he consulted in the collection in Philadelphia. The illustrations were made with a camera lucida, attached to a Zeiss binocular microscope.

1. Last ventral segment not notched laterally, at most emarginate and the part anteriad of the emargination not pointed.....2
   Last ventral segment notched, the part anteriad of notch sharply pointed..19
2. Last dorsal segment with the end upturned into a small spicule.....3
   Last dorsal segment not upturned at apex.....7
3. Last dorsal segment very sparsely punctured at base.....**obtusiventris** n. sp.
   Last dorsal segment closely punctured at base.....4
4. Punctures of first dorsal abdominal segment separated by less than a punctured width.....5
   First dorsal abdominal segment sparsely punctured.....6
5. First recurrent vein received by second submarginal cell almost half as far from base as length of first transverse cubital in the ♂ and slightly less in ♀.....**gilensis** Ckll.
   First recurrent vein received by second submarginal cell one-third or less as far from base as length of first transverse cubital in ♀ and still less in ♂.....**deani** Ckll.
6. Here run **modesta** Sm. and **scitula** Cress., the descriptions affording no points for separation.
7. Last ventral segment towards apex with a long strong fringe of hairs along margin.....8
   Last ventral segment not strongly fringed.....12
8. Legs black.....9
   Legs, except coxae, red.....11
9. Last dorsal segment without a median carina or this only indicated at tip.....10
   Last dorsal segment with a median carina.....**angelica** Ckll.
10. Penultimate ventral segment with small punctures interspersed among the larger ones.....**apacheorum** Ckll.
    Penultimate ventral segment without smaller punctures among the others.....**alternata** Sm.
11. Fourth antennal joint distinctly longer than third; last ventral segment with subparallel sides and a broadly rounded apex.....**texana** Cress.
    Fourth antennal joint hardly longer than third; last ventral segment with the sides converging apically and apex more narrowly rounded. **hunteri** n. sp.

12. Last dorsal segment near apex with two small flattened projections pointed caudad.....**piercei** n. sp.
Last dorsal segment without projections on disk.....13
13. Legs red.....13a
Legs dark.....14
13a. Front at top of inner orbits with a swollen granular area, narrowed centrad and extending to lateral ocelli.....**deplanta** Cress.
Front without such a spot, being coarsely punctured, not different from surrounding area.....**sculptifrons** n. sp.
14. Scutellum strongly triangularly produced, medially almost impunctured. **dolichos** Fox
Scutellum medially closely punctured and not strongly produced.....15
15. Last ventral segment with the sides entire.....**alternata** Cress.
Last ventral segment with the sides emarginate.....16
16. Thorax above with lines of appressed pubescence.....17
Thorax above with only erect hairs.....18
17. "Scutellum medially produced into a tubercle".....**aperta** Cress.
Scutellum medially not produced into a tubercle.....**grindeliae** Ckll.
18. Pubescence white.....**ribis** Ckll.
"Pubescence ochreous; basal part of third abdominal segment more sparsely punctured than in above".....**ribis** var. **kincaidii** Ckll.
19. Clypeus near apex bilobed (viewed from above i. e. not emarginate at apex).....20
Clypeus flat or convex.....21
20. Transverse furrows on segments 2 and 3 deep; punctures on middle of segment 2 basad of furrow close, separated by about a puncture width; arcuate edge of pronotum much more strongly produced, translucent; legs red.....**novomexicana** Ckll.
Transverse furrows on segments 2 and 3 shallow; punctures on middle of segment 2 basad of furrow separated by much more than a puncture width; arcuate edge of pronotum not strongly produced, black; legs with femora usually dark.....**sayi** Robt.
21. Clypeus medially triangularly produced and somewhat reflexed, **banksi** n. sp.
Clypeus apically truncate, gently round, emarginate or tuberculate.....22
22. Basal abdominal segment at least entirely red.....23
Basal abdominal segment black (at most with sides red).....25
23. Scutellum sparsely punctured, somewhat produced medially and slightly reflexed.....**menthae** Ckll.
Scutellum closely punctured.....24
24. Abdominal segments 1-3 red; wings, except extreme bases dusky, **slossoni** Vier.
Segment 1, only, red; wings with only apical part dusky, **slossoni** var. **arenicola** n. var.
25. Legs red.....26
Legs, at least femora, dark.....31
26. Scutellum with a strong median projection.....**germana** Cress.
Scutellum medially at most tuberculate.....27
27. Third joint of antennæ hardly longer than second, about half as long as fourth.....**asteris** n. sp.
Third joint of antennæ distinctly longer than second, almost as long as fourth.....28
28. Last dorsal segment narrowed at almost a right angle; first abdominal segment closely punctured laterally.....**coquilletti** n. sp.
Last dorsal segment not narrowed at almost a right angle, at most at a very obtuse angle.....29
29. Last ventral segment very narrow, strongly bent downward; apex of last dorsal segment cephalad of notch of last ventral by one and one-half times the distance from notch to apex of segment.....**insita** Cress.
Last ventral segment broad, the sides diverging basad, not strongly bent downward.....30

30. Face with many erect brown bristle-like hairs among the appressed light ones; punctures of first abdominal segment laterad less than a puncture-width apart.....**pratti** n. sp.
Face without dark bristle-like hairs; first abdominal segment sparsely punctured laterad.....**octodentata** Say.
31. Last dorsal segment strongly angularly narrowed.....32
Last dorsal segment at most roundly narrowed.....33
32. "Part of last dorsal beyond constriction much larger than wide," **rufitarsis** Smith
"Part of last dorsal beyond constriction almost as wide as long" **comstockii** Cress.
33. "Larger, 13 mm. long".....**lucrosa** Cress.
Smaller, hardly 12 mm. long; abdomen more slender and more closely punctured.....**moesta** Cress.

Cœlioxys obtusiventris new species.

Length about 11 mm. Black, the tegulæ and legs, except coxæ, ferruginous; face coarsely rugoso-punctate, vertex coarsely punctured; the punctures separated by much less than a puncture width; scape and pedicel (rest of antennæ missing) dark, obscurely reddish; face with white hair, dense along inner orbits, interspersed with long bristle-like hairs; mesoscutum and scutellum with punctures as on vertex; scutellum with a tubercle medially on posterior margin; lateral teeth long; mesonotum with pubescence along anterior margin and base of scutellum (badly worn); wings infuscated, apically more deeply so; abdomen sparsely, rather coarsely punctured; segments 1-5 with apical bands of white hair; second, third and fourth segments with transverse furrows, interrupted medially, apicad of these furrows there is an almost impunctate line, the extreme apices of these segments with a few punctures; last segment with a few scattered finer punctures, constricted, the apical portion covered with erect brown hairs, the extreme tip upturned; ventral segments, except apex of last, coarsely, closely punctured, last ventral very broad, not notched, medially produced into a long straight spine, with a very strong fringe of brown hair.

One specimen from the C. F. Baker collection with the record "Florida; Palm."

Type specimen Cat. No. 18217, U. S. N. M.

Although the single specimen is badly rubbed it is described since it is easily separated from the other species having the last dorsal segment turned up at apex and by that segment being almost impunctured. The spine at the apex of the segment is also much longer, in the other species being hardly more than an angulation of the apex.

Cœlioxys alternata Say.

In the table this species occurs twice since the fringe of hairs along the margin of the last ventral segment is not very strong and there might be some difficulty on this account if the species were not listed under both categories

Cœlioxys texana Cresson.

For comparison with *C. hunteri* camera lucida drawings of the last ventral segment and of antennal joints 2-5 of the female are given. (Fig. 1).

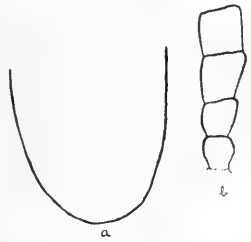

Fig. 1. C. texana Cress. (a) Last ventral segment (b) antennal joints 2-5 of female.

In the antennæ, the third joint is shown to be hardly longer than the second (exclusive of bulbous base) and the fourth is distinctly longer than the third.

Cœlioxys hunteri new species.

Female. Length about 13-15 mm. Black, with red legs; the scape and pedicel, tubercles, carinate lateral edges of pronotum and tegulæ, reddish; lateral margins of basal abdominal segments sometimes obscurely reddish; face rather finely rugoso-punctate with a median impunctate line from in front of anterior ocellus to base of clypeus and indistinctly indicated on clypeus; anterior ocellus enclosed by two cresent-shaped raised impunctate areas which are finely reticulate; upper inner orbits each with a similar sculptured spot; face with rather abundant white hair, thicker along inner orbits and around antennæ;

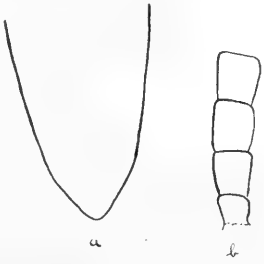

Fig. 2. C. hunteri Cwfd. (a) Last ventral segment (b) antennal joints 2-5 of female.

second joint of antenna (not counting bulbous base) much shorter than third, the third about as long as fourth; (See Fig. 2, b); vertex and mesoscutum with large rather sparse punctures, each with an appressed

white hair; scutellum and its lateral spines shaped about as in **texana**; wings dusky, with the apical margins more deeply infuscated; coxæ black with more or less obscure reddish at apices; tarsi mostly dark; spines on anterior coxæ short; mesonotum at base and along lateral margins with lines of appressed, slightly ochreous hair, at base forming two spots near middle; scutellum at base with two transverse spots of similar pubescence; under side of scutellum at apex and metanotum with dense subappressed white hair; propodeum and pleuræ with long white hair; abdomen shiny, with sparse rather coarse punctures, last segment with a silky lustre the punctures longitudinally elongate, the last dorsal and ventral (Fig. 2, a) segments (Fig. 2, a) shaped about as in **alternata;** basal margin of segment one and apical margins of segments 1-5 with lines of appressed white pubescence; segments 2-4 with diagonal lateral lines of similar pubescence near bases.

Type-locality: Hearne, Texas.

Described from five females collected "at nests in bogs", July 23, 1906, by F. C. Bishopp.

The species is named in honor of Mr. W. D. Hunter in charge of the investigation from which these specimens were obtained.

Type—Specimen: Cat. No. 18218, U. S. N. M.

This species in the structure of the apical plates is near *texana* and *alternata;* the last has dark legs; *texana* has the last ventral segment with almost parallel sides and apically broadly rounded; *altenata* and *hunteri* have this segment narrowed apically and consequently pointed at apex; in *alternata* the last dorsal segment is shiny and with sparse small punctures.

Cœlioxys piercei new species.

Female. Length about 9.5 mm. Black, including the legs, only the apical joints of the tarsi somewhat reddish; face rather finely rugoso-punctate; antennæ black; vertex and mesoscutum closely, coarsely punctured, scutellum slightly coarser rugoso- punctate; face and dorsum of thorax with slightly ochraceous pubescence, more abundant on sides of face and around antennæ and forming lines along anterior and lateral margins of mesoscutum and indistinctly so along base of scutellum; pleuræ with abundant lighter colored hair; lateral teeth of scutellum moderate in length, slightly incurved; tegulæ black; wings slightly dusky with the apical margins broadly deeply infuscated; abdomen closely, rather coarsely punctured, the last segment more closely and finely punctured, segments 2 and 3 with a deep and segments 4 and 5 with a shallow transverse furrow; segments 1-5 with apical bands of appressed white pubescence and segment 1 with the lateral margins with similar hair; base of first segment with an indistinct band of slightly ochraceous hair; last dorsal segment with a median longitudinal carina,

the segment rather suddenly constricted, near apex with a flattened projection on each side of carina (see fig. 3); last ventral segment extending a little beyond last dorsal, seen from below subtriangular in outline, the lateral edges straight, with only weak hair and without a projecting point.

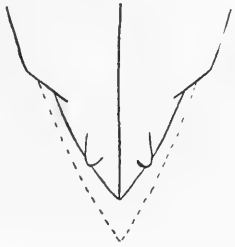

Fig. 3. C. piercei Cwfd. Last dorsal segment of female (last ventral indicated by dotted line).

Described from one female from Cotulla, Texas, April 17, 1906, on *Verbesina encelioides*, F. C. Pratt, collector.

Type—Specimen: Cat. No. 18219, U. S. N. M.

The two curious flattened projections on the last dorsal segment readily distinguish this from any species known to me.

Named in honor of Mr. W. Dwight Pierce who was actively interested in the work which resulted in the accumulation of the splendid collection of Texan Hymenoptera.

Cœlioxys edita Cress.

This species was described from a male. Female from Texas which I have associated with this species are *deplanata* Cress. and I am inclined to think that *edita* should be classed as a synonym of this species, although the association of sexes I have made may be incorrect.

Cœlioxys sculptifrons n. sp.

Female. Length about 11.5 mm. Black, with the tegulæ and the legs, except coxæ, ferruginous; clypeus rugoso-punctate with smaller punctures interspersed, the apical margin with five short teeth; face above insertion of antennæ coarsely, closely punctured, more sparsely so laterad of the ocelli; mesoscutum and scutellum coarsely punctured, the punctures except on disk of scutum crowded; lateral teeth of scutellum short, pointed; sides of face with dense long white subappressed pubescence, pubescence on clypeus finer and not so conspicuous; lateral and posterior margins of mesoscutum with indistinct lines of white appressed pubescence; pleuræ with dense long white hairs; wings dusky, with the apical margin more densely infuscated; apical margins of dorsal

and ventral abdominal segments 1-5 with bands of appressed white pubescence; first abdominal segment rather coarsely and closely punctured; second and third segments with distinct, complete, transverse impressions, the second with rather fine punctures basad of its impression, the punctures about a puncture width apart; apicad of the impression, the punctures sparse averaging two or more times a puncture width apart and finer and sparser toward middle, third segment basad of impression with the punctures somewhat wider apart than on base of second segment; apicad of the impression the punctures about as far apart as on apical part of second segment; fourth and fifth segments apically punctured about as apex of third segment; sixth segment with a distinct median longitudinal carina, basally finely punctured, the punctures slightly more than a puncture width apart; apically the punctures become slightly larger and crowded; near apex on each side of the median carina a depressed area bounded laterally by an elevated margin which is very indistinctly irregularly carinated; ventral segments 1-4 coarsely, closely punctured; fifth coarsely punctured at base, the apical part minutely very closely punctured; last ventral segment with the sides emarginate near apex.

Type-locality: Ithaca, New York.

Described from one specimen with the record, July, 1–7, from the collection of Mr. Nathan Banks.

Type—Specimen: Cat. No. 18220, U. S. N. M.

This species resembles *C. deplanata*, but differs as shown in the table and also by the sparser punctures on the abdominal segments apicad of the transverse impressions on second and third segments and by the sparse punctures on segments 4 and 5. In *deplanata* the punctures on the last segment are coarser at base, the impressions near apex are not so deep nor do they extend so far laterad.

This species differs from *C. immaculata* Ckll. described only in the male sex in the punctation of the second abdominal segment beyond the transverse impression and since the two sexes in this genus agree very closely in such characters, I do not think it possible for this species to be the same as the one described by Prof. Cockerell.

Cœlioxys sayi Robertson.

C. octodentata Cresson (not Say).

The synonomy of Mr. Robertson of this species and of *C. octodentata* Say (*C. altilis* Cress.) is adopted for it is evident that he has correctly interpreted the original description of Say.

Cœlioxys banksi n. sp.

Female. Length about 11 mm. Black, femora black, the rest of the legs ferruginous with the middle of the tibiæ obscured with blackish and the tarsi dark toward apices; face above antennæ very coarsely punctured, the clypeus medially triangularly produced and somewhat reflexed; mesoscutum amd scutellum very coarsely punctured, the punctures well separated on the disk; lateral teeth of scutellum rather short, pointed; scutellum gently rounded posteriorly; middle of face with appressed long white pubescence, clypeus with similar short pubescence; suture between mesoscutum and scutellum with a line of appressed white pubescence, a spot of similar hair at the posterior end of tegulæ; mesopleuræ with the anterior and posterior margins densely clothed with similar pubescence, as is the region immediately in front of and below tegulæ; the punctures of mesoscutum each with a long white delicate hair; tegulæ dark, obscurely reddish on disk and outer margin; wings dusky, with the apical margins more densely infuscated; dorsal and ventral segments 1-5 with apical bands of appressed white pubescence; first abdominal segment rather coarsely and sparsely punctured, the second and third with transverse impressions, basad of them the punctures about a puncture width apart, apicad of them the punctures slightly larger, laterad about as dense as basad of impressions but medially very sparse; fourth dorsal segment punctured about as third, with a transverse impression which is interrupted medially; fifth segment with the punctures finer, basally less than a puncture width apart, apically the punctures more than their own width apart; last dorsal segment with a median carina, the punctures close, the apical production of the last segment almost as long as the basal part of the segment; apex of last dorsal segment basad of notch of last ventral segment by about one and one-half times the length of the distance from notch to apex of segment; ventral segments 1-5 coarsely, closely punctured, punctures on fifth segment decreasing in size apicad; last ventral long, narrow, the apical portion bent downward, the sides near apex with a distinct notch.

Type-locality: Falls Church, Virginia.

One specimen, collected August 20, from the collection of Mr. Nathan Banks, after whom the species is named.

Type—Specimen: Cat. No. 18221, U. S. N. M.

The peculiar form of the clypeus easily distinguishes this species. In this table if this character be omitted the species would run to couplet no. 33, but the two species in that couplet both have the legs entirely black as well as the clypeus differently formed, etc.

Cœlioxys slossoni Viereck.

In the collection of the U. S. Nat. Mus. are two badly rubbed females which agree with Viereck's original description, one with the record "Palm Beach, Fla., 3-'00, collection C. F. Baker", the other without locality from the Ashmead collection. The Palm Beach specimen has the apex of the third segment dusky.

Cœlioxys slossoni arenicola new variety.

Female. Length about 13.5 mm. Differs only in having the abdomen, except basal segment, black (one has segments 2 and 3 in part obscurely reddish) and the wings subhyaline with dusky margins.

Male. Length 10.5 mm. Similar to the female in sculpture and color; the apex of the abdomen with 4 teeth the upper pair blunt somewhat flattened and divergent the lower pair longer pointed subparallel; base of last segment with a tooth on each side; fifth segment not toothed.

Type-locality: Brownsville, Texas, (April 17, 1895, C. H. T. Townsend, collector).

Allotype male from San Diego, Texas.

Other localities: Calhoun, Co., Texas, J. D. Mitchell, collector, one female; Nuecestown, Texas, 4–28–'96, C. L. Marlatt, collector, one male; also two paratype females from Brownsville, Texas, and one male from San Diego, Texas.

Type—Specimen: Cat. No. 18222, U. S. N. M.

It is most probable that the species recorded from Galveston, Texas, by Brues* as *menthae* is this form.

Cœlioxys asteris new species.

Female. Length about 14 mm. (abdomen unduly extended). Black with the tegulæ reddish-testaceous and the legs, except coxæ, ferruginous; face below antennæ finely rugoso-punctate, above antennæ coarsely punctured with an impunctured but lineolate area laterad of each lateral ocellus but none in front of and beside anterior ocellus; third joint of antennæ much shorter than fourth (see fig. 4, b,); reflexed lateral margins of pronotum strongly developed, translucent; mesoscutum with coarse, close punctures; scutellum rugoso-punctate and with a rather indistinct median longitudinal carina; lateral teeth of scutellum rather long, somewhat incurved, thick dorso-ventrad and carinate above along inner edge; wings deeply infuscated, more so along apical margins; abdomen finely, sparsely punctured, segments 2-4 each with a shallow transverse impression broadly interrupted medially; caudad of these furrows the segments almost impunctured; base of last segment more

*Entom. News, XIV, 83, 1903.

finely and closely punctured, the apical constricted portion finely rugoso-punctate; last ventral segment broad, notched near apex (see fig. 4, a,); ventral segments 1-4 rather coarsely punctured, five with similar punctures at base and fine ones at apex.

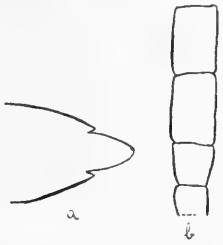

Fig. 4. C. asteris Cwfd. (a) Last ventral segment (b) antennal joints 2-5 of female.

Type-locality: Victoria, Texas.

The type collected Nov. 6, 1904, by Mr. A. J. Leister, "on aster"; a paratopotype with the same date and collector is only about 11 mm. long.

This species resembles *octodentata* which has the third joint of the antennæ almost as long as the fourth.

Type—Specimen: Cat. No. 18223, U. S. N. M.

Cœlioxys coquilletti new species.

Female. Length about 12 mm. Black with ferruginous tegulæ and legs; face below antennæ finely rugose, above, coarsely so without any smooth spots; third joint of antennæ almost as long as fourth; face with abundant pubescence at sides (rest worn ?); mesoscutum coarsely rugose all over; with a short lateral carina on each side near tegulæ; reflexed lateral margins of pronotum strongly elevated, translucent; an interrupted line of appressed white pubescence (worn ?) at base of mesoscutum, a line at base of scutellum and one at lateral margins of mesoscutum;

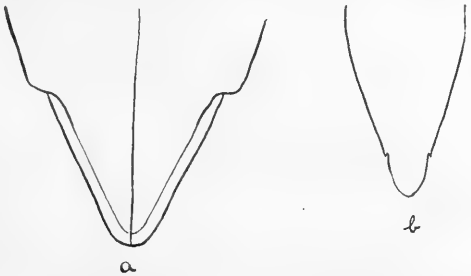

Fig. 5. C. coquilletti Cwfd. (a) Last dorsal segment (b) last ventral segment of female.

scutellum slightly more finely rugose than mesoscutum, the lateral teeth rather long and slightly incurved; propodeum and pleuræ with long white hair; wings slightly dusky with the apical margins somewhat more so; spines on anterior coxæ long; abdomen with the venter largely reddish and the edges of dorsal segments close to venter somewhat reddish (to be seen only from below); first segment of abdomen closely punctured, the punctures laterad separated by less than a puncture width; segment 1 with a basal and segments 1-5 with white apical hair bands; segments 2 and 3 deeply and 4 rather shallowly transversely impressed; the segments basad of the impressions closely punctured, apicad of them very sparsely so; last dorsal segment suddenly angularly constricted, and with a median carina (see fig. 5a); last ventral notched at sides (see fig. 5b); ventral segments 1-5 with apical hair bands and coarsely punctured.

Habitat: Los Angeles, Co. Cal., (D. W. Coquillett, collector).

Type—Specimen: Cat. No. 18224, U. S. N. M.

In general this resembles *octodentata* but differs in the vertex being rugose and without smooth areas, in the rugose mesoscutum (in *octodentata* the punctures on the disk of the mesoscutum are well separated); in the abruptly narrowed last dorsal segment, and in the closely punctured first segment of the abdomen. In this last character it resembles *pratti* but differs in all the other characters quoted above; *pratti* has the mesoscutum more closely punctured than *octodentata* but it is not rugose. In the shape of the last dorsal segment this resembles *rufitarsus* from which it differs in addition to the difference in the color of the legs by the first segment being closely punctured, by having the second and third segments basad of the transverse impressions more closely punctured and by having the fifth ventral, except apex, with coarse punctures, etc.

Cœlioxys insita Cresson.

The apex of the ventral segment as illustrated and marked on the figure is the approximate point to which the last dorsal segment comes (indicated by a U in the sketch). (Fig. 6.)

Fig. 6. C. insita Cress. Last ventral segment of female.

Cœlioxys pratti new species.

Female. Length 11.5 mm. Very similar to *C. octodentata* but differs in the clypeus having many erect, brown, bristle-like hairs among the dense white pubescence, the eyes with longer, much denser and distinctly brownish pubescence, the punctures of the mesonotum somewhat finer and denser, the first abdominal segment with close punctures, those laterad separated by much less than a puncture width; fifth ventral abdominal segment with coarse punctures only at base.

One female with the record Kerrville, Texas, April 14, 1907, on *Marrubium vulgare*, H. Durham, collector.

Type—Specimen: Cat. No. 18225, U. S. N. M.

C. octodentata has the punctures of the mesonotum well separated medially, the first segment with the punctures toward sides separated by more than a puncture width and the fifth ventral segment with coarse punctures except on the apex.

This species is named for Mr. F. C. Pratt through whose efforts the large amount of material from the type-locality of this species was secured.

Cœlioxys rufitarsis var. **rhois** Ckll.

This differs from the typical form only in having the tegulæ black and the veins of the wings darker than normal, and would run out in the table where the typical form does.

CONNECTANT FORMS BETWEEN THE MUSCOID AND ANTHOMYIOID FLIES.

By Charles H. T. Townsend,
Director of Entomological Stations, Lima, Peru.

The object of this communication is to point out certain forms which appear to be transitional between the muscoid and anthomyioid types, to call attention to their evident affinities, and to suggest characters which may be used for establishing a boundary line between these two natural groups of flies.

Girschner's system, proposed in 1893, recognizing two groups which he called *Tachiniden* and *Anthomyiden*, contains many elements of truth. It has resulted in demonstrating muscoid affinities in certain forms hitherto accepted without question as anthomyioid. Bezzi and Stein have followed this system in their catalogue, and Schnabel and Dziedzicki have recently attempted to reinforce it in their treatment of the anthomyioid flies. What concerns us chiefly in the present consideration is the fact that *Musca* and its immediate allies fall in the *Anthomyiden* according to this system. The concept is fundamentally wrong nomenclatorially, however it may be justified otherwise. Whatever group *Musca* is found to fall in must take its name from that genus. If Girschner's group *Anthomyiden* be adhered to as it stands, its name must be *Musciden* according to all accepted rules of nomenclature. But it is certain that many characters remain to be investigated before this grouping can safely be pronounced a natural one, for the main separation is founded practically on a single character—the presence or absence of hypopleural bristles.

The solution of the question practically hinges on whether *Musca* is, or is not, more closely allied to *Anthomyia* than it is to *Calliphora*. Wherever *Musca* goes, it will carry with it a considerable contingent—*Stomoxys*, *Muscina*, *Mesembrina*,

Glossina, all their immediate allies, and quite probably a block of forms hitherto classed as Anthomyiidæ. The position of *Calliphora* has never been questioned, but the other forms are more or less connectant between *Calliphora* and *Anthomyia*, and the affinities of *Musca* have long been confused with those of the truly connectant forms. We are thus practically in the rather paradoxical position of being unable to place taxonomically the type of the superfamily Muscoidea, which seems inclined to fall in the Anthomyioidea.

If *Musca* prove to be more nearly related to *Anthomyia* than to *Calliphora*, then one of two things must result. Either the Muscoidea in the writer's sense must extend itself to include all the anthomyioid flies; or the latter must be grouped with *Musca* and the connectant forms into a totally different superfamily to be known as the Muscoidea, thus completely changing the sense of the name and leaving the Calliphorinæ and higher groups to form a superfamily by themselves. It is therefore evident that a pressing necessity exists for fixing definitely the status of *Musca* with relation to the connectant forms that intervene between *Anthomyia* and *Calliphora*.

Certain students, not caring to proceed farther, will adopt the former solution of the difficulty and thus dismiss the whole subject. But this is not the correct solution, for it obscures the real affinities of the two groups. The anthomyioid flies, as a whole, present a far greater contrast with the rest of the Schizometopa, which is to say Muscoidea, than do the various groups of the latter with each other. Moreover, there are at least two family types— *Coenosia* and *Anthomyia*—represented in the Anthomyioidea, and it is a question whether *Drymeia* does not constitute a third and *Fannia* a fourth. Nor can we reduce the value of the taxonomic groups one notch, thereby considering the whole Schizometopa as one superfamily, for such action would only compel the inauguration of a new category farther down the line in order to preserve a proper conception of relationships. The anthomyioid flies constitute a superfamily of the atypic class, which is to say that they occupy a position entirely outside the proper limits of the superfamilies Muscoidea and Borboroidea (Holometopa excl. Conopidæ), but intermediate between the two. As such they claim separate recognition.

In order to fix permanently the taxonomic status of *Musca*, a comparative study must be made of *Anthomyia pluvialis* L., *Calliphora erythrocephala* Mg., *Musca domestica* L., the connectant forms and the main anthomyioid types, along the following lines:

(1) Chaetotaxy.

(2) Pilotaxy—This term is coined to designate the disposition of hairs and pile in the Diptera in general and the Muscoidea in particular.

(3) Pleural and other external thoracic anatomic characters.

(4) Venation.

(5) Male reproductive system.

(6) Female reproductive system.

(7) Hypopygium.

(8) Egg.

(9) First-stage maggot.

Lowne has worked out *Calliphora erythrocephala* quite extensively, and Hewitt has done the same for *Musca domestica*. *Anthomyia pluvialis* needs similar attention before exact comparisons can be instituted. As to male reproductive-system characters in the connectant and anthomyioid forms, *Stomoxys* has been worked out by Roubaud, and verified by others including the writer. *Othellia*, *Haematobia*, *Hypodermodes* and *Morellia* have been worked out by Thompson, the last two not yet published; *Muscina*, *Synthesiomyia*, *Morellia*, *Limnophora*, *Leucomelina*, *Fannia* and Gen. Indet. have been worked out by the writer. In addition to these many nonconnectant muscoid forms have been investigated as to the male reproductive system by both Thompson and the writer, and *Auchmeromyia* and *Choeromyia* have been similarly worked out by Roubaud. All of the above named connectant and anthomyioid genera except *Fannia* agree with *Musca* in lacking the male accessory glands. *Fannia* and all the nonconnectant muscoid forms possess such glands, though they may be rudimentary in the higher forms.

The writer has worked out the female reproductive system and egg in *Stomoxys*, *Muscina*, *Synthesiomyia*, *Leucomelina*, *Limnophora* and *Spilogaster*, besides many nonconnectant muscoid genera. The first three agree with *Musca* and the Calliphorinae in egg characters, but the last three differ considerably from them in these characters. Available data on the lines above specified are presented below.

CHAETOTAXY AND PILOTAXY.

Higher Muscoidea	Hypopleural bristles present in a more or less vertical row, pteropleural bristles present; when 3 sternopleural bristles present, their formula is either 2.0.1 or 1. 1. 1—All muscoid families except Muscidæ, Oestridæ, Cuterebridæ.
	True hypopleural bristles present, pteropleural bristles absent but in their place hairs or pile; sternopleural bristles 2. 0. 1 or 1.0.1—Bengaliinæ (Calliphorinæ).
	Macrochaetæ entirely absent; row of hypopleural hairs present homologous with true hypopleural bristles—Gastrophilus and Cobboldia.
Typical Muscoidea.	True hypopleural bristles absent, hypopleural hairs and pile absent; pteropleural bristles present, also often pteropleural hairs or pile; sternopleural bristles 1. 0. 2—Musca, Morellia and Glossina.
Connectant Muscoidea	Hypopleural hairs present, pteropleural hairs absent; sternopleurals 1. 0. 2 or 0.0.2—Synthesiomyia and Graphoymia.
	Hypopleural hairs and bristles both absent; pteropleural hairs, sometimes of a bristly nature, present; sternopleurals none, 0.0.1, 1.0.1, or 1.0.2-4—Haematobia, Hypodermodes, Mesembrina, Eumesembrina, Pyrellia, Orthellia.
	Hypopleural and pteropleural hairs present; sternopleurals 0.0.1—Stomoxys.
	Neither hypopleural nor pteropleural hairs, pile or bristles present; sternopleurals normally only 3 and formula 1.0.2 (abnormally 2.0.2)—Muscina, Myospila, Clinopera, Leucomelina, Gen. Indet., Limnophora, Aricia, Spilegaster.
Anthomyioidea	Neither hypopleural nor pteropleural hairs; sternopleurals 3 or more and rarely 1.0.2—Anthomyia, Fannia, Coenosia.

PLEURAL ANATOMY

The name *squamopleura* is hereby proposed for the inferior swollen lobe of the metapleura of authors, being the lower lobe of the lateral plate of postscutellum (Hewitt). The sclerite in question is a part of the mesothorax. The term metapleura is thus misapplied here, since metapleura can have no place in mesothoracic terminology. The metathorax is represented in the Muscoidea by the metasternum, whose lateral wings are termed the hypopleuræ; and by the true metapleura which is situated behind the hypopleura, the metanotum being practically evanescent.

The squamopleura exhibits characters in connection with the hypopleura and the posterior thoracic spiracle which are at times of importance. It therefore requires a special designation though it is not apparently a separate sclerite. It is sometimes bare, often pilose or hairy, sometimes bristly, while the position of the spiracle with reference to it and the hypopleura may be used in the separation of groups among the connectant forms.

Higher and Typical Muscoidea	Posterior thoracic spiracle behind vertical axis of squamopleura and hypopleura—Musca, bulk of Muscoidea, Leucomelina, Limnophora, Spilogaster, Gen. Indet., Fannia.
Anthomyioidea Connectant Muscoidea	Posterior thoracic spiracle squarely interposed between the squamopleura and hypopleura—Muscina, Synthesiomyia, Morellia, Aricia (last judged from figures).

VENATION

Higher and Typical Muscoidea	Fourth vein when complete or apical crossvein when present reaching margin at or before extreme wingtip, the hind cross-vein always joining fourth vein well before bend of latter or origin of apical crossvein—Musca, bulk of Muscoidea, but including only Cobboldia among the Oestridæ and allies. Fourth vein always complete and reaching margin before wingtip, the apical cross-vein not present, the hind cross-vein practically in line with the last section of the fourth vein—Glossina, Cuterebridæ, Hypoderminæ, Oestrinæ. Fourth vein incomplete, not reaching wing margin; apical and hind cross-veins obsolete—Gastrophilus.
Connectant Muscoidea	Fourth vein always complete, reaching margin behind extreme wingtip, always bowed forward apically; no apical crossvein—Stomoxys, Haematobia, Lyperosis, Hypodermodes, Eumesembrina, Muscina, Myospila, Clinopera, Pararicia, Leucomelina; the last three with least forward bow to fourth vein and thus most approaching the anthomyioid type.
Anthomyioidea	Fourth vein not bowed forward in any part of its extent, but often bowed backward apically—Limnophora, Spilogaster, Fannia and other Anthomyioidea.

Of the above Haematobia furnishes an aberrant form of the *Stomoxys* type, and *Glossina* an aberrant form of the *Musca* type. Only *Clinopera*, *Pararicia* and *Leucomelina* are intermediate between the *Stomoxys* and *Anthomyia* types. A number of forms are intermediate between the *Stomoxys* and *Musca* types.

REPRODUCTIVE SYSTEM.

Higher Muscoidea	Male with accessory glands always more or less developed, at least their rudiments visible; female usually with a large number of ovarioles—All Muscoidea down to and including the Calliphorinæ.
Typical Muscoidea	Male without accessory glands, with very long and curled ejaculatory duct whose head is developed into a very elongate vesicula seminalis; female without uterus, with many functioning ovarioles—Musca, Muscina, Synthesiomyia.
Connectant Muscoidea	Same as preceding, but ejaculatory duct of male much shortened, not over 3 to 5 times as long as the vas deferens, with more than half of it functioning as vesicula seminalis—Morellia, Stomoxys, Haematobia*.
	Male without accessory glands; female with only one or two functioning ovarioles, one or two maggots or eggs developing at a time in the uterus—Glossina,* Dasyphora,* Mesembrina, Hylemyia.*
	Male without accessory glands; female with few ovarioles, depositing large eggs which hatch shortly into maggots omitting the second stage and developing rapidly—Hypodermodes, Eumusca,* Myospila.*
	Male without accessory glands; female with few ovarioles, depositing a small number of large eggs—Orthellia, Graphomyia,* Pyrellia.*
	Male without accessory glands, with very long vas deferens communis present and long vesicula seminalis; female with few ovarioles, depositing a small number of large eggs—Leucomelina, Limnophora, Spilogaster*.
	Male without vas deferens communis or accessory glands, with very short ejaculatory duct—Gen. Indet.
Anthomyioidea	Male without vas deferens communis, with accessory glands, with bulbous vesicula seminalis at head of the very short ejaculatory duct—Fannia.

The term *vas deferens communis* is here proposed for the slender tube present in some forms extending from the union of the two vasa deferentia to the beginning of the swollen and more or less elongate vesicula seminalis, and apparantly not to be interpreted as a part of the ejaculatory duct. It is short in certain Borboroidea (*Paralimna* sp. for example) and Syrphoidea (*Volucella* sp.), but very long in *Leucomelina* and *Limnophora*. It seems to be the homologue of the common oviduct of the female, notwithstanding Berlese's homologies in his Gli Insetti (p. 841).

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*Some doubt exists as to whether the 9 starred genera agree with the male characters given.

HYPOPYGIUM

Worked out by Schnabl and Dziedzicki for a large number of connectant as well as true anthomyioid forms. The characters agree in a general way throughout the connectant forms much as do those of the female reproductive system, not appearing to furnish variations of sufficient scope for definite separation into two main groups, except to mark off the Coenosiidæ from the other forms. But they will doubtless be of much use in the separation of small groups. The Calliphorine and higher muscoid groups need the same careful study for comparison with the excellent results of these authors on the forms which they have investigated.

EGG

Leucomelina, *Limnophora* and *Spilogaster* differ considerably in egg structure from *Musca*, *Muscina*, *Synthesiomyia*, *Stomoxys*, the *Calliphorinæ* and higher groups. They deposit a small number of very large elongate eggs, either heavily striate longitudinally or ribbed, or very minutely scaled-reticulate, very slightly curved, yellowish-whitish in color, with thick chorion, translucent-enameled in appearance.

It is probable that these approximate the characters of the eggs of *Orthellia*, *Graphomyia*, *Pyrellia*, *Myospila*, *Eumusca* and *Hypodermodes*, all of which deposit only a small number of very large eggs.

The egg may be expected to furnish important characters for the separation of the connectant forms.

MAGGOT

The position of the anterior spiracle in the third-stage maggot of *Fannia* is quite in contrast to its position in *Musca*, being situated well forward on the third segment. Whether this holds good for *Anthomyia* and *Coenosia* is doubtful. The first-stage maggot characters, especially the cephalopharyngeal skeleton and anal stigmata, should differentiate the connectant forms from the true anthomyioids.

It appears from the foregoing that the most serviceable characters for defining the natural boundary between *Musca* and *Anthomyia* will be found in the egg, first-stage maggot, male reproductive system, chaetotaxy and pilotaxy; while the venation, thoracic sclerites, female reproductive system and hypopygium will furnish supplementary characters of value.

The indications from the very incomplete data which it has been possible to present are that *Musca* is much more nearly related to *Calliphora* than to *Anthomyia*, but final judgment must be reserved until all the main types concerned can be investigated and the results compared and correlated. The present meager notes will form a starting point for an extended study of the subject.

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Volume VII. Number 3.

ANNALS

OF

The Entomological Society of America

SEPTEMBER, 1914

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PUBLISHED QUARTERLY BY THE SOCIETY
COLUMBUS, OHIO

Entered as second class matter April 11, 1908, at the Post Office at Columbus, Ohio, under the Act of Congress of March 3, 1879.

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Volume VII SEPTEMBER, 1914 Number 3

SPIDERS COLLECTED BY MR. C. WILLIAM BEEBE IN BURMA AND BORNEO.

With Plate XXVI.

ALEXANDER PETRUNKEVITCH, PH. D.

Family Theraphosidæ.
Haplopelma Doriæ (Thorell). One female from Kuching, Borneo.

Family Drassidæ.
Drassodes Drydeni n. sp. One male from Pongatong, Burma.
Drassodes ignobilis n. sp. One female from Tabu Pum, Burma.

Family Pholcidæ.
Pholcus phalangioides Fussl. One female from Wahsaung, Burma.

Family Theridiidæ.
Theridion sarapus Thorell. Two females from Pongatong, Burma.
Dipoena tristis n. sp. One female from Tabu Pum, Burma.
Enoplognatha marmorata L. One immature female from Tabu Pum, Burma.

Family Linyphiidæ.
Erigone longipalpus F. Two males and two females from Tabu Pum, Burma.
Linyphia sp? One immature female from Tabu Pum, Burma.

Family Clubionidæ.
Clubiona tabupumensis n. sp. One female from Tabu Pum, Burma.
Clubiona sp? One young from Tabu Pum, Burma.
Clubiona sp? Two young from Wahsaung, Burma.
Palystes sp? One young from Wahsaung, Burma.

Family Argiopidæ.

Nephila maculata F. One female from Wahsaung, Burma.
Nephila clavata L. Koch. Two females from Tabu Pum, Burma.
Leucauge tesselata (Thorell). One female from Pongatong, Burma.
Gasteracantha arcuata F. One female from Kuching, Borneo.
Gasteracantha frontata Bl. Two females from Kuching, Borneo.
Theridiosoma sp? One young from Tabu Pum, Burma.
Araneus microtuberculatus n. sp. One female from Tabu Pum, Burma.
Araneus Beebei n. sp. One female from Wahsaung, Burma.

Family Thomisidæ.

Philodromus tabupumensis n. sp. One female from Tabu Pum, Burma.
Bomis sp? One young without abdomen, from Wahsaung, Burma.
Porrhopis sp? One young from Wahsaung, Burma.

Family Lycosidæ.

Lycosa stictopyga Thorell. One female from Tabu Pum, Burma.
Lycosa (Pirata) sp? One immature female from Tabu Pum, Burma.
Lycosa sp? One young from Tabu Pum, Burma.

Family Oxyopidæ.

Oxyopes sp? One young from Wahsaung, Burma.
Oxyopes sp? Two young from Wahsaung, Burma.

Family Salticidæ.

Evophris sp? One young from Wahsaung, Burma.
Evophris albopatella n. sp. One male from Wahsaung, Burma.
Cobanus Beebei n. sp. One male from Central Borneo.
Ballus tabupumensis n. sp. One female from Tabu Pum, Burma.
Attulus sp? One young from Wahsaung, Burma.
Thiania sp? One young from Wahsaung, Burma.

Description of new species.

Drassodes Drydeni* n. sp. (Plate XXVI, figs. 1 and 2).

Total length 7.4 mm. Cephalothorax and all appendages brown, abdomen grey. Sternum oval, pointed behind, broadly truncated in front. Lip much longer than wide. Laminæ maxillares strongly impressed. All femora slightly thickened. Cephalothorax much narrower in front than in middle. Anterior row of eyes recurved, posterior procurved. AME half their diameter apart, subcontiguous with ASE. Eyes of second row aequidistant. ASE separated from PSE by less than half their diameter. AME slightly larger than ASE. Anterior row viewed from in front curved downward. Clypeus as high as AME. First tarsus and metatarsus with a heavy scopula. Second tarsus with a scopula only in its distal half. Second metatarsus without scopula.

* In honor of Mr. John Dryden Kuser.

Heavy spines on all legs. Femur of pedipalp with a short blunt subterminal apophysis on the inside. (Plate XXVI, fig. 2). Copulatory apparatus with an extremely long and thin embolus (Plate XXVI, fig. 1).

One male from Pongatong, Burma.

Drassodes ignobilis n. sp. (Plate XXVI, fig. 3).

Total length 5.9 mm. Cephalothorax and all appendages brown, abdomen dark grey. All femora slightly thickened. Tarsi without scopulæ. Sternum oval, broadly truncated in front, pointed behind. Lip longer than wide. Laminæ maxillares strongly impressed. Fourth legs with spines. All femora with two long, upright spines in median dorsal line. No spines on other joints of first, second and third leg. Anterior row of eyes recurved, posterior row procurved. PME about their diameter apart. PSE about half diameter from PME. Eyes of anterior row equal in size, contiguous. Anterior row viewed from in front curved downward. Side eyes separated by about half their diameter. Clypeus as high as AME. Epigynum as figured, much higher than wide.

One female from Tabu Pum, Burma.

Dipoena tristis n. sp. (Plate XXVI, fig. 4).

Total length 4.8 mm. Cephalothorax and legs reddish brown, Abdomen dark greyish brown with a narrow dark median line and two pairs of transverse whitish bands. No spines on legs. Sternum triangular. Anterior coxæ widely apart. Lip wider than long. Anterior row of eyes strongly recurved, posterior row straight, longer than anterior. Eyes of posterior row aequidistant and equal in size. Side eyes contiguous, equal. AME smaller than the other eyes. Eyes of anterior row aequidistant. Clypeus as high as quadrangle. Epigynum as figured.

One female from Tabu Pum, Burma.

Clubiona tabupumensis n. sp. (Plate XXVI, fig. 5).

Total length 7.8 mm. Cephalothorax and all appendages yellowish brown, abdomen grey. Anterior row of eyes much shorter than posterior row, slightly recurved. Posterior row almost straight. Quadrangle wider than long, much narrower in front than behind. Eyes of anterior row aequidistant, separated from each other by somewhat less than their diameter. PME somewhat farther from each other than from the PSE. Distance between the PME equal to about 2½ their diameter. Clypeus not more than half the diameter of the AME. Sternum a long oval, pointed behind, truncated in front. Lip much longer than wide. First and second tarsi and metatarsi with a thick scopula. Similar scopula on distal half of third and fourth tarsi. First tibia with 2-2 long spines below, first metatarsi with 2 long spines at base below. Third and fourth tibiæ with a row of 3 spines in median line below, 2 laterals inside

and 2 laterals outside. Third and fourth metatarsi with spines below, above and laterals. Epigynum very small, considerably in advance of genital slit.

One female from Tabu Pum, Burma.

Araneus microtuberculatus n. sp. (Plate XXVI, figs. 6, 7, 8).

Total length 2.8 mm. Cephalothorax high, without groove or stria. Abdomen with two tubercles or shoulders in front and two prominent tubercles behind. (Plate XXVI, figs. 7, 8). Integuments soft. Side eyes subcontiguous, on black tubercles. ASE much smaller than PSE. Both rows of eyes recurved. Quadrangle wider behind than in front, wider than long. PME much larger than AME. Clypeus lower than quadrangle, about twice the diameter of the AME. Sternum triangular, broadly truncated in front. It is also truncated behind, between the hind coxæ which in consequence are separate. Lip triangular, very wide. Chelæ smooth, inferior margin with 3 teeth, superior with 4 teeth. Pedipalpi with a claw. One dorsal spine at end of all patellas. One inside lateral spine on first femur and tibia. Upper claws almost cordate, with four teeth each. Third claw smooth. Epigynum as figured. (Plate XXVI, fig. 6). Color in alcohol: cephalothorax brown with a median white spot. Chelæ brown, legs brown, femora lighter than other joints. Sternum dark brown, lip and laminæ with tips of lighter color. Abdomen above mottled with white and brown, tubercles dark. Sides whitish with three dark lines. Below almost black. Spinnerets brown.

One female from Tabu Pum, Burma.

Araneus Beebei n. sp. (Plate XXVI, figs. 9, 10).

Total length 2.5 mm. Cephalothorax with a somewhat recurved groove. Clypeus not half the diameter of the AME. Quadrangle much wider in front than behind. Anterior row strongly recurved, posterior row slightly recurved. AME are the largest eyes. Chelæ distinctly longer than thick. Inferior margin with 3 teeth, superior margin with 4 teeth. Abdomen oval, considerably overlapping cephalothorax. Sternum triangular, widely truncated in front, produced behind between the fourth coxæ which are separate. Pedipalpi with a claw. Legs with many spines. Two rows of long bristles below all femora, especially on those of the first and second pair. Epigynum as figured, brown and relatively very large. (Plate XXVI, fig. 9). Color in alcohol : cephalothorax greyish brown, legs yellow, sternum, lip, laminæ, pedipalpi and chelæ also yellow. Abdomen (Plate XXVI, fig. 10) above grey with white iridescent spots, a transverse anterior black band and a large median more or less triangular black spot pointed backwards. Below grey with iridescent white spots.

One female from Wahsaung, Burma.

Philodromus tabupumensis n. sp. (Plate XXVI, fig. 11).

Total length 4.8 mm. Cephalothorax 1.8 mm. long, 2.0 mm. wide. Legs 2134. Anterior row of eyes shorter than the posterior row and recurved. Posterior row very slightly recurved, almost straight. Anterior eyes about equal in size, AME farther from each other then from the ASE. PME smaller than the PSE, the distance between the PME much larger than between the PME and the PSE. Quadrangle narrower in front than behind, about as wide as long. Clypeus 1½ diameters of the AME. Sternum longer than wide, emarginate between hind coxæ which are widely separate. Spines on all segments of legs and palpi, except tarsi. First femur 2.2 mm. long, second 2.6 mm. Color in alcohol: cephalothorax light brown with black marginal and three black longitudinal parallel bands. A narrow, curved black band runs in front of the eyegroup, touches the PSE on each side of the head and merges with the median longitudinal band at the posterior margin of the cephalothorax. Legs yellow, spotted above with dark brown. Abdomen above light brown with two dark brown V-shaped spots pointed forward, sides dark brown, underside altogether light yellow. Epigynum as figured.

One female from Tabu Pum, Burma.

Evophris albopatella n. sp. (Plate XXVI, figs. 12, 13).

Total length 2.7 mm. Legs 4312. Inferior margin of chelæ with one tooth, superior with a row of eight teeth. Of these only the proximal two are large, while the others are exceedingly small. (Plate XXVI, fig. 12). Cephalic part shorter than thoracic. Eyegroup wider in front than behind. ASE very prominent. Eyes of second row minute, situated in middle. Iridescent white scales above AME, between side eyes on face and along the edge of the cephalothorax which is very dark brown. First, second and third femur, patella and tibia dark brown above and below. Fourth femur yellow with a dark brown spot above at distal end. Fourth patella and tibia yellow above with two lateral dark brown lines, below yellow. All other joints of all legs yellow. Palpi dark brown except patella which is covered with white iridescent scales. Sternum, lip and laminæ dark brown with yellow edges. Chelæ reddish brown. Abdomen above yellow with two parallel longitudinal dark brown bands and white iridescent scales. Below yellow with a median dark brown broad band. Tibia of pedipalp with a curved apophysis, copulatory apparatus as figured. (Plate XXVI, fig. 13).

One male from Wahsaung, Burma.

Cobanus Beebei n. sp. (Plate XXVI, figs. 14-18).

Total length without mandibles 9.0 mm. Cephalothorax 3.8 mm. long, 3.1 mm. wide. Chelæ long, with long, curved fang. Length of chelæ without fang 3.8 mm. Superior margin with two teeth of

which the subapical one considerably larger than the proximal. Inferior margin with two teeth. (Plate XXVI, fig. 14). Legs 3142. Cephalothorax high. Eyes of second row small, situated behind the middle. Measurements of legs: First leg—femur 4.6 mm., tibia+patella 5.5 mm. metatarsus+tarsus 4.8 mm.; Second leg—femur 3.3 mm., tibia+patella 3.5 mm., metatarsus+tarsus 3.6 mm.; Third leg—femur 5.2 mm., tibia+patella 5.1 mm., metatarsus+tarsus 5.8 mm.; Fourth leg—femur 3.0 mm., tibia+patella 3.7 mm., metatarsus+tarsus 4.5 mm. All legs with many heavy spines. Tibia of first leg curved, with 4-4 spines below. First metatarsi straight, with 2-2 long spines below and laterals. A heavy comb of black hair above and below first patella, a comb of shorter hair on distal half of femur and one of quite short hair on back of first tibia (Plate XXVI, fig. 15). Claws as figured (Plate XXVI, fig. 17). Sternum longer than wide, lip not reaching half of laminæ. (Plate XXVI, fig. 16). Tibia of pedipalp with a straight apophysis, copulatory apparatus as figured (Plate XXVI, fig. 18). Color in alcohol: cephalothorax red-brown, with two lateral white patches and a fringe of brown hair around the eyes. Chelæ above red-brown, below black. Fang black with red-brown tip. Pedipalpi yellow. First femur and patella very dark brown, tibia yellow with dark brown distal end, metatarsus and tarsus dark brown. Other legs brown, fourth leg lighter. Lip and laminæ dark brown, sternum reddish brown. Abdomen dark grey above and below.

One male from Central Borneo.

Ballus tabupumensis n. sp. (Plate XXVI, figs. 19, 20).

Total length 5.7 mm. Legs 1423. Cephalothorax flat and square. Eyegroup wider behind than in front. Pars cephalica longer than pars thoracica. Eyes of second row minute, situated considerably in front of middle. Posterior row somewhat shorter than width of cephalothorax. Chelæ short and heavy (Plate XXVI, fig. 20) with a humped back carrying a row of tubercles. Inferior margin with three teeth of which the middle one is the smallest. Superior margin with a row of 12 very small teeth. Sternum much longer than wide, posterior coxæ contiguous. Lip longer than broad, laminæ very long with emarginate outer edge, wider at end than at base, inclined over lip. First leg much heavier than the others. First femora dilated. First tibia with 3 - 3 heavy spines below and no laterals. First metatarsus with 2 - 2 very heavy spines below, the first pair reaching beyond the middle of the article and the second pair almost to the base of the claws, no laterals. Claws with a single tooth. Epigynum as figured (Plate XXVI, fig. 19). Color in alcohol: cephalothorax, chelæ and first leg very dark brown. Abdomen and femora of second, third and fourth pair brown. Other joints of second, third and fourth leg yellow with dark spots. Underside dark brown.

One female from Tabu Pum, Burma.

EXPLANATION OF PLATE XXVI.

Drassodes Drydeni n. sp.—male.
Fig. 1. Copulatory apparatus of male.
Fig. 2. Femoral apophysis of pedipalp.

Drassodes ignobilis n. sp.—female.
Fig. 3. Epigynum.

Dipoena tristis n. sp.—female.
Fig. 4. Epigynum.

Clubiona tabupumensis n. sp.—female.
Fig. 5. Epigynum.

Araneus microtuberculatus n. sp.—female.
Fig. 6. Epigynum.
Fig. 7. Sideview of abdomen and cephalothorax.
Fig. 8. Dorsal view of abdomen.

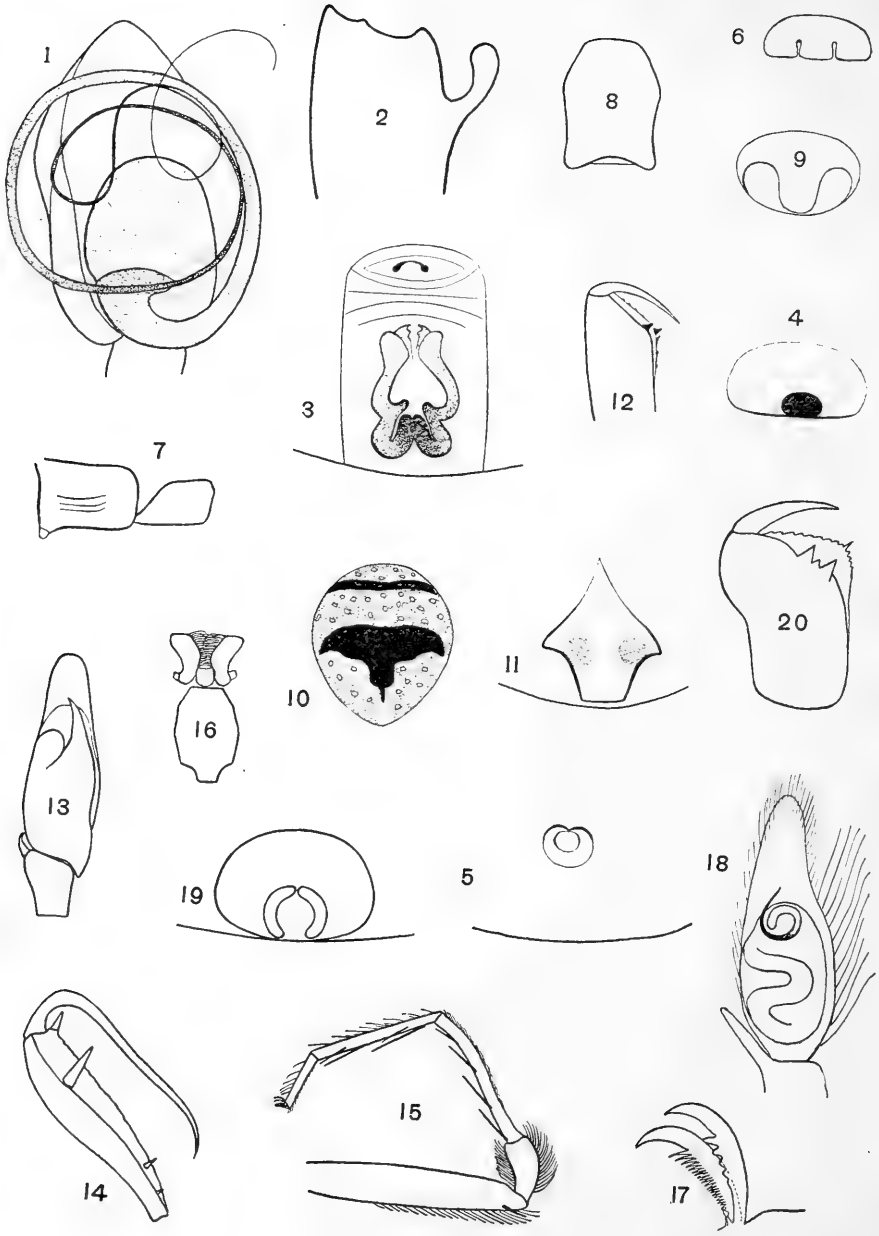
Araneus Beebei n. sp.—female.
Fig. 9. Epigynum.
Fig. 10. Dorsal view of abdomen.

Philodromus tabupumensis n. sp.—female.
Fig. 11. Epigynum.

Evophrys albopatella n. sp.—male.
Fig. 12. Chelæ.
Fig. 13. Copulatory apparatus.

Cobanus Beebei n. sp.—male.
Fig. 14. Chelæ.
Fig. 15. First leg.
Fig. 16. Sternum, lip and laminæ.
Fig. 17. Claws.
Fig. 18. Copulatory apparatus.

Ballus tabupumensis n. sp.—female.
Fig. 19. Epigynum.
Fig. 20. Chelæ.



A. Petrunkevitch.

THE RAVAGES, LIFE HISTORY, WEIGHTS OF STAGES, NATURAL ENEMIES AND METHODS OF CONTROL OF THE MELON FLY (DACUS CUCURBITAE COQ.).

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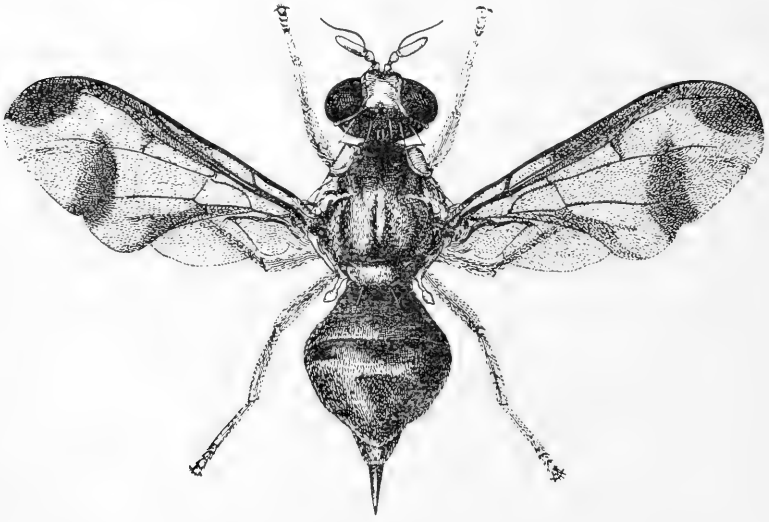
I. Introduction.

The most destructive pest of the Cucurbitaceæ in the Hawaiian Islands is commonly called the Melon Fly (Dacus cucurbitæ Coq.) or the Bitter Gourd Fruit Fly in other parts of the world. Previous to the accidental introduction of this insect into Hawaii, melons were sold at ten cents each, but today the consumer often pays from fifty cents to one dollar for a watermelon. It has been estimated that the loss in the Hawaiian Islands amounts to almost a million dollars annually, in tribute to this fly, or a little over five cents a day for a family

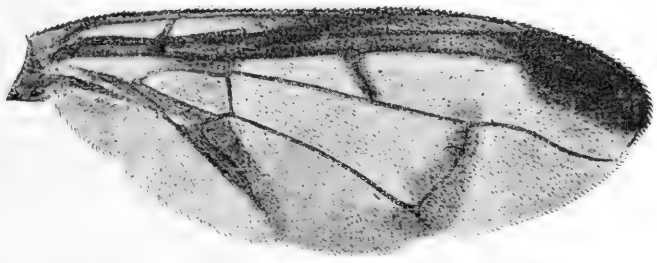


Text Fig. 1. Melon fly, Dacus cucurbitæ Coq. (After Perkins).

of four, on an estimated population of 192,000. When one stops to consider that the Hawaiian Islands are smaller than the state of Rhode Island, that the principal agricultural products are sugar, pineapples, coffee and rice, one realizes what a tremendous amount of injury this fruit fly causes to the limited vegetable crops grown in the islands. This trypetid has been allowed to play havoc unmolested for a period of sixteen years or more, so that today in many localities swarming with the pest, barely do the seeds of some cucurbits germinate, when the seedlings are "stung" by the flies; the larvæ which hatch from the eggs devour the tissue of the stems and cause decay, then the maggots penetrate into the roots and completely destroy the plants.

II. Native Home.

Some difference of opinion exists as to the native home of the melon fly. Muir (5, p. 17) "found that India was its original home" and later on, Froggatt's (5, p. 17) investigations showed that the melon fly was widely distributed over India and also Ceylon. Perkins (10, p. 36) believes "its true home is no doubt in China or Japan." In a map showing the fruit fly regions with steamship connections to California, Compere (2, p. 728) records the danger of introducing the pest into that state from the following sea ports: Hawaiian Islands, Timor, Manila, Nagasaki, Hongkong, India and Singapore. Compere claims that this pest is rarely found in the Philippine Islands and he informed the writers that the melon fly was originally native of these islands. It was imported from one of the above mentioned countries into the Hawaiian Islands about the year 1897.



Text Fig. 2. Wing of melon fly. (After Froggatt).

III. Description of Melon Fly.

The melon fly is wasp-like in its general shape and behavior and resembles a hornet (Polistes) somewhat in color but is less than half as large. The head is yellow in color; the thorax is reddish yellow marked with a number of light yellow areas and the abdomen is yellow on the first two segments and reddish-yellow on the others. At the base of the second, abdominal segment is a transverse black line, which unites with a black, dorsal, median line on the next three segments. A lateral, brown spot is usually present on the fourth and fifth segments. The transparent wings are marked with brown bands. A brown band extends along the front margin of each wing and ends in a large spot at the apex; another brown band extends along a fold of the wing near the body; between the distal ends of these bands is a transverse marking (Text fig. 2). The legs are light yellow in color.

Compere (2, p. 710) recognized the melon fly as a new species in Hawaii and sent specimens to Coquillet (3, pp. 129-130) whose original description follows:

"*Dacus cucurbitæ.*—Head light yellow; the occiput, except the sides and upper margin, reddish-yellow, an ocellar black dot, front marked with a brown spot in front of its centre, and with three pairs of orbital brown dots, a black spot on each side of the face near the middle, and a brown spot on the middle of each cheek; antennæ, palpi, and proboscis yellow, the latter mottled with brown; thorax, reddish-yellow, the humeri, a median vitta on the posterior half of the mesonotum, another on each side, above the insertion of the wings, uniting with an irregular band which extends upon the pleura to the upper part of the sternopleura, also a large spot on each side of the metanotum, encroaching upon the hypopleura, light yellow; scutellum, except its extreme base, light yellow, bearing two bristles; abdomen light yellow on first two segments, reddish-yellow on the others, the extreme base, a fascia at the bases of the second and third segments, usually a lateral spot on the fourth and fifth, also a dorsal vitta on the last three segments, blackish or brownish; first segment of the ovipositor of the female slightly longer than the fifth segment of the abdomen. Wings hyaline, the apex of the subcostal cell, from a short distance in front of the apex of the auxiliary vein, the marginal and submarginal cells, the median third of the first basal cell, and a large spot in upper outer corner of the first posterior cell, brown, this colour encroaching on the third posterior cell and bordering the sixth vein almost to its apex; posterior cross vein bordered with brown, this colour extending to the hind margin of the wing; upper end of the small cross vein is also bordered with brown. Halteres light yellow. Legs light yellow, the broad apices of the femora and the last four joints of the tarsi reddish-yellow; hind tibiæ reddish-yellow or dark brown. Length, 6 to 8 mm. Type No. 4,207 in the United States National Museum."

IV. Field Observations in a Pumpkin Patch.

Casual observations on the injuries caused by the melon fly have been put on record but no intensive study of its destructive work has as yet been published. In our work careful examinations were made of different parts of pumpkin plants to ascertain the following points: (1), where the pest deposits

its eggs under natural conditions; (2), the external indication of egg deposition and (3), the injury caused by the larvæ. Observations were also noted on other host plants injured by this fruit fly, but these were not so extensive as those made on pumpkin plants.

1. *Oviposition in stems of pumpkin vines.*—The melon fly often deposits its eggs in the stems of cucurbit seedlings. In pumpkin vines the eggs are often laid within the tender stems near the growing ends (plate XXVII, fig. 3), but the pest is not able to puncture the older and tougher stems with its needle-like ovipositor. A gummy substance exudes from the wound and hardens in the form of a small, resinous lump on the stems (plate XXVII, figs. 1 and 2).

2. *Oviposition in petioles of leaves.*—Occasionally the melon fly deposits its eggs within the petioles of the leaves. The external indication of oviposition, as in the case of the stems, is shown by the resinous material which accumulates at the region where the petiole was punctured by the ovipositor.

3. *Oviposition in pumpkin flowers.*—Eggs were found on the outer and inner surfaces of the corolla and its lobes (plate XXVII, figs. 4 and 7). When the melon fly oviposits on the inner surface of a corolla, it punctures the closed flower, glueing the eggs either at one end in a mass or scattering them loosely on the inner surface of the corolla and its lobes. At that region where the flower has been punctured it becomes discolored (plate XXIX, figs. 20 and 21).

Dacus often oviposits within a receptacle formed by its ovipositor in the anthers or column of the stamens of the staminate pumpkin flowers. More often, however, eggs are deposited in the tissue of the cup-shaped disc formed by the union of the calyx and corolla, or the eggs are simply dropped loosely into this cup-shaped disc. Occasionally, the eggs may also be found within the peduncle of the staminate flowers.

The pest also deposits its eggs in the stigmas and styles of the pistillate flowers. The trypetid does not enter the male or female pumpkin flowers to lay its eggs, but punctures the corolla from the outside with its ovipositor. Wherever the ovary of the pistillate flower has been "stung" by the female fly, a resinous material covers the wound (plate XXIX, fig. 18). Within the ovary, the ovipositor forms a small receptacle in which the eggs are laid (plate XXVII, figs. 5 and 8). Eggs

are often deposited in the constriction between the perianth and ovary, as is shown by the resinous substance found frequently in this region (plate XXIX, fig. 19).

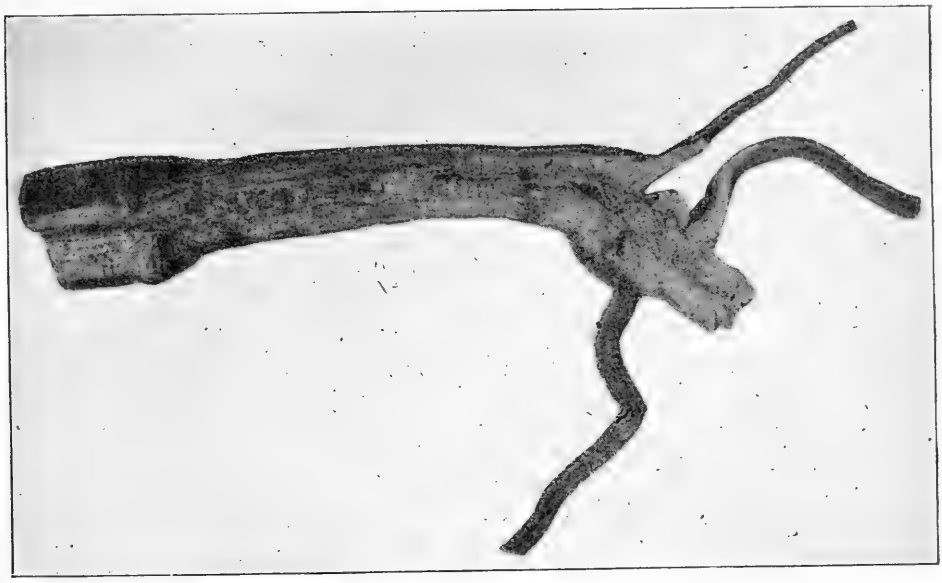
Green staminate and pistillate buds are often "stung" by the fly, the eggs being laid in the various parts of the unopened flowers (plate XXVII, fig. 6), as has just been described for the mature flowers.

4. *Oviposition in pumpkins*—The trypetid deposits its eggs in small, green pumpkins, but the larger, uninjured pumpkins are immune from the attacks of the pest, because the fly is unable to pierce a hard rind with its ovipositor. If, however, the rind of a large pumpkin has been injured, the fruit fly will lay its eggs within the wound. The insect will oviposit in an exceedingly small hole extending through the resinous substance of a healed wound, such as is often due to a previous infestation by the pest (plate XXVIII, fig. 10). On a pumpkin in the field, eighteen melon flies were counted with their ovipositor inserted within a crack extending through the resinous exudation of such a wound and new arrivals were coming continuously to oviposit in the same place. At the end of that day the resinous material was removed, and hundreds and hundreds of eggs were found closely packed in the pulp beneath the crack.

After the melon fly "stings" the unripe pumpkin and squash, the tissue surrounding the receptacle in which the eggs are laid is killed, probably by a secretion which the fly pours over the eggs. In the further development of these cucurbits a depression results (plate XXVIII, figs. 9, 11 and 12) wherever oviposition has occurred. Small pumpkins which have been "stung" repeatedly, may assume all sorts of abnormal shapes in their further growth (plate XXVIII, fig. 12).

5. *Injury to stems.*—The recently hatched larvæ devour the tissue of the tender stems of young cucurbits and cause decay, then they penetrate the roots and destroy the plants entirely. Several acres of watermelons under observation were replanted a number of times and, without exception, every plant was destroyed in this way. The maggots often destroy the terminal shoots of old pumpkin vines by penetrating from one internode to another and feeding on the tissue of the tender stems. A yellowish substance, probably the excrement of the pest, stains the undevoured fibrous tissue of the stems. No maggots were found in the old stems or roots.

The old stems of the pumpkin vines are often infested with the larva of a Cerambycid (Apomecyna pertigera) which is able to penetrate through the hard nodes. More often, however, this beetle larva was found in the roots of the pumkin plant (Text fig. 3.)



Text Fig. 3. Root of a pumpkin vine split open lengthwise showing the larva of a Cerambycid (Apomecyna pertigera) which feeds on the tissue of the roots and occasionally of the stems.

6. *Injury to petioles.*—Melon fly larvæ, which had recently hatched, were found within the petioles of leaves, but nearly, full-grown maggots were never observed within this part of the plant. In order to ascertain whether the pest could complete its larval period within a petiole, ten maggots of different sizes were placed within a half dozen leaf-stalks. All of the larvæ obtained sufficient nourishment from the wall of the petioles to complete their development. While most of the maggots bored out of the petioles to pupate, others pupated within the leaf-stalks close to the node of the stem.

7. *Injury to flowers.*—The larvæ that hatch from the eggs deposited in the anthers, first feed upon and destroy these structures (plate XXIX, fig. 28); then they may eat out the

column of the stamens (plate XXIX, fig. 29); next the pests may work their way down into, and entirely destroy the cup-shaped disc beneath the column and finally they may penetrate into the long peduncle. The flower often drops from its stalk (plate XXIX fig. 30) on account of a decay which follows an infestation. The wall of the peducle is now eaten until only a thin, papery envelope remains, which encloses a yellowish substance similar to that observed in the infested stems. No evidence was found that the larvæ pass through the node which shuts off the hollow peduncle from the stem, but at this node puparia were occasionally found.

In the pistillate flowers the larvæ devour the stigmas and styles, leaving a decayed mass to which the corolla clings. The maggots then descend into the ovary and often the withered corolla becomes detached (plate XXIX, fig. 25) and drops to the ground, leaving a black, flower scar (plate XXIX, fig. 22). As the ovary is devoured, decay sets in, the pulp becomes spongy (plate XXIX, figs. 23 and 24) and the channels are filled with wriggling maggots. After the larvæ bore out, the ovary turns black and either detaches from the pumpkin vine (plate XXIX, fig. 27) and drops to the ground, or remains adhering to the vine as a dried, shriveled mass (plate XXIX, fig. 26).

8. *Injury to pumpkins.*—A green pumpkin which is infested with a small number of melon fly larvæ may continue to grow after the maggots have bored out, but when attcked by a large number of the pest, the pumpkin turns black and decays. After the larvæ have bored out of a green pumpkin, the wound becomes covered by a gummy substance (plate XXVIII, fig. 10). During the further development of this cucurbit, the resinous material often cracks and a second oviposition may occur in the crevices. If a ripe pumpkin is reinfested with a large number of maggots a rapid decay changes the pulp into a semi-liquid mass possessing a most sickening rancid odor. The rind may now collapse (plate XXVIII, fig. 15), and the thick, liquid contents then oozes out. After the maggots bore out, only the rind containing the seeds remains. A glance at plate XXVIII, figures 13 and 14, shows the remains of two pumpkins which were turned over to show the side that had been resting on the ground. In such cases the seeds drop to the ground and often germinate. When a ripe pumpkin is reinfested with a small number of larvæ the rind does not collapse (plate XXVIII, fig. 16) and the seeds within the semi-liquid pulp may then decay.

9. *Injury to string beans.*—An examination was also made of the injury which the melon fly larvæ cause to the seeds and pods of green-podded string beans. It was found that the maggots feed upon the seeds and also the fleshy part of the pods (plate XXX, figs. 31 and 32). After these portions have been consumed the inner surfaces of the pods turn black (plate XXX, fig. 33).

Dead Dacus larvæ were found within the seeds and pods of string beans. Sometimes the dried bodies of the maggots were found protruding from the pods (plate XXX, fig. 39); these evidently died in the process of boring out of the host. Pupation, which normally occurs in the ground, often takes place within the dried pods (plate XXX, figs. 36 and 37).

V. Food Plants.

In the Hawaiian Islands the melon fly has been bred from the following food plants:

VEGETABLES.	FRUITS.
Cucumber	Mango. Bred by Terry (11, p. 32).
Egg Plant	?Orange. Bred by Ehrhorn (4, p. 337).
Kohlrabi	Papaya.
Muskmelon.	
Pumpkin.	
Squash.	
String bean.	
Tomato.	
Watermelon.	
Wild cucurbit (Sycos sp.). Bred by Van Dine. (11, p. 32).	

In India, Froggatt (5, p. 18) bred Dacus cucurbitæ from melons, bitter gourds and egg plants.

10. *Number of melon flies bred from the food plants.*—To determine whether the pest could obtain sufficient food material from the corolla of pumpkin flowers to complete the larval development, the corolla was removed from six staminate flowers in the field and each corolla was then placed in a breeding jar together with recently, hatched, melon fly maggots. The larvæ during their development obtained no other food than that furnished by a single corolla. One male and one female melon fly succeeded in completing their life history on this food supply.

An experiment was now performed to determine the number of melon flies which could be bred from an entire staminate flower including its long peduncle. A dozen, infested, stam-

inate flowers were cut from pumpkin vines in the field and placed in twelve breeding jars. The following figures indicate the number of adults which were reared from each flower: 10, 14, 19, 23, 24, 25, 31, 32, 33, 37, 63 and 64; a total of 375 or an average of 31 flies for each flower.

A similar experiment was performed with a half dozen pumpkins. The cucurbits were of different sizes and were taken from the field and placed in separate breeding jars. The following figures show the size of the pumpkins and the number of adults reared from each.

From a pumpkin 2½ inches long,	277 melon flies were bred.
From a pumpkin 3 inches long,	183 melon flies were bred.
From a pumpkin 3½ inches long,	378 melon flies were bred.
From a pumpkin 3½ inches long,	464 melon flies were bred.
From a pumpkin 4 inches long,	637 melon flies were bred.
From a pumpkin 4¾ inches long,	283 melon flies were bred.
	2222 total.

From twelve, infested, green-podded string beans gathered in the field, the following number of melon flies were reared: 4, 7, 11, 11, 12, 14, 15, 15, 16, 16, 18 and 26; a total of 165 or an average of 13 flies for each pod.

VI. Life History.

Although the melon fly has been very destructive during the past sixteen years in Hawaii, the duration of the different stages of its life history have never been determined. Clark (1, p. 6) makes the following statements on the life history of this pest. The fly "stings" not only the fruit with its ovipositor, but also the young and tender growth of the vines, depositing a number of eggs, which soon hatch into small, white maggots that feed on the tissues of the fruit causing it to decay. After the maggot has attained its growth, it descends into the soil where it develops into a small chrysalis of a light, yellowish brown color, and in about ten or twelve days comes out a perfect insect, ready to repeat its mission of destruction. I do not know how many generations it will produce in a year, but in the warmer and drier districts I believe it will breed the year through, except possibly a while during the winter months, and then its development is only retarded by the cooler weather, which prevents the chrysalis maturing so rapidly."

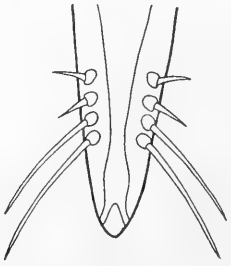
Van Dine (11, pp. 32-34) gives the following contribution on the life history of the melon fly: The life history covers a period of about three weeks. The number of eggs which the female deposits varies from 5 or 6 to as many as 15. After hatching from the egg, the larvæ burrow into the tissue of the melon and feed on the interior. When fully developed the larvæ leave the infested melon or vine and enter the soil directly beneath, where at a distance of an inch or so from the surface they pupate.

Marsh (9, p. 156) writes, "In the insectary an effort was made to work out the life history of this fly, but little progress was made owing to the fact that the cages in which the specimens were confined were too small."

11. *Methods of inducing oviposition.*—Various methods were adopted to induce melon flies to lay their eggs in different food plants placed in a pumpkin patch swarming with the pest. One method followed was to cut a non-infested, ripe pumpkin in half and the trypetids which were probably attracted by the odor of the pulp, would visit the cut surfaces and deposit their eggs. Even the removal of a small piece of the rind from a pumpkin or squash would be sufficient to attract and induce the insects to oviposit. Another method used was to make a semicircular cut through the peel and pulp near the surface of cucumbers, egg plants and tomatoes and the loose flap was then pinned back like a lid. After the females had deposited their eggs in the pulp, the lid-like peel was pinned into its normal position again, thus covering the eggs.

In one experiment about a square inch of the rind of a pumpkin was removed and in a short time melon flies began to visit the injured vegetable. The flies wandered about upon the rind until they found the exposed pulp, when they began to feed upon the exuding juices. At times as many as twenty-five specimens were clustered together in this small area. So closely crowded were the insects that their wings, which are usually held at almost right angles to the long axis of the body, overlapped. More and more individuals were attracted to the cut area until the newcomers were actually forced to walk over the bodies of the earlier arrivals, some of which were now laying eggs without apparently being disturbed, for the ovipositor was not withdrawn.

12. *Tactile bristles of the ovipositor.*—The melon fly often seeks a suitable place wherein to oviposit by walking about on the cucurbit with the tactile bristles at the end of the ovipositor (Text fig. 4) in contact with the rind. These tactile bristles probably assist in locating a hole in the rind, or possibly discriminate between hard and soft surfaces. One specimen was observed with its ovipositor inserted within a pin hole which was made in a pumpkin and another female fly in orienting itself over this wound, would take a step or two backwards, grope around with the tactile bristles and finally push the ovipositor into the same hole. When a piece of the rind has been removed the flies apparently seek a soft area in the pulp with the tactile bristles of the ovipositor. The fruit flies will readily locate and oviposit in a slit which has been cut in the pulp.



Text Fig. 4. Distal end of the ovipositor of Dacus cucurbitæ showing the tactile bristles.

13. *Process of oviposition.*—The process of oviposition can readily be observed in the field with a hand lens. When once the fruit fly has found a suitable place, the abdomen is bent at right angles to the long axis of the body and then the distal, needle-like part of the ovipositor moves up and down in the proximal, tube-like portion. As the ovipositor is forced into the food plant, the female, in endeavoring to get a firmer foot-hold, will let go with the tarsi and claws of the middle and hind legs and grasp a new hold. The tube-like, proximal portion is thrust deeper and deeper until it disappears entirely and the eggs are then deposited. If, however, this tube has not been pushed entirely into the host plant, the eggs can actually be seen gliding through the ovipositor at the rate of one in about every fifteen or thirty seconds. Two specimens were timed during oviposi-

tion and it required seven and nine minutes respectively to complete the egg laying period.

14. *Number of eggs deposited in a receptacle.*—The number of eggs which the pest lays within a receptacle varies from one to forty. The insect often punctures various parts of the host plant with its ovipositor and yet does not deposit any eggs.

15. *Number of ripe eggs in ovaries.*—In order to ascertain the number of ripe eggs present in the ovaries, eighteen melon flies were captured in the field and dissected. The average number of mature eggs found in the two ovaries was forty-eight; the largest number of fully-developed eggs dissected from one specimen was seventy-four and the smallest number obtained from an individual was twenty-two. The number of eggs which one female is able to lay during its natural life was not determined.

16. *Duration of the egg, larval and pupal periods.*—After melon flies had been induced to oviposit in pumpkins, squash, egg plants, tomatoes, cucumbers and string beans in the field, the vegetables were transferred to breeding jars and a careful record was taken of the different periods of the life history. The following table shows the duration of the egg, larval, and pupal periods of Dacus:

TABLE I.

DURATION OF THE EGG, LARVAL, AND PUPAL PERIODS OF DACUS CUCURBITÆ.

Host	Egg period (hours)	Larval period (days)	Pupal period (days)
Pumpkin	30	4–7	10–13
Squash	32	5–7	11–14
Egg plant	31	5–11	12–14
Tomato	36	5–8	12–13
Cucumber	33	5–9	12–14
String bean	31	5–10	11–12

17. *The effect of temperature on the egg period.*—Pumpkins containing eggs which had been recently laid were exposed to the hot sunshine, while others were kept in the shade under field conditions, but no marked difference in the duration of the egg period was observed.

18. *The effect of decay of food on the rate of development of the larvæ.*—One important factor upon which the rate of development of the melon fly larvæ depends, is the rapidity of decay of

the host plant which follows an infestation of the pest. A large number of maggots in a ripe pumpkin cause decay more rapidly than a smaller number in a similar host of the same size. The following table shows a comparison of the rate development of the pest in rapidly and slowly, decaying, food plants:

TABLE II.

COMPARISON OF THE RATE OF DEVELOPMENT OF THE MELON FLY LARVÆ IN RAPIDLY AND SLOWLY DECAYING HOSTS.

Rapidly decaying hosts	Number of larvæ	Larval period (days)	Slowly decaying hosts	Number of larvæ	Larval period (days)
Pumpkin	211	3¾	Pumpkin	1	4
	201	4¾		52	5
	55	5¾		26	6
	6	6¾		8	7
				1	8
Egg plant	4	5	Egg plant	4	8
	11	6		45	9
	16	7		11	10
	38	8		1	11
Cucumber	2	5	Cucumber	6	9
	14	6			

It is possible that the rapid decay of vegetables is caused not only by the enzymes secreted by bacteria, but also by the enzymes of the saliva of the melon fly larvæ. The enzymes change the pulp into a thick liquid and it may be possible that the maggots absorb some of this food directly through the body wall. Larvæ swallowing and possibly absorbing liquified food probably would require less time to complete their development than maggots feeding upon solid food.

19. *The effect of drying food on the larvæ.*—In string beans which gradually dry up during an infestation, there is a marked individual variation in the growth of the melon fly larvæ, even when hatched from the same batch of eggs. In a dried, bean pod the larval period is longer than in a decaying one. In the laboratory the maggots often died in the seeds and the pods of dried string beans, a fact that was also observed in the field. In all probability, these larvæ died from lack of moisture due to the drying up of the string beans.

20. *Respiration of larvæ in liquified pulp.*—Melon fly larvæ in a decayed tomato were observed to obtain a fresh supply of air by pushing the posterior spiracles above the surface of the liquified pulp. The stem of this tomato had been cut out and many maggots were found suspended from the surface film with their bodies immersed in the liquid. When the finger was snapped against the tomato, the larvae wriggled down into the liquified pulp, but sooner or later, they would come up to the surface film to breath.

21. *Jumping habit of larvæ.*—When nearly, full-grown, melon fly larvæ are removed from the host, they exhibit a peculiar habit of jumping, but this behavior is not manifested by the smaller maggots. The larvæ curl the body in a circle (plate XXVIII, fig. 17), the jaws attach to the posterior end of the body, and then by a sudden muscular relaxation, they spring about six to eight inches into the air.

22. *Feeding habits of the melon flies.*—As a rule, Dacus feeds during the early morning from sunrise to about ten o'clock. During the hottest part of the day thousands of these insects may be found at rest under large leaves of plants in or near an infested field of cucurbits. The flies were frequently found several hundred feet away from their breeding grounds, feeding upon the flowers of the glue bushes, sunflowers and Chinese bananas. Not a single fruit fly was ever seen entering and feeding within the carolla of pumpkin flowers or morning glories, but after a rain, specimens were occasionally observed lapping up the small droplets of water on the lobes of the corolla of morning glories. Melon flies feed upon the juices of injured or infested cucurbits in the field. Many individuals were observed feeding on the juices exuding from sweet corn. One adult was noticed feeding on a dead and partly decomposed caterpillar.

When a piece of the rind of a pumpkin was removed, large numbers of the pest were attracted to the exposed pulp and fed upon the exuding juices. When a common house fly also visted the pulp to feed and approach a melon fly already enjoying a meal, the latter would dart forward and chase the former away, but when laying eggs the fruit fly would not withdraw its ovipositor even when the house fly crawled over its body.

23. *Do melon flies manifest fear?*—A melon fly is keenly aware of movements within its field of vision. When a large Odonata flies above a melon fly at rest on a cucurbit, the trypetid may tilt its head to follow the flying insect with its eyes. When one approaches a pumpkin slowly and carefully upon which a specimen is feeding, the fly may tilt its head and sway its body from side to side by bending the legs at the tibiofemoral joints. At such times a slight movement on the part of the observer will cause the fruit fly to take wing. The swaying movements of the alert insect may possibly be interpreted as an external indication of fear. Howlett (7, pp. 415-416) believes that this swaying movement "seems to be associated with 'courtship' in all species of Dacus that occur at Pusa." When the head of Dacus cucurbitæ is lowered, however, and the insect walks about with the wings held almost at right angles to the long axis of the body one can then approach the pest without danger of causing flight.

24. *Number of days required before the adults begin to oviposit.*—An attempt was made to determine the number of days required before the egg-laying period begins, after the melon flies issued from the puparia. A large number of adults upon emerging, were kept in breeding jars and fed on diluted molasses, fruit and vegetable juices and on water. After having been kept in captivity for eight days, three females were dissected but no fully-developed eggs were found in the ovaries. A daily dissection of three fruit flies was continued from now on, and at the end of fourteen days twenty-three ripe eggs were counted in the two ovaries of one fly, but others did not show mature eggs in the ovaries at the end of sixteen days. At the end of seventeen days, thirty-one eggs were dissected from the ovaries of another specimen. In all probability, the effect of confining the insects in breeding jars plays an important part in the rate of development of the eggs.

25. *Summary of stages of the life history.*—The duration of the different stages of the life history of Dacus cucurbitæ may be summarized as follows:

	DAYS	
Egg period	1¼— 1½	
Larval period	3¾—11	
Pupal period	10 —14	
Egg laying begins	14 —17	after the adults emerge.
	29 —43½	

26. *Number of generations annually.*—In the Hawaiian Islands one brood of melon flies is followed by another throughout the year. Since the duration of the complete life cycle may vary from twenty-nine to forty three days, one would expect from eight to twelve generations a year. Assuming that a single female produces only ten descendants and that the sexes are produced in equal numbers at the end of the year she would be the ancestor of from 100,000,000 to 1,000,000,000,000 offspring.

VII. Weights of the Eggs, Larvae, Puparia and Adult Melon Flies.

Accurate weighings of the following stages in the life history of Dacus cucurbitæ were taken: eggs (plate XXXI, fig. 46) a few hours after these were deposited and again shortly before hatching; larvæ after hatching and every day thereafter (plate XXXI, figs., 47 and 52); recently, formed puparia (plate XXXI, fig. 53) and male and female melon flies.

Pumpkins, in which melon flies had been induced to deposit their eggs, were taken from the field to the laboratory and three hours after oviposition, the eggs were removed and counted in two lots, each containing one hundred eggs. Each batch of eggs was placed upon a small piece of filter paper and weighed in a weighing bottle. The eggs were then transferred from the filter paper into a pumpkin and twenty four hours later, the same eggs were removed and weighed again. The weights of the eggs three hours and twenty-seven hours after deposition were as follows:

TABLE III.

WEIGHT IN MILLIGRAMS OF EGGS OF DACUS CUCURBITÆ AFTER DEPOSITION, BEFORE HATCHING AND LOSS IN WEIGHT.

	3 hrs. after deposition	27 hrs. after deposition	Loss in wt. in 24 hrs.
Wt. of first 100 eggs....	7.2	6.	1.2
Wt. of second 100 eggs..	7.5	6.1	1.4
Average wt. of 1 egg...	.0735	.0605	.013

The result shows that each egg on an average, lost .013 milligrams in weight, during the twenty-four hours between the two weighings.

After the second weighing, the first lot of one hundred eggs was put back into the pumpkin and the second batch was placed between moist filter paper. These lots hatched respectively in thirty and thirty-two hours after deposition. The hatching of the first batch of eggs was observed under a binocular microscope in order to remove the larvæ before they had an opportunity to feed. The weight of the maggots and the difference in weight between the eggs and larvæ are recorded in the following table:

TABLE IV.

WEIGHT IN MILLIGRAMS OF RECENTLY HATCHED LARVÆ OF DACUS CUCURBITÆ, AND DIFFERENCE IN WEIGHT BETWEEN EGGS AND LARVÆ.

Wt. of 100 recently hatched larvæ		Difference in wt. between eggs and larvæ	
		3 hrs. after deposition	27 hrs. after deposition
Hatched from first 100 eggs.....	4.2	3.	1.8
Hatched from second 100 eggs.....	5.6	1.9	.5
Average wt. of 1 larva.....	.049	.0245	.0115

The two hundred, recently hatched maggots weighed one-third less than the eggs after deposition and about one-fifth less than the eggs before hatching. This loss can be attributed, in part, to the shedding of the chorion and vitelline membrane.

The one hundred larvæ which hatched from the first batch of eggs were fed upon a hard, dry pumpkin while the other one hundred maggots were fed on a soft, juicy pumpkin. The following table shows the weights of the larvæ after they had fed a day.

TABLE V.

WEIGHTS IN MILLIGRAMS OF LARVÆ OF DACUS CUCURBITÆ FED UPON A HARD, DRY PUMPKIN AND A SOFT, JUICY PUMPKIN.

	Fed on dry, hard pumpkin	Fed on soft, juicy pumpkin	Difference in wt.
Wt. of 100 larvæ 1 day old.....	26.6	63.6	37.
Wt. of 1 larva 1 day old.....	.266	.636	.37

It is evident from this table that the larvæ which fed on the soft, juicy pumpkin for one day weighed over twice as much as the maggots which fed on the dry, hard pumpkin. Furthermore, the former had increased their initial weight over eleven times and the latter over six times at the end of one day.

Fifty of the one hundred larvæ which fed on the soft, juicy pumpkin were weighed at intervals of one day throughout their larval life. In order to remove all of the pulp, which adhered to the bodies of the maggots, they were carefully washed and dried with filter paper before each weighing. The following table shows the daily increase in weight of the larvæ, daily increase over the initial weight, and increase or decrease of weight over the previous day:

TABLE VI.

DAILY INCREASE IN WEIGHT, DAILY INCREASE OVER THE INITIAL WEIGHT AND INCREASE OR DECREASE IN WEIGHT OVER THE PREVIOUS DAY IN MILLIGRAMS OF THE LARVÆ OF DACUS CUCURBITÆ.

Age of larvæ	Wt. 50 larvæ	Wt. 1 larva	Increase in wt. of 1 larva over initial wt.	Increase or loss of wt. of 1 larva over previous day
At hatching.	2.8	.056		
1 day.....	31.8	.636	.58	.58 increase
2 days....	101.2	2.024	1.968	1.388 "
3 days....	801.6	16.032	15.976	14.008 "
4 days....	1021.7	20.434	20.378	4.402 "
4½ days....	1004.3	20.086	20.03	.348 loss

The daily increase in weight over the initial weight may be stated as follows:

After feeding 1 day a larva weighs 11.3 times its initial weight.

After feeding 2 days a larva weighs 36.1 times its initial weight.

After feeding 3 days a larva weighs 286.2 times its initial weight.

After feeding 4 days a larva weighs 364.8 times its initial weight.

After feeding 4½ days a larva weighs 358.6 times its initial weight.

The minimum increase over the initial weight occurred during the first day of the larval life and the maximum increase took place during the third day.

The daily increase or decrease in weight over the previous day may be put as follows:

The first day a larva acquires 10.3 times the weight at hatching.

The second day a larva acquires 2.1 times the weight of the first day.

The third day a larva acquires 6.9 times the weight of the second day.

The fourth day a larva acquires .27 times the weight of the third day.

In 4½ days a larva lost .017 times the weight of the fourth day.

The minimum increase in the daily weight of the larvæ over the previous day occurred during the fourth day and the maximum increase took place during the first day. During the last twelve hours of the larval period, the maggots decreased in weight. In all probability, this loss may be attributed in part, to the evacuation of the contents of the alimentary canal previous to pupation.

After the fifty larvæ bored out of the pumpkin in 4½ days they were allowed to pupate in moist sand. Twelve hours later the sand adhering to the newly-formed puparia was washed off and the moisture adhering to them was absorbed with filter paper. After the puparia were thoroughly dried they were weighed in a weighing bottle. Other melon fly maggots which bored out of pumpkins in 3¾ and 4 days were weighed, and twelve hours later the newly-formed puparia were weighed. The following table shows the average weights of the mature larvæ, the puparia twelve hours after the larvæ bored out of the pumpkins, and the loss in weight after pupation:

TABLE VII.

AVERAGE WEIGHTS IN MILLIGRAMS OF MATURE MELON FLY LARVÆ, WEIGHTS OF THE PUPARIA TWELVE HOURS AFTER THE LARVÆ BORED OUT OF THE PUMPKINS AND THE LOSS IN WEIGHT AFTER PUPATION.

Age of larvæ	Average wt. 1 larva	Average wt. 1 puparium	Loss in wt. after pupation	Loss in wt. %
4½ days.....	20.086	18.95	1.136	5.6
4 days.....	22.509	20.336	2.173	9.6
3¾ days.....	20.87	19.0534	1.8166	8.7

The results show that twelve hours after the melon fly larvæ bored out of the pumpkin and transformed into puparia, there was a loss of 5.6 to 9.6% in weight.

Is there a difference in weight of the male and female melon flies upon emerging from the puparia? The following table shows the weights of two lots of flies shortly after the wings were expanded:

TABLE VIII.

WEIGHTS IN MILLIGRAMS OF MALE AND FEMALE MELON FLIES SHORTLY AFTER EMERGING FROM THE PUPARIA.

Number of flies	Weight	Weight 1 fly	Difference in weight of a ♂ and ♀ fly
50♂	47.52	.9504	
50♀	48.9	.978	.0276
40♂	51.	1.275	
30♀	45.69	1.523	.248

It is evident from this table that the female melon flies are heavier, on an average, than the males shortly after they issue from the puparia.

VIII. Natural Enemies.

Predaceous insects sometimes prey upon the melon fly. At all times of the day the yellow dragon fly (Panatala flavescens Fab.) was observed flying over a pumpkin patch teaming with pest, and one would be inclined to believe that the melon flies are sometimes preyed upon by this predaceous insect. A number of dragon flies were captured in this field and the contents of their alimentary canal was examined, but no remains of the melon fly were found. A predaceous bug (Zelus peregrinus Kirkaldy) was observed sucking out the juices of a melon fly on a sunflower. Staphylinids or rove beetles were frequently seen within infested pumpkins but whether or not these feed upon the melon fly maggots was not determined.

The European, horn fly parasite (Spalangia hirta Haliday) was bred from the puparia of the melon fly. These puparia were gathered from beneath infested pumpkins; some of these puparia were partly exposed from the ground; while others were taken from one to four inches below surface of the soil, the usual depth, however, being one to two inches. From five hundred puparia which were collected on March 25, three parasites emerged on May 4, 1912. It is evident that this parasite is of little importance in the control of the melon fly.

IX. Methods of Control.

27. *Experiments in destroying infested vegetables.*—Van Dine (11, p. 35) formerly stationed at the Hawaiian Agricultural Experiment Station, recommends that all melons and vines infested with melon fly larvæ should be collected at intervals of five or six days and covered with earth to a depth of several inches.

A number of experiments were performed to determine the distance that melon flies, after issuing from the puparia, were able to burrow through sand and soil. In the first experiment several, hundred puparia were placed on two inches of dry, sterlized sand at the bottom of a cylindrical, museum jar (24x11½ inches) and this jar was then filled with more of the same kind of sand. A similar vessel, half filled with dry sand, was then inverted over the top of the above mentioned jar. This was done by placing a heavy, glass plate over the mouth of the jar to be turned upside down, inverting the same above the other vessel and then pulling the glass plate out from between the two jars. A similar experiment was conducted with wet sand which had been previously sterlized. The puparia in both experiments were arranged in a circle close to the wall of the jars so that when the fruit flies emerged and burrowed through the sand their paths might be seen. When the trypetids emerged, many would bore up to the region where the jars came in contact with one another and then escape through the small spaces between the jars. These small spaces were due to particles of sand which rested on the rims of the jars. One could scarcely believe that these large flies were able to flatten their bodies to such an extent as to squeeze through such small spaces as existed between the jars.

It was evident that some of the melon flies were not able to burrow as far as others, for many died at the upper end of the channels before obtaining their liberty (plate XXXI, fig. 45). Flies would frequently bore into an excavation made by other specimens and if the union of the channels would form a more or less circular path, some of the individuals would continue to burrow slowly round and round and finally die in this endless passage. Usually, however, most of the trypetids showed a definite orientation and bored directly upward. This nega-

tive reaction to gravity is common with many insects after emerging from the egg or pupa.

As there was a possibility that the melon flies might have been hindered by being against the glass, holes two and three feet deep were drilled in hard soil with a fence-post borer. At the bottom of these holes 500 puparia were placed. The puparia were then covered with sterlized dry or wet sand or soil. After these pits were filled each hole was covered at the surface with a large mouthed jar which rested tightly against the solid earth. The following table shows the number of melon flies which succeeded in boring through two and three feet of sand or soil:

TABLE IX.

NUMBER OF DACUS CUCURBITÆ WHICH BURROWED THROUGH TWO AND THREE FEET OF SAND OR SOIL.

Number of feet puparia were buried.....	2	3
Number of puparia buried in each hole.....	500	500
Number of flies that bored through dry sand..	34	2
Number of flies that bored through wet sand..	8	0
Number of flies that bored through soil.....	5	0

It is evident from this table that a larger number of melon flies were able to bore through dry sand than wet sand, and that very few specimens succeeded in making their way through the more lumpy soil.

Burying infested cucurbits and the vines in three feet of soil would require a considerable amount of labor. Lime, which is often thrown into the garbage-can to destroy the larvæ of the house fly and blue bottle fly, would probably destroy the melon fly maggots if it was buried in sufficient quantity with the infested vegetables, but this method would increase the cost.

In an experiment melon fly maggots were submerged in fresh water for a period varying from two to four days, in order to determine whether such larvæ would pupate and give rise to flies. Larvæ were selected which had bored out of a pumpkin and were ready to pupate. These maggots were submerged in seven inches of distilled water which was renewed daily. After remaining in the water for two, three or four days, the larvæ were transferred to filter paper and after pupation, the puparia were placed in moist sand in a breeding jar. The following table indicates the results obtained.

TABLE X.

NUMBER OF MELON FLY LARVÆ WHICH PUPATED AND ISSUED AS ADULT FLIES, THE LARVÆ BEING SUBMERGED IN SEVEN INCHES OF WATER FOR A PERIOD OF TWO TO FOUR DAYS.

Number of larvæ	Days submerged in water	Number pupated	Number of dead pupæ	Adults reared
100	2	75	28	47
100	3	16	11	5
100	4	0	0	0

From this experiment one could conclude that infested vegetables may be submerged in a barrel or tank of water for a period of four days and then plowed under without danger of having melon flies emerge from this material. By following this method a valuable fertilizer is added to the soil. Undoubtedly, certain chemicals could be added to the water which would destroy the melon fly larvæ in the infested vegetables in less time, but this again, would increase the cost.

Burning or boiling maggoty vegetables is somewhat expensive on account of the fuel consumed. The old vines in seriously, infested, cucurbit fields were often pulled out of the ground, raked together in piles, the infested vegetables were scattered within these piles and then all was burned. Some kinds of infested vegetables could be boiled and then fed to hogs.

28. *Screening or netting.*—Attempts to grow the various kinds of Cucurbitaceæ in Hawaii are carried on mostly by Japanese and Chinese. Many of these cultivators screen the newly set cucurbits with pieces of gunny sac, paper bags, newspapers or straw. Some of the growers screen their melon and cucumber beds with cheese cloth or mosquito netting but as Froggatt (5, p. 18) states, "though it kept the flies out it also kept all the bees and small insects that, under ordinary conditions, fertilize the flowers, so that very few melons ever set and matured." Hand pollination could be resorted to, but this method would require a considerable amount of labor. One individual who attempted to grow pumpkins hired a Japanese who removed from the vines, the staminate flowers which were seriously infested with the larvæ. Screening the vines is not at all practical except possibly for a few vines in a

garden. Covering the newly set cucurbits requires constant attention and cannot be recommended, if the question of labor is taken into consideration.

29 *Trap crops.*—Marsh (9, pp. 155-156) made a test of a trap crop by planting cantaloupes among cucumbers. "It was thought that the cantaloupes would prove more attractive to the flies than cucumbers, but such was not the case, as the cucumbers were more badly damaged than the cantaloupes, and in the end both crops were practically destroyed by the larvæ."

30. *Traps.*—In Honolulu a Japanese glass fly trap is used by many of the Oriental merchants to capture house flies, blue bottle flies etc.; the insects enter the trap to feed and are drowned in soapy water within the apparatus. As this trap is similar to our American style of glass fly trap, a description of the Oriental type is not necessary. A Japanese fly trap with molasses as a bait was wired in a large orange tree and in twelve days nineteen male and fifty-eight females Mediterranean fruit flies and three male and one female melon fly were found drowned in the soapy water. Two of the American style of glass fly traps with molasses as a bait were placed upon the ground in a pumpkin patch but no trypetids were caught in these. A dozen of the common, mosquito, screen, fly traps with molasses diluted either with water or stale beer as a bait were fastened to sticks above the pumpkin vines but not a single fly was found in the traps during the five days that they were kept in the field.

31. *The use of vegetable, animal and petroleum oils to trap the melon flies.*—Recent investigations have shown that certain vegetable and petroleum oils attract enormous numbers of male fruit flies of different species. Howlett (7, pp. 412 and 414) found that citronella oil has an attraction for the males of the peach fruit fly (Dacus zonatus Saund.) and the three-striped fruit fly (Dacus diversus Coq.) but the attraction in the last case, however, seems perhaps a trifle less powerful than with Dacus zonatus. Froggatt (5, pp. 13 and 17) found that the mango fruit fly (Dacus ferrugineus Fab.) is also attracted to citronella oil but that the melon fly (Dacus cucurbitæ Coq.) never came to this oil. According to Illingworth (8, p. 160) the apple maggot or railroad worm (Rhagoletis pomonella Walsh) avoids citronella oil.

We found that many of the oils derived from crude petroleum attracted the males of the Mediterranean fruit fly (Ceratitis capitata Wied.), but rarely was a specimen taken in animal or vegetable oils. Our experiment with kerosene shows that of every thousand Mediterranean fruit flies captured only three, on an average, were females, the remainder being males. It is noteworthy to mention that the Queensland fruit fly (Dacus tryoni Frogg.) and the Mexican or Morelos orange worm (Anastrepha ludens Loew.) are not attracted to kerosene.

The vegetable, animal and petroleum oils listed in the following table were poured in pans and placed upon the ground in a pumpkin patch which was swarming with melon flies. The number of pans used, the number of days each oil was tested and the results obtained are stated in the following table:

TABLE XI.

NUMBER OF MALE AND FEMALE MELON FLIES CAPTURED IN ANIMAL, VEGETABLE AND PETROLEUM OILS.

		Pans		♂	♀
Vegetable oils	Citronella	2	5 days	1	2
	Turpentine	1	16 hours	0	0
	Cocoanut	2	5 days	0	2
Animal oils	Whale	2	5 days	2	4
	Fish	2	5 days	1	1
Petroleum oils	Kerosene about 120° Bé	3	5 days	2	3
	Gasoline about 86° Bé	1	16 hours	0	0
	Benzine about 63° Bé	1	16 hours	0	0
				6	12

In all probability, the specimens were not attracted to these oils but came within the sphere of influence by accident, became stupefied and dropped into the oil.

32. *Night traps.*—As the melon flies show a strong positive reaction to light, an attempt was made to capture the pest with a night trap. Herrick's moth trap was placed in a pumpkin patch but not a specimen was caught. A seventy candle-power hunting lamp was placed above the moth trap and the light rays were directed towards thousands of melon flies resting under sunflower leaves in the pumpkin patch but not a single specimen was attracted to the light.

33. *Poisoned bait spray.*—Striking demonstrations have been made of the effectiveness of the poisoned bait spray in the control of the olive fly (Dacus oleæ Rossi) in Italy and France

and the Mediterranean fruit fly (Ceratitis capitata Wied.) in South Africa.

Recently similar control measures have been used in the United States and Canada against the apple maggot (Rhagoletis pomonella Walsh), the cherry fruit flies (Rhagoletis cingulata Loew. and Rhagoletis fausta O. S.) and the currant or gooseberry fruit fly (Epochra canadensis Loew.). We have tested the effectiveness of the poisoned bait spray to control the Mediterranean fruit fly under Hawaiian conditions. The method adopted was to wire ten kerosene traps in different parts of an orchard containing about four hundred fruit trees. The total number of fruit flies captured in five weeks was 10,239; of this number 10,203 were males and only 36 were females. During the following five weeks the poisoned bait spray was applied to the trees about once a week. The total number of fruit flies captured in the kerosene traps during these five weeks was 182, of which number 93 were caught during the first week.

As already stated Dacus cucurbitæ requires at least two weeks under laboratory conditions before the egg-laying period commences. Under natural conditions, the flies seek food during this period and subsist on a variety of sweet substances already discussed under the feeding habits of the melon fly. In captivity, the adults show a fondness for diluted molasses and they fed on this liquid until their abdomens became greatly distended. One can readily understand that if this insect is attracted to diluted molasses under natural conditions, that the greediness of the fruit flies for this sweet when poisoned, would be the weak point in the life history to attack the pest. If this poisoned bait is applied in the form of a spray to the food plant, when the trypetids issue from the puparia, no doubt large numbers would be killed before the egg-laying period begins.

The poisoned bait was prepared according to the following formula:

Brown sugar	2½ lb.
Arsenate of lead	5 oz.
Water	4 gal.

The solution was prepared by dissolving the brown sugar and lead arsenate through cheese cloth in cold water so as to strain out all foreign material including ants, which in the Hawaiian Islands frequently gnaw through the paper sacs

containing the sugar. The mixture was thoroughly agitated by pumping the liquid back upon itself with a common, garden, brass spray-pump. To kill the enormous numbers of melon flies quickly in a badly infested cucurbit field, one ounce of a soluable poison such as potassium arsenate or sodium arsenite dissolved in a small quantity of water, was added to the solution instead of arsenate of lead. The pump was provided with a rose, sprinkler nozzle which throws a fine, mist-like spray.

Shortly after sunrise the insecticide was applied to all of the foliage within the pumpkin patch and also to the vegetation bordering the same, such as glue bushes, algeroba trees, bananas, sunflowers, castor oil beans, weeds and grass. As already stated in the discussion of the feeding habits of the adults, the pest was found feeding on flowers about a hundred yards away from the breeding grounds. To spray all of the feeding grounds which often consisted of dense brushes of glue bushes, would be practically impossible. The results obtained after spraying were rather striking. Before spraying, thousands and thousands of melon flies could be found resting on the lower surface of the leaves of the sunflower and castor oil plants, but after spraying, only here and there could a specimen be found. In all probability, these living flies had recently emerged from puparia, or came in from the neighboring feeding grounds or from surrounding cucurbit fields. The soluble poisons, however, burned the foliage and can not be advocated.

A few days after the application of the first spray, all of the pumpkin vines and bean plants were pulled out of the ground and raked together in piles. The infested pumpkins were scattered within these piles and then all was burned.

To determine whether the melon flies coming from their feeding grounds or from the surrounding fields of cucurbits could be controlled, watermelon seeds were planted in a field adjacent to the former pumpkin patch. The seeds sprouted before we were able to make a vigorous campaign in surrounding cucurbit fields. The watermelon plants were sprayed with the bait, using arsenate of lead, but frequent rains washed off the thin film of sugar and left the plants subject to the attacks of the pest coming from outside sources. As soon as the weather became settled, a fresh application of the bait was made to the watermelon plants and surrounding vegetation, but the tender stems of many of the

watermelon plants were already infested. Whether the pest, which has been allowed to increase unmolested during the past sixteen years, can be controlled under Hawaiian conditions when one individual sprays and his neighbors do not, is problematical. In all probability, better results could be obtained with the poisoned bait spray in a well isolated cucurbit field away from the valleys where rains are less frequent during the summer months.

Marsh (9, p. 155) tested a poisoned bait spray to control the melon fly in the Hawaiian Islands. He writes, "The baits were prepared by sweetening water with molasses and adding to the solution arsenate of lead or Paris green. These baits were then applied, at frequent intervals, to the foliage of infested cucumbers with a gardener's syringe. With the aid of the syringe the poisoned liquids were shot into the air above the beds of cucumbers and allowed to fall on the foliage in fine drops. In the experiment with Paris green the application was made daily from September 9 until October 14. The formula used in this experiment was as follows:

Molasses	1 quart.
Paris green	¼ ounce.
Water	1½ gallon.

Neither the experiment with arsenate of lead or with Paris green proved effective. The flies were frequently observed feeding on the poisoned liquids, but evidently they did not relish them, and so failed to consume a fatal dose."

Fuller (6, p. 26) stationed in Natal, South Africa, tested the poison bait spray to control the Mediterranean fruit fly and melon fly. Trials which have been made in several citrus orchards to control the Mediterranean fruit fly with the poisoned bait spray "have been attended with remarkable effects, and where treatment has been applied for the melon fly which attacks, squashes, marrows, pumpkins and the like, it has proved equally successful."

EXPLANATION OF PLATES.

Plate XXVII.

Fig. 1. Resinous lump which heals the wound produced by the ovipositor of the melon fly, in the tender stems near the growing ends of the pumpkin vines.
Fig. 2. Resinous lump somewhat enlarged.
Fig. 3. Split stem of pumpkin vine near growing end, showing the eggs deposited by the melon fly.
Fig. 4. Eggs deposited on the outer surface of the corolla and its lobes.
Fig. 5. Longitudinal section of the ovary of a pumpkin, showing the eggs deposited within a receptacle.
Fig. 6. Green pistillate bud with the corolla cut open, showing the eggs deposited on the style and inner surface of the corolla.
Fig. 7. Eggs deposited on the inner surface of the corolla.
Fig. 8. Cross section of the ovary of a pumpkin, showing the eggs deposited within a receptacle.

Plate XXVIII.

Fig. 9. Squash showing depressions caused by the oviposition of the melon fly during the early development of this cucurbit. The tissue surrounding the receptacle in which the eggs are deposited is probably killed by a secretion, and in the further development of the cucurbit a depression results.
Fig. 10. Healed wounds due to a previous infestation of the melon fly. This trypetid is unable to puncture the hard rind of the larger pumpkins with its ovipositor, but often the resinous material covering the wound cracks and oviposition may then occur in the crevices.
Fig. 11. Depressions and healed wound in a ripe pumpkin.
Fig. 12. Pumpkin, abnormal in shape, as a result of being "stung" by the melon fly during its early development.
Figs. 13 and 14. Remains of two pumpkins which were turned over to show the side resting on the ground. After the maggots bore out of a seriously reinfested pumpkin, only the rind and seeds remain.
Fig. 15. The rind of a seriously reinfested pumpkin collapsing due to decay caused by the larvæ.
Fig. 16. When the pumpkin is not seriously reinfested with the melon fly larvæ, the rind does not collapse. Such partly decayed cucurbits often serve as hosts for other insects which complete the work of destruction.
Fig. 17. Pumpkin cut in half showing the decayed pulp and seeds, and the larvæ which have jumped out of the decayed mass.

Plate XXIX.

Fig. 18. Resinous material which exudes from the wound produced by the ovipositor of the melon fly in the ovary of a pumpkin.
Fig. 19. Resinous substance in the constriction between the flower and the ovary where the eggs are often deposited.
Fig. 20. Discoloration on the corolla indicating the region where the fly has punctured the closed flower to deposit its eggs within the stigma or style.
Fig. 21. Discoloration on the corolla where the pest has punctured the closed flower to deposit its eggs on the inner surface of the corolla lobes.
Fig. 22. The corolla of one of the flowers has detached and dropped to the ground, leaving a black flower scar. The larvæ in this case devoured the stigmas and styles and descended into the ovary.
Figs. 23 and 24. Longitudinal sections of two ovaries showing a spongy decayed pulp caused by the maggots.
Fig. 25. Corolla detaching from the ovary after the larvæ have devoured the stigmas and styles and descended into the ovary.

Fig. 26. Dried and shriveled pistillate bud still adhering to the pumpkin vine after the larvæ have bored out of the ovary.
Fig. 27. Pistillate bud detaching from pumpkin vine after the larvæ have bored out of the ovary.
Fig. 28. Two anthers of pumpkin flowers; one anther has been partly devoured by the maggots.
Fig. 29. After the larvæ have destroyed the anthers, the pest devours the column of the stamens.
Fig. 30. The maggots finally penetrate into the long peduncle of the staminate flowers and feed on the wall of the stalk. The flower often drops from its stalk due to decay caused by the larvæ.

PLATE XXX.

Figs. 31 and 32. String beans split open showing the melon fly larvæ feeding on the seeds and flesh of the pods.
Fig. 33. After the seeds and flesh of the string beans have been devoured the inner surfaces of the pods turn black.
Figs. 34 and 35. External appearance of the infested bean pods.
Figs. 36 and 37. Melon fly pupæ inside of pods.
Figs. 38 and 39. Melon fly larvæ which have died while attempting to bore out of the string beans, probably due to the drying of the pod.
Figs. 40 to 44. Dried and shriveled string beans after the melon fly larvæ have bored out. These bean pods do not drop to the ground but remain adhering to the plant.

PLATE XXXI.

Fig. 45. Channels in moistened sand made by melon flies after emerging from the puparia. The black areas in the channels represent flies which died in their attempt to burrow through the sand.
Fig. 46. Egg of melon fly.
Fig. 47. Recently hatched melon fly larva.
Fig. 48. Melon fly larva after feeding one day.
Fig. 49. Larva after feeding two days.
Fig. 50. Larva after feeding three days.
Fig. 51. Larva after feeding four days.
Fig. 52. Mature melon fly larva after feeding four and one-half days.
Fig. 53. Puparium of melon fly.

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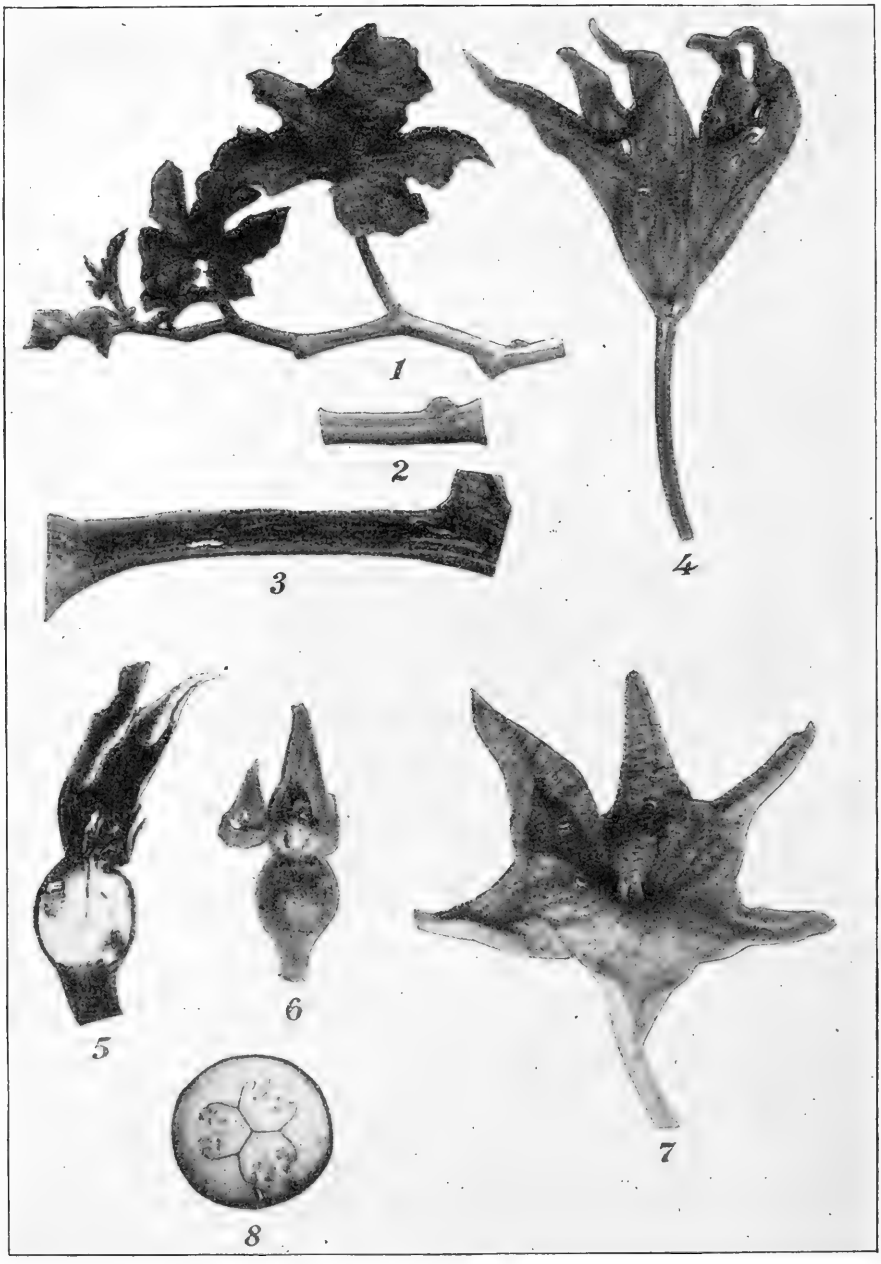

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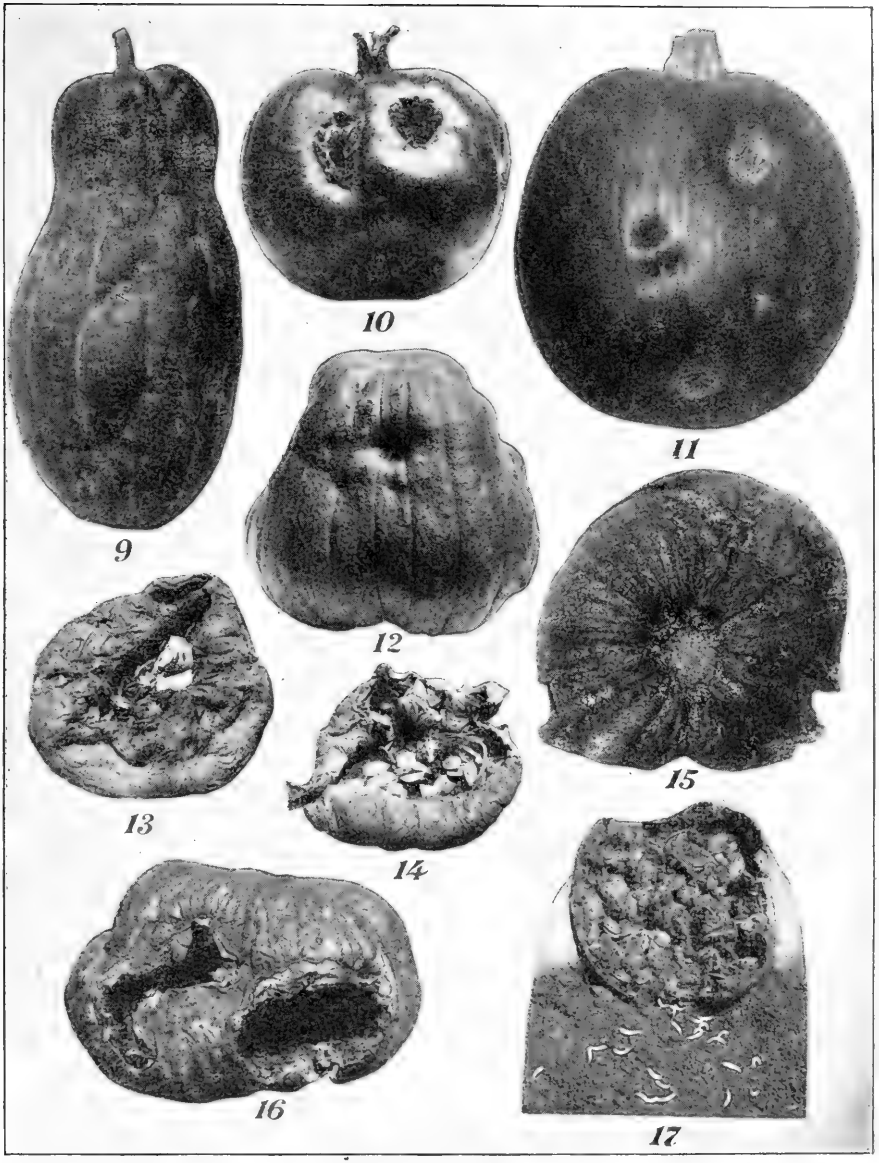

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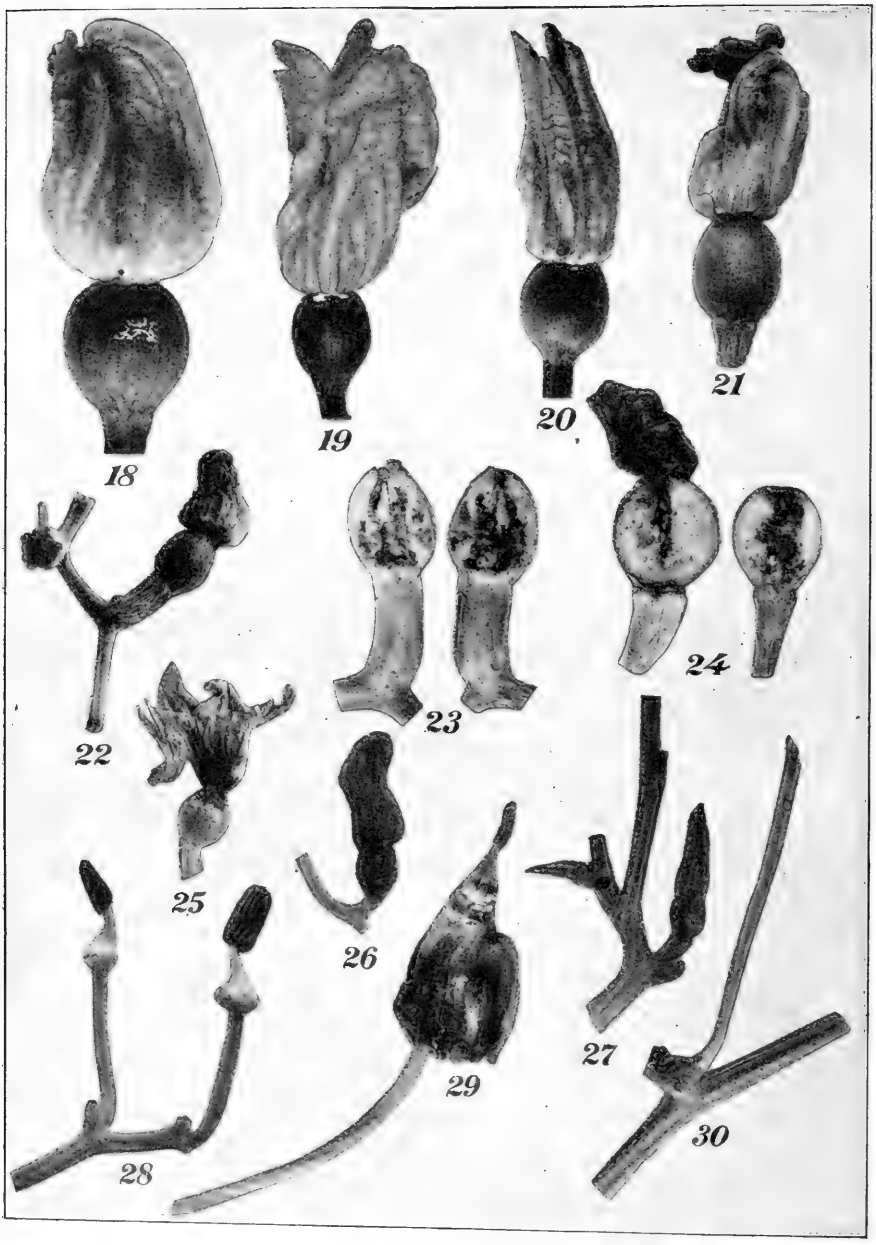

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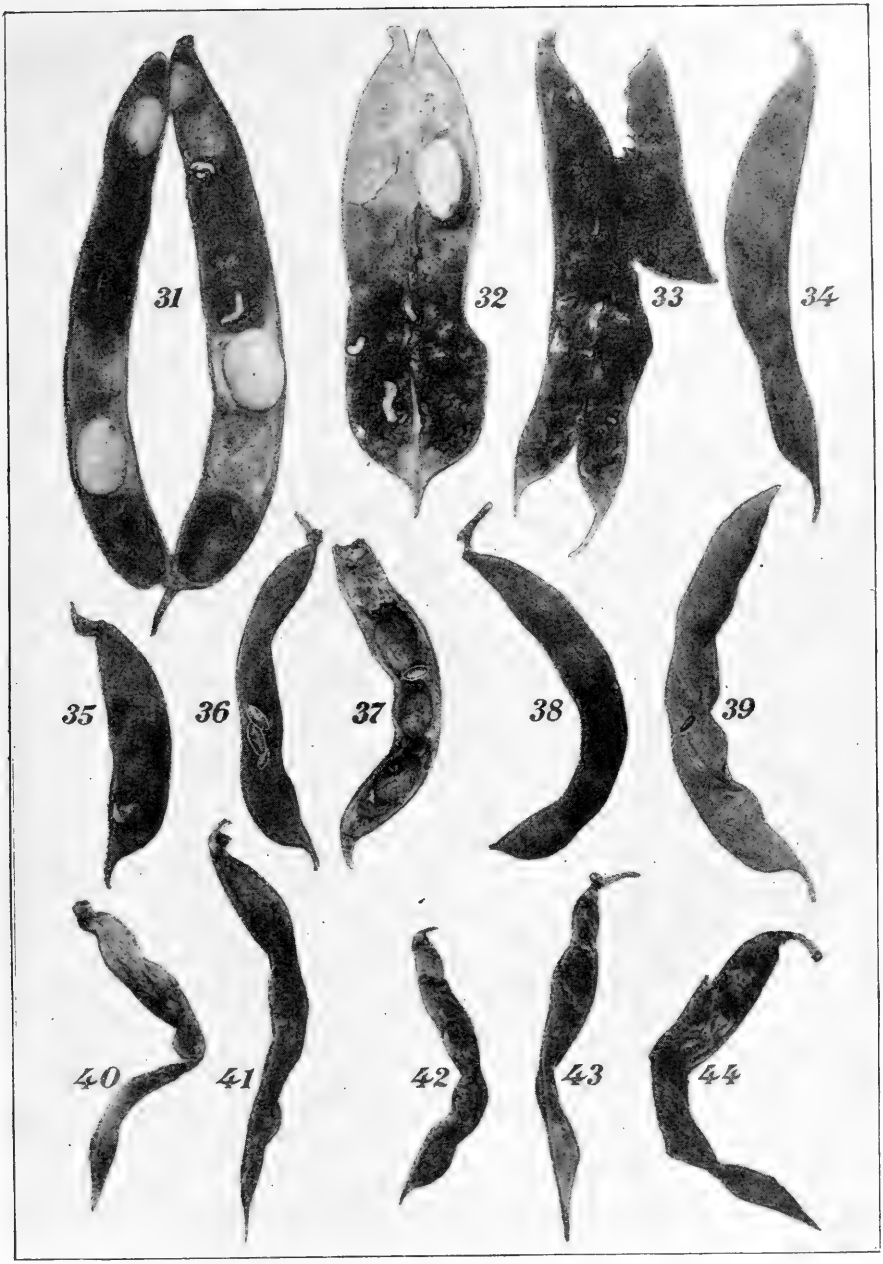

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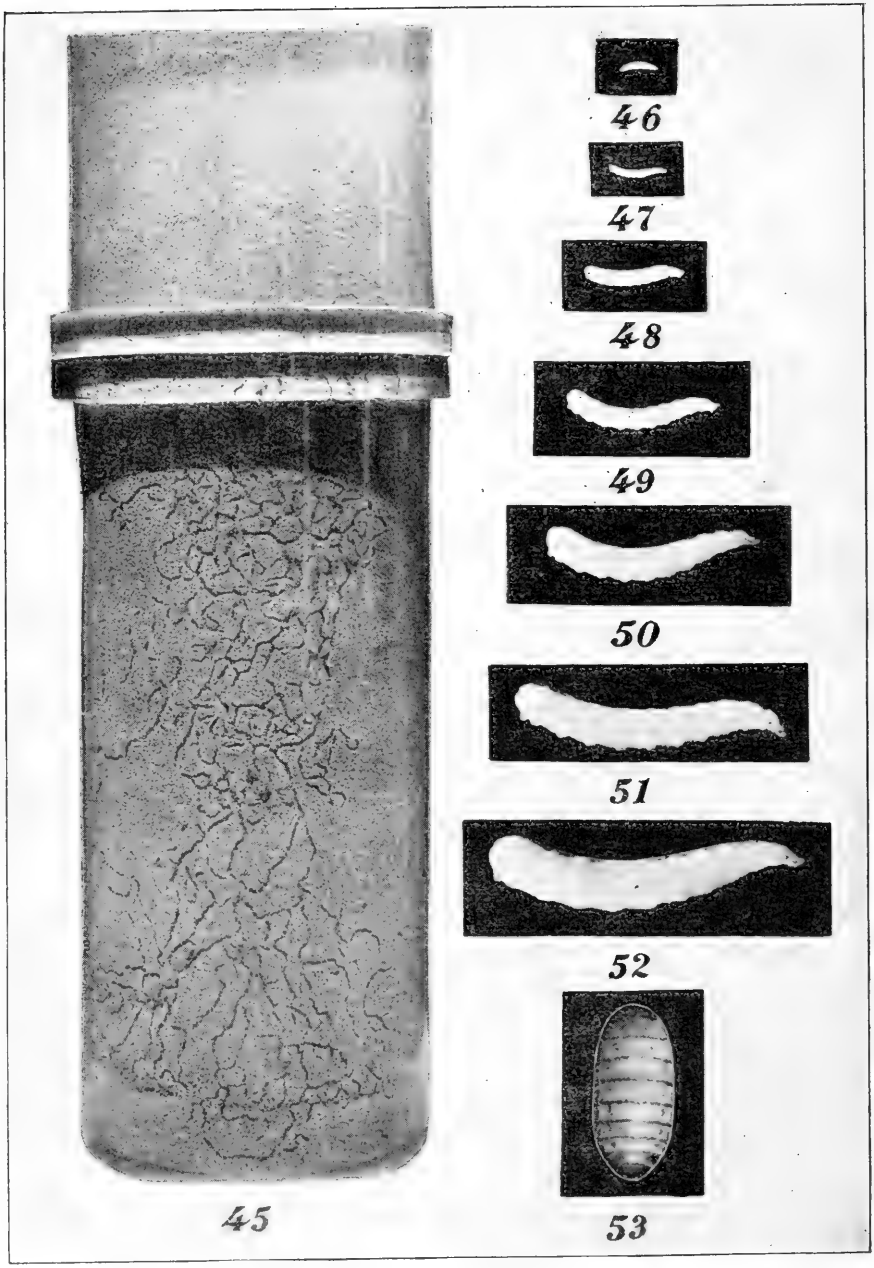

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SOME NOTES ON LIFE HISTORY OF LADYBEETLES.*

By Miriam A. Palmer

The species treated in this paper are the more common forms found in Colorado; namely, *Hippodamia convergens* Guer., *Coccinella 5-notata* Kirby, *Coccinella monticola* Muls., *Coccinella 9-notata* Hbst., and *Adalia melanopleura* Lec., *annectans* Crotch, *coloradensis* Casey, and *humeralis* Say; also incidentally, *Olla abdominalis* Say, *Hippodamia sinuata* Muls., and *parenthesis* Say, *Coccinella sanguinea* Linn., and *Scymnus* sp. Special attention was paid to the duration of the life cycle, and habits regarding egg-laying and feeding, with incidental observations on injurious influences and other points, also descriptions were made of the beetles in all stages.

Hippodamia convergens Guer.

This is our most common species, and may be described as follows:

Adult: Fig. 1, Plate XXXII.

Head black, with pale frontal spot connected laterally with the eyes; pronotum black with pale narrow border along apical and lateral margins; the two discal marks distinct and converging posteriorly; elytra yellowish red, each with a scutellar spot and with six other spots rather small in size and never united; the three posterior ones more developed and constant. The spots are frequently lacking altogether and the elytra immaculate. Legs black; length 6 to 7 mm.; width 3.5 to 4 mm.

Egg: Fig. 2, Plate XXXII.

Pale to deep amber yellow, even as deep as yellow cadmium in some cases; length 1.13 to 1.33 mm.; width .49 to .55 mm.

Larva: Fig. 3, Plate XXXII.

First instar: Entirely black with exception of pale area on lateral and dorso-lateral margins of first abdominal segment; meso- and metathorax each with two large setaceous areas and small setaceous spot laterally; abdomen with three pairs of rows of setaceous areas. Second instar: Same as first except that margins of pronotum are often pale yellowish and the pale spots on the first abdominal segment are now light orange colored, and in addition to these, faint orange spots are seen similarly placed on the fourth segment. Third instar: Same as before except that it is more orange colored in the light spots. Fourth

*This paper is an outgrowth of breeding cage work with the Coccinellids, assigned me by Professor Gillette as a part of his Adams fund project on Life Histories of the Plant Lice and Their Enemies. Acknowledgments are also due to Professor C. P. Gillette and Mr. L. C. Bragg for determination of Plant Lice herein mentioned.

instar: Same as third except for the addition of pale orange spots on the 6th and 7th segments on dorso-lateral portion, not extending laterally. Some larvæ show quite a bluish frosted appearance over the black, more especially toward the later stages. Length about 9.5 mm. for a full grown larva.

Pupa: Fig. 4, Plate XXXII.

Ground color brownish yellow throughout; pronotum with black lateral margin and an anterior and a posterior pair of black spots; wing pads black along posterior margin and over apical half; each segment with sublateral and medio-lateral spots. Spiracles black. Sometimes much lighter in general color and only a dot found on wing pad at basal third. Legs black. Length 5 mm.

Life cycle records* were made as follows:

Egg stage (22 records*) 3-7 days, mostly 3 days;
Larva stage (22 records) 10-28 days, mostly 14 days;
Pupa stage (22 records) 4-9 days, mostly 4-5 days;
Egg to adult, mostly 21 days.
Adult stage (13 records) 3-4 months for the summer generations.

A hibernating female lived 8 months and 12 days, dying May 25th, having laid eggs from April 27th to May 19th. This female would doubtless have lived longer under natural conditions. The weather was wet and unfavorable and the female was evidently in a weak or unhealthy condition as evidenced by the poor hatching of all the eggs. Another hibernating female lived until July 6th. All the females which had laid eggs before going into hibernation died either during the winter or in the spring before laying any eggs. A male which had hibernated lived 9 months and 8 days, dying June 13th.

The earliest egg record obtained was April 27th, the latest record in 1908 was September 3rd, and in 1907, was October 30th. The earliest beetles reared emerged June 22nd and the last one lived until September 22nd. Under natural conditions and in early spring, doubtless the first generation emerges as soon as the latter part of May or even earlier, according to the season. There were at least three generations obtained in a season.

The females would usually begin to lay within five days after emerging and the longest egg-laying record obtained was 1 month and 18 days. Several egg counts were made. They are as follows: 130 eggs (in 20 days), 199 eggs, 296 eggs, 312 eggs (in 1 month and 15 days), and 399 eggs, by different

*The term, record, in this sense shall be understood to mean, not notes made on a single individual, but on an egg patch and the beetles resulting therefrom.

females respectively. These numbers are certainly far below what the beetles are able to lay under favorable conditions in a state of nature. The number of eggs laid in a single batch was usually about 30, though the number varies considerably both above and below this number. When in good laying condition a female will deposit from one to two batches a day.

Food records.—Several records were taken on the feeding capacity of both larvae and adults for plant lice. One larva ate 50 *Prociphilus fraxinifolii* Riley, another half grown, ate 33 *Macrosiphum gaurae*, and another half grown, ate 105 *Chait. negundinis* Thos., in a single day. Entire counts of the whole number of lice eaten during the larval period were taken in four cases and are as follows: 264 (57 *M. gaurae*, 56 *Chaitophorus negundinis*, 151 *P. fraxinifolii*), 309 (71 *M. gaurae* 137 *C. negundinis*, *101 P. fraxinifolii*), 585 (423 *C. negundinis*, 72 *P. fraxinifolii*, 90 *M. rosae* Linn., small), and 576 (263 *C. negundinis*, 54 *M. rudbeckiae* Fitch, 114 *P. fraxinifolii*, 57 *S. schizoneura lanigera* Hausmann, and 88 *M. rosae*), of all sizes, by each larva respectively.

A pair of beetles, male and female, ate 150 *Chaitophorus populifolii* Fitch, in one day, and 120 *Aphis setariae* Thos., on another day. A male made the following records on different days respectively: 200 *M. gaurae* Will., 30 *M. rudbeckiae*, 33 *A. torticauda* Gill., 60 *C. negundinis*, and 75 *M. cerasi* Fab., these lice being of all ages and sizes.

A female ate on different days, 36 *M. rudbeckiae*, 180 *C. negundinis*, 165 *M. cerasi*, 110 *A. helianthi* Monell, and 120 *A. setariae* respectively.

The amount eaten varied very considerably on different days. For 12 hours before molting the larvae would sometimes eat comparatively little, while for several days before pupating they would be extremely voracious. Female adults always ate the most when laying eggs. The temperature also affected their appetites very remarkably, the highest records being made on dry hot days, while in damp cool weather they often ate almost nothing.

The state and temperature of the weather was indeed a very important factor in the welfare of these insects. Cold damp weather would very much retard the rate of growth of the larvae and the egg-laying of the females and would seem to

encourage diseases. Another injurious influence was the practice of cannibalism among the larvae and also the eating of eggs and pupae by both adults and larvae. A female would often eat her own eggs. As a rule, these habits were not practiced unless there was scarcity of food and in some cases not even then, while in other cases these deeds would be perpetrated with apparently no excuse. Individuals seemed to differ widely in this respect. Some kinds of lice proved injurious in the breeding cage. Large lice such as *M. rudbeckiae* and *M. ambrosiae* Thos., caused the death of several beetles by smearing their mouths shut by means of the glue extruded from the cornicles so that the beetles starved to death. Probably the results would not have proved fatal, had the beetles not already been somewhat weakened by other injurious influences, and were it not for the unnatural conditions of the breeding cage so that the lice were restless and walking about constantly.

The larvae, especially in the younger stages, seemed to prefer smaller lice in the cages, though out of doors they were frequently found feeding on large ones with no apparent difficulty. This protective function of the cornicles, however, would probably, even in nature have more or less of an injurious effect on the beetles.

This ladybeetle seems to be a very general feeder on plant lice. One beetle was observed to eat a larva of *Aphidoletes marina*, a dipteron, which is also predaceous on plant lice, but whether it would make a practice of this in nature was not ascertained, probably not, as in other cases the larvae of *Aphidoletes* were rejected. An unusually hungry beetle or larva would often chew or suck about on the leaves which were put into the cage with the lice. They seemed to do no visible injury to the leaves and were probably only sucking and licking off the honey dew left by the aphids. Both the beetles and larvae refused to eat chrysomelid eggs and membracid larvae which were offered to them. No evidence was obtained of their feeding, to any appreciable extent, on anything besides the living plant lice. They do not seem to touch even newly laid eggs of Aphididae.

The species of aphididae which were used for food in the breeding cage were as follows: *Aphis gossypii* Glover, *A. oxybaphi* Oest., *A. carbocolor* Gill., *A. torticauda* Gill., *A. helianthi*

Mon., *A. pomi* De Geer, *A. cerasifolii* Fitch, *A. medicaginis*, Koch, *Phorodon humuli*, Schrk., *A. oenotherae* Oest., *A. brassicae* Linn., *Chaitophorus negundinis* Thos., *C. populicola* Thos., *C. populifolii* Fitch., *Macrosiphum ambrosiae* Thos., *M. rudbeckiae* Fitch., *M. pisi* Kalt (?), *M. rosae* Linn., *Hyalopterus arundinis* Fab., *M. cynosbati* Oestl., *Lachnus* sp., *Melanoxantherium smithiae* Monell, *Myzus cerasi* Fab., *Prociphilus fraxinifolii* Riley, *S. lanigera* Hausm, and *Melanoxantherium bicolor* Oestl.

Outdoors they were observed feeding on *A. pomi*, *M. rudbeckiae*, *C. negundinis*, *Myzus cerasi*, *Mac. on Euphorbia*, *A. atriplicis* Linn., *M. pisi*, and *M. cynosbati*. Although these were all the lice noted, *H. convergens* has been found feeding on practically all of the common plant lice; in fact, it does not seem to be at all particular, and, both because of the wide range of its feeding habits, and on account of the comparative hardiness of constitution, probably does as much or more in controlling the plant lice than any other *Coccinellid*.

Hippodamia sinuata Muls.

This species also is a comparatively common ladybeetle about Fort Collins Colorado though it does not seem to rank very high in economic importance in this vicinity.

Adult: Fig. 5, Plate XXXII.

Head black with fine apical line of whitish and median pale spot connected laterally with the eyes. Pronotum black with pale border along anterior and lateral margins with tendency to abbreviated acute line before, though this is often wanting; two converging discal marks as in *convergens;* elytra yellowish red with suture black from one to three-fourths of entire length and each with four spots, the first near humeral angle, the second, a large one, just back of the middle, near the suture, the third slightly caudo-lateral of this, and another at apical fourth, the second and third spots very often united and frequently humeral spot, also, joined to second spot by means of vitta, coalescence of third and fourth spots occasionally occurs, thus completing the entire amalgamation of all the spots; legs black; general shape rather narrow; length 5-6 mm., width 3-3.9 mm.

Egg: Fig. 8, Plate XXXII.

Amber yellow; length 1.4 mm.; width .6 mm.

Larva: Fig. 7, Plate XXXII.

First instar: Black except pale spot on lateral margin of first abdominal segment and lateral and dorso-lateral of fourth abdominal segment. Second instar: same as first except that pale spots are more pronouncedly yellowish. Third instar: same as preceding but spots

have become orange and in addition the anterior and posterior borders of the pronotum have become yellow orange (pale), also dorso-lateral spots of yellow on posterior margin of metathorax, (which seems to be a distinguishing mark in this species) and faint yellow spots dorso-laterally placed on fifth, sixth, and seventh segments, and whitish median line on all thoracic segments; length 8.5 mm.

Pupa: Fig. 6, Plate XXXII.

Ground color amber yellow covered with black except median line of yellow throughout though somewhat broken at segment margins; pronotum bordered with black; wing pads black except light spot on shoulder, meso- and metathorax with pair of black spots, abdominal segments black except median area and yellow orange spots on first and fourth segments laterally placed, fainter ones similarly placed on fifth, sixth, and seventh segments; legs black; length 5.7 mm.

Life cycle records were made as follows:

Egg stage (3 records) 3-6 days.
Larva stage (3 records) 21-23 days.
Pupa stage (1 record) 8 days.
Egg to adult, 32 to 37 days.

From these figures it would appear that the life cycle of this species was considerably longer than in the other species studied. This may, however, be partly due to the fact that these records were all made in the latter part of the summer so that the beetles were overtaken by cool weather towards the end of the larval stage.

In nature this species does not seem to be a very general feeder, being found, by Mr. Bragg, almost exclusively in the grass, or more especially on the *Carex*, feeding on *Rhop. braggii* Gill., and *Callip., flabellus* Sanb. In the breeding cage, however, it readily fed on *Mac. rudbeckiae, Mel. Smithiae, Aphis cornifolii, Rhop. pastinaceae* Linn., *Aphis heraclei* Koch, and *Chait. populicola.*

Hippodamia parenthesis Say.

This species ranks about equal with *H. sinuata* in economic importance.

Adult: Fig. 9, Plate XXXII.

Head black with pale abbreviated median dash from the front and a spot next each eye, usually connected with median line, sometimes entire front portion of face pale; thorax black with anterior and lateral margins and median abbreviated acute line before white, also square spot at base; elytra pale reddish with yellowish area in middle of posterior half, marked with common large spot near the base connected with the scutel, and each with humeral spot, and pair of parenthesis shaped

dashes on posterior half sometimes united into a single large lunule; legs blackish to black, tarsi brownish; general shape, somewhat pointed posteriorly; length 4-5 mm., width 2-3 mm.

Egg: Fig. 10, Plate XXXII.

Amber yellow; length 1 mm., width .4 mm.

Larva: Fig. 11, Plate XXXII.

First instar; general color grayish or blackish; head shining black except medio-anterior portion, setaceous spots black, as in all the other species reared, dorso-lateral and lateral portions of first and dorso-lateral portions of fourth abdominal segment pale, nonsetaceous portions of thoracic segments rather pale. Final instar; head black except medio-anterior portion, which is brown; pronotum bordered with pale, meso- and metathorax with whitish median portion; yellow markings as follows, lateral and dorso-lateral spots on first and dorso-lateral spots on fourth abdominal segments orange yellow, and faint indications of dorso-lateral spots on fifth, sixth, and seventh segments pale yellow; length 8 mm.

Life cycle records were made as follows:

Egg stage (1 record) 3 days.
Larva stage (1 record) 11 days.
Pupa stage (1 record) 6 days.
Egg to adult, 20 days.

This life cycle appears relatively short, but this is probably due to the fact that this batch was reared in July when the weather was specially favorable.

This species, like *H. sinuata*, has been found chiefly in the grass and *Carex* feeding on *Rhop. braggii* and *Chait. fabellus*, tho in the breeding cage it seemed to thrive on *Rhop. pastinceae.*

Coccinella 5-notata: Kirby.

Ranking next in order, or perhaps equal with *H. convergens* in economic value, is *Coccinella 5-notata.* This is somewhat larger and more robust species and may be described as follows:

Adult: Fig. 12, Plate XXXII.

Head black with triangular pale spot next each eye; pronotum black with subquadrate pale spot at the anterior angles; elytra brownish red, marked with common subbasal fascia and a transverse spot on each elytron before the middle, near the suture, and another at apical fourth. Sometimes the subbasal fascia is broken into three spots, sometimes there is also a dot on the anterior lateral portion of the elytra. Length 5.5 to 7.5 mm.; width 4.5 to 5.5 mm.

Eggs: Fig. 13, Plate XXXII.

Light to deep amber yellow in color; length 1.31 to 1.37 mm.; width .53 to .60 mm.

Larva: Fig. 14, Plate XXXII.

Indistinguishable from that of *H. convergens* until it reaches the third or fourth instar when the head becomes pale, except on the posterior and lateral margins, which remain black. Also, the yellow spots on the abdomen are usually a stronger orange color and the dorso-lateral spots on the 6th and 7th segments are lacking. The light blue frosted appearance is sometimes more pronounced than in *H. convergens*. Length about 12 mm., for a full grown larva.

Pupa: Fig. 15, Plate XXXII.

Ground color pale brownish yellow, tinged in places with pinkish, paler, as a rule, than in the case of *H. convergens*. Pronotum with narrow black margin all around, except on median posterior portion; wing pads black on posterior and apical two-thirds of anterior margin, also two spots, one at basal third, and the other at apical third. These spots often coalesce, darkening the whole apical two-thirds of the wing pad. On the metathorax is a pair of black spots on the posterior margin, medio-laterally placed; spots similarly placed on 2nd to 7th segments inclusive, which segments also show another spot just within the spiracles which often runs into the first mentioned spots along the posterior margin. On the 3rd segment, the black often covers the entire surface clear to the lateral edge, leaving only a pale line on the median. Seventh segment often pale or nearly so. The amount of black varies somewhat and is often less extensive, but the pupa can usually be distinguished from that of *H. convergens* by the more extensive black markings, and by the paler ground color, but this does not always hold. Legs black. Length, 6 mm.

Life cycle records were made as follows:

Egg stage (15 records) 3-5 days, mostly 3 days;
Larva stage (13 records) 11-19 days, mostly 13 days;
Pupa stage (12 records) 3-8 days, mostly 4 days;
Egg to adult, mostly 20 days.
Adult stage (4 records) 2-3 months for the summer generations.

The efforts to carry this species through hibernation all resulted in failure, but seven beetles were captured before May, 19, 1908, which, in all probability, had hibernated, as no larvae had been observed before that time or for some time afterwards. The last of these beetles lived until August 14th, and must have lived for nearly a year, as the beetles in the cages which went into hibernation began to emerge August 6th. In the cage of these seven captured beetles, eggs were found from May 19th to August 7th, a period of two months and eighteen days.

Egg records were made as follows: 368 eggs (in 2 months and 9 days); 469 eggs (in 1 month and 11 days), 532 eggs (in 1 month and 8 days), 539 eggs (in 1 month and 2 days) respectively. Single egg batches often contain as many as 60 eggs; the

average size, however, would be nearer 30 to 50. A beetle in good laying condition would often lay one or two batches a day, though in the breeding cage this rate was not kept up very long at a time.

The female would usually, under favorable conditions, begin to lay from four to ten days after emerging and continued in one case for one month and eleven days, and in another, the longest record, for two months and fourteen days. The third generation was reached in a season in the breeding cage and both 2nd and 3rd generation beetles went into hibernation but none survived, the hibernating quarters being unsatisfactory. The earliest eggs obtained in the spring were found May 19, 1908; the first generation began to emerge June 17th, and their first eggs were laid June 26th. The last of this brood lived until September 21st. The latest record of eggs obtained was September 14th. That year there was much cold wet weather during August, which very considerably checked the egg laying so that the beetles would very probably have laid for at least a month later under favorable conditions.

Records on the feeding capacity of both larvae and adults were taken as follows: One larva ate 595 and another 621 aphids during the entire larval period. The lice used in these counts were of all ages and sizes. One ate *C. negundinis* 333, *M. gaurae* 24, *P. fraxinifolii* 128, and *M. rosae* 110, total 595; the other *C. negundinis* 445, *M. gaurae* 18, *P. fraxinifolii* 88, and *M. rosae* 70, total 621. These lice were of all sizes. It will be seen that *C. negundinis* was used more than any other one species. One larva made the following records on single day counts: during the first instar, 30 *C. negundinis* in a day; 2nd instar, 84 *C. negundinis*; 3rd instar, 100 *C. negundinis* in a day. These were days when all was favorable and the larva was on full feed. An adult female when in best condition ate 200 *A. helianthi* in a day.

The plant lice used for feed were the same as used for *H. convergens*. This species seems to be just as general a feeder as *H. convergens* and, being somewhat larger, would naturally be expected to consume a few more lice, but it seemed to be more delicate in constitution so that it succumbed more easily to unfavorable conditions in the breeding cage. This species was affected by the same injurious influences as were mentioned for *H. convergens*.

In 1907 and 1908 this species, from casual local observations, seemed to rank next to *H. convergens*, which was first in numbers, but in 1909 it seemed to rank about fifth, with *H. convergens* sixth. During this year, the first in numbers seemed to be *C. monticola* which, during the two previous years, had ranked third.

Coccinella monticola Muls.

This species is quite similar in general appearance to *C. 5-notata* and may be described as follows:

Adult: Fig. 16, Plate XXXIII.

Head black with triangular spot next each eye as in *C. 5-notata;* pronotum black with quadrate pale spot at the anterior angles; elytra brownish red, with common scutellar spot, and on each a broad transverse oblique median fascia and a shorter subapical one black. Sometimes the median fascia is broken, leaving a small spot laterally. Legs black. Length 5 to 7.5 mm.; width 4 to 4.75 mm.

Egg: Fig. 17, Plate XXXIII.

Same as in *C. 5-notata.*

Larva: Fig. 18, Plate XXXIII.

Same as in *C. 5-notata*, except that in 3rd and 4th instars the head is pale clear to the posterior margin, while *C. 5-notata* almost always has a line of black along the posterior margin. Length of full grown larva about 12 mm.

Pupa: Fig. 19, Plate XXXIII.

Ground color pale brownish yellow, usually paler than in *C. 5-notata*, sometimes with pinkish spots on lateral portions of 1st and 4th segments of the abdomen where the orange spots were in the larva. Black markings were as follows: Three spots on anterior edge of pronotum, and one on posterior lateral margin, wing pads with two transversely duplex spots, one at basal third and the other at apical third, and a spot at base close to posterior lateral margin, which margin is also black; median pair of spots on metathorax, also on 2nd to 6th abdominal segments inclusive, smallest on 2nd; 3rd to 6th abdominal segments also with spot within spiracles largest on third and inclined to extend to the very margin of the segment. Knees black, remainder of legs usually paler. Length 6.5 mm. The pupæ of this species can usually be distinguished from those of *C. 5-notata* by the less extensive black markings, though the two species vary so as often to be indistinguishable.

Life cycle records were taken as follows:

Egg stage (17 records) 3-8 days, mostly 4 days;
Larva stage (11 records) 12-14 days, mostly 13 days;
Pupa stage (11 records) 4-8 days, mostly 6 days;
Egg to adult, mostly 23 days.
Adult stage (2 records of summer generation) 2 months and 6 days, and 3 months and 12 days respectively.

Three beetles captured July 15, 1907 hibernated and the last one died August 31, 1908, 13 months and 16 days from date of capture. In this cage, during 1907, only four eggs were laid, though it contained 9 beetles, but after hibernating, eggs were laid rather abundantly, though they were infertile, by one or more of the surviving three from May 11, 1908 to July 18, 1908, a duration of 2 months and 7 days. Three other beetles which were captured May 15, 1908, and in all probability had hibernated, lived until September 8, 1908, so they must have been a year old, at least, eggs having been laid from May 18, 1908 to August 18, 1908, a period of three months.

No egg records were taken on this species, as only captured females laid at all satisfactorily and these had doubtless laid a portion of their eggs while still out of doors, so a complete record could not be gotten. The earliest eggs obtained in the spring were found May 11, 1908, laid by females which had hibernated in captivity; June 16, 1909, from captured females. The latest record obtained in the fall was September 3, 1909, but as this was the only year that a record was taken and as August was very wet and cool, the beetles would probably be able to lay for a month later, at least, under favorable conditions.

The earliest generation reared emerged June 24, 1908, and began to lay July 17, 1908, and the last beetle died September 15, 1908, probably due to the unfavorable weather. Later batches of the same generation which emerged July 4, 1908, later went into hibernation but died during the winter. Beetles emerging July 5, 1909, the earliest generation obtained that year, went into hibernation.

It seems that this species may have both one and two generations in a year, since some of what were evidently first generation beetles went into hibernation while others of this same generation laid eggs, infertile though they were, and died before winter.

In feeding capacity they were about the same as *5-notata*. One larva from time of hatching to pupation ate 388 plant lice, (23 *A. torticauda*, 65 *C. negundinis*, 165 *C. populicola*, 90 *A. setariae*, 45 *M. ambrosiae*); another ate 376 plant lice, (12 *A. torticauda*, 120 *A. setariae*, 174 *C. negundinis*, 40 *C. populicola*, 30 *M. ambrosiae*). another ate 901 plant lice, (150 *A.*

gossypii, 480 *A. helianthi*, 19 *A. setariae*, 82 *C. populicola*, 140 *A. pomi*, 30 *M. rudbeckiae*); and another, 962 plant lice, (774 *A. gossypii*, 108 *M. pisi*, 80 *Myzus cerasi*). One larva during the first instar ate 30 *A. gossypii* in a single day; in the 2nd instar, 100 to 130 *A. gossypii*; third instar, 150 *A. gossypii*. Of course these records were made when all conditions were favorable. No records were taken on the adult.

The range of feed seemed to be the same as for *H. convergens* and *C. 5-notata*. They were observed out doors feeding on *A. pomi*, *H. arundinis*, *M. cynosbati*, and *S. lanigera*. Though these were the only observations recorded they seem to feed on practically every common species of plant lice.

As to injurious influences, they seemed to be affected by the same factors as the foregoing species but seemed to stand cool wet weather rather better. Some of these beetles got rather badly pasted up by the glue from the cornicles of *M. rudbeckiae* but it did not result fatally. One beetle was found with one front foot glued fast to its head, probably the result of an attempt to clean itself for which operation the beetle was not sufficiently vigorous, the foot sticking fast until it dried.

A nearly full grown larva was observed to attack a good sized pupa of *M. ambrosiae*, biting it in the side of the third abdominal segment. The louse immediately struck the larva in the face with its cornicle and discharged a quantity of glue. The larva paid no attention to this but continued until it had finished the louse, and, inside of fifteen minutes, every trace of glue was removed. Evidently when the beetles and larvae are in vigorous condition this protective device of these aphids produces little result beyond temporary annoyance.

This species seems to be peculiar in several points of its life history as compared with the other *Coccinellidae* studied; first in the fewer generations in a season, and the consequent greater longevity of the beetles; and second, in the non-activity of the males. Mr. Bragg, who had dissected at least 100 *monticola* specimens, found only one male and he has some doubt as to its really being this species. No *monticola* has been observed in coition either indoors or out except with *C. 9-notata* or *C. 5-notata* males. The eggs of a female captured mated with *C. 9-notata* all proved infertile, even though the male was kept with the female for over two months and was frequently

observed in coition and the female laid a considerable number of eggs. A male of *9-notata* was introduced into a cage of *monticola* which had been laying infertile eggs and though he mated readily no fertile eggs were produced. One female *monticola* was taken in coition with a male *5-notata*. The eggs were fertile and produced all *monticola*, but this female may have been previously fertilized by another male so there is no evidence that the *5-notata* male had any effect.

There is a possibility of the males being weaker than the females and so being killed in the struggle for existence before they matured in the breeding cage, since about 50 per cent. were, as a rule, lost when a number were reared together. All the larvae from several batches were reared in individual cages. In this way 90 percent were brought to maturity and in the adult state all were put together in the same cage, but they always died down to the usual 50 percent before there was time for sexual development to be really completed, so that there is a probability in these cases of the males having been lost because of having a more delicate constitution than the females. This would also account for their scarcity out of doors.

Two batches were reared in individual cages, maturing 17 beetles from 18 larvae and 12 beetles from 23 larvae respectively. These beetles were not put together but were dissected by Mr. L. C. Bragg as soon as mature, the first lot proving to be 7 male and 9 female and the second lot 9 male and 3 female. This latter case seems evidence against the possibility of the males being weaker than the females, as in this batch little over 50 percent matured and 75 percent were males. The only explanation remaining seems to be a sexual non-activity for some reason.

A good share of the females captured proved to be infertile, when, however, a female is once fertilized it seems to suffice for the season. Females captured May 15, 1908, laid fertile eggs until August 18, 1908, a period of over three months, after which they very soon died.

In spite of this seemingly weak point in its life history, this beetle seems to rank quite high as an enemy of plant lice.

Coccinella 9-notata Hbst.

Description of adult, Fig. 20 Plate XXXIII.

Head black with pale triangular spot next each eye, or these spots may be connected so as to form a broad white band across the face; pronotum black with quadrate pale spot at anterior angles, and apical margin usually pale, often broadly pale; elytra bright brownish red or red ochre, with common scutellar spot, and each with four other spots, the two small ones sometimes connected by a fine line, one in humeral angle and the other near the lateral margin before the middle, and two large ones, one near the suture and before the middle, the other rather transverse and near the apex. Length 6-7.5 mm.; width 5-6 mm.

Egg: Fig. 21, Plate XXXIII.

Same as the foregoing species except, perhaps, a little smaller on the average.

Larva: Fig. 22, Plate XXXIII.

First instar: Entirely black or blackish gray, except pale dorso-lateral spots on first abdominal segment, and with setaceous tubercles as in the foregoing species. Second instar: Same as 1st except that median and anterior portion of head and anterior and posterior margins of pronotum are slightly pale or dusky, the spots on the first abdominal segment more yellow, and paler spots begin to show similarly placed on 4th abdominal segment. Third instar: Same as last except that pale portions of head and pronotum are lighter, and spots on abdomen are more orange colored. Fourth instar: Same as last except pale portion of head which is light yellow. The larvæ of this species seem to be identical in appearance with those of *5-notata* but do not grow to quite as large a size. Length of full grown larva 9.5 mm.

Pupa: Fig. 23, Plate XXXIII.

Ground color light reddish or brownish yellow, often with pinkish spots on 1st and 4th abdominal segments where the orange spots were located in the larva. Pronotum with a pair of black dashes on anterior margin, and a pair of black dots on the posterio-lateral margin; a median pair of black spots on metathorax and 2nd to 7th abdominal segments inclusive; Spiracles black; Wing pads with posterio-lateral margin black and a round black spot at basal third. This marking of the wing pad is comparatively constant and nearly always distinguishes it from all of the foregoing species, though sometimes this spot seems to spread apically so that the pupa cannot be distinguished from *5-notata*. Length about 6 mm.

Life cycle records were taken as follows:

Egg stage (14 records) 3-6 days, mostly 4 days;
Larva stage (8 records) 10-21 days, mostly 11-14 days;
Pupa (8 records) 4-5 days, mostly 5 days;
Egg to adult, mostly 20-23 days.
Adult (7 records) 2 to 3 months for the summer generations.

Some of the beetles which went into hibernation were then nearly four months old but did not survive the winter, probably on account of improper winter quarters. Only one beetle survived. It had emerged September 14, 1908, and lived until April 9, 1909

Four egg records were taken as follows:

435 eggs (in 1 month and 9 days); 493 eggs (1 month and 22 days); 950 eggs (in 2 months and 22 days); and 1047 eggs (in 2 months and 14 days). They laid from 40 to 68 eggs a day when in full laying condition. Some of these beetles began to lay as soon as one day after emerging. Others began at 7 days, and one at one and a half months after emerging. This latter was in all probability not normal.

The 2nd generation was reached in the season when the experiments were carried on, but, as a rather late start was made in the spring, it is more than probable that they are able to attain to the third generation when the spring is early. The earliest eggs obtained were June 11, 1909 and the latest record was September 2, 1909.

No exact feeding records were made with this species, but judging from general observation they seemed to consume as much as the foregoing species. Being as a rule somewhat smaller than *5-notata* and *monticola*, they probably ate a little less. They seemed to take to the same range of feed as the foregoing species in the breeding cage. This species seemed to be susceptible to all of the injurious influences already mentioned and besides these, several cases of parasitism were observed in beetles captured out of doors. After emerging, the parasite formed a silky cocoon underneath the beetle. The beetle, though still alive, seemed unable to leave the cocoon of its enemy and clasped it with all of its feet as though to protect it. One was carefully examined and found to be perfectly free from any attachment and the only reason for its remaining there seemed to be a partial paralysis. When taken off the cocoon, which was accomplished with considerable difficulty because of the beetle holding so persistently with its tarsi, the beetle seemed to be unable to walk or even stand, and when offered food it made vain attempts to eat. It seemed absolutely helpless from inability to co-ordinate its movements.

There were no serious results in this species from the glue thrown out from the cornicles of the large species of lice but this was probably only accidental and not because of any specific resistent character. Once, a small larva, apparently in the second instar, was observed to seize a full grown apterous *Macrosiphum ambrosiae* which appeared to be three times the size of itself. It first caught it by the right hind foot. The louse struggled, dragging the larva about for a minute or two and extruded glue from the left cornicle. The larva then managed to get hold just behind the right cornicle and proceeded to feed on the louse, though dragged about somewhat by the latter. Two and a half hours later it was found still feeding on the louse, which was still living, but had extruded no glue from the right cornicle on which side the larva was holding it. Unless for some reason the right cornicle contained no glue, this action of the louse seems to be explained only by awkwardness or stupidity. Indeed, the cases were extremely few when the louse seemed to make any well directed effort to smear its enemy.

Perhaps next in order might be classed several forms of *Adalia* Muls., namely, *melanopleura* Lec., *annectans* Crotch, *coloradensis* Casey, and *humeralis* Say. As these four forms interbreed freely and seem to be identical in life history it seems best to treat of them here as one species, which indeed they undoubtedly are. In the descriptions of the adults, however, they must be treated separately. In the larval and pupal stages they seem to be identical in appearance but in the adult state are strikingly different.

For full description of adults of these forms, see Annals of the Entomological Society of America, Volume 4, page 283.

Egg: Fig. J, Plate XIX*.

Pale to deep amber yellow in color as in the foregoing species. Length about 1 mm.; width about .5 mm.

Larva: Fig. I, Plate XIX*.

First instar: Head and pronotum shining black, rest of body dull black or dark grayish with a median row of paler spots from pronotum to tip of abdomen; 2nd instar, the same except lateral and mediolateral pale whitish spots on 1st abdominal segment and a median pair of whitish spots on 4th abdominal segment; pronotum bordered all around with whitish and with median pale line; 3rd and 4th instars; color often blackish gray or blue; median and anterior portion of head

*Annals E. S. A. Vol IV, Sept. 1911.

dusky or pale, a pair of pale spots on anterior lateral margin and three on posterior margin of pronotum; also a pale median line, and pale median portion of meso- and meta-thorax quite noticeable; spots on abdomen more noticeable than in previous instars. Legs black. Length of full grown larva 8-9 mm.

Pupa: Fig. H, Plate XIX*.

Ground color pale to sordid flesh color, tinged in places with brownish. Pronotum with pale median line and broad lateral portion pale, remainder dusky to black. Wing pads brownish to black, meso- and meta-thorax dusky to black except median pale line; each abdominal segment with three pairs of rows of dusky to black spots, median row lighter on 1st and 2nd segments, giving a lighter appearance to that part of the pupa. In dark specimens the markings are so extensive as to almost coalesce, giving quite a melanic appearance. Legs brownish to blackish. Length 4-5 mm.

Life cycle records were taken as follows:

Egg stage (84 records) 3-7 days in the spring, 2-6 in summer, mostly 3-5.
Larval stage (68 records) 11-18 days in the spring, 7-18 summer, mostly 15 spring and 11 summer.
Pupa stage (68 records) 5-9 days in the spring, 3-9 summer, mostly seven.
Egg to adult, mostly 21 to 23 days.
Adult (9 records) 1 month to 4 months, for the summer generations.

The records taken in the spring, April and May, it will be noted, covered more days than those taken in the summer, owing to the cooler temperature. Five beetles of first to third generation that had laid a considerable number of eggs and were from three to four months old, went into hibernation. One of these lived until April 4th the next spring, aged 8 months and 6 days. The rest died during the winter, though the hibernating quarters were excellent. As there is a probability that the first female captured, May 13, 1910, and with which the start was made in the breeding cage, was not a hibernating female, there is some uncertainty as to the number of each generation. The beetles which survived hibernation were the 4th or 5th generation and they survived in large numbers, about 150 beetles in all.

A pair of beetles, the female of which was 3rd or 4th generation *humeralis* that had laid no eggs, and the male 2nd or 3rd generation *annectans*, hibernated successfully, and in the spring the female laid eggs abundantly until June 12, 1911, and they both lived until June 16, 1911, the female aged nine months and the male nine months and four days. Almost all of the hibernating beetles which were cared for were still living May

23, 1911, aged about eight months, and a number were living June 12, 1911, but all died soon after, some being nine months old or more.

The females would usually begin laying about six days after emerging and continue for about three weeks. One continued for three months, by far the longest record made, but probably the most nearly correct as most records were doubtless cut unnaturally short on account of the great difficulty of keeping the beetles healthy in captivity. The hibernating females of all the three forms began to lay in six days after having been brought in from hibernating quarters and given food.

There seemed to be at least four, and possibly five generations during the season that the experiments were carried on, though 3rd generation and possibly 2nd generation individuals hibernated successfully. There was no evidence of any females which had laid eggs before winter hibernating and laying again in the spring, though it may possibly take place. The hibernating quarters used for these beetles were excellent and apparently gave the beetles every chance.

The earliest eggs were obtained April 10, 1911, and the first of the first generation reared emerged May 8, 1911. The latest eggs in the fall were obtained September 16, 1910, but if there had been no prematurely cold weather, the beetles might have kept on laying for several weeks longer. From two or three tests made, a female seemed not to be able to lay fertile eggs longer than three or four weeks after being separated from a male. If a new male was introduced, however, it seemed to affect the eggs almost immediately and after two or three days none of the progeny showed any of the characters of the former male, even when little or no interim existed between the males.

No feeding or counts were taken on this species as all the time in the work with these beetles was used in heredity investigation * and only such life history data as took but little time were noted. On general observation it was evident that they eat much less than the foregoing larger species, and in the breeding cage, at least, will not eat as large lice as the above ladybeetles. Probably out of doors, when the lice are quiet instead of restless as in the cages, they may feed upon

*See "Some Notes on Heredity in the Coccinellid Genus, Adalia Muls." Annals of Ent. Soc. of Am., Vol IV, No. 3.

larger species. Mr. Bragg says that he found them in numbers with *Prociphilus fraxinifolii*, a species which, from their large size and great quantities of honeydew, would have certainly brought disaster in the breeding cage, for great care had to be exercised in feeding these even to the larger species of beetles. They seemed to thrive in confinement on *C. negundinis*, *A. setariae*, *A. helianthi*, *C. populifolii*, *C. populicola*, *M. sanborni* Gill., *Myzus persicae*, Sulz., *Rhopholosiphum pastinacae*, *Aphis heraclei* Koch, *M. cynosbati*. Outdoors they were found with *P. fraxinifolii*. n 1910 and 1911 this species seemed especially abundant. In the spring of 1910 the box-elders were extremely lousy but by June 26, it was extremely difficult to find any *C. negundinis* excepting the dimorphic form which the ladybeetles seemed unable to eat. This species of beetles, together with Syrphus larvae, seemed to be chiefly responsible for the destruction of the lice. Again this spring, 1911, they seem to be the chief factors in cleaning up the box-elder lice which were almost killing some trees.

These beetles seemed to have a more delicate constitution than the other species reared and had to be tended with more care, and even with the best care, hardly 25 percent could be matured, and often less in the pure strains. The hybrids were much more vigorous, and of them it was often possible to rear 50 percent to maturity. These beetles were susceptible to all of the injurious influences which have been named, and besides, they seemed to object to what might have been an odor left by a certain species of ants, as the cottonwood *C. populifolii*, which is abundantly attended by ants, was rejected at times and accepted at others with no other apparent reason. On the occasion of rejection they would turn cannibal and almost the entire cage of larvae would be lost in one day, as though they had been left without any feed at all. It seems, however, that in spite of their seemingly rather frail constitution, they hold their own in nature pretty well, as during 1909 and 1910 and the spring, at least, of this year (1911) they ranked high in comparative numbers out of doors and doubtless have been very beneficial.

Olla abdominalis Say.

This species is sometimes found, though it is rather rare. One larva was found on a boxelder tree with *C. negundinis* June 25, 1909, and was reared to maturity. It was taken when nearly full grown.

Larva: Fig. 25, Plate XXXIII.

General color black, except medio-anterior portion of the head which was pale yellow to dusky; anterior portion of pronotum and median spot on posterior margin pale; median spots of pale yellow on meso-and meta-thorax; dorso-lateral yellow spots on first abdominal segment, and dorsal and dorso-lateral on 4th abdominal segment; lateral tubercles pale or partly so. Median pale spot on median posterior margin of each segment becoming larger toward caudal end of abdomen and giving the appearance of a pale median longitudinal line the entire length of the abdomen. Legs black.

This larva resembled the *Adalia* larvæ very much but grew to be somewhat larger than they did. Length of full grown larva 10 mm.

Pupa: Fig. 26, Plate XXXIII.

Ground color whitish tinged with yellowish and brownish in places. Markings as in *Adalia*. Length 5 mm.

Adult: Fig. 24, Plate XXXIII.

Head white except two black spots on the posterior margin; pronotum with (M) design as in *Adalia*, but with the white more extensive so that the pale spots often run together in places; elytra pale maize yellow, each with a row of four basal spots, a row of three just before the middle, the inner one crescent-shaped, also one subapical near the lateral margin. Sometimes this apical spot and the middle row are all connected into a triangular black patch. Legs brownish yellow. Length 4-6.5 mm.; width 4-5 mm. No work has been done with this beetle further than the rearing of the one larva found. This larva was found with *C. negundinis* on boxelder.

Coccinella sanguinea Linn.

This seems to be the species designated by Casey as *Cycloneda rubripennis* Casey, and by C. W. Leng as Subgenus *Cycloneda sanguinea* var. *rubripennis* Casey.

This species is comparatively if not indeed quite rare about Fort Collins, Colorado, but seems to occur more plentifully in the vicinity of Boulder, Colorado.

Adult: Fig. 27, Plate XXXIII.

Head black with broad white border next each eye, often also median pale spot and in many cases entire front of head white; pronotum black with rather narrow pale border along sides and extending posteriorly and internally along the base to about lateral sixth, apical pale line quite narrow with median acute line often rudimentary, also isolated sublateral pale spot which is sometimes narrowly connected to

the pale apical margin; elytra deep and bright scarlet with transverse pale spot on each side of scutellum; legs black to brownish, tarsi brownish; general shape broadly oval and rather strongly convex. Length 4.5 to 5.5 mm.; width 3.5 to 4.75 mm.

Egg: Fig. 28, Plate XXXIII.

Pale amber yellow; length 1.36 to 1.5 mm.; width .63 to .7 mm.

Larva: Fig. 30, Plate XXXIII.

First instar: Black or dusky with pale lateral spot on first abdominal segment, setaceous spots black as in other species. Second instar: Same as first except that fourth abdominal segment shows pale lateral and dorsal spots, and sometimes lateral pale spot appears on fifth and sixth segments, median of meso- and meta-thorax whitish to yellow. Third instar: Same as previous except that yellow spots on fifth and sixth segments and on median of thoracic segments are always pronounced and anterior margin of pronotum is also pale, median of abdominal segments whitish, giving effect of light median stripe; median and anterior portion of head brownish, while lateral and posterior portion is deep black; legs, especially front pair unusually long. Fourth instar: Same as preceding except that the spots are more yellow and lateral margins of all thoracic segments are pale whitish or yellowish; legs still longer than those of the other species studied; general color dark bluish. This larva strongly resembles the larva of *Olla abdominalis.*

Pupa: Fig. 29, Plate XXXIII.

Ground color pale maize yellow, darker in spots, especially in the depressions between the abdominal segments, a broad band along anterior and lateral margins and a round spot within lateral margin on each side of pronotum. Wing pads dark maize to honey yellow or sometimes quite brownish with posterior margins always brown; black markings as follows: Pronotum with a pair of black spots on anterior and another on posterior margin, also an anterio-lateral pair less pronounced, a pair of median spots on meso- and meta-thorax and on abdominal segments two to six inclusive, third segment with three pairs of spots; legs brownish honey yellow. Length 5 mm.

Life cycle records were made as follows:

Egg stage (7 records) 3-5 days, mostly 4 days.
Larva stage (7 records) 9-16 days, mostly 11 days.
Pupa stage (7 records) 3-5 days, mostly 4 or 5 days.
Egg to adult, 15 to 20 days.

This species has been observed by Mr. Bragg feeding on *Mac. solidaginis*, and in the breeding cages it did well on *Aphis heraclei* Koch., *Rhop. pastinaceae, Mac. gaurae, Mel. smithiae, Aphis setariae, Aphis oxybaphi*, and *Aphis helianthi.*

Some larvae of *Scymnus* species, determined by Major Casey as probably a new species somewhere in the vicinity of *cockerelli* Casey and *consobrinus* Lec., were reared but no life history notes were taken.

Adult: Fig. 31,Plate XXXIII.

Head black, yellowish red between the eyes; pronotum black with lateral thirds yellowish red; elytra black; legs brownish red; entire beetle covered with hairs; length 2.5 mm.; width 1.7 mm.

Egg:

Same color and shape as foregoing species but much smaller.

Larva: Fig. 32, Plate XXXIII.

Pale brownish throughout, but covered with six large tufts of waxy secretion on each segment so as to render the larva quite conspicuous.

In the pupa the larval skin is not pushed down as tightly as in the other *Coccinellids* studied, so that it gives the pupa a white cottony appearance and doubtless affords it considerable protection.

This species has often been found doing valuable service in keeping *A. setariae* in check on the plum. Professor Gillette has often found it abundant with *Schiz. lanigera* on the apple.

GENERAL SUMMARY.

In general appearance and color pattern these species of ladybeetles resembled each other most in the larval and pupal stages. *Coccinella 5-notata*, *9-notata*, and *monticola* resemble each other so much as to form one group. They of course had some characteristic differences but they often intergraded and merged together so as to be indistinguishable until they matured.

H. convergens, together with *H. parenthesis* and *H. sinuata* seemed pretty distinct in these stages but an occasional individual was found which seemed to show no distinguishing character. The *Adalia* beetles, *O. abdominalis*, and *C. sanguinea* seemed to form another group in color pattern of the larva and pupa. The forms of the *Adalia* seemed to be exactly identical in these early stages. *Scymnus*, of course, with its covering of waxy secretion, was entirely different.

In life cycle periods from egg to adult, all the species thus studied, *H. convergens*, *C. 5-notata*, *9-notata*, *monticola* and the genus *Adalia* seemed practically alike. From egg to adult in *H. convergens* took, as a rule, 21 days; in *C. 5-notata*, 20 days; in *C. monticola*, 23 days; in *9-notata*, 20-23 days; *Adalia*, 21-23 days. The age to which the adults lived seemed practically the same, two to three and perhaps four months for the summer generations. In *C. monticola*, however, it seemed that the first generation commonly hibernate so that these beetles would live to a greater age than even the hibernating beetles of the other species in which only the beetles emerging

later in the season hibernated. There did not seem to be any certain fixed generation to hibernate in any of the species but there was no evidence of any females that had laid eggs before winter hibernating and laying again the next spring, and none ever hibernated in other than the adult state.

Of all the species studied, *C. monticola* was the only one where there was any difficulty in breeding males in captivity; in all other species about half of the beetles reared were males, but here there was no evidence of any, and only females captured already fertilized, laid eggs which would hatch. Many of these captured laid infertile eggs or none at all, and none reared in captivity ever laid a fertile egg and most did not lay at all. For three years, no undoubted instance of the finding of a male occurred either biologically by myself, or by Mr. Bragg, who used dissection on captured specimens and had no difficulty finding males in any of the other species. Finally, however, two batches of eggs were reared with special care, one lot producing sixteen beetles from eighteen larvae hatched, and the second producing twelve beetles from twenty-three larvae hatched. The first lot proved, on dissection, to consist of seven males and nine females. The second lot consisted of nine males and three females. Why none have been observed mated, either in captivity or out of doors, and why Mr. Bragg found so much difficulty in capturing males, still remains unknown.

The egg laying periods seemed to be approximately the same for all these species where records were taken, both for the length of time for the individual, and for the laying season. A female would often lay before being fertilized but not as well as after. A female of *Adalia* would not seem to be able to lay fertile eggs for more than about three weeks after being isolated from a male. In *C. monticola*, on the other hand, if a female was once fertilized, it sufficed for the season. In *Adalia*, when a female was changed from one male to another, the later male would take precedence over the former one, almost immediately, so that the eggs laid two or three days after and later would develop the characters of the later male in every case.

In the individual egg records, *C. 9-notata* ranked first, the four highest records being from 435 to 1047; *C. 5-notata* next, with 368 to 539; then *H. convergens* with 199 to 312, these numbers representing the four highest records of each species.

respectively. Owing to the difficulty in getting these beetles to lay their full number of eggs in captivity, many of the numbers here may fall far short of what the beetles are able to do, and the differences between the species may have been more or less accidental, though *C. 9-notata* seemed very decidedly to be the most prolific.

Considering the feeding capacity of the larvae and adults of these species, there seemed little difference between them. A larva of *H. convergens* was able to eat 100 *C. negundinis* in a single day, and the highest entire record was 576 aphids of different kinds. A larva of *C. 5-notata* could eat 100 *C. negundinis* in a day and the highest entire record was 620 aphids. A larva of *C. monticola* ate 144 to 190 *A. cornifolii in* a single day, and the highest entire record was 962 aphids. An adult of *H. convergens* ate 120 *A. setariae* in a single day, and one of *C. 5-notata*, 200 *A. helianthi.*

Both in the per day, and the entire record of the larva, *C. monticola* leads, and *C. 5-notata* ranks second. These species are on the whole practically alike in feeding habits and what differences there seem to be may be partly accidental as counts were taken on only four larvae of *H. convergens*, only two of *C. 5-notata*, and five of *C. monticola*, and only two counts of *C. monticola* exceeded the other species, the other three being no higher than in the others. The amount eaten per day varied greatly with the larvae according to the weather and the size of the larva, and in the adult it varied with weather and egg laying.

In range of feed *H. convergens*, *C. 5-notata*, *C. monticola* and *C. 9-notata* seemed practically alike and seemed to comprise everything in the way of aphids except aphid eggs, though the smaller species seemed to be preferred in the breeding cage. Out of doors they all seemed to feed on the large species as well as the smaller ones. For these four species of ladybeetles the following plant lice were used as feed: *A. cerasifolii*, *A. gossypii*, *A. oenotherae*, *A. carbocolor*, *A. taraxici*, *A. torticauda*, *A. oxybaphi*, *A. helianthi*, *A. setariae*, *A. medicaginis*, *A. brassicæ*, *H. arundinis*, *Lachnus* sp., *C. negundinis*, *C. populidola*, *C. populifolii*, *M. gaurœ*, *M. cynosbati*, *M. pisi*, *Myzus cerasi*, *Macrosiphum ambrosiæ*, *M. rudbeckiæ*, *Prociphilus fraxinifolii*, *Phorodon humuli*, *S. lanigera*, *Melanoxantherium bicolor* and *M. smithiæ.*

There was no evidence of any of these species feeding on vegetable matter, though they often chew and suck about on the leaves when very hungry and one newly emerged *Adalia* beetle seems to have chewed up a portion of a half dried boxelder leaf.

The *Adalia* beetles had to be fed on only the smaller species of plant lice in the breeding cages, though out of doors they were found by Mr. Bragg to be quite abundant with *P. fraxinifolii*. Early in the spring, 1910 and 1911, they were very abundant with *C. negundinis* and together with the Syrphus larvæ they cleaned these lice off the boxelder trees, though they had been very badly infested. The species used successfully in the laboratory were *C. negundinis*, *M. sanborni*, *Myzus persicæ*, *A. setariæ*, *A. helianthi*, *R. pastinacæ*, and *Macrosiphum cynosbati*.

The injurious influences affecting these species were cool damp weather, which *C. monticola* seemed to stand better than the other species, very large lice that would extrude large quantities of glue from their cornicles, a fungous disease resulting from too much dampness in the cage or perhaps from the decaying bodies of half eaten lice, and frequently beetles were destroyed by a hymenopterous parasite known as *Perilitus americanus*. Ants, also, seemed to be hostile, in one instance killing a larva and in another, an adult, this even in the breeding cage where the ants felt strange and were frightened. Much loss was occasioned by cannibalism, eggs, larvæ, pupæ, and even newly emerged adult beetles, while still soft, being eaten by hungry brothers either larvæ or adults.

As to members in nature, the different species seem to rank differently in different years. From casual local observations, in 1907 and 1908, *H. convergens* ranked first, *C. 5-notata* second, *C. monticola* third, *C. 9-notata* fourth, and *O. abdominalis* and *Adalia* quite rare. In 1909, *C. monticola* was first, *Adalia annectans* second, *H. convergens*, *C. 5-notata*, and *C. 9-notata* not very abundant, and *O. abdominalis* only occasional.

EXPLANATIONS OF PLATES.

Plate XXXII.

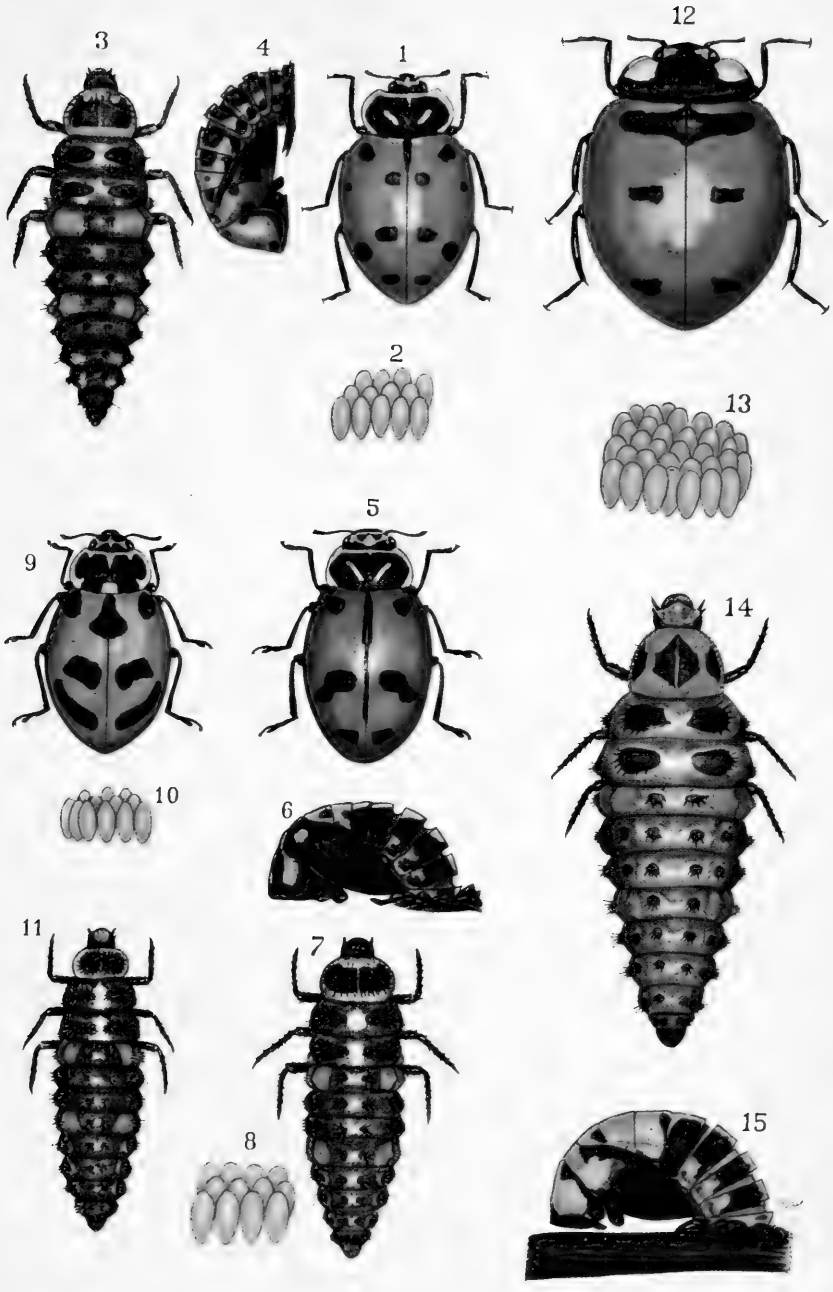
Fig. 1. Adult of *Hippodamia convergens* Guer.
Fig. 2. Eggs of *Hippodamia convergens* Guer.
Fig. 3. Larva of *Hippodamia convergens* Guer.
Fig. 4. Pupa of *Hippodamia convergens* Guer.
Fig. 5. Adult of *Hippodamia sinuata* Muls.
Fig. 6. Pupa of *Hippodamia sinuata* Muls.
Fig. 7. Larva of *Hippodamia sinuata* Muls.
Fig. 8. Eggs of *Hippodamia sinuata* Muls.
Fig. 9. Adult of *Hippodamia parenthesis* Say.
Fig. 10. Eggs of *Hippodamia parenthesis* Say.
Fig. 11. Larva of *Hippodamia parenthesis* Say.
Fig. 12. Adult of *Coccinella 5-notata* Kirby.
Fig. 13. Eggs of *Coccinella 5-notata* Kirby.
Fig. 14. Larva of *Coccinella 5-notata* Kirby.
Fig. 15. Pupa of *Coccinella 5-notata* Kirby.

All drawings magnified five diameters.

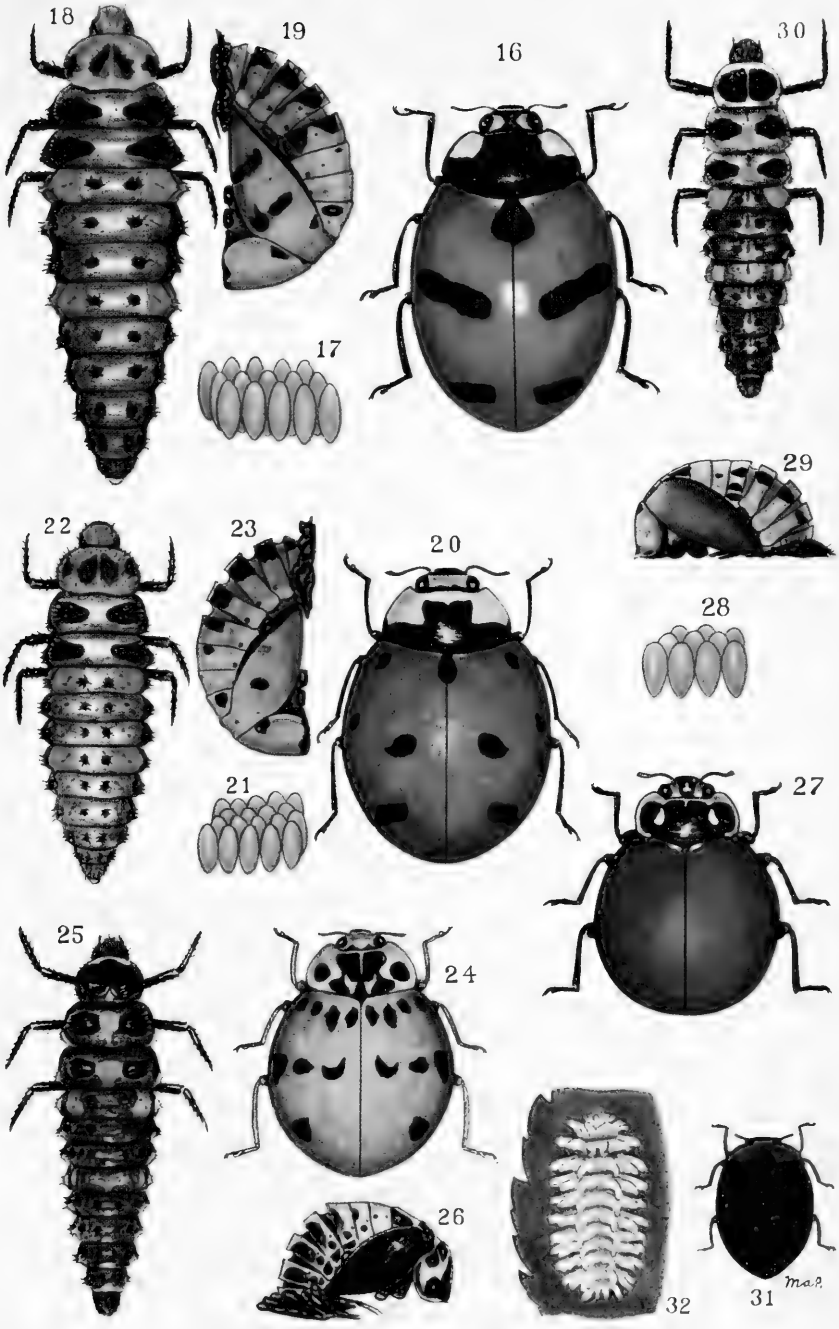
Plate XXXIII

Fig. 16. Adult of *Coccinella monticola* Muls.
Fig. 17. Eggs of *Coccinella monticola* Muls.
Fig. 18. Larva of *Coccinella monticola* Muls.
Fig. 19. Pupa of *Coccinella monticola* Muls.
Fig. 20. Adult of *Coccinella 9-notata* Hbst.
Fig. 21. Eggs of *Coccinella 9-notata* Hbst.
Fig. 22. Larva of *Coccinella 9-notata* Hbst.
Fig. 23. Pupa of *Coccinella 9-notata* Hbst.
Fig. 24. Adult of *Olla abdominalis* Say.
Fig. 25. Larva of *Olla abdominalis* Say.
Fig. 26. Pupa of *Olla abdominalis* Say.
Fig. 27. Adult of *Coccinella (Cycloneda) sanguinea* Linn.
Fig. 28. Eggs of *Coccinella (Cycloneda) sanguinea* Linn.
Fig. 29. Pupa of *Coccinella (Cycloneda) sanguinea* Linn.
Fig. 30. Larva of *Coccinella (Cycloneda) sanguinea* Linn.
Fig. 31. Adult of *Scymnus sp.* magnified 8 diameters.
Fig. 32. Larva of *Scymnus sp.*

All drawings except Fig. 31 are magnified five diameters.



Miriam A. Palmer



Miriam A. Palmer

ON A COLLECTION OF CRANE-FLIES (TIPULIDAE DIPTERA) FROM THE FIJI ISLANDS.

By Charles Paul Alexander, Ithaca, N. Y.*

The following crane-flies were included in material sent to Mr. Harry H. Knight by Dr. James F. Illingworth. The only published reference to the Tipulid fauna of these islands is included in Skuses Diptera of Australia (vol. IV, 2nd series, 1889) and his records are mentioned herewith. I am indebted to Dr. Illingworth and Mr. Knight for this material. The types are in the collection of the author.

Family **Tipulidae.** Subfamily **Limnobinae.** Tribe **Limnobini.**

Dicranomyia saltens Doleschall.

1857 *Limnobia saltens* Doleschall; Nat. Tijd. Ned. Ind., vol. 14, p. 390, pl. 2, fig. 3.

Two, a male and a female, from Nadi on July 27. This seems to be the most easterly station so far made known for this species; it has been recorded from southern India, Java, the Philippine Islands, etc.

Dicranomyia illingworthi, sp. n.

Wings hyaline with sparse brown markings; Sc short ending just beyond the origin of Rs.

Male, length, 4.6 --5 mm.; wing, 5.2 --6.8 mm.

Male: Rostrum and palpi brown. Antennæ dark brown, the flagellar segments globular in shape. Head dark brown.

Thorax rather uniformly dark brown, stripes on the praescutum not well-defined, lobes of the scutum a little darker. Pleuræ uniform brown. Halteres pale, stem moderate in length. Legs, coxæ light brown, trochanters brown. Wings hyaline, veins brown; a small rounded brown stigmal spot; pale seams at Sc_2, base of Rs and on the cross-veins and deflections of veins along the cord and outer end of cell 1st M_2. Venation: (See fig. 1.) Sc short, ending just beyond the origin of Rs. Basal deflection of Cu_1 before the fork of M.

Abdominal tergites slightly darkened, the sternites pale, the abdomen rather transparent. Hypopygium with the pleurites short, cylindrical; dorsal appendage chitinized short, slightly curved and acute at apex; ventral appendage large, pale, almost white, with the outline rounded, the inner lobe produced mesad into a cylindrical, feebly chitinized, point that bears two bristles which are directed caudad. (See fig. 7.)

*Contribution from the Entomological Laboratory of Cornell University.

Holotype, ♂, Nadi, Fiji Is., 7-28, 13. Paratypes, 4 ♂s, with the type.

Libnotes strigivena Walker.

Limnobia strigivena Walker, Journ. Linn. Soc. Lond., V, 229, 1861.

This species is recorded by Skuse (Diptera of Australia, Proc. Linn. Soc. N. S. Wales, IV, series 2nd, 787, 1889).

Tribe **Antochini.**

Teucholabis fijiensis, sp. n.

Head dark; thorax with three brown stripes, pleuræ spotted with brown; wings yellowish with brown spots.

Male, length, 7 mm.; wing, 7.4 mm.

Male: Rostrum brown, palpi dark brown. Antennæ with the basal segments of the flagellum rounded, brown. Eyes large, contiguous on the vertex; head dark greyish black.

Pronotal scutum dull yellow, brown medially above; a brown spot on the lateral end. Mesonotal praescutum light yellow with three stripes of which the median one is longest and broadest, extending from the cephalic margin to the transverse suture. The lateral stripes are short and narrow, behind, crossing the transverse suture and ending on the anterior border of the scutal lobes; the lateral margin of the sclerite is suffused with dark brown. Scutum and scutellum brown except the median portion of the former which is pale. Postnotum dark brown. Pleuræ dull yellow, the episternites of the pro- and mesothoraces brown. Halteres pale. Legs, coxæ, fore and middle, brown, hinder pair paler; trochanters pale yellow; femora yellowish brown with a broad brown subapical ring; tibiæ and tarsi brown. Wings yellowish, stigmal spot large, prominent, a small seam on Sc_2; seams at the base of Rs, along the cord and on the outer end of cell 1st M_2. Venation: (See fig. 2.) cross-vein r at the tip of the long R_1 and so placed slightly beyond the middle of R_{2+3}.

Abdominal tergites dark brown, the caudal margin a little more yellowish; the basal two or three sternites yellowish, the others more brown. Hypopygium with the ninth tergite having the caudal margin rounded and very feebly notched medially. Pleuræ short, clothed with sparse long hairs. Dorsal appendage of the pleurite jointed at the base, pale, clothed with numerous long hairs at the base, at the tip slightly bifid underneath. The ventral appendage is a long elongation of the pleura, not jointed at its base, darker and more chitinized; toward the tip it is constricted, the actual apex expanded and bearing a few small hairs. (See fig. 8).

Holotype, ♂, Nadi, Fiji Is., 7-28,'13.

Tribe **Eriopterini.**

Gonomyia (Leiponeura) fijiensis, sp. n.

Thorax brown, lateral margin of the praescutum yellow; wings with the costal margin yellow, the membrane light brown and hyaline diversified, stigma lacking.

Male, length, 4.9 mm. Female, length, 4.8-5.1 mm.; wing, 4.3-4.4 mm.

Male: Rostrum and palpi dark brown. Antennæ light sulphur yellow, the flagellar segments a little paler. The head bright sulphur yellow with three pale brown marks, a median one on the frontal tubercle and others on the sides of the vertex.

Pronotum light yellow. Mesonotal praescutum dark clove-brown the lateral margin between the pseudosuture and the transverse suture yellow, scutum, scutellum and postnotum dark brown. Pleuræ light yellow, a broad brown lateral stripe, deepest ventrally fading into the yellow of the dorsal pleurites above, extending from the ventral surface of the cervical sclerites through the halteres to the posterior portion of the mesonotal postnotum; the area between this stripe and the praescutum is light yellow suffused with brown near this stripe; sternites dark brown. Halteres light sulphur-yellow. Legs, fore coxæ light sulphur-yellow except the extreme tip which is dark brown; trochanters light brown; remaining coxæ dark brown on the basal half, paler brown apically and on the trochanters; remainder of the legs broken off and confused in the vials with the legs of several other species, but they are probably uniform dark brown. Wings with the costa and the subcosta conspicuously bright sulphur-yellow, remaining veins brown; wing suffused with brown and variegated in places with hyaline, as in cell R_1 which completely lacks a stigma, in cell R, 1st M_2 and elsewhere. Venation as in figure 3.

Abdominal tergites brown, broadly edged with yellow on the caudolateral margins, the brown always continuing to the caudal margin as a narrow median line except in the 8th tergite where the lateral and caudal margin is broadly yellow all around; sternites brown, very narrowly edged with paler on the caudal margin; pleurites broadly and conspicuously yellowish. Hypopygium with the 9th tergite short, broadly concave, yellow. Pleurites rather short, cylindrical, yellow, clothed with long pale hairs, bearing at the tip two appendages; the dorsal appendage is entirely fleshy with two arms, the one directed caudad, the other cephalad, the caudal arm densely clothed with abundant pale hairs, the cephalic arm with a chitinized bristle at the tip and about four smaller bristles on either side, subequal in length and evenly spaced. The ventral appendage is a long simple curved hook, very strongly chitinized. The 9th sternite is very high, convex and bears at its tip two strongly chitinized forked appendages that are directed caudad, the outer fork being cylindrical, acute, the inner fork flattened, twisted and directed entad. The penis-guard viewed from above (fig. 9) is narrow at the base, broadening toward the tip, the lateral edges chitinized and

passing into two sharp chitinized points; viewed from the side (fig. 10) these sharp tips are directed strongly ventrad and viewed from beneath (fig. 12) they are seen to be decussate. Gonapophyses short, directed dorsad at the tip which is blunt and truncated.

Female: Similar to the male but the head of one specimen is entirely dark, the dorsal brown stripe on the pleuræ clearer and narrower not grading insensibly into the yellow of the dorsal pleurites.

Holotype, ♂, Nadi, Fiji Is., 7-28, '13. Allotype, ♀, and paratype, ♀, with the type.

Gonomyia (Gonomyia) varipes, sp. n.

Head yellow with a brown vertical spot; thoracic dorsum brown; legs banded brown and white; wings with the costal margin conspicuously bright yellow.

Female, length, 4.6 mm.; wing, 3.6 mm.

Female: Rostrum and palpi brown. Antennæ with the two basal segments light yellow above, brown on the under surface; the two or three basal flagellar segments are yellowish, the remainder brown. Head light yellow, a narrow transverse brown mark across the front behind the antennæ and a V-shaped brown mark on the vertex with its point directed cephalad.

Pronotum light brown except the scutellum which is very light yellow, a continuation of the dorsal pleural stripe. Mesonotal praescutum very dark clove-brown, uniform; scutum similar except the median portion and the outer caudal angles of the lobes which are paler; scutellum brown, the apical two-thirds pale; mesonotum light brown. Pleuræ and sterna brown except a broad yellow line extending from the wing-root along the dorsal pleurites to the pronotum and a second broad whitish yellow stripe extending from the fore coxæ, above the middle coxæ to underneath the halteres. Halteres uniform light sulphur yellow. Legs,—fore legs, coxæ light yellow at the base, the tip brown; trochanters brown; femora brown; tibiæ, extreme base and apical two-fifths brown, the remainder china-white; metatarsus with the basal half white, remainder of the tarsi brown. One other leg is loose in the vial and belongs to either the middle or hind legs,—here the base of the femur is yellowish passing into brown at the tip; the tibiæ all white except the very narrow base and slightly broader apex which are brown and the metatarsus is white except the tip which is broadly brown; remaining tarsal segments brown. Wings, costa very conspicuously pale sulphur-yellow, remaining veins brown; wing-membrane with a light brown suffusion; cell R_1 paler and containing the oval brown stigma. Venation as shown in figure 4.

Abdominal tergites and sternites dark brown, the pleural region paler.

Holotype, ♀, Nadi, Fiji Is., 7-28, '13.

Erioptera (Erioptera) oceanica, sp. n.

Halteres dark at tip; wings light brown; male hypopygium with the pleura bearing a chitinized knob at tip.

Male, length, 6.3 mm.; wing, 5.4 mm.

Male: Rostrum and palpi brownish yellow. Antennæ rather long, the flagellar segments rather elongate-oval; if bent backward the organ would extend beyond the wing-base; scape brown, the flagellar segments a little paler. Head dark brown and sparsely hairy.

Pronotum brown, clothed with brown hairs. Mesonotal praescutum light brownish yellow without apparent stripes but with a row of hairs on either side of the middle line; scutum, scutellum amd postnotum brownish yellow, the latter with a narrow brown median line. Pleuræ light brownish yellow. Halteres rather long, pale, the knob dark. Legs pale yellow with the two apical tarsal segments brown. Wings with a pale brown tinge, the costal region a little more yellowish; veins brown. Venation as in figure 5.

Abdomen long and slender, pale yellow, the seventh sternite brown. Hypopygium with the pleurites very long and slender, densely clothed with long yellow hairs; at the tip of the pleurite are two appendages, the one a dorsal chitinized appendage, slender at the base, swollen at the tip and slightly roughened apically, and a ventral, flattened fleshy lobe that is rather truncate at the tip. (See fig. 13).

Holotype, ♂, Nadi, Eiji Is., 7-28, '13. Paratype, ♂, with the type.

Mongoma fijiensis, sp. n.

Trentepohlii group; wings subhyaline, indistinctly if at all marked; legs without white bands.

Male, length, 6.8 mm.; wing, 5.5-5.6 mm.

Female, length, 8-8.6 mm.; wing, 6.4-6.6 mm.

Male and female: Rostrum and palpi yellowish. Antennæ with the basal segments pale yellow, the flagellar segments brownish. Head dark brown. Neck elongate, brown dorsally, yellow beneath. Mesonotal praescutum light yellow with three elongate brown stripes, the median one broadest in front, narrowed behind and ending at the transverse suture; the lateral stripes are narrower, beginning just back of the pseudosutural foveæ and continue back to the scutum where they suffuse the lobes. Scutum yellow, except the central portions of the lobes which are brown; scutellum and postnotum dark brown except a narrow margin of yellowish. Pleuræ light yellow, the sterna a little suffused with brown. Halteres rather short, pale yellow. Legs, coxæ and trochanters pale yellow, femora, tibiæ and the first tarsal segment brown, the remainder of the legs broken off. Wings with a pale yellow suffusion; veins light brown; stigma rather pale; indications of slightly darker seams along the cord. Venation: (See figure 6). Fusion of 1st A and Cu_2 slight.

Abdominal tergites dark brown medially, this mark in the shape of a long triangle with its point directed cephalad; sternites pale yellow.

Holotype, ♂, Nadi, Fiji Is., 7-28, '13.
Allotype, ♀, and paratype, ♀, with the type.

Mongoma, sp.

A species belonging to the *fragillima* and *australasiae* group in the Macleay collection mentioned by Skuse (Dipt. Aust., vol. 4, series second; Proc. Linn. Soc. N. S. W., Sept. 25, 1889; p. 832, 833.)

Conosia irrorata, Wiedemann.

Sixteen females taken at a lamp at Nadi, Fiji Islands, July 28, 1913. This series shows a great difference in size in the different individuals. It was previously recorded from these islands by Skuse who noted a specimen in the Macleay collection. (l. c., p. 837, 838). The reason that this entire series consisted of females is undoubtedly due to the nocturnal oviposition in this species. Series of photophilous craneflies always show a preponderance of the female sex and many of these are gravid specimens ready to deposit their eggs, the others having laid the clutch earlier in the evening. When males occur at lamps or in trap-lanterns it is probable that copulation takes place in the twilight or early evening.

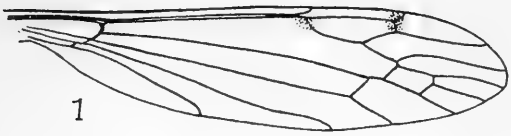
EXPLANATION OF THE PLATES.

Plate XXXIV.

Fig. 1. Wing of *Dicranomia illingworthi,* sp n.
Fig. 2. Wing of *Teucholabis fijiensis,* sp. n.
Fig. 3. Wing of *Gonomyia* (*Leiponeura*) *fijiensis,* sp. n.
Fig. 4. Wing of *Gonomyia* (*Gonomyia*) *varipes,* sp. n.
Fig. 5. Wing of *Erioptera* (*Erioptera*) *oceanica,* sp. n.
Fig. 6. Wing of *Mongoma fijiensis,* sp. n.

Plate XXXV.

Fig. 7. Hypopygium of *Dicranomyia illingworthi;* dorsal aspect of the pleurite.
Fig. 8. Hypopygium of *Teucholabis fijiensis;* dorsal aspect of the pleurite.
Fig. 9. Hypopygium of *Gonomyia* (*Leiponeura*) *fijiensis;* dorsal aspect. d—dorsal appendage; v—ventral appendage; p—penis-guard.
Fig. 10. Hypopygium of *Gonomyia* (*Leiponeura*) *fijiensis;* lateral aspect. p—penis-guard; pl—pleurite; s—9th sternite.
Fig. 11. Hypopygium of *Gonomyia* (*Leiponeura*) *fijiensis;* ventral aspect of the 9th sternite.
Fig. 12. Hypopygium of *Gonomyia* (*Leiponeura*) *fijiensis;* ventral aspect of the penis-guard.
Fig. 13. Hypopygium of *Erioptera* (*Erioptera*) *oceanica;* pleurite, lateral aspect. d—dorsal appendage; v—ventral appendage.



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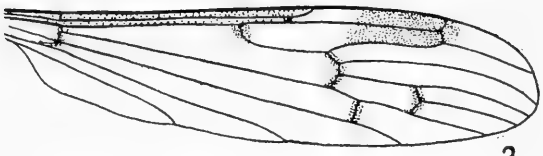

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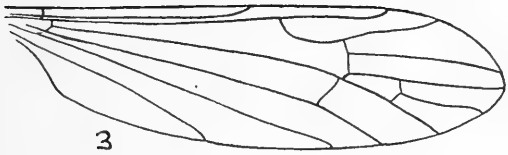

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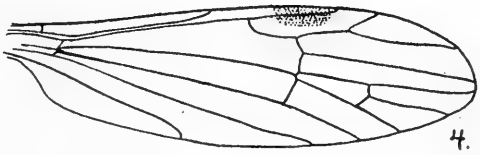

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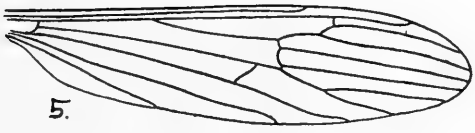

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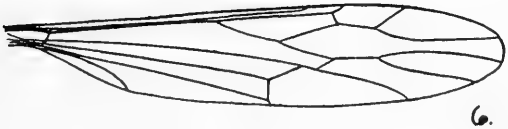

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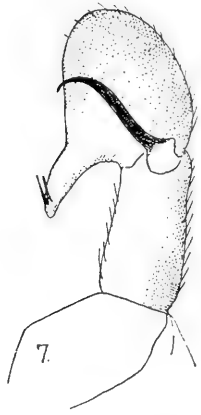
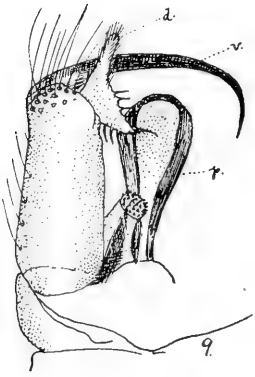
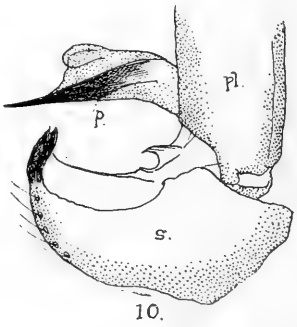
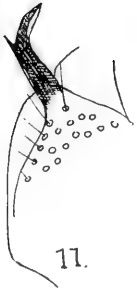
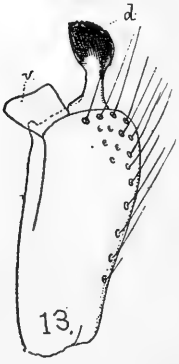
C. P. Alexander.











C. P. Alexander.

A NEW SPECIES OF CHEILONEURUS WITH A KEY TO THE DESCRIBED SPECIES FROM THE UNITED STATES.

By A. B. Gahan,
(Assistant, Cereal and Forage Insect Investigations, Bureau of Entomology.)

The new species of Cheiloneurus below described makes the ninth species to be recorded from the United States. In order to more easily distinguish this new form from those already described a key to the species is included.

Superfamily Chalcidoidea.
Family Encyrtidæ.
Subfamily Encyrtinæ.

Key to the Described Species of Cheiloneurus from the United States.

1. Females....2
   Males....9
2. Wings hyaline; last two funicle joints pale....*diaspidinarum* How.
   Forewing fuscus....3
3. First funicle joint longer than the pedicel....8
   First funicle joint equal to or shorter than the pedicel....4
4. Body wholly pale testaceous, except the middle coxæ more or less of the mesosternum, the pedicel, first funicle joint, fifth and sixth funicle joints and the club which are brownish....*swezeyi* Ashm.
   Thorax not wholly testaceous, with a part at least of the mesonotum metallic or black....5
5. Antennal club nearly as long as the funicle and much enlarged; pedicel as long as the two succeeding funicle joints....*dactylopii* How.
   Antennal club much shorter than the funicle and not much enlarged; pedicel not as long as the two following funicle joints....6
6. Funicle joints all white; scrobes shallow and triangular....*albicornis* How.
   Funicle joints not white; scrobes deeply impressed and semi-circular....7
7. Scape flattened and somewhat expanded beneath, brown with a whitish stripe from base to apex; pedicel and first funicle joint nearly equal; antennæ compressed; ocelli less than their own width from the eye margin....*lineascapus* Gahan.
   Scape slender, pale; pedicel distinctly longer than the first funicle joint; antennæ only slightly compressed; ocelli about their own width from the eye margin....*cushmani* Crawford
8. Whole funicle as well as the club strongly compressed, all funicle joints except the first distinctly wider than long....*amplicornis* n. sp.
   First and second funicle joints subcylindrical, following joints and club not as strongly compressed; all funicle joints except the last distinctly longer than wide....*cupreicollis* Ashm.
9. Scutellum rust red....*dubius* How.
   Scutellum black....10
10. Marginal vein very short, scarcely longer than thick....*dactylopii* How.
    Marginal vein much longer, three or four times as long as thick....11
11. Forewing with a distinct clouded area below the marginal vein; scape not appreciably expanded beneath....*cushmani* Crawford
    Forewing without a cloud; scape distinctly though not greatly expanded beneath....*lineascapus* Gahan.

Cheiloneurus amplicornis new species.

Female—Length 1.5 mm. Head finely closely punctate, from in front much lengthened, the transfacial line about half the length of the facial line, malar space long, scrobes short and very shallow, frons narrow; ocelli in an acute angled triangle, the lateral ocelli scarcely separated from the eye-margins; scape slender, pedicel distinctly shorter than the first funicle joint; all funicle joints strongly compressed, the first a little longer than its apical width, following joints much wider than long; club compressed, not quite so long as the funicle and about equal to the two preceding funicle joints in length; mesoscutum faintly punctuate and closely covered with short pale pubescence; scutellum and axillæ minutely sculptured and opaque, the latter with a tuft of stiff bristles before the apex; propodeum polished; abdomen apparently smooth above. Head reddish testaceous, eyes and antennal flagellum black; scape testaceous; mesocutum black, more or less metallic; scutellum and axillæ pale orange-yellow; tegulæ, pleuræ and most of the abdomen reddish testaceous, propodeum and base of the abdomen above polished metallic green; anterior wings fuscous, a narrow apical border and the basal one-third hyaline; middle and anterior legs concolorous with the pleuræ, posterior legs dark brown, fore tarsi and the apical joint of the median pair brownish as are the posterior tarsi.

Type locality—Dalhart, Texas.

Type—Cat. No. 18801, U. S. National Museum.

Five specimens from the type locality reared by C. N. Ainslie from a coccid, *Eriococcus* sp., infesting *Bouteloua* and recorded in the Bureau of Entomology under Webster No. 5571.

NOTE ON THE NUMBER OF SPIRACLES IN MATURE CHALCID LARVÆ.

By Daniel G. Tower, M. Sc.,
Lafayette, Ind.

During a recent trip to Washington, D. C., while discussing the life history of *Prospaltella perniciosi* Tower a chalcid parasitic on the San Jose Scale, *Aspidiotus perniciosus* Comst., with Mr. J. C. Crawford of the National Museum, he called my attention to a translation of a Russian work published in 1912 entitled, Parasitic and Hyperparasitic Insects, by Iv Chewyreuv, and in particular to a statement made by the author on page 16, which is quoted in full: "In the same paper the author named gave* (25, 35) a much enlarged drawing of *Dibrachys boucheanus* Rtzb. This figure shows not a single spiracle, as if the larva has not got them. While as a matter of fact it does have them, and under the magnification it was drawn, they must be quite evident; nothing is said about spiracles in the description either. The fact is that the arrangement of spiracles in mature chalcid larvæ is very peculiar and as will be shown later, makes it possible to recognize them at once and to distinguish them from the larvæ of allied families. They have nine pairs of spiracles, two of which are on the meso- and metathorax and the rest on the first seven abdominal segments; hence, there are no spiracles on the prothorax and last two abdominal segments. This is the peculiarity Howard did not bring out in his drawing which is therefore incorrect."

The statement made in the above quotation that all mature chalcid larvæ have nine pairs of spiracles does not hold true in the case of *Prospaltella perniciosi*, for the adult larva of this chalcid has only eight pairs of spiracles, two pairs of which are thoracic and six pairs abdominal.

In tracing the tracheal system of this scale parasite through its two larval forms, one finds the tracheal system to consist in the first larval stage of two longitudinal main trunks lying near the surface, one on either side, each bearing ten short, stub-like

*(25, 35) refers in the author's bibliography to Dr. L. O. Howard's paper, "A Study on Insect Parasitism"—U. S. Dept. Agri., Div. Ent. Techn. Ser. No. 5, p. 35, 1897.

branches. During the growth of this form the two longitudinal main trunks join anteriorly and posteriorly, forming an oval. Spiracles are not developed during this stage.

In the second larval stage the tracheal system is at first similar to that of the mature first stage larva, except that it lies deep within the body of the larva. As this larval form grows the first, second and fourth to ninth inclusive short branches of each longitudinal main trunk grow rapidly and terminally at the surface of the body develop spiracles during the last stages of this instar. The third and tenth branches remain short and do not develop spiracles.

The above shows the manner in which the eight pairs of spiracles originate, thus proving that the statement made by Iv Chewyreuv does not hold true.

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The regular annual subscription price for the ANNALS is in the United States, Cuba, Porto Rico, Hawaii and Mexico, $3.00; Canada, $3.50; other countries, $4.00. Checks, drafts or money orders should be drawn payable to ANNALS ENTOMOLOGICAL SOCIETY OF AMERICA, and addressed to Biological Building, State Univ., Columbus, Ohio, U. S. A.

Volume VII. Number 4.

ANNALS

OF

The Entomological Society of America

DECEMBER, 1914

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PUBLISHED QUARTERLY BY THE SOCIETY
COLUMBUS, OHIO

Entered as second class matter April 11, 1908, at the Post Office at Columbus, Ohio, under the Act of Congress of March 3, 1879.

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Volume VII DECEMBER, 1914 Number 4

THE BIOLOGY OF THE NET-SPINNING TRICHOPTERA OF CASCADILLA CREEK.*

Miss Alice Ayr Noyes.

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I. Introduction.

The net-spinning Trichoptera are confined to the members of the old Family Hydropsychidæ, which has been subdivided (Ulmer 1909) into four families, Hydropsychidæ, Philopotamidæ, Polycentropidæ, and Psychomyidæ. Nets of some of the genera of the first three families have been described, but as far as is known, larvae of the Psychomyidæ spin no catching-nets. (Wesenberg-Lund, 1911). The only nets described in this country up to this time have been of the genus Hydropsyche. Most of the work on the catching-nets has been done within the last six years and almost entirely by Danish investigators.

Contribution from the Limnological Laboratory of Cornell University.

This paper is a preliminary study of the net-spinning Trichoptera of Cascadilla Creek with special reference to the nets—the method of construction, their efficiency as a plancton-catching apparatus, and the closely related problems of food and feeding habits.

Since the net-spinning caddis-worms are found in still as well as swift flowing water, and their nets are such interesting and beautiful structures, it seems strange that they should have been overlooked for so long a time. I have found nets representing some of the genera of the families Hydropsychidæ, Philopotamidæ, and Polycentropidæ, and will treat them by families in that order. In each family I have first given extracts or a brief summary of the work published on the nets up to this time and have then added my own observations.

This work was carried on under the supervision of Prof. James G. Needham, to whom I am especially grateful for his valuable suggestions and encouragement at all times.

II. Catching-nets of the Families Hydropsychidae, Philopotamidae, Polycentropidae.

Family Hydropsychidæ.

The first description of a catching-net is found in Dr. F. Muller's work (1881). He describes and figures the net of one of the Hydropsychidæ, a southern Brazilian sp. of the Genus Rhyacophylax. He always found the houses on the upper side of stones, made of irregularly interwoven plant fibres or of small stones. Each house has a funnel-shaped vestibule or verandah, whose sidewalls are generally constructed out of interwoven fibres. These serve as a covering for a very delicate silken net with square meshes, generally from 0.2 to 0.3 mm. in diameter. The entrance to the vestibule is always directed up stream, so that the water coursing through it catches and holds back organisms which serve as food for the caddis-worm. The larvae rarely live alone, but generally construct their houses very close to one another so that sometimes continuous rows of them are formed.

In the year following, the first work on the nets of the Genus Hydropsyche appeared in this country in an article by Miss Cora Clarke. In a later paper, 1891, she mentions these larvae and their nets again, but gives no additional data.

To quote from the first article: "The typical form of the structure resembles a tunnel attached to the surface of a stone, having at its mouth a vertical framework with a net stretched across it. An open mouth or entrance to the case is always close to this net on the side towards the current, so that without wholly leaving its house the larva can remove from the net anything eatable, which the current may have lodged there. The mode of building varies considerably. The case is usually about half an inch long and a little curved, loosely attached to the stone by its edges and without any bottom. It may be composed entirely of sand or of bits of plants or both combined. The supporting framework of the net is always formed of vegetable bits, and is sometimes a simple arch, sometimes a complete ring, and sometimes a short cylinder. It is occasionally stayed or held in position by silken cords stretching from it to suitable points on the stone. It is stiff enough to stand erect even when removed from the water. When it is in the shape of a cylinder or broad arch the net is always stretched across that end of it which is down stream and the entrance usually opens under the shelter of the arch. * * * * In a stream in Brookline, Mass., are large communities of these larvae. The stones in the stream are covered with mud, leaves and rubbish.

Sometimes a stick which has fallen into the brook has a row of cases and nets built upon it. Often a stone will have a row of them side by side along one edge, or there may be only a few of these structures scattered separately upon its surface." She mentions having received a net and larva from Mt. Desert, Me.

In 1886 L. O. Howard found similar nets of a Hydropsyche larva on the Simulium-covered rocks in the swift water of Rock Creek, near Washington. "The cases varied greatly in size, the mouth of the funnel in some instances not more than 3 mm. in diameter and in others reached fully 10 mm. The tube of the funnel was in every case bent at nearly right angles with the mouth and the larva ensconced within it waited for its prey to be caught in the broadened mouth.

The broad funnel-shaped expansion was woven in fine meshes with exceedingly strong silk and was supported at the sides and top by bits of twigs and small portions of stems of water plants. The central portion was so open as to allow the water to pass through readily."

In 1888 the same author mentions finding the larvae in a similar situation in Ithaca, the nets and cases being very abundant on the Simulium-covered rocks. "The nets differed from those found at Washington and the species is probably different."

In his Insect Book (1901) we find the following: "The cases were preferably placed at the edge of slight depressions in the rocky surface so that the tubular portion was protected from the full force of the current. On the surface of a rock about 18 inches in diameter 166 of these nets were counted."

Adele M. Fielde (1887) writes from Swatow, China, of a net similar to those previously described. "During last January I found on the level surface of the coarse sand which covers the bottom of an aqueduct near here, under an inch or two of clear running water, little structures resembling a gray net spread to catch fish or a tiny cave with a gauze awning stretched over the entrance. The arches had a span of from an eighth to half an inch and always opened towards the current. They were to be seen in scores with a buttress of coarse sand in the rear, and a minute aperture in the floor. The occupant of the wee grotto was in every case a caterpillar not more than five-eighths of an inch long. It burrowed in the sand of the floor, stretched its head forth vertically, and fed upon what had been caught in the delicate roof of its den."

Comstock, J. H., (1895) in speaking of Hydropsyche larvae says: "Stretched between two stones near by can be seen his net. This is made of silk. It is usually funnel-shaped, opening up stream; and in the center of it there is a portion composed of threads of silk extending in two directions at right angles to each other, so as to form meshes of surprising regularity. These nets occur in rapids between stones, but in many places they are to be found in greater numbers along the brinks of falls. Here they are built upon the surface of the rock, in the form of semi-elliptical cups, which are kept distended by the current. Much of the coating of dirt with which these rocks are clothed in summer is due to its being caught in these nets."

Betten, C. (1901), says of a Hydropsyche sp. (near phalerata, Hagen), that there was "no larval case, only strands of silk between the rocks."

Comstock, Anna B., (1903), in describing the snare of Hydropsyche writes, "It is formed like a dip-net and fastened with silk to a frame of leaves or pebbles, so that its distended mouth is directed up stream. Near the frame it consists of fragments of vegetation woven into a silken tapestry and is finished at the end with a bag of coarse, even mesh. The regularity of this bit of netting is beautiful to behold, and its use shows the cleverness of the builder. This large mesh allows the water to flow through freely, and thereby leave entangled in the seine any little creature not small enough to pass through. * * * On the side of this tiny seine toward the current of the stream is a little passage which leads to the seine-builder's house."

The work on the net-spinning Trichoptera was next taken up in Europe and it is to the Danish investigators that we owe our most extended knowledge of the various kinds of nets, and whose work stimulates a desire to carry their efforts farther. E. Petersen, in 1908, found the catching nets of Hydropsyche instabilis in a brook north of Silkeborg (Denmark). The larger stones were completely covered with Potamogeton pectinatus, Fontinalis antipyretica and Jungermannia sp., and on them the trumpet-shaped catching nets were placed in rows and connected with one another. The nets were small, being only 8-10 mm. in diameter at the mouth, and their depth about 7 mm. The nets were always supported by the plants and parts of these were often woven in. In many cases one net was placed a little behind the others and connected with them by a strong web. At the base of the net lurked the larva.

In 1909 Ussing described a catching-net of H. instabilis that he had found in Hornbek brook in the vicinity of Randers. Being unable to obtain this paper, I have translated an extract from it, which was quoted in Wesenburg-Lund's (1911) article. "The nets are placed obliquely in front of the opening of the larva's tunnel, built of very fine, square meshes (0.2 mm. in diameter), propped up by bits of plants. The dwelling of the larva is built out of mud and half decayed fragments of plants; the tube is spun fast to a stone on the bottom of the brook. I have often found whole rows of these dwellings with nets placed between the separate occupants. The nets turn their expanse against the stream, which is always very

swift and in spite of their delicate construction, they stand the considerable pressure of the water very well. I have never noticed that the dwellings or nets protruded above water."

One of the most interesting of the descriptions of Hydropsyche catching-nets comes from Dr. Wesenberg-Lund. In his paper (1911) he has compiled the records of all known cases of net-spinning and extended our knowledge greatly by personal observations. He studied the nets of H. pellucidula and H. angustipennis, and gives a very full description of the beautiful structures of the latter which he studied in July, 1909, in the outlet of Foenstrup pond in Gripwalde. The larvae had utilized the leaves of Lemna triscula in the construction of their dwellings, and chains of these, arranged in rows, were placed obliquely across the stream. Every chain was composed of the dwellings of a number of larvae. Each house had a funnel-like entrance facing up stream which led into a vestibule about 1-2 cm. long and of the same height, covered with Lemna leaves. In the farther corner was the entrance to the larval dwelling which was 2-3 cm. long. This is always laid obliquely to the principal course of the chain, and was made of small bits of decayed wood and pebbles interwoven in the silken mesh and covered with Lemna leaves. In the wall of the vestibule towards the entrance to the dwelling was a circular window about 1 cm. in diameter covered by a beautiful screen. This served as the larva's catching-net and was woven of strong threads crossing nearly at right angles and of wonderful regularity in the centre, but irregular and of a coarser mesh toward the framework, which was made of small pieces of straw finely fastened together. The cases were submerged in the water, but the upper part of the vestibule and window projected over the surface of the water. I have copied a diagramatic figure of a Hydropsyche house from his paper. (See Plate XXXVII, Fig. 1).

In regard to the seasons when the nets are found he gives the following data: "Up to December, beautiful larval dwellings and nets are found; from December to the last of April no nets observed. During this period the larvae were found rolled up under stones or in crevices in boards, probably taking only a little food. At the beginning of May and during the whole of June the nets were put up again."

His observations agree completely with those sent him by Ussing, who made regular observations on the nets of H. instabilis during the winter of 1909-10 at "Hornbek brook." "On the 24th of October, 1909, the nets were very numerous; on November 7, beautiful catching nets; on January 2, and January 19, 1910, none. The animals build no catching-nets in winter. The larvae lie rolled up in a spiral and are not active, moving reluctantly. They do not live in the usual case, but in an irregular net with small pebbles interwoven. He believes that the Hydropsyche larvae lie in a dormant condition and take no food in winter.

My observations were started the latter part of October, 1912, and at this time, although the nets were numerous everywhere in the creek, they were inconspicuous, owing to a thick coating of diatom ooze and silt, and they were badly torn by the large numbers of fallen leaves swept along by the current. Only rarely during November did I find a perfect net, and during the winter months no nets at all. Heavy rains the last week in March made any observations impossible, as the turbid water rushed along in torrents. On my next visit, however, on April 12, it was as if the stones had been touched by some magic wand, for nets had sprung up everywhere. They were found on the upper surface of stones or shelving rocks wherever there were irregularities or crevices against which the cases might be built; on submerged twigs, on the underside of stones, and between stones on the bottom. The nets were also thick along the edges of the stream, many distended pockets being found in the tangle of roots which floated out into the current. In July similar nets were observed in the mats of Cladophora, but these were generally the tiny pockets of very young larvae. I could find no definite dwelling tube in either of these instances, but the larvae were found crawling among the roots or algal filaments.

On the brinks of the waterfalls were rows of vertically placed nets, so that a continuous stream of water was pouring down their open mouths. On the creek bottom the nets were generally fastened between two stones, some being of the "dip-net" type, while others formed a horizontal net. In both instances, however, the net was composed of coarse, irregular mesh at its entrance and a fine regular mesh behind.

Although there are six species of Hydropsyche larvæ common in Cascadilla Creek, I have not been able to find any specific differences in their nets, so will describe them collectively. The case in which the larva lives, I found as described by others, except Miss Clarke, to be made of vegetable bits, pebbles, or a combination of both woven into an irregular cylindrical tube. In front of this, opening toward the current is a net. Mrs. Comstock's word "dip-net" best describes its shape. Beginning at the entrance and generally extending for a little more than one half the depth of the net is a very irregular, coarse silken mesh, the bottom of the net being composed of a wonderfully beautiful, regular mesh. This latter is the catching surface proper from which the larva feeds. The tube in which it lives extends a very short distance into the net, so that its entrance opens under the fine mesh. The tube opens into the net either from the right or left side, and is found either extending back in a straight line with the net or almost at right angles to it. When the stones are taken from the water, some of the nets stand upright owing to the supports of plant tissue woven into the coarse mesh. Sometimes there is a complete supporting arch, but often there is only an oblique prop on either side, anchored to the stone by silken guy lines. The threads of the catching surface are somewhat distensible, and when seen in the water it is concave, but when removed, it appears as a flat, almost circular disc in its supporting framework. In many cases, however, the nets collapse completely when there is no current to distend them, there being no supporting bits of any description. See Plate XXXVII, fig. 2. In summer many of the nets have long green streamers of Cladophora filaments, which have become entangled in the nets and float back several inches behind them.

The average expanse of the nets at the entrance is about 8 mm. although some of the largest ones have an expanse of 20 mm., with a depth of 15 mm., while those of the very young larvæ have an expanse of 1½ to 2 mm. and a depth of 1 mm. These nets and dwellings I have always found completely submerged, and the true catching surface placed at the end of the vestibule, instead of in its sidewall as in that of H. angustipennis described by Wesenberg-Lund (1911). The threads are very firm so that they may withstand the force of the current and there is no difficulty in seeing the meshwork with the naked eye.

Family Philopotamidæ.

The only descriptions of catching nets of this family are those of Thienemann. He gave a brief account of a net of Philopotamus ludificatus in 1906; as I was unable to obtain this paper, however, I will summarize a fuller description which appeared in 1908.

Two similar species P. ludificatus McL., and P. montanus Don., are found in great numbers in the swift mountain brooks of Middle Europe. These build dwellings which are very much alike. The house is a broad sac-like structure of loose mesh about as long as one's finger. At the front end where the opening is found, it is fastened to a stone on the bottom of the brook. The blind end of the sac floats freely; and in the bottom of it is found the larva which can feed on organic particles caught in the net. Occasionally the larvæ also stretch their houses between two neighboring stones and so construct for themselves, in this way, a kind of catching-net. Only one larva is found in each net.

No descriptions have appeared before of nets of the Genus Chimarrha. The nets of Chimarrha aterrima, which I found, are long, narrow pockets built entirely of a very fine mesh of delicate silken threads. (See Plate XXXVIII, Fig. 1). The average size of the net of the growing larva is about 25 mm. long and 3 mm. wide. The nets are rarely found singly, but generally placed five or six in a row. Sometimes the front edges of these are joined together, but in most cases each net is entirely separate from that of its neighbors. There is a large opening at the end facing the current, and a tiny opening at the hinder end just large enough for the larva to slip through and make its escape when alarmed. This opening is very hard to see, not only because of its size, but owing to the fact that the nets are generally brown with a coating of diatoms, etc., over much of their surface. The nets are fastened at the entrance by their entire lower edge, the rest of the sac floating freely, and kept distended by the current. They are found fastened to the underside of stones or to their upper surface when they are covered by other stones. I have also exposed them on the upper surface of the shelving rocks by pushing aside the covering mats of Cladophora. The orange or yellowish larva, of which there is only one to a sac, is usually seen

toward the hinder part of the net. It does crawl around, however, feeding over the whole surface of the net. It does not use its front legs to assist it in getting its food which is entirely of microscopic plants. All observations must be carried on in swift water, for the net collapses into a brown slimy mass when the pressure of the current is removed. The separate threads of the net are only clearly seen with the highest power of the microscope when it is seen that the units of the mesh are rectangular in shape, one dimension being about eight times the other. The double nature of the silken threads is not recognizable, as is that of the Hydropsyche's, when examined with a microscope.

At times grains of sand and small pebbles are found on and about the large nets. I believe this to be a preparation for pupation, as the pupal cases are constructed of these.

Family Polycentropidæ.

The nets of five genera in this family have been observed and described.

Neureclipsis.

In the year 1900 Wesenberg-Lund first noticed the plancton-catching-nets of Neureclipsis bimaculata in Western Jutland. Later he also found them at three different places in Zealand. They were not described, however, until 1907 when E. Petersen wrote an account of them. His observations were extended by Wesenberg-Lund (1911). The nets of this larva are trumpet-shaped, from 69 to 90 mm. long; the expanded mouth is 25 to 35 mm. broad, and the hinder end about 10 mm. In some cases the hinder end of the tube is attached to some object, in other cases it floats freely. The nets show a regular variation in color due to the plancton caught in their meshes; in the spring they are brown or grayish from diatoms, in the summer bluish-green from the Cyanophyceæ. The net is kept distended by the force of the current and collapses into an unrecognizable mass when taken from the water. The plancton-organisms Bosmina, Daphnia and the remains of Cyanophyceæ become caught in its walls as the water filters through and serve as food for the larva which is generally at the hinder end of the net. Many thousands of these nets span the stream in Hennebach so that a greater part of the water filters through them.

These writers believe that the imago probably lays her eggs in loose, web-like masses which are doubtless a conglomeration of old nets and that the young larvæ live together in them for a long time.

Plectrocnemia.

Miall (1895) gives a description of a Plectrocnemia net written by Mr. T. H. Taylor. "Plectrocnemia finds its home in streams where the water flows swiftly over a stony bed. If a stone be lifted out, the under side is often found to be covered with patches of mud from which brown larvæ emerge and begin to crawl over the surface. The muddy particles are evidently held together by some binding substance, and the whole forms the retreat of the Caddis-worms, corresponding to the cases of Phryganea. When a larva is placed in a vessel of clear water, it at once begins to explore its new quarters, and eventually selects a site for its dwelling. This is made of silken threads secreted by the large silk glands, and when completed the structure consists of a tube considerably longer and broader than its occupant and open at both ends. It is supported and strengthened by a meshwork of silken threads, which spread out for a considerable distance, and are attached to the surrounding objects.

From time to time the larva turns round in its case and even leaves it for a short space. Generally, however, it remains quiet inside, apparently on the alert for prey. If a Chironomus or other small aquatic larva approaches, it is almost certain to get entangled in the network of silken threads. At once the Caddis-worm in its retreat perceives the presence of a possible victim. The long hairs which cover the body are possibly tactile, and receive slight disturbances of the silken network. The Plectrocnemia then proceeds warily to determine the cause of the disturbance. Should the Chironomus be entangled near the middle of the tube, the Caddis-worm does not hesitate to bite its way through the side, and its jaws very soon quiet the struggles of the prey.

There is some resemblance between the snare of the Plectrocnemia and the web of a spider, but the Plectrocnemia is effectually concealed by the mud which clings to its retreat."

The net of Plectrocnemia conspersa Curt. is described by Wesenberg-Lund (1911). The larvæ—at least from April until

June—build large, flat catching-nets about a square decimeter in size. In the centre is an opening, (about 8 to 10 mm.,) which leads into a funnel about 5 to 6 cm. long—the hiding place of the larva. This is hidden under a stone or leaf. The mesh is very coarse on the outer edges of the net. The water being very shallow in the brook, the nets lie nearly horizontally on the stones. The organisms caught in the nets by the larvæ are principally gnat-larvæ, Asellidæ, etc., which are swept along by the stream into the net.

Polycentropus.

The net of Polycentropus flavomaculatus Pict. was first described and figured by Petersen (1907). The nets resemble swallows' nests and are about 30 mm. long, 20 mm. wide at the entrance, and about 15 mm. high. They are found singly on the bottom of slowly flowing brooks attached by their fore corners to small stones. The mouths face the current and are held expanded by the water. The larvæ are always found in the bottom of the net. When found on vertical banks, the mouths stand perpendicularly. The nets are also found on the wave beaten shores of the larger lakes. The nets are bluish-green in color.

Holocentropus.

The larvæ of the genera Holocentropus and Cyrnus live in quiet water, principally among algæ and water plants of the smaller lakes and pools. The nets, which are hard to observe, have been completely overlooked before Wesenberg-Lund's paper (1911). He first saw the net in June 1909.

He figures three forms of nets which he found made by Holocentropus dubius. One type of net is in the form of a shallow funnel attached by silken threads to Sium leaves. In the centre is an opening which lands into a thick web-like tube which extends to the main stem of the plant. In this passage the larvæ live and may escape through an opening at the hinder end. The second type is found where there are thick mats of filamentous algæ, as Spirogyra. In this loose mass may be seen perpendicular tunnels 8 to 10 cm. long, covered with spinning; these are open below and also open at the surface in the middle of a shallow funnel-like net of very fine mesh. The larvæ sit at the bottom of the funnel-like recess

watching for prey. There is often at least one side passage branching off from the main tunnel. Another type is a funnel-like net spun between the angles of the main stalk of the grasses and the side shoots, and fastened at the upper end to leaves as Potamogetons.

On account of lack of light the study of the nets of Holocentropus picicornis Steph. was unsatisfactory. The deep brown color of the nets was due to a thick deposit of iron bacteria.

The larva of Cyrnus flavidus McLach. lives in lakes in the Chara-and Elodea-zone at a depth of about 4 m. In summer the larva spins funnel-shaped nets to the leaves of Potamogeton lucens when it reaches the surface. In the autumn long threads emerging from the plants are seen floating about in every direction. Plancton organisms become entangled in the threads and the larva runs along these and siezes its prey. In October and November the larvæ sink down with the Potamogeton on to the Elodea and Chara zone again.

In a little arm of Cascadilla Creek (See Plate XXXVI, Fig. 1) where the water is rather quiet and from 1½ to 2 feet deep, larvæ of two genera are found belonging to this family.

The larva of Cyrnus pallidus (?) is small—8 mm. long by 1.2 mm. broad—very rapid in its movements. The body is whitish, dorso-ventrally flattened; the head yellowish with a large brown spot covering almost the whole dorsal surface. In the centre of this spot is a yellow cross-shaped figure and eleven yellow dots around the margin. The yellowish pronotum is brown posteriorly with yellow dots. On removing a stone from the water the dwellings of this larva might easily be overlooked, for they resemble patches of sediment clogging the crevices. If placed in a pan of water, however, and examined under the microscope, they prove most facinating objects for study. Stretched across crevices in the stones, preferably along its edges, but also occasionally on the upper and lower surfaces is the roof of the larval dwelling. The tube of a full grown larva, is about 9 mm. long by 3 mm. broad and is dorsoventrally flattened. (See Plate XXXVIII, Fig. 2). It is spun of fine silken threads so closely woven that it has a felty texture. It is always brown with a coating of diatoms. At either end a little flap hangs from the roof which acts as a

stopper, closing against the opening when the stone is removed from the water. Radiating in all directions from the floor of its retreat, at either end, may be seen threads of silk about 7 mm. long. These are fastened to the stone at their outer ends and a microscope reveals the fact that they are connected with one another by a loose irregular mesh which floats up from the surface of the stones and entangles many small organisms. The larva lurks in its little cave, and welcomes visitors gladly at its front or back door. Any movement on the silken strands in front of its doors causes it to dart out the front part of its body with lightning-like rapidity, sieze the intruder and draw back again, all in the twinkling of an eye. Large numbers of Vorticella and other Ciliates, rotifers, Chaetonotus, Chironomids and diatoms were found entangled in the meshwork.

The larva of the Polycentropus sp. (?) is large and more deliberate in its movements. It is 19 mm. long and 2 mm. broad; the head and prothorax yellowish-brown with many small, brown dots, and the abdomen of a pinkish-lavender color, iridescent when the sunlight strikes it. It sometimes looks bluish. The larva lives on the under side of stones in a delicate silken dwelling which falls together into an unrecognizable, brown slimy mass when removed from the water. It was not until I had examined a large number of these nets that I was able to detect a trace of any definite form. The larva lives in a very delicate, silken tube fastened to the stones along its whole undersurface. It is shaped like a flattened cylinder and slightly curved. (See Plate XXXVIII, Fig. 3). The tube is 21 mm. long and 5½ mm. wide with an expanded opening at either end. Connected with each opening and along either side is a mass of tangled, silken threads, about 20 mm. square and loosely attached to the stone. This tangled mass may float partially over the tube and so obscure it.

I have never observed the larva feeding but do not doubt that Mayfly nymphs and Chironomid larvæ become entangled in the meshes as they crawl about over the stones, for remains of these forms are abundant in the stomach contents.

III. The Aquatic Situation.

All of my collecting and observations on the net-spinning Trichoptera were confined to a very limited area in Cascadilla Creek, not exceeding a half mile in extent. For a preliminary study this presented advantages, one of the most important being an abundance of material within a few minutes walk from the laboratory. This made it possible to observe conditions frequently and to spend more time in the field than would have been possible had the Creek been at a distance. The use of the Fish Hatchery, situated on the bank of the Creek, also offered opportunities for studying things to the best advantage, for all necessary equipment as microscopes, instruments and glassware could be kept there. It also furnished a place where rearing and experimental work might be carried on, undisturbed and under natural conditions.

The depth of the Creek varies from a few inches, where it spreads over the large, flat rocks, to two and a half feet or more in the middle of the stream. The creek-bed averages from ten to fifteen feet in width but broadens out in places to thirty feet or more, where the larvæ abound, the bottom is rocky and of two types—loose stones, both large and small, (See Plate XXXVI, Photo 1), and continuous shelving rocks with gradual descents of a few inches to steep descents of five feet or more. (See Plate XXXVI, Photo 2). In early spring and fall the water rushes along in torrents over the rocks, but by midsummer the swift water is confined to the middle of the creek-bed. Large areas of the broad, shelving rocks remain dry and where there is water it does not exceed an inch in depth.

Most of the typical swift-water forms of insect nymphs and larvæ were found associated with the Hydropsychids. Of the Trichoptera, Rhyacophila, Helicopsyche, Silo, and a Hydroptilid sp.; of the Diptera, Simulium, Chironomid and Blepharocera larvæ were very abundant on the upper surface of the stones; of the Mayflies and Stoneflies, the nymphs of Heptagenia, Chirotonetes and Neoperla were found in numbers on the under side of the stones. The rocks presented various colors—the browns of diatom ooze, large black patches of Simuium larvæ, and in places thick green carpets of Cladophora. The swift water and great abundance of food made it an ideal situation for the larvæ.

IV Food.

In most of the literature one finds the larvæ of the old family Hydropsychidæ spoken of as carnivorous, but Siltala (1907) gives the following general statements. "The larvæ of the true Hydropsychidæ are less exclusively carnivorous than those of the other campodeoid larvæ. Both animal and vegetable food are found, remains of insects, Crustacea, algal filaments, pieces of moss and phanerogam leaves, also pollen grains of Conifers." In an earlier paper (1910) he speaks of their ability to utilize hard vegetable stuff, gnawing grooves nearly 8 cm. deep in the logs of a bridge.

"The data were insufficient in the case of the Family Philopotamidæ to form any judgment. The Polycentropidæ are purely carnivorous, eating insects, Cladocera and Ostracods."

He also points out that a relation exists between the structure of the mandibles and the kind of food. He extends Ulmer's (1902) observation that forms with blunt-toothed mandibles are herbivorous and those provided with sharp teeth are carnivorous, and points out the importance of the presence or absence on the mandibles of a median tuft of hairs. All forms with the median tuft on both mandibles are herbivorous; those lacking it are either exclusively carnivorous or at least eat as much animal as vegetable food; larvæ with the tuft only on the left mandible vary in respect to their food and among them are found carnivorous, herbivorous and omnivorous forms.

My results in regard to the food of the larvæ are based entirely on observations upon freshly killed animals taken from their natural habitat. The alimentary canal was removed immediately after the collecting trip and examined at once, or placed in four per cent formalin for later study.

Collections of Hydropsyche larvæ were made on November 14, 1912, November 21, November 30, January 31, 1913, February 18, March 20, April 12, May 6, June 2 and July 7. As many as five specimens were always examined, and in some cases as many as ten. The food as stated by Siltala was made up of both animal and vegetable matter. There was, however, a seasonal difference; in the fall and winter diatoms formed the bulk of the food, and in the spring and summer animal food predominated; while at all times algal filaments were present in moderate amount.

Of the diatoms, Gomphonema, Cocconema and Navicula were the most abundant forms, though Synedra, Melosira, Encyonema and Fragillaria appeared in smaller numbers.

Ulothrix and Oedogonium and Cladophora of the green algæ were found all of the year, and in the spring and summer Merismopædia and Cilyndrospermum of the blue-greens appeared.

Heptagenia nymphs, and Chironomus larvæ made up the bulk of the animal food, although Simulium larvæ and Ostracods were abundant. Difflugia shells were found a few times.

These results do not agree with the statements of Wesenberg-Lund (1911) and Ussing (1907) that the larvæ are inactive, lying rolled up in a spiral and taking little or no food in the winter. The collection made in February came at a time when the Creek was covered with ice. The larvæ were found on the underside of stones in the stream, either in a case of pebbles loosely held together or a mass of roots spun into a tubular form. When the stones were removed from the water and placed on the bank, the larvæ came out of their tunnels at once and crawled about over the stones. There was also an abundance of food in the stomach in every case.

In examining the contents of the stomach of Chimarrha aterrima (Family Philopotamidæ) one is greatly surprised to find vegetable food exclusively. The mandibles are strongly developed, with sharp teeth, and lack the median tuft completely, which, according to Siltala, would point to an exclusively carnivorous form. Examinations were made on November 14, November 30, June 11 and July 14. On the first three dates, the stomach contents consisted of diatoms exclusively, the same forms as were found in the Hydropsychids. On the last date, however, Euglena was very abundant, as were the simple green alga Scenedesmus and other Protoccocales; also desmid zygospores. In every instance there was very much silt mixed in with the food.

Only one examination of food was made on the two larvæ of the Family Polycentropidæ. This was on July 14, when ten specimens of each species were examined. The food of Polycentropus sp. was made up entirely of insects, Chironomids being the principal diet, and Heptagenia nymphs quite numerous.

Except for one Chironomid head there were no recognizable contents in the alimentary tract of the Cyrnus sp.—only a dark brown fluid exuded. After watching it feed, however, on the soft bodied forms of microscopic organisms, one can account for this fact.

V. Experimental Work on Hydropsyche Nets.

To one who tries to study the method of construction of the nets, feeding habits, etc., in the field, the following difficulties present themselves. The threads of the net quickly become covered with diatoms, silt and algæ which obscure the mesh to some extent; the ripples on the surface of the water make it necessary to work with a water-glass which cuts out some of the light; also the nets are so low down that one can only view them satisfactorily from above.

Although the Hydropsyche larva will construct its dwelling tube in a dish of water in the laboratory, it builds no catching-net. The larvæ, however, made perfect nets in a trough supplied with a steady stream of partially filtered water from Cascadilla Creek. The trough stood on a framework three feet high and was tilted slightly, the end nearest the water-pipe being the higher. The side boards of the trough were grooved (¼ in. by ¼ in.) their entire length, and the stream of water striking the end board was carried down into the grooves as well as into the trough. On each side, at the point where the water from the groove met the overflow from the trough (See Plate XXXVI, Photo 3.) the current was the swiftest. As might be expected these spots were chosen in preference to others as building sites. The only caution taken was to induce the larva to begin its spinning very near the end of the groove so that the net would come within the focus of a lens held in front of the groove. The making of the larval dwelling could best be observed from above, but observations on the construction of the net and the feeding habits could be seen to best advantage when one knelt in front of the groove so that the eye came on a level with it. In all cases a glass slide was placed over the groove to smooth the surface of the water.

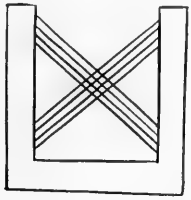
By the above methods, the following results have been obtained.

1. Time of building.—Many Trichoptera larvæ build their dwellings chiefly during the night, but these build their tubes and nets at all times, during the day as well as at night.

2. Time required for building.—On watching the construction of several larval dwellings, I found the average time for the completion of the tube and net to be from two and a half to three hours. The larva spent about an hour in spinning its tube and the remainder of the time on its net.

3. Different species of Hydropsyche larvæ placed in the trough built similar dwellings.

4. There were no temporary construction threads in the net as described for the web of orb-weaving spiders, (Comstock, J. H., 1895, p. 37), all of the threads being permanent.



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2

Text Figs. 1 and 2. 1. Diagram showing usual method of crossing of threads to form the regular mesh of the net. 2. Attachment of threads. (a) at beginning of thread; (b) continuation of same thread at point of departure from supporting surface.

5. There seemed to be no definite order in which the threads of the net were laid down. Sometimes the coarse, irregular mesh was spun immediately after the building of the larval tube, while at other times the fine, regular mesh was spun first. The larva at times left its work on the net and went back to add a few threads to the case. In general the catching surface was formed of threads crossing each other in the fashion shown in figure 1. Threads were fastened in the manner shown in figure 2, the double thread being split for a short distance and each half attached separately.

6. I have never observed the larvæ cleaning their nets with the dorsal tuft of hairs on the anal prolegs, a function which Lund (1911) stated as a probable one. They have always removed particles from the net with their mouth-parts.

I believe that the thick cluster of bristles on the outer edges of the labrum are used in removing the microscopic plants from the meshes.

7. The larva used its front legs in combination with the mandibles for seizing, and holding in position until fastened with silk, any bits which it might wish to weave into its tube or use as supports for the net.

8. The position indicated in Plate XXXVII, Fig. 5 is the one usually assumed by the larva in spinning its net and in feeding. Since no pebbles or vegetable bits were placed in the groove, the larva spun its tube entirely of silk, and so its position could be clearly seen. The larva rested ventral side up with the hooks of the anal prolegs fastened in the roof of the tube. Usually only the head and thorax protruded from the entrance, but if the larva needed to reach out farther than the stretching of the abdomen would permit, the body was moved forward in the tube. The front legs were directed forward, and were used chiefly for clinging on to the net during its construction. The tarsal claws were passed rapidly along a thread near to the one which was being spun. The second and third pairs of legs were also used for holding on, being stretched out on either side and shifting only as the movements of the larva demanded it.

9. Feeding Habits.—The larva never was so intent upon finishing its net but that it stopped and picked off particles of food adhering to the threads, ate them and then continued its labors. As soon as it finished its net, and while the mesh was practically clean, I put insect food (Simulium larvæ and Heptagenia nymphs) into the groove. One specimen was used at a time, and the net was effective in holding back food as the water filtered through. The larva siezed any intruder almost immediately with its front legs and mandibles and pulled it down toward the mouth of its tube. It was not without a struggle that its victims were subdued, sometimes as long as five minutes being required. The larva seemed to swallow its food whole, with little chewing of it, and shoved it into its mouth with its front legs. Perfect or only slightly mutilated specimens of Chiromid larvæ and Heptagenia nymphs found in the œsophageal region seemed also to point to this method of feeding.

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PLATE XXXVI.

Photos by J. T. Lloyd.

Photo 1. Cascadilla Creek below Fish Hatchery. Taken in midsummer when the water is low to show character of creek bed. Earlier in the season, the Hydropsyche nets stretched between the stones on the bottom are very numerous. In the quiet water at the left the larvae of the Family Polycentropidæ are found.

Photo. 2. Cascadilla Creek in the spring as it rushes over the shelving ledges beside the Hatchery. A favorite spot of the Hydropsyche larvae.

Photo 3. Trough where experiments were carried on. Water entered through pipe above, and spilled over at corners at lower end, through grooves in the sides, where the Hydropsyche larvae built perfect catching-nets. Under the trough is a water-glass used in field work, and beside it, a folding bench for use while making observations in the stream.

PLATE XXXVII.

Fig. 1. Diagrammatic figure of a house of Hydropsyche angustipennis, copied from Wesenberg-Lund (1911) (Plate IV, Fig. 22). At the left is the tube in which the larva lives. In front of it is a vestibule with a catching surface of fine mesh in its side wall. Near this net is the opening of the larval tube.

Fig. 2. A typical Hydropsyche dwelling in which the coarse, irregular meshwork of the net is not strengthened by any supporting bits. Enlarged x 2.

Fig. 3. End view of one of the grooves of the trough with the Hydropsyche dwelling built in it.

Fig. 4. Hydropsyche dwelling built in trough, and viewed from above.

Fig. 5. Usual position assumed by the Hydropsyche larva in spinning its net or in feeding.

PLATE XXXVIII.

Fig. 1. Catching-net of Chimarrha aterrima. Natural size.

Fig. 2. Dwelling of Cyrnus pallidus (?). Larva lives in the tube, and at either opening is the catching-net. This is composed of radiating strands of silk fastened at their outer ends to the stone, and connected with one another by an irregular mesh. Enlarged x 2.

Fig. 3. Dwelling of Polycentropus sp. (?) Delicate silken tube in which larva lives, slightly curved, and surrounded on all sides by a delicate irregular mesh which functions as a catching-net. Enlarged x 2.

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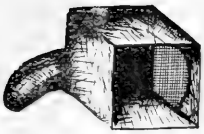

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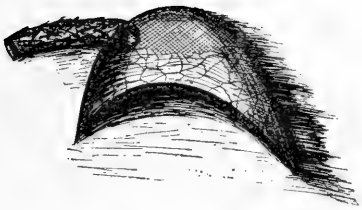

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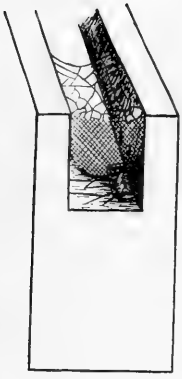

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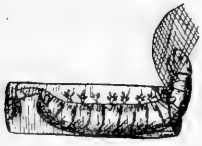

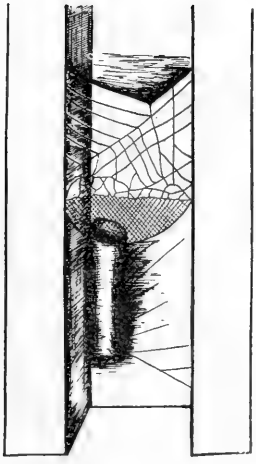

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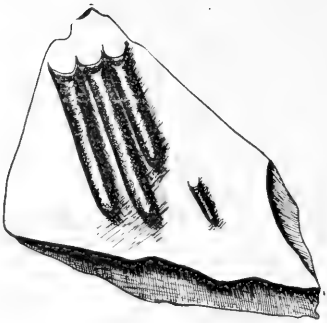

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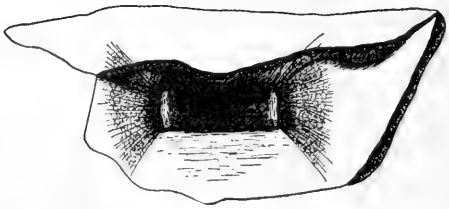

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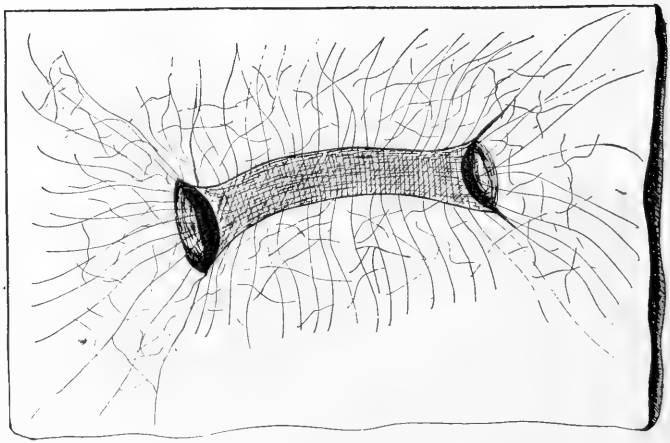

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THE CLASSIFICATION OF THE PUPAE OF THE CERATOCAMPIDÆ AND HEMILEUCIDÆ.

EDNA MOSHER.

The pupae belonging to the superfamily Saturnioidea may be identified by the following characteristics: Fifth and sixth abdominal segments free in both sexes; body surface hard and firm, always with setae, but these rarely long enough to be observed with the unaided eye; face-parts never with distinct sutures; antennal suture obsolete; labial palpi or maxillary palpi never visible; distinct cases for the mandibles never present, these structures often represented by an elevation or a distinct tubercule adjoining the caudo-lateral angles of the labrum; antennae usually showing distinct pectinations, the width at least one-fifth the length and usually much wider, the stem of the flagellum distinctly raised above the level of the pectinations, or if the stem of the flagellum is not distinct, then the body with the cephalic margins of the movable segments produced into distinct flange-like plates; maxillae, measured on the meson, seldom more than one-sixth the length of the wings, if longer, then the body surface without visible setae; third pair of legs very seldom visible; pupae usually more than an inch in length.

The pupae of this superfamily are found either in thick silken cocoons or thin "papery" ones, or in the ground. More than twenty genera are found in North America; of these, the pupae of only sixteen genera were available for study.

The material on which the following descriptions and tables are based was borrowed in part from the Illinois State Laboratory of Natural History. A large series of pupae was purchased from the American Entomological Co., the Kny-Scheerer Co. and Ward's Natural Science Establishment, with funds provided by the Graduate School of the University of Illinois.

Dr. A. D. MacGillivray has given many helpful suggestions as to the preparation of this paper, for which I wish to express my appreciation.

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* Contribution from the Entomological Laboratories of the University of Illinois, No. 44.

The superfamily Saturnioidea may be divided into three families as follows:

A. Pupae with the movable segments provided with flange-like plates which prevents their being telescoped, their lateral margins distinctly tapering caudad and each segment noticeably smaller than the segment cephalad of it; wings never elevated dorsad above the surface of the body; a distinct cremaster always present; stem of the flagellum of the antenna never elevated and distinct.

B. Pupae with a distinctly bifurcate cremaster; body usually roughened with spines on the exposed surface of the thorax and abdomen; metathorax with prominent oblong tubercles on each side the meson extending one-third or more of the distance between the meson and the margin of the first pair of wings; pupae always found in the ground..... **Ceratocampidæ**

BB. Pupae without a distinctly bifurcate cremaster; body never roughened with spines on the exposed surface of thorax and abdomen; metathorax never with prominent oblong tubercules; pupae found either in cocoons or in the ground .... **Hemileucidæ**

AA. Pupae with the movable segments never provided with flange-like plates which prevent their being telescoped, the lateral margins approximately parallel so that the segments appear of equal size and are usually telescoped so that only the caudal margins of the segments are visible; wings prominently elevated dorsad above the level of the body, the caudal portion of the mesonotum and metanotum always depressed adjacent to the wings; a distinct cremaster rarely present; stem of the flagellum of the antenna always elevated and distinct. **Saturniidæ**

THE FAMILY CERATOCAMPIDÆ.

Body with the margins of the free abdominal segments usually bearing a row of spines, and the exposed surface of the thorax and abdomen usually roughened with spines; antennae never broadly pectinate throughout, but broadly pectinate and almost parallel for about one-half the length, then narrowed rapidly to about half the greatest width, tapering gradually to a pointed tip, the stem of the flagellum never distinct, the surface convex and the central axis of the antenna usually bearing one or two rows of small spines; maxillae, measured on the meson, never less than one-fourth the length of the wings; tips of the tarsi of the second pair of legs meeting obliquely on the meson, never lying adjacent on the meson; proleg scars very prominent on abdominal segments five and six, the scars for the anal prolegs often very conspicuous; first pair of wings with the anal angles broadly rounded, usually located at the cephalic margin of the fourth abdominal segment and never reaching ventrad to the caudal margin of the fourth segment; second pair of wings never produced below anal angle of first wing and

never visible in ventral view; metathorax with distinct tubercules more or less oblong in outline on each side the meson and extending more than one-third the distance from the meson to the margin of the wing; the suture between the seventh and eighth segments never deep with distinct crenulations on its margins; cremaster always present, usually long and bifurcate at tip. Five genera of this family have been described. One genus, *Syssphinx*, consisting of three species, was not available for study. The remaining genera of Ceratocampidæ can be separated by the following table:

A. Surface of pupa never spinose; cremaster broader than long, broadly and shallowly bifurcate, never over 2 mm. in length..... **Citheronia**

AA. Surface of pupa spinose; cremaster at least twice as long as broad, bifurcate at tip, always more than 2 mm. in length.

B. Thorax rugose with short isolated spines, abdominal segments not spinose, but bearing a row of spines along both cephalic and caudal margins of segments 1 to 7, the spines along the caudal margins of segments 5 to 7 much longer than the spines of the cephalic rows..... **Basilona**

BB. Thorax and abdominal segments densely spinose; abdominal segments 1 to 7 with a row of spines along both cephalic and caudal margins, the spines in the cephalic rows on abdominal segments 5 to 7 usually much longer than the spines in the caudal rows; maxillæ, measured on meson, one-fourth the length of the wings.

C. Usually with prominent scattered spines on the thoracic segments, at least four times as long as those covering the segments; antennae with the central axis bearing a row of prominent spines curved caudad; if without prominent spines on the thoracic segments and antennae, then the maxillae, measured on meson, one-third the length of the wings.

D. Eighth abdominal segment never with a prominent transverse ridge in the middle of the segment bearing a row of spines; glazed eye-piece always lighter in color than the remaining surface of the body; species always more than an inch in length. **Adelocephala**

DD. Eighth abdominal segment always with a prominent transverse ridge in the middle of the segment bearing a row of spines; glazed eye-piece always the same color as the remaining surface of the body; species never more than an inch in length.. **Dryocampa**

CC. Without prominent scattered spines on the thoracic segments, the longest never four times the length of those covering the segments; antennae with the central axis never bearing prominent spines, the spines never curving caudad; maxillae, measured on meson, always one-fourth the length of the wings..... **Anisota**

Genus Citheronia Hübner.

Face-parts and appendages not at all elevated; body surface not roughened with spines; eye-pieces both present; invaginations for the anterior arms of the tentorium small but distinct; clypeo-labral suture present; labrum a little wider than long; maxillae, measured on the meson, about two-fifths the length of the wings, but little longer than the greatest width, triangular in outline; tips of the tarsi of the first and second pair of legs meet obliquely on the meson; median line distinct on all thoracic segments; mesothorax with a few minute tubercules at the bases of the wings; metathorax with a prominent oblong tubercule or plate, irregularly sculptured at the sides, on each side the meson, extending more than half the width of the segment and nearly its whole length; cephalic margins of abdominal segments 5 to 7 produced into thin, plate-like ridges; spiracular line curved slightly ventrad; cremaster short and bifurcate at tip.

This genus is found principally east of the Mississippi and consists of two species, *C. regalis* and *C. sepulchralis*. Specimens of the latter were not available for study. The pupae of *C. regalis* have a peculiar odor somewhat resembling laudanum.

Citheronia regalis Fabricius. Color dark brown, almost black; body surface usually polished, occasionally roughened with indeterminate transverse striations; antennae in both sexes with the length more than four times the greatest width and reaching about half way along the exposed portion of the second pair of legs; face parts with a slightly raised line on each lateral margin of the clypeus extending cephalad from the proximo-lateral margins of the labrum to the proximal ends of the antennae; labrum variable, five-sided, pointed at the distal end; maxillae much longer than broad, the proximal margin sinuate; prothoracic spiracle with elevated margins, the cephalic margin forming a prominent rounded ridge; mesothorax with a small tubercule on each side the meson on the caudal half of the segment, a tubercule scar laterad of each tubercule and in line with it, and a smaller tubercule near the caudal margin of the alar area on each side; abdominal segments 2 to 7 with a row of punctures near the cephalic margin, in

the movable segments, at the caudal margin of the ridge and extending all around the segment; segmentation in abdominal segments 8 to 10 hard to determine; the eighth segment usually polished, its dorsal cephalic margin roughened and plate-like, with a row of punctures along the cephalic margin of the plate and opening cephalad; abdominal segments with two dorsal rows of tubercule scars and one ventral row; cremaster short, never exceeding two millimeters in length, broader than long and broadly and shallowly bifurcate at tip. Length $1\frac{3}{4}''$–$2\frac{1}{2}''$; girth about equal to length.

Genus Basilona Boisduval.

Face parts slightly elevated above the level of the appendages; body surface roughened with spines; eye-pieces both present; invaginations for the anterior arms of the tentorium small and indistinct; clypeo-labral suture present; labrum with the length and breadth approximately equal; maxillae, measured on the meson, with the length twice the greatest width and one-half the length of the wings, triangular in outline; tips of the tarsi of the first pair of legs usually meeting on the meson, but sometimes falling short so that the tips of the maxillae lie between them; tips of the second pair of legs always meeting obliquely on the meson; median line distinct on prothorax and mesothorax and sometimes showing on the cephalic half of the metathorax; metathorax with a prominent oblong roughened tubercule with fluted edges on each side the meson, extending half the distance between the meson and the margin of the first pair of wings; cephalic margins of abdominal segments 5 to 7 never with any indications of a plate or ridge; spiracular line curved slightly ventrad; cremaster long, bifurcate at tip.

This genus contains a single species, *Basilona imperialis*, found in the states east of the Mississippi.

Basilona imperialis Drury. Color dark brown; body surface with indeterminate sculpturing and roughened with spines; antennae with the length four times the greatest width, the central axis set with a row of short spines directed caudad; face parts roughened with spines irregularly arranged, with the exception of a row extending cephalad from each proximolateral angle of the labrum to the proximal end of the antenna,

sometimes confused with the general sculpturing; labrum variable, usually five-sided, pointed at the distal end; maxillae with the length twice the breadth, each half quadrilateral; prothorax slightly wrinkled, with a row of spines around entire margin except in the region of the spiracles; mesothorax with fine indeterminate transverse striations and very small spines, a spinose area extending from the meson to the alar area, a few small spines at the base of the wings; wings with the venation outlined with short spines; abdominal segments 1 to 8 with an interrupted row of very small spines along the cephalic margin dorsally, and with many large semicircular to ovate punctures caudad of the spines, distributed over the cephalic third of the segment and the spiracular region, the remainder of the segment sparsely covered with smaller circular punctures; caudal margins of all abdominal segments with a row of small curved spines directed caudad, the spines larger than those on the cephalic rows, the largest on segments 8 to 10; lateral cephalic margins of abdominal segments 5 to 7 cephalad of the spiracles with three prominent transverse ridges with distinct furrows between; cremaster from 5 to 7 millimeters in length, a smooth dorsal concavity at the cephalic end, then strongly rugose to the bifurcate tip. Length 1¾″ to 2″; girth about equal to length.

Genus Adelocephala Herrich-Schaeffer.

Face parts very slightly raised above the level of the appendages; body surface roughened with spines; eye-pieces both present, the glazed eye-piece always lighter in color than the remaining body surface; invaginations for the anterior arms of the tentorium small, but distinct; clypeo-labral suture present; labrum broader than long; maxillae, measured on the meson, never less than one-fourth the length of the wings, triangular in outline; distal two-thirds of the tarsi of the first pair of legs adjacent on the meson, the tips of the tarsi of the second pair of legs meeting obliquely on the meson; median thoracic line distinct on prothorax and mesothorax; metathorax with an oblong tubercule on each side the meson, not prominently elevated, but slightly rugose and polished; cremaster long, bifurcate at tip.

This genus contains two species, *bicolor*, found in the Mississippi Valley and the Southern Atlantic states, and *bisecta*, found in the Ohio Valley. The species may be separated as follows:

A. Antennae with prominent spines; spines of cephalic margins of abdominal segments 5 to 7 larger than those on the other segments.....**bicolor**

AA. Antennae without prominent spines; spines on the cephalic margins of abdominal segments 5 to 7 not larger than those on the other segments.....**bisecta**

Adelocephala bicolor Harris. Color dark reddish brown; head, thorax and appendages finely spinose; abdominal segments both punctate and finely spinose; antennae with the length four times the greatest width, strongly convex, with two rows of spines, the outer row, large, prominent and curved caudad, the mesal row minute; face parts with an elevated spiny ridge on each side extending cephalad from the proximo-lateral angles of the labrum to the proximal end of each antenna, bearing a prominent spine near the cephalic end and a smaller one half way between this and the labrum; epicranial area with two prominent spines on each side the meson at the proximal end of each antenna; sculptured eye-piece with a prominent spiny tubercule; labrum usually six-sided, broader than long, maxillae with length and greatest width equal, each half quadrilateral, the length measured on meson, one-fourth the length of the wings; first and second pair of legs elevated and convex; cephalic portion of prothorax prominently elevated on meson sloping gradually to lateral margins, the larger spines on the elevation pointing dorsad, a slight elevation with larger spines near the meson at caudal margin on each side the meson; prothoracic spiracles with cephalic margins arcuate; mesothorax with a slightly elevated ridge each side the meson with at least two bifid spines, a prominent spine at the base of each wing and another half-way between these spines and the meson; abdominal segments 1 to 4 with rows of minute spines along the cephalic and caudal margins of the exposed portion; abdominal segments 5 to 7 having the cephalic margins dorsad between the spiracles with sharp transverse ridges and distinct furrows between, ventrad with large circular punctures, the margins produced into flange-like ridges set with broad, flat, erect spines, many of them bifid; the caudal margins of abdominal segments 5 to 7 with similar but very much smaller spines, the spines of both cephalic and caudal rows much smaller

on the venter; abdominal segments 8 to 10 thickly punctate, the eighth segment with a distinct lateral protuberance on each side and a prominent tubercule on the meson; ninth and tenth segments with some larger spines on the lateral margins; cremaster with a smooth V-shaped area on the proximal end at dorsum, with the point of the V prolonged down the middle of the cremaster, the remainder of the surface irregularly rugose and bifurcate at tip for about one-fourth the length, the tips divergent. Length 1½″ to 1¾″, cremaster one-seventh of total length; girth slightly less than length.

Adelocephala bisecta Lintner. Color dark reddish brown; head, thorax and appendages very finely spinose; antennae with the length about three times the greatest width, sometimes exceeding this, slightly convex and without prominent spines; face parts without prominent ridges or spines; labrum somewhat six-sided, tuberculate; maxillae with the length greater than the breadth, the length measured on meson, one-third the length of the wings; thorax without any prominent spines; abdominal segments 1 to 8 with rows of minute spines along the cephalic and caudal margins of the segments; segments 9 and 10 with rows of spines near the caudal margins, and without any prominent lateral spines; cremaster very rugose, bifurcate at tip for less than one-fourth its length, the tips but slightly divergent. Length 1½″ to 1¾″, the cremaster about one-ninth the total length; girth about equal to length.

Genus Dryocampa Harris.

Face parts elevated above the level of the appendages; body roughened with spines; antennae with a row of prominent spines curving caudad on each central axis; eye-pieces both present; invaginations for the anterior arms of the tentorium small, but distinct; clypeo-labral suture present; labrum a little wider than long; maxillae, measured on meson, one-fourth the length of the wings, triangular in outline; about half the exposed portion of the first pair of legs lying adjacent on the meson; tips of the tarsi of the second pair of legs meeting obliquely on the meson; median line elevated on prothorax and distinct on mesothorax, represented on the cephalic two-thirds of the metathorax by a clear elevated area; metathorax with a prominently elevated, polished tubercule on each side the median elevation, slightly rugose and extending at least one-third the distance from the meson to the margin of the

first pair of wings; cephalic margins of abdominal segments 5 to 7 produced into prominent flange-like ridges directed cephalad and set with spines; abdominal segments 9 and 10 with prominent lateral spines; cremaster long, over one-seventh the total length of the body, bifurcate at tip.

This genus includes a single species, *Dryocampa rubicunda*, found east of the Mississippi.

Dryocampa rubicunda Fabricius. Color dark brown to black; exposed surface of head, thorax and appendages finely spinose, the abdominal segments both punctate and spinose; face parts with an elevated spiny ridge on each side extending cephalad from the proximo-lateral angles of the labrum to the proximal end of each antenna, bearing two or three prominent spines; epicranial area with a prominent laciniate spine on each side the meson at the proximal end of each antenna directed cephalo-laterad and giving the pupa a horned appearance; glazed eye-piece usually one-third or more the entire width, the sculptured portion bearing at least one prominent spine; labrum six-sided, usually slightly sunken, pointed at distal end; maxillae with the greatest width and length approximately equal, each half triangular; prothorax with a few slightly larger spines on each side the median line; prothoracic spiracles with the cephalic margins arcuate; mesothorax with two prominent spines along cephalic margin near the meson, a large scattered group at base of wing and half way between these two groups on each side the largest thoracic spine; abdominal segments 1 to 4 with a row of minute spines along both cephalic and caudal margins; abdominal segments 5 to 7 with the margins punctate, produced into flange-like ridges directed cephalad and bearing a row of large sharp spines occasionally bifid or trifid and about one-third the length of the segment, the caudal part of these segments with a distinct furrow near the caudal margin separating the cephalic spinose portion from a narrow smooth portion, with a row of small spines between it and the transverse conjunctiva; eighth abdominal segment with a row of large spines dorsally on the summit of a median transverse ridge, extending laterad and becoming indistinct on the ventral aspect; abdominal segments 9 to 10 with prominent lateral spines curving caudad; cremaster irregularly, longitudinally rugose, bifurcate at tip with the points widely divergent. Length 7-8″ to 1″; girth less than length.

Genus Anisota Hübner.

Body with the cephalic margins of abdominal segments 5 to 7 produced into flange-like ridges directed cephalad, and set with spines; exposed surface of head and thorax spinose, the abdominal segments both spinose and punctate; both eye-pieces present, the sculptured portion spinose; invaginations for the anterior arms of the tentorium small, but distinct; clypeo-labral suture present; labrum variable, small, never twice as broad as long; maxillae, measured on the meson, always one-fourth the length of the wings, triangular in outline; tarsi of the first pair of legs adjacent on the meson, tips of the tarsi of the second pair meeting obliquely on the meson; metathorax with a prominent oblong tubercule on each side the meson, extending more than one-third the distance between the meson and the margin of the first pair of wings; cremaster always long and bifurcate at tip.

This genus includes at least five species commonly found in the United States, one of these, *A. skinneri*, is reported from Arizona, the other four from the states east of the Mississippi.

These five species can be separated by means of the following table:

A. Cremaster one-eighth or more of the total length of the body; spines on the epicranial area at the proximal end of each antenna large and prominent, extending beyond the margin of the body in ventral view and giving the pupa a horned appearance.
  B. Cremaster more than one-eighth the total length of body and bifurcate for less than one-fourth its length; small species, less than one inch in length..... **virginiensis**
  BB. Cremaster about one-eighth the total length of the body and bifurcate for one-fourth its length; species one inch or more in length.
    C. Face parts prominently elevated above the level of the appendages; mesothorax with at least one laciniate spine on each side the meson near the cephalic margin. **stigma**
    CC. Face parts not elevated above the level of the appendages; never with a laciniate spine on each side the meson near the cephalic margin..... **senatoria**
AA. Cremaster less than one-eighth the total length of the pupa; spines of the epicranial area at the proximal end of each antenna never extending beyond the margin of the body in ventral view, so that the pupa does not present a horned appearance.
  B. Each metathoracic tubercule very prominently elevated, its length more than half the length of the segment and extending at least half the distance from the meson to the margin of the first pair of wings; color black..... **skinneri**
  BB. Each metathoracic tubercule somewhat diamond shaped, never very prominently elevated, its length never as much as half the length of the segment, and never extending half the distance between the meson and the margin of the first pair of wings; color bright reddish brown..... **consularis**

Anisota virginiensis Drury. Color dark brown to black; abdominal segments 1 to 4 and 8 to 10 with few spines and more large circular punctures as compared with the remainder of the surface; each antenna with two rows of minute spines on the central axis, the length three times the greatest width; face parts prominently elevated above the level of the appendages, an elevated densely spinose ridge extending cephalad from the proximo-lateral angles of the labrum to the proximal end of each antenna with a large spine at its cephalic end; epicranial area with one large spine and several smaller ones on each side the meson near the proximal end of each antenna; labrum variable, usually six-sided, with two small tubercules or spines, the width greater than the length, pointed at distal end; maxillae with the length and breadth approximately equal, each half quadrilateral; median thoracic line distinct on all segments; prothorax with the median line slightly elevated; mesothorax without prominent spines, usually with two tubercule scars on each side the meson, sometimes spine-like, seldom all prominent; metathoracic tubercules wedge-shaped, irregularly impressed, black and polished, each extending less than half the distance from the meson to the margin of the first pair of wings; abdominal segments 1 to 3 with an indistinct row of minute spines along both cephalic and caudal margins of the segment; abdominal segments 5 to 7 with the cephalic margins punctate and produced into flange-like ridges projecting cephalad and set with stout spines less than one-sixth the length of the segment; caudal margins of segments 4 to 7 with a slight depression, the elevation adjacent to the transverse conjunctiva set with two rows of minute spines; eighth segment with a transverse ridge in the middle of the segment set with spines, with slightly larger spines on the lateral margins of the segment; ninth abdominal segment with prominent lateral spines and the tenth with a prominent hooked spine on each side the base of the cremaster; cremaster longitudinally rugose, bifurcate for less than one-fourth its length, the tips divergent. Length 7-8″; cremaster about one-seventh the total length; girth less than length.

Anisota stigma Fabricius. Color dark reddish brown; antennae in both sexes with the length about three times the greatest width, central axis bearing a row of minute spines;

face parts prominently elevated above the level of the appendages, an elevated ridge extending cephalad from each proximolateral angle of the labrum to the proximal end of each antenna, bearing a large laciniate spine near its cephalic end; epicranial area with a stout curved spine on each side the meson near the proximal end of the antenna; labrum variable, usually hexagonal, with two small tubercules or spines and pointed at the distal end; prothorax with the median line generally elevated, more densely spinose on each side adjacent to the meson than on the remainder of the segment; mesothorax with one and sometimes two laciniate spines on each side the meson near the cephalic margin with sometimes one or two smaller spines, a scattering group of spines at the base of each wing and one spine on each side, half-way between the base of the wing and the meson, which is larger than those covering the segment; metathoracic tubercules rugose, somewhat diamond-shaped, each extending about half the distance from the meson to the margin of the first pair of wings, subadjacent on the meson; abdominal segments 1 to 3 with a row of minute spines along both cephalic and caudal margins of the segment; cephalic margins of abdominal segments 5 to 7 punctate and produced into flange-like ridges directed cephalad, bearing a row of prominent, erect, triangular spines, less than one-fourth the length of the segment; caudal margins of abdominal segments 4 to 7 with a furrow near the caudal margin of the segment and a row of spines on the elevation at the junction of the segment and the transverse conjunctiva, these spines about one-third the size of the spines in the cephalic rows; abdominal segments 8 to 10 with fewer spines and more punctures on the surface; the eighth abdominal segment with a prominent transverse ridge in the middle of the segment, with a slight protuberance on each lateral margin, the transverse ridge set with spines similar to those along the caudal margins of segments 4 to 7, a smaller row along the caudal margin of the segment; ninth abdominal segment with two rows of spines near the caudal margin with two or three prominent ones along each lateral margin; tenth segment with two or three prominent spines along each lateral margin at the proximal end of cremaster; cremaster with a smoother, triangular depressed area dorsad at proximal end, the remainder of the surface rugose with wavy longitudinal ridges, the caudal end bifurcate for

less than one-fourth of the length, the tips divergent. Length 1″—1 1-8″; cremaster about one-ninth the total length; girth equal to length.

Anisota senatoria Smith and Abbott. Color dark brown to black; antennae scarcely convex, each central axis with two rows of minute spines, length about three times the greatest width; face parts slightly elevated above the level of the appendages; no prominent ridge extending cephalad from each proximo-lateral angle of the labrum, but a prominent curved spine on each side the cephalic part of clypeal area adjacent to the proximal end of each antenna; epicranial area with a prominent curved spine at the proximal end of each antenna and usually one or two smaller ones; labrum usually six-sided, broader than long, usually with two small tubercules, slightly pointed at the distal end; maxillae with the length slightly greater than the greatest width, each half quadrilateral; prothorax with a dense row of slightly larger spines on each side the median line; mesothorax with a tubercule scar on each side the meson indicated by a small polished area; mesothorax without prominent spines; metathorax with the tubercules oblong, slightly rugose, black and polished, each extending less than half the distance from the meson to the margin of the first pair of wings; abdominal segments 1 to 3 with a row of minute spines along the cephalic and caudal margins of each segment; cephalic margins of abdominal segments 5 to 7 with one distinct furrow dorsally and punctate around entire segment, produced into flange-like ridges bearing stout spines about one-fourth the length of the segment; abdominal segments 4 to 7 with a distinct depression near the caudal margin of the segment and with a caudal row of small spines between the segment and the transverse conjunctiva, with an interrupted row of smaller spines just cephalad; eighth abdominal segment with a distinct median transverse ridge bearing spines similar to those on the cephalic margins of segments 5 to 7, a row of small spines along the cephalic margin of the ninth abdominal segment with two rows of spines near its caudal margin and several prominent lateral spines; tenth abdominal segment with one or two prominent lateral spines at the proximal end of the cremaster, smaller than those on the ninth segment; cremaster with a slightly depressed

heart-shaped area at the proximal end with fine longitudinal ridges, about three-fifths of the remaining length finely rugose, the distal end smooth, bifurcate for about one-fourth its length, the tips slightly divergent. Length 1 1-8″—1¼″; cremaster about one-ninth the total length; girth less than length.

Anisota skinneri Biederman. Color dark brown to black; antennae with the length three times the greatest breadth, a row of minute spines on the central axis of each antenna; face parts slightly raised above the level of the appendages, the ridge extending cephalad from each proximo-lateral angle of the labrum scarcely indicated, a medium sized laciniate spine on the face parts near the proximal end of each antenna; epicranial area with a long laciniate prominence or ridge, which is never horn-like, with a small spinose tubercule caudad of it on each side the meson near the proximal end of each antenna; labrum variable, usually five-sided, broadly rounded or slightly pointed at the distal end; maxillae with the length and breadth approximately equal, each half quadrilateral; prothorax more densely spinose on each side adjacent to the median line; mesothorax without any especially prominent spines; metathoracic tubercule strongly elevated, ovate, irregularly impressed, almost adjacent on the meson, and extending half the distance from the meson to the margin of the first pair of wings; abdominal segments 1 to 4 with a row of minute, closely set spines along both cephalic and caudal margins of the segment; cephalic margins of abdominal segments 5 to 7 dorsad with sharp transverse ridges with distinct furrows between and punctate around entire segment, produced into flange-like ridges set with spines only about one-eighth the length of the segment; abdominal segments 4 to 7 with a distinct furrow near the caudal margin of the segment and two distinct rows of minute spines between the segment and the transverse conjunctiva; eighth abdominal segment with a slightly elevated transverse ridge in the middle of the segment set with small spines and another row at the caudal margin of the segment; ninth abdominal segment with two rows of spines at the caudal margin of the segment, some spines slightly more prominent at each lateral margin; tenth abdominal segment with a small lateral spine on each side the cremaster;

cremaster with a small, triangular, slightly depressed area at the proximal end of cremaster dorsad, but rugose much like the remainder of the surface, bifurcate at tip for less than one-fourth the length, the tips not divergent. Length 1 3-8″—1 5-8″; cremaster about one-tenth total length; girth exceeding length.

Anisota consularis Dyar. Color bright reddish brown; antennae with the length about four times the greatest width; face parts slightly raised above the level of the appendages, an elevated ridge extending cephalad from each proximo-lateral angle of the labrum to the proximal end of each antenna and bearing several prominent spines; epicranial area with a large spine on each side the meson near the proximal end of each antenna; labrum variable, usually five-sided, broader than long and bearing two minute tubercules or spines, slightly pointed at the distal end; maxillae with the length greater than the breadth, each half quadrilateral; prothorax with a larger spine on each side the median line near the middle of the segment; mesothorax without any especially prominent spines, a few longer ones at the base of each wing; metathoracic tubercules irregular, somewhat diamond-shaped, black and polished, irregularly impressed or punctate, each tubercule extending less than half the distance from the meson to the margin of the first pair of wings; abdominal segments 1 to 4 with a row of very minute spines on each cephalic and caudal margin; abdominal segments 5 to 7 with the cephalic margins punctate and produced into flange-like ridges directed cephalad and set with spines less than one-sixth the length of the segment, a smooth band at the caudal margin of the segments and a row of small spines along the segment adjacent to the transverse conjunctiva, almost wanting on the seventh segment; eighth segment with a row of spines on a slight transverse ridge in the middle of the segment, becoming indistinct in ventral view, the caudal row of spines indistinct dorsad, but very distinct laterad and ventrad; ninth abdominal segment with a caudal row of spines, a prominence on the lateral margin set with longer spines; the tenth segment with two prominent lateral spines on each side of the cremaster; cremaster with a small, triangular depressed area, much smoother than the remainder of the surface, which is longitudinally rugose, bifurcate for about

one-fourth the length, the tips divergent. Length 1 1-8″—1 3-8″; cremaster less than one-eighth the total length; girth equal to length.

THE FAMILY HEMILEUCIDÆ.

Margins of the free segments never with a row of spines; the body surface never roughened with spines; antennae with the stem of the flagellum never distinct, the central axis never set with spines, the antennae tapering gradually from the part with the greatest width; maxillae measured on the meson never more than one-sixth the length of the wings; proleg scars seldom prominent on abdominal segments five and six and rarely with the anal proleg scars visible; first pair of wings with the anal angles broadly rounded, usually at the cephalic margin of fourth abdominal segment, and usually reaching the caudal margin of the fourth abdominal segment ventrally; second pair of wings never produced below the anal angles of the first pair of wings and never visible in ventral view; metathorax never with prominent tubercules; abdominal segments 5 to 7 with their cephalic margins produced into thick oblique flange-like plates directed caudad; cremaster short, never bifurcate at tip.

Altho not usually included with the Hemileucidæ the genus *Automeris* is placed in this group owing to the very evident relation of the pupae to those of the genera *Hemileuca* and *Pseudohazis*. Morphologically they seem to be more nearly related to the Hemileucidæ, but they are found in cocoons like the Saturniidæ.

The description of this family is of necessity very incomplete owing to lack of material. According to our available knowledge of the subject the three genera may be separated as follows:

A. Cremaster bearing setae arranged in a transverse row and spreading out fan-like..... **Pseudohazis**

AA. Cremaster never with setae, either with curved spines or without spines or setae of any kind.

B. Cephalic part of segment above the flange-like plate either smooth or with fine longitudinal striations; pupae found in ground. **Hemileuca**

BB. Cephalic part of segment above the flange-like plate with sharp, transverse ridges, deep furrows between; pupae found in cocoons **Automeris**

Genus Hemileuca Walker.

Face parts slightly elevated above the surface of the body; antennae with the stem of the flagellum indistinguishable from remainder of surface, entire surface flat to uniformly convex, tapering gradually to a point at the distal end; invaginations for the anterior arms of the tentorium distinct; eye-pieces both present; clypeo-labral suture generally distinct; maxillae, measured on meson, never more than one-sixth the length of the wings, each half quadrilateral; less than half the exposed tibiae and the tarsi of the first pair of legs with the tips of the second pair of legs adjacent on the meson; second leg visible for almost entire tibial and tarsal length; median thoracic line always distinct on prothorax and mesothorax, seldom on metathorax; first pair of wings with the anal angles broadly rounded near cephalic margin of fourth abdominal segment; second pair of wings visible along entire dorsal margin of first wing, its margin entire, but never produced beyond anal angle of first pair of wings and never visible on the ventral surface; spiracular line almost straight; cephalic margins of abdominal segments 5 to 7 produced into thick, oblique flange-like plates; suture between the seventh and eighth abdominal segments deep, both margins usually strongly crenulate, the crenulations of the two sides fitting together like a set of teeth; cremaster short, pointed, never exceeding two millimeters in length.

This genus includes at least nine species found in the United States, only three of which are described here. The most common species is *H. maia*, which is found from the Atlantic states westward to the Rocky Mountains. The others are reported from the western states. These moths spend their pupal life in the ground. The species described can be separated by the following key:

A. Suture between the seventh and eighth abdominal segments very deep, the edges distinctly crenulate.

B. Clypeal region strongly convex; labrum strongly elevated; maxillae short, inconspicuous, each half triangular in outline and length on meson less than a millimeter; mesothorax with a tubercle on each side the meson outlined by a depressed ring. **burnsi**

BB. Clypeal region not strongly convex; labrum not elevated; maxillae conspicuous, each half quadrangular in outline and meeting on meson for at least a millimeter; mesothorax without tubercules on each side the meson..... **maia**

AA. Suture between the seventh and eighth abdominal segments not very deep, the edges without distinct crenulations..... **oliviæ**

Hemileuca maia Drury. Color dark brown; face-parts and appendages with fine transverse striations, remainder of surface shagreened, excepting abdominal segments 8 to 10; face-parts without a prominent convexity in clypeal region; antennae in male with length four times the width, the sides parallel for at least the proximal two-thirds of their length and then tapering rapidly to a point, reaching just below the tips of the first pair of legs; clypeo-labral suture sometimes indistinct; labrum about twice as broad as long; quadrate and broadly truncate at distal end; maxillae, measured on meson, one-sixth the length of wings, its median length less than its greatest breadth; first pair of wings with their anal angles at the cephalic margin of fourth abdominal segment; abdominal segments 1 to 4 and 7 to 8 with distinct furrows between, their margins wavy, more apparent on the cephalic margins of the segments; abdominal segments 5 to 7 with their cephalic margins produced into thick flange-like plates covered with fine longitudinal striations and a distinct smooth furrow at the caudal margin of the segment, adjoining the transverse conjunctiva; cremaster nearly two millimeters in length, indefinitely rugose, triangular in outline, pointed at distal end, which bears many hooked spines. Length, abdomen retracted, about 1″, girth about 1¼″.

Hemileuca maia var. lucina Hy. Edwards. Specimens of this variety from the New England Entomological Exchange, collected in New Hampshire, show little general difference from *H. maia*. They are much smaller, however, varying from 9-16″ to ¾″ in length.

Hemileuca burnsi Watson. Color dark brown; face-parts and appendages with fine, transverse striations, the remainder of the body surface shagreened; face-parts with a prominent convexity in the clypeal region; antennae of male with length three times the width, tapering from the region of greatest width to form a long, pointed tip at distal end, ending opposite the tips of the first pair of legs; clypeo-labral suture distinct, labrum elevated, somewhat shield-shaped, rounded at distal end; maxillae very short, scarcely visible, each half of maxilla triangular, much broader than long; prothoracic spiracles with strongly elevated margins; mesothorax with a prominent tubercule on each side the meson, outlined by a depressed ring;

first pair of wings with their anal angles nearly opposite the caudal margin of the fourth abdominal segment; sutures between abdominal segments 1 to 4 distinct, margins of adjoining segments crenulate, suture between segments 7 and 8 very prominent, the dorsal cephalic margin of the suture with longitudinally corrugate ridges, the caudal margin crenulate; abdominal segments 5 to 7 with their cephalic margins produced into a prominent, flange-like plate, with longitudinal striations, never more than indications of a furrow at caudal margins of segments, an elevated roughened line between the caudal margin of the segment and the transverse conjunctiva; cremaster short, not more than a millimeter in length, triangular, rugose, ending in a blunt tip at distal end, without spines. Length about 7-8″; girth about 1″.

Described from one male specimen, for which we are indebted to Dr. Wm. Barnes, of Decatur, Illinois.

Hemileuca oliviæ Cockerell. Color dark brown; surface of body with interrupted transverse striations or impressions; face-parts slightly elevated, but without a prominent convexity in clypeal region; antennae in male with length a little more than three times the width, the sides parallel for at least two-thirds of the distance and then tapering to form a blunt, rounded tip, ending opposite tips of second pair of legs; clypeo-labral suture distinct; labrum with length and breadth approximately equal, five-sided, with a sharp point at distal end; maxillae, measured on meson, about one-seventh the length of the wings, each half the maxilla quadrilateral, distance between the parallel sides about equal to the length on meson; prothoracic spiracles with slightly raised roughened margins; first pair of wings with their anal angles nearly opposite the caudal margin of the fourth abdominal segment; sutures between abdominal segments 1 to 4 distinct, cephalic margin of sutures approximately smooth, caudal margin of sutures irregularly corrugated and on the fourth segment depressed, suture between segments 7 and 8 not deep, the caudal margin of the seventh segment slightly raised above the eighth segment; abdominal segments 5 to 7 produced into thin flange-like plates, the margins slightly undulate, a distinct furrow at the caudal margin adjoining the transverse conjunctiva, cremaster triangular, the

distal end covered with sharply recurved spines. Length 7-8″—1″; girth about 1¼″.

Described from one male specimen, for which we are indebted to Dr. Wm. Barnes, of Decatur, Illinois.

Genus Pseudohazis Grote and Robinson.

Median thoracic line distinct on the prothorax and mesothorax, faint on the metathorax; first pair of wings with the anal angles broadly rounded, near the cephalic margin of the fourth abdominal segment; second pair of wings visible along entire dorsal margin of first wing, its margin entire, but never produced beyond the anal angle of first pair of wings and never visible in ventral view; spiracular line straight; cephalic margins of abdominal segments 5 to 7 produced into thick, oblique, flange-like plates directed caudad; suture between the seventh and eighth abdominal segments deep, the cephalic margin with distinct crenulations along both margins, the cephalic margin with quadrangular depressions, the caudal margin with deep longitudinal furrows; cremaster short, bearing a fan-shaped group of long straight setae.

This genus and species have been described from a single specimen kindly loaned by the American Museum of Natural History through the kindness of Mr. J. A. Grosbeck. Unfortunately the specimen had lost its prothorax, face-parts, and all appendages except the wings. These descriptions are included, however, to show the relationship of this genus to the genus *Hemileuca*. Little is known of its life history, but it spends its pupal life in the ground. There are three species named in Dyar's "List of North American Lepidoptera," all from the western part of the United States.

Pseudohazis eglanterina Boisduval. Color dark reddish brown; exposed surface of thorax, wings and abdomen coarsely shagreened; abdominal segments 5 to 7 with their flange-like plates shagreened like the remainder of the segment, except for a few faint longitudinal striations near the margin; abdominal segments 4 to 8 with a raised transverse line near the caudal margin of the segment; cremaster about one millimeter in length, indefinitely rugose, conical, bearing a fan-shaped group of coarse, straight setae. Length, abdomen expanded, about 1 1-8″; girth 1½″.

Genus Automeris Hübner.

Face-parts not noticeably elevated above the body surface; antennae pectinate throughout, tapering gradually to a point at the distal end, the stem of the flagellum never noticeably raised above the level of the pectinations; sexual differences, if any, very slight; invaginations for the anterior arms of the tentorium obscure; eye-pieces both present; clypeo-labral suture usually distinct; maxillae, measured on meson, never more than one-sixth the length of the wings, triangular in outline; less than half the exposed tibiae and the tarsi of the first pair of legs and tips of the second pair adjacent on the meson; second leg visible for almost entire tibial and tarsal length; median thoracic line faint, and seldom found on all segments; first wing with anal angle broadly rounded, near the cephalic margin of fourth abdominal segment; second wing visible around the entire dorsal margin of first wing, its margin entire and produced around anal angle of first wing to form a prominent angle on the fourth abdominal segment, scarcely visible in ventral view; spiracular line slightly curved ventrad; cephalic margins of abdominal segments 5 to 7 with sharp, transverse ridges having distinct furrows between, and produced into an oblique flange-like plate, generally hidden when segments are retracted; abdominal segments 8 to 10 taper gradually to caudal end; cremaster always distinct and set with hooked spines.

This genus includes perhaps more than a dozen species in North America of which four species are described here. These all spin coccoons. Our common species, *A. io*, which is found all over the Eastern United States and Mexico, spins a thin brown "papery" cocoon much like *Tropaea luna*, but thinner and more shapeless. They are found on the ground, usually with a protecting leaf attached and are thin enough so that the pupa may usually be seen through the cocoon. *A. pamina* is described from Arizona and Mexico. Its cocoon is much like that of *A. io*, with many small leaves securely fastened to it. The cocoon of *A. incarnata* of Mexico is very similar to the preceding forms, but thicker and covered with leaves. The cocoon of *A. leucana* is shaped much like that of *Samia cecropia* and covered with small pieces of bark. It is also a Mexican species. These four species can be separated by using the following table:

A. Cremaster triangular, at least two millimeters long, with a transverse row of hooked spines curving dorsad; cephalic margins of abdominal segments 5 to 7 produced into an oblique, flange-like plate with an undulate margin produced into prominent curves dorsad of the spiracular line..... **leucana**

AA. Cremaster never triangular, usually only a button-like constriction with a thickly set group of strongly recurved spines, the tips curving outward in all directions; cephalic margins of abdominal segments 5 to 7 produced into an oblique flange-like plate with its margin entire, never produced into curves dorsad of the spiracular line.

B. Mesothorax with fine indeterminate transverse striations; body setae conspicuous..... **io**

BB. Mesothorax never with fine indeterminate transverse striations; body setae inconspicuous.

C. Mesothorax rugose; a small tubercule each side the meson on the metathorax and first three abdominal segments. **pamina**

CC. Mesothorax tuberculate with blunt conical projections; never with small tubercules each side of the meson on the mesothorax and first three abdominal segments. **incarnata**

Automeris pamina Neumoegen. Color dark brown; body setae inconspicuous, light brown, few in number; face parts and appendages with fine, indeterminate transverse striations; exposed surface of thorax rugose, remainder of surface finely shagreened; length of antennae in both sexes more than four times the breadth and ending in line with the tips of the first pair of legs; labrum variable, length and breadth approximately equal, usually six-sided and pointed at distal end; maxillae, measured on meson, about one-sixth the length of the wings, triangular in outline, median length greater than the greatest width; cephalic margins of abdominal segments 5 to 7 with fine ridges, becoming indistinct on the meson of both dorsal and ventral surfaces, the margin produced into a flange-like plate with its margin entire, never produced into prominent curves; dorsal surface of abdominal segments 4 to 7 with a smooth, elevated line just cephalad of the junction of segment and transverse conjunctiva, extending laterad and ending beyond the spiracles on ventral surface; dorsal and lateral surfaces of tenth abdominal segment rugose with irregular, longitudinal depressions at the base of cremaster. Cremaster short, constricted slightly at base and forming a rounded protuberance with a closely set group of strongly recurved spines, the tips turning outward in all directions. Length, abdomen expanded, from 1 1-8″ to 1¼″; girth about 1¾″.

Automeris io Fabricius. Color dark brown; body setae conspicuous, light brown, sparsely distributed over entire surface excepting appendages, most numerous on thorax; body often noticeably depressed; face parts, appendages, except the wings, and exposed surface of thorax with fine, indeterminate, transverse striations, remainder of surface shagreened, with the projections in transverse rows; antennae in both sexes with length three times the width and quite reaching the tips of the first pair of legs; labrum variable, broader than long, usually five-sided and pointed at the distal end; maxillae, measured on meson, about one-sixth the length of wings, median length always less than the greatest width, each half the maxilla quadrilateral, sometimes modified so that entire maxilla appears heart-shaped; median thoracic line narrow, usually visible on all segments; abdominal segments 5 to 7 with the cephalic margins covered with sharp transverse ridges, with distinct furrows between, the furrows becoming shallower at the meson on the ventral surface, the flange-like plate with its edges entire; abdominal segments 4 to 7 with a distinct furrow of varying width between the segment and the transverse conjunctiva, which becomes indistinct in the region of the proleg scars on the ventral surface, its cephalic margin being indicated by a raised line; abdominal segments 8 to 10 with segmentation distinct; dorsal surface of tenth abdominal segment with deep, longitudinal ridges at base of cremaster; tip of cremaster with a small group of closely set, sharply recurved spines, the hooks turning outward in all directions. Length, abdomen retracted, 7-8″—1¼″, expanded, 1″—1 3-8″; girth 1¾″—2″.

Automeris leucana Hübner. Color dark brown; body setae light brown, inconspicuous; face parts and appendages with indeterminate, transverse striations, exposed surface of thorax rugose, with interrupted transverse ridges; remainder of surface coarsely shagreened; antennae in both sexes with the length more than four times the breadth, not extending as far caudad as the tips of first pair of legs; labrum variable, length and breadth approximately equal, pointed at tip, usually five-sided; maxillae, measured on meson, about one-seventh the length of wings, the greatest width about one and one-half times the median length, each half the maxilla quadrilateral;

median thoracic line very narrow, only distinct on the mesothorax; abdominal segments 5 to 7 with the cephalic margin ridged, produced into an oblique flange-like plate with an undulate margin having prominent curves dorsad of the spiracular line, the median line of cephalic margin indicated by oblique ridges, a slightly raised, smooth line cephalad of the junction of the segment and the transverse conjunctiva; tenth abdominal segment having the dorsal and lateral margins of the cremaster with semi-longitudinal ridges at base of cremaster; cremaster at least two millimeters in length, triangular in outline, tapering rapidly to a pointed tip with a transverse row of sharply recurved spines, the tips curving dorsad. Length, abdomen expanded, 1¼″—1 5-8″; girth about 1¾″.

Automeris incarnata Walker. Color dark brown to blackish, transverse conjunctiva lighter; body setae light brown, inconspicuous; face parts and appendages with wavy, indeterminate, transverse striations, exposed surface of thorax tuberculate with blunt, conical projections; antennae in both sexes with length about four times the width and ending opposite the tips of the first pair of legs; labrum variable, broader than long, usually five-sided, pointed at distal end; maxillae, measured on meson, about one-sixth the length of the wings, median length less than the greatest width, each half quadrilateral, lateral margins concave, basal half sculptured and roughened; median thoracic line wanting except on metathorax; dorsal and lateral portions of cephalic margins of abdominal segments 5 to 7 with fine, sharp, transverse ridges becoming indistinct in the region of the proleg scars, the cephalic margin narrower in this region and produced all around segment into a very narrow, flange-like plate with a distinct longitudinal impression at meson; abdominal segments 4 to 7 with a raised line cephalad of the line between the segment and the transverse conjunctiva; tenth abdominal segment rugose at base of cremaster; the cremaster short, rounded, constricted at base and set with a small group of closely set, sharply recurved spines, the tips turning outward in all directions. Length, abdomen contracted, about 1″, expanded, about 1 1-8″; girth about 1½″.

NOTES ON THE LIFE HISTORY AND ANATOMY OF SIPHONA PLUSIÆ Coq.

By William Bloeser, Stanford University, Calif.

LIFE HISTORY.

The Tachinid fly, *Siphona plusiæ*, was described by Coquillet in 1897. It was bred from a cut-worm. The specimens that I have obtained, however, were parasitic in the larvæ of *Phryganidia californica*, gathered from oak trees at Stanford University.

The Phryganidians were more than plentiful during the fall of 1913, and consequently there was an abundance of parasites. *Siphona* is only one among a dozen or more parasites that are nursed in their infancy by the accommodating Phryganidian, but notwithstanding the ravages of all these parasites, and the scourge of a fungus disease, which killed nearly one third of the caterpillars, there were still many left, sufficient to insure a great number of moths again in the following spring.

The following notes on *Siphona plusiæ* are the result of observations made in the fall of 1913:

The Egg. The adult female fly lays one or more eggs on the outer body wall of the Phryganidian larva. The dipterous parasites are not as careful as the hymenopterous parasites, and they lay their eggs indiscriminately, often laying three or four eggs on one host.

The Larvæ. After the eggs have hatched the young larvæ make their way into the body cavity of the Phryganidian, where they remain from ten days to two weeks, feeding on their host until fully grown, when they measure about five-sixteenths of an inch in length. They have eleven segments; well developed mouth parts, in the form of great hooks; two large posterier spiracles and two smaller anterior ones.

The larvæ are loosely attached or held in a sort of cicatrix, in the body of the host, by several rows of small hooks that encircle the tenth and eleventh segments. From this position the head and anterior portion of the body are free to swing in the body cavity. Some larvæ are found, however, moving

about freely in the body cavity, while those that were attached could be easily removed or could themselves change their position.

About one hundred Phryganidia were dissected and ten *Siphona* parasites were found, three of these being taken from a single caterpillar. It would be hard to estimate with much accuracy the probable percentage of parasites, but ten per cent, I believe, would not be too high an estimate.

Some of the Phryganidia were kept alive in a cage, and from these there issued several fly larvæ, which pupated in about two hours. In no instance did the parasites issue from Phryganidia pupæ, but all seem to leave the Phryganidia while the host is still in the larval stage. After freeing itself from the host the larva soon begins the period of pupation. It begins by drawing itself together and changing to a darker color, and within a couple of hours it is a brown segmented pupa about three-sixteenths of an inch in length. One pupa remained from the sixth of October to the twenty-fourth, a period of eighteen days, before the imago finally appeared. Other larvæ were alllowed to pupate, but from eight pupæ only the one fly issued, while from the seven others, there issued hymenopterous hyperparasites, which have not yet been determined. These issued somewhat later, taking twenty-three to twenty-five days to come from the pupa cases.

This percentage of hyper-parasites is almost certainly more than the average, as they came from Phryganidia that were gathered from a single oak tree situated in a flower garden. It is to be hoped that further investigation will reveal a smaller percentage of hyper-parasites, as their abundance will greatly check the beneficial work of *Siphona plusiæ*, which has so greatly aided in controlling the Phryganidia in California, especially in the Santa Clara Valley.

The Adult. The adult has been described by Coquillet,* but practically nothing of the life history has been heretofore given. The general characteristics of the adult are shown in text-fig. 2, a special character being that the proboscis has two geniculations, one near the base and the other near the middle.

* Canadian Entomologist, Vol. 27, p. 125.

ANATOMICAL NOTES.

External Appearance. The larvæ are white and nearly translucent, and the colors exhibited are at either end. The great hooks (text-fig. 1) which form the most important part of the mouth structure, are jet black. On the last segment there are two large posterior spiracles, which are of a deep brown color. There are also several rows of little dark colored hooks around the tenth and eleventh segments (text-fig. 1).

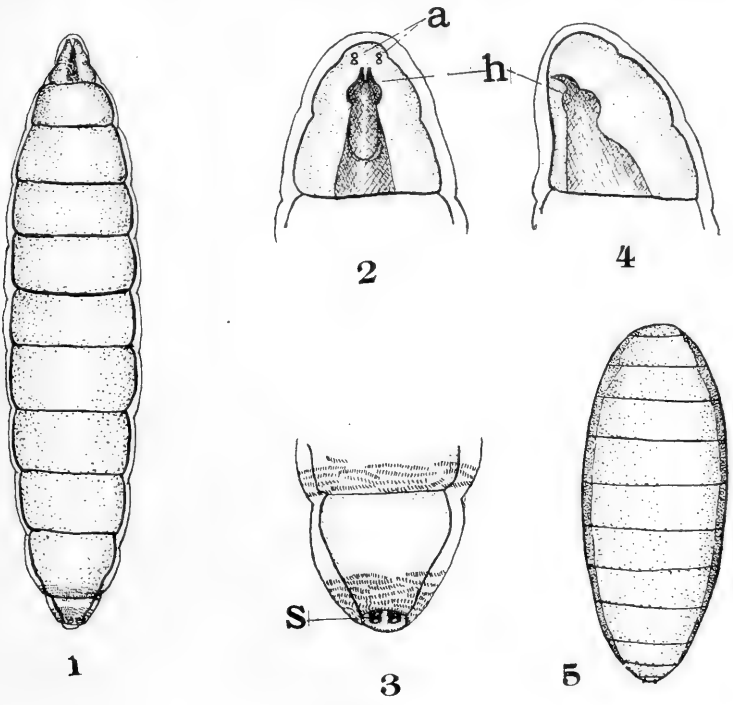


Fig. 1.

1. Dorsal view of full grown larvae.
2. Ventral view of first segment; a, antennae (?); h, great hooks.
3. Dorsal view of last two segments, showing rows of little hooks and s, posterior spiracles.
4. Lateral view of first segment; h, great hooks.
5. Dorsal view of pupa.

The opening of the two large tracheæ at the anterior end are less plainly visible. The main tracheal trunks narrow towards the head, and each branches out into two fine tubes which terminate in small spiracular openings at about the beginning

of the second segment. These, however, disappear after the larva has made two or three moults, and there are no longer any anterior spiracles.

At the extreme tip of the first segment, on either side of the great hooks, there is a pair of wartlike processes, as shown in text-fig. 1. These are probably rudimentary antennæ.

Internal Anatomy. The alimentary canal and Malpighian tubules, (shown in Plate XL, Fig. 1.) are quite characteristic, in their many turns and loops, of Dipterous larvæ in general, especially those of the Muscid kinds. The parasitic life of the larva seems to have resulted in no considerable structural modification of the digestive system.

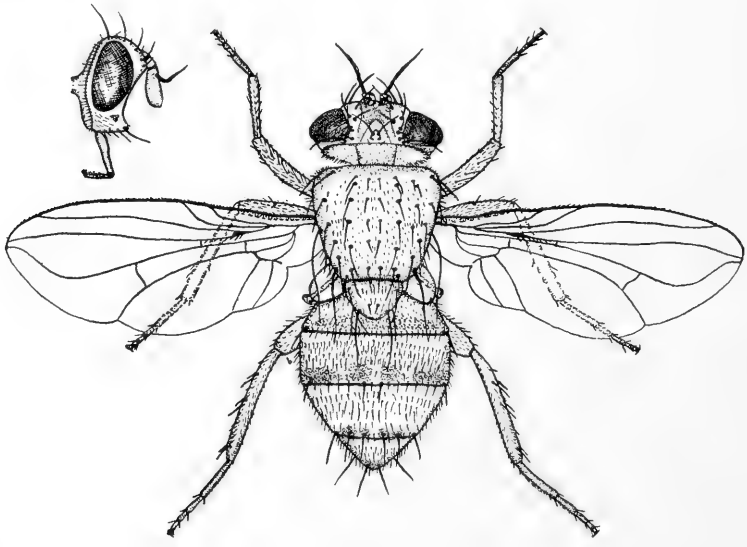


Fig. 2.

Adult fly, dorsal view, showing general characteristics; also lateral view of head, showing proboscis with two geniculations, one near the base and the other near the middle. (Greatly enlarged).

The oesophagus, starting at the mouth, extends backward as a narrow cylindrical tube, passing through the supraœsophageal ganglia, or brain, and then passing above the ventral ganglion and entering the proventriculus, which lies in about the fourth segment of the body. From the proventriculus, the mesenteron, or portion of the canal from the proventriculus to

the Malpighian tubules, is a nearly uniform tube of considerable size, the anterior portion being the chyle stomach and the posterior portion, the intestine.

The Malpighian tubules in this insect are particularly interesting in regard to their position in the body cavity. They arise from the alimentary canal, as shown in the drawing, as two lateral tubes, each of which divides into two tubes. The two from the right side swing forward and the two from the left side run towards the posterior end. This is somewhat different from what would be expected, and is a departure from the general rule. The usual number of tubes is four in the dipterous larvæ, but all four either turn and run posteriorly, keeping to their respective sides, as in the blow fly, or else the right and left branch, each sending one tube forward and one backward.

The portion of the alimentary canal from the entrance of the Malpighian tubules to the anus is the metenteron. This portion is considerably smaller and shorter than the mesenteron and has a thick muscular coat.

The dorsal blood vessel or heart; the tracheal system; the nervous system, and the salivary glands, are shown in plate XL, Fig. 2.

The heart is a thin-walled muscular tube which extends nearly the length of the body, lying in the pericardial cavity just beneath the dorsal wall. It tapers from a good-sized sac to a fine tube as it runs forward.

The tracheal system is composed of two main trunks with large spiracles opening on the posterior segment. Branches are given off from the two main trunks at each body segment and these finer tubes wind in about the alimentary canal. The anterior spiracles are wanting, except in the very young larvæ.

The salivary glands, which extend from the mouth, starting as a single narrow duct, branch out beneath the pharynx and extend, one on either side of the alimentary canal, for more than a third of the length of the body.

The brain and body ganglion, shown in the same figure, compose the nervous system of the larva. The hemispheres encircle the oesophagus just forward of the proventriculus, and the main body of the body ganglion extends backward on the ventral side nearly the same distance that the salivary glands extend on the lateral sides.

The muscles and fat cells are conspicuous, but do not differ particularly from those of other dipterous forms.

I limit my description of the anatomy to the fewest words possible, as the figures and plates tell the story sufficiently. The interesting thing about the anatomy of the larva is that it is so little different from that of any free-living, outside-feeding dipterous larva of Muscid type. Either the parasitic habit makes no less demands on alimentary canal, respiratory, circulatory and secretory systems than the free life habits, or this insect has so recently adopted a parasitic habit that no considerable structural changes in its organs have yet been brought about in connection with it.

This paper was prepared in the Entomological Laboratory of Stanford University.

EXPLANATION OF PLATES.

Abbreviations used:

Antennae	a	Metenteron	Y
Anus	A	Muscle	L
Brain	B	Body Ganglian	N
Fat Cells	F	Oesophagus	O
Great Hooks	h	Proventriculus	P
Heart	H	Salivary Glands	G
Imaginal Discs	I	Spiracles	S
Malpighian Tubules	M	Trachae	T
Mesenteron	X		

PLATE XXXIX.

Cross sections through larvae.

Fig. 1. Section through anterior portion, about the second segment; T, trachea; I, imaginal discs; G, salivary glands; O, oesophagus; L, muscles.

Fig. 2. Section through neuroblast, about the third segment; H, heart; T, trachae O, oesophagus; B, brain; N, sub-oesophageal ganglion; G, salivary glands.

Fig. 3. Section through proventriculus, about the fourth segment; H, heart; F, row of fat cells; T, trachea; P, proventriculus; N, ganglion, G, salivary glands.

Fig. 4. Section through many folds of the alimentary canal, about the fifth segment; H, heart; T, trachea; M, Malpighian tubules; C, alimentary canal; L, muscles.

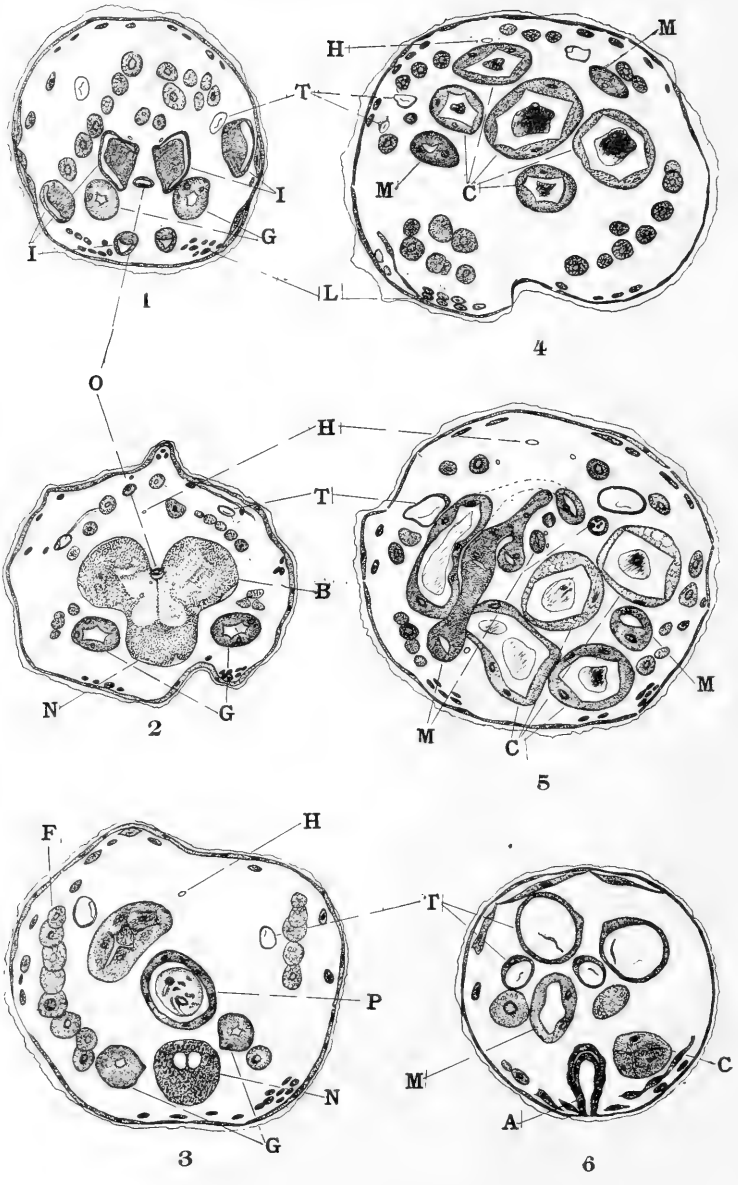
Fig. 5. Section showing Malpighian tubules branching from alimentary canal, about the eighth segment; H, heart; T, trachea; M, Malpighian tubules; C, folds of alimentary canal.

Fig. 6. Section near posterior end; T, trachea; M, Malpighian tube; C, alimentary canal; A, anus.

PLATE XL.

Fig. 1. Horizontal longitudinal view of larva, showing, O, oesophagus; P, proventriculus; X, folds of the mesenteron; Y, the metenteron; M,anterior and posterior Malpighian tubules.

Fig. 2. Vertical longitudinal view of larva, showing, S, spiracle; G, salivary glands; B, brain; N, ganglion; F, row of fat cells; T, trachea; H, heart; L, muscles.



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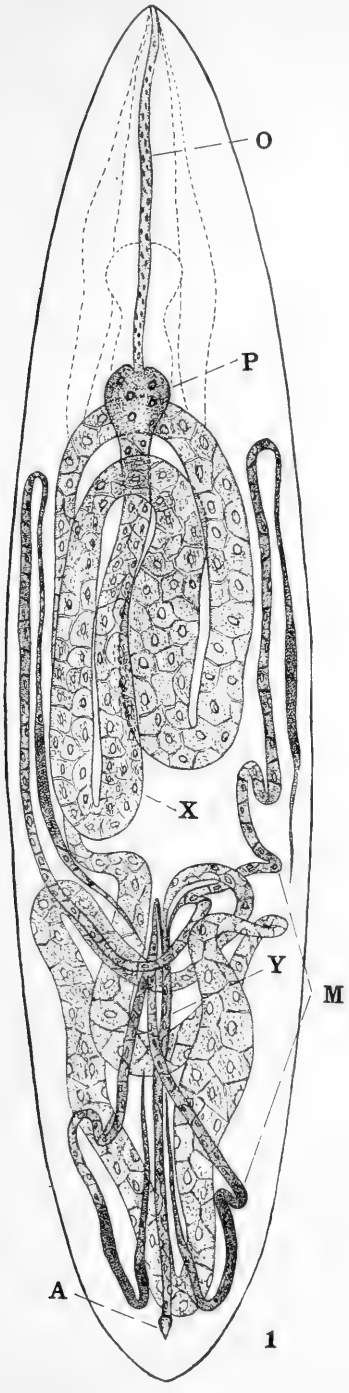

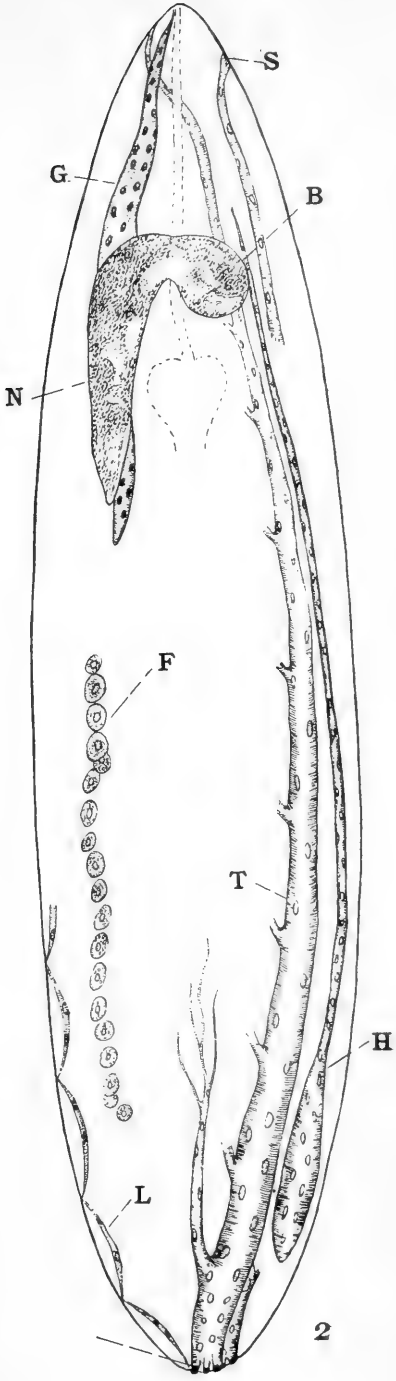

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SOME NOTES ON DIGESTION AND THE CELL STRUCTURE OF THE DIGESTIVE EPITHELIUM IN INSECTS. (Plate XLI.)

By E. J. Newcomer, Stanford University, California.

The ultimate structure of the cell, as it is understood in animal and plant life, is still largely a matter of theory among biologists. A cell appears as a tangible unit, apparently definitely set off from its fellows, and easily discernible with low powers. Yet its exact constitution and its exact relationship to the surrounding cells are not known. So far, scientists have had to imagine how such a structure, with the known functions that it possesses, ought to be composed; it has not yet been possible by actual observation to prove this composition. Many things enter into this difficulty. Cells are very small structures and cannot be viewed with the naked eye. The interposition of a lens or lenses increases the possibility of error. Especially when using lenses of high power is there very little certainty about what is seen. The difficulty of seeing cells in their natural state is great, and resort is had to material that is killed and fixed. Here, even though one is sure of what he sees, he cannot be certain that it is the same as in life. Again, the diversity of cells in different organs and organisms is illimitable, and it is known that even in the same cell the cytoplasm can change its appearance: so that the problem of getting at the typical and final structure and the behavior of this cytoplasm is by no means an easy one.

It was with the hope of possibly finding out some facts that might have a bearing on the general problem of animal cell structure and behavior that I have undertaken a special study of the make-up and behavior of the digestive epithelium in insects, which study permits me to offer the statements and illustrations embodied in the present paper. The digestive epithelium of insects is notable as a cell layer in which rapid changes occur, with a continual production and destruction of cells. Hence it may be presumed to be a tissue in which cell origin and growth may be advantageously studied.

Incidentally, the behavior of the digestive canal of insects is only imperfectly known, and though I have nothing to add either to the various cell-structure theories or to the theories concerning digestion, yet these notes recording what seem to be the actual histologic conditions of the digestive epithelium in a number of insects, and suggesting some possible significance of these conditions, may have a little interest.

First, let us take up the matter of cell structure and cell relationship. The old idea that cells were like so many bricks, each to be considered separately, has had to be discarded; and a multicellular organism can no longer be compared to a brick building. At first sight this may seem to be a proper comparison, but reflection will show that the differences are great. For the cells of an organism are by no means constant; they are continually being built up and destroyed. A cell is injured, or it completes the work for which it was created: it disappears, and a new one takes its place. Cell walls are not mere rigid boundaries; they are elastic, permeable, capable of radical change. These things all go hand in hand with a specialization and consequent interdependence of cells, which makes imperative a study of the behavior of many cells rather than of single cells.

A study of insect digestive cells soon makes it apparent that here a definite and constant cell structure does not exist. Digestive cells are extremely active. Two important types of cell secretion may be distinguished, called by Haseman the holocrine and merocrine types. In the former the whole cell contents is discharged at once, and new cells arise. In the latter the discharge is gradual and continuous and the cell remains active for a long period. I shall take up this matter of secretion more fully in connection with the subject of digestion. The important thing here is to note the marked difference in behavior between the two types of cells.

The holocrine type is very well represented by the digestive cells of the dragon-fly (Needham), or by those of almost any predaceous beetle (Fig. 6). Here the cells are formed in nests or nidi, using Needham's term, and gradually develop and increase in size until they are capable of secretion. Upon the introduction of stimulus in the form of food, the largest cells burst, pouring out their contents to mix with the food, and the

cells in size take their places. Thus we have a regular progression of cells from the very small and scarcely distinguishable ones in the nidi to the full-grown secretive cells. The most interesting point here in connection with the study of cell structure and behavior is the existence of the nidi. What these are and how they originate is a question. They have been variously called "cryptes," "drusenkrypten," and "epithelial buds." None of these terms is very specific, and the idea of these bodies being glandular can hardly be retained, for a gland which secretes nuclei or cells is inconceivable. The nidus appears as a group of nuclei, exactly like those in the fully-developed cells except smaller, crowded together, and with very little protoplasm about them. (Figs. 1 and 2, n). In some instances this group of nuclei is enclosed in a sort of sac protruding out into the muscles surrounding the alimentary canal (Faussek, Frenzel, Rengel), and to this type in particular the term "drusenkrypt" has been applied. More often, however, the nidus is an integral part of the wall of the canal, and there seems to be no special limiting membrane. Are these cell "anlagen" of which the nidus is composed split off from a mother cell? If so, where is this mother cell? Each nucleus of the nidus looks exactly like each other nucleus. Or is the nidus as a whole a cell which produces these nuclei, perhaps by division of its own nucleus? But this approaches the gland idea. As I look at it, it is simply impossible to apply the ordinary theories of cell constitution and cell existence to this structure, this nidus. We must look elsewhere. Mobusz, quoting Adlerz, mentions the presence of a network of protoplasm between the basement membrane and the cell bases, from which new cells arise. We may have to advance a theory of something similar to this to account for the origin of the nuclei in the nidi. If they are not formed by division from others, can they by any possible means be formed from a net of protoplasm? A further and more careful study of these nidi is essential, and will undoubtedly throw light on the general question of cell origin.

Let us turn to the merocrine type of digestive cells, that is, the type where the cell contents is only partly dicsharged as a digestive fluid. This type is to be seen in the alimentary canal of an insect that feeds continuously, thus demanding a con-

tinuous flow of digestive fluid. Haseman describes the larva of Psychoda as possessing this type of cells. It is also the type present in Lepidopterous larvæ, such as the silkworm (Fig. 11), or in the Coccidæ (Fig. 4), which after once settling down, remain attached to their food-plant, and continuously suck in the plant juices. A study of these cells makes it clear that, although no nests of nuclei are present from which the cells are replaced, nevertheless the cells *are* replaced. Haseman has very carefully worked this out in the case of Psychoda and finds that the cells are replaced at the molting period. The old cells degenerate and slough off, and new ones, which he calls regenerating cells appear along the basement membrane. Haseman describes the growth of these cells, but makes no attempt to explain their origin. At once Adlerz' notion of a basal protoplasmic network suggests itself. For, to judge from Haseman's drawings the old cells degenerate completely and no part of them composes the new cells, except, as Haseman mentions, that some of the old material may be absorbed by these cells. We must look elsewhere, then, for their origin, and it is not incomprehensible that some sort of basilar protoplasm may exist, from which these cells spring. My preparations of the silkworm are unfortunately not numerous enough to show all stages of this degeneration and replacement, but it seems evident that it takes place here, in a measure as it does in Psychoda. Fig. 7 is from a sagittal longitudinal section of a young silkworm killed just before molting. There are many large, distended cells (d. c.) which appear to be pouring out their whole contents, but as none of these protruding droplets has ever been found detached, it seems more reasonable to suppose that the cells are degenerating, and that the protrusion is an artifact produced by improper killing. Between these cells are others (ab) with a basal nucleus and a clear lumen. This lumen I believe also has been produced artificially, but aside from this these cells are quite different from the others, and may perhaps be absorptive or mucous cells. Along the basement membrane are numbers of small cells (r. c.), each with a nucleus or occasionally two. These cells I take to be the regenerating cells. Fig. 8 shows a cross section near the basement membrane of this same epithelial layer. The three types of cells appear distinctly.

In Fig. 11 we have in section a portion of the epithelium of a larva that has just molted. Here the large, loosely composed cells are not in evidence, and many of the small basal cells have grown out until they reach the intima. The other type of cell is present also, but is not shown in the drawing. The nodules projecting from the cells here and in Figs. 9 and 10 are interesting in that they seem to have pushed through the intima instead of having stretched it as appears in Fig. 7. They may be artifacts, or more likely they are drops of digestive fluid, such as van Gehuchten has described and figured in Ptychoptera, though I have never found them floating free as he has shown them.

The larva of Dendroctonus, a Scolytid beetle, which burrows into the living wood of pine and other coniferous trees, affords a good example of an insect which feeds continuously, and hence must possess digestive cells which gradually and continuously pour out their secretions. Here the cells are exceedingly regular, each one like the next. There are no nidi to be seen, and no protruding portions are present. The secretion evidently oozes gradually through the intima in small droplets. The only good preparation that I have shows the basal half of these cells to be very compact and darkly staining while the distal half is open and loose. The nuclei are situated just at the bounadry between these two halves of the cells. This particular larva appears, to judge from the condition of the cuticle, to be upon the point of molting, and this division of the cells may be similar to that which Folsom and Welles have described in Collembola.

The digestive epithelium of the Coccidæ, as represented by Lecanium, is very simple (Fig. 4). It consists of a row of more or less regular cells, with here and there one which is greatly enlarged. These large ones are evidently the active, secreting cells, while the smaller ones are developing. Frequently these contain two nuclei, indicating that they are formed by direct division. It would be interesting to see what happens to these cells at molting time, but as the Lecaniums only molt twice (Quayle), and these moltings come while they are still quite small, it would be rather difficult to get preparations.

The digestive phenomena of various insects have been mentioned above briefly and I now propose to take up in order

the insects I have studied, and give more fully some notes regarding this process, and describing the epithelial cells. I shall consider, first, however, the Isopods, which are not insects but Crustaceans.

Murlin, in an excellent paper on the digestive system of the Isopods, shows that here most of the digestive fluid is secreted in a separate organ, the hepatopancreas, the giant cells of which, however, pour out the secretion in much the same manner as those of the digestive epithelium of many insects. The Isopods have proved to be a very interesting and valuable group with which to begin such a study, both because of the simplicity of their organization, and ease of preparing material, and also because of the very large size of the cells.

The Aptera, the lowest group of insects, will always be the source of a great deal of information regarding digestion, and a thorough study of such forms as Lepisma and Japyx would be valuable. Campodea, I found, has a digestive apparatus very similar to Collembola, as worked out by Folsom and Welles, even down to the apperance of the cells. Japyx (Fig. 1) is quite different. Here the mid-intestinal cells are very open, and have a somewhat alveolar appearance. The cell contents is irregularly granular, and contains numerous large clear vacuoles of varying size, which sometimes compose nearly the entire contents. Here and there are scattered dark granules which probably are concretions. The nuclei are small and basally situated, and stain almost black with iron hæmatoxylin, while in preparations stained with Ehrlich's acid hæmatoxylin they are nearly invisible. The cells evidently arise from nidi, although the latter appear to contain more definite cells than is usual. The intima is very thin, and sometimes slight amounts of secretion may be observed in the digestive lumen along the intima.

Lepisma has an extremely interesting digestive system, including a remarkable muscular crop, the posterior end of which protrudes into the mid-intestine. Here the same condition exists which Needham describes as occurring in the Odonata, but in lesser degree (Fig. 2). The active secreting cells, two to four in a group (s. c.) are very sharply marked off from the young, forming cells (y. c.), staining much darker, particularly with the iron hæmatoxylin stain. At the base of

the lighter cells the nidi (n) are to be found, mere rough groups of nuclei containing each a nucleolus and many granules or perhaps alveoles of varying sizes. The developing cells stain very slightly and frequently contain vacuoles. The active cells are longer, and, on account of the secretion which they contain, stain darkly. Both kinds have a fibrillar or palisade-like appearance basally, which extends as far as the nucleus. The inner portions of the active cells are alveolar, or possibly composed of a network, and contain many small highly refractive concretions. There are no distinct cell walls, but there is a periodical thickening of the fibrils, which give the cells a distinct appearance. The intima is moderately thick and traversed by pore canals. Frequently numerous droplets of secretion (sec) may be seen between this and the peritrophic membrane, and sometimes the secretion appears to be streaming from the active cells. In the region just behind the large crop the cells are smaller and more compact.

The termites have a very peculiar digestive epithelium which perhaps can be correlated with their habit of feeding on dead wood. The stomach is bordered with from ten to twenty lobe-like projections, one of which is shown in Fig. 3. Each of these has at its base a nidus of many nuclei, and extending from this to the inner tip of the lobe, the cells overlap each other in a very curious scale-like manner which is evidently only a variation of the typical holocrine method of cell-formation. It is noteworthy that this method should occur in the termites, which live in the wood they feed upon, and at least have the opportunity of feeding continously, whether they actually do or not.

In the order Hemiptera, I have only studied the rather abnormal Coccidæ (Fig. 4), which I have already mentioned. It looks here as though the large cells discharged their contents and were replaced by the smaller ones, which are formed by simple cell division, though I have not observed the process. In contrast to this arrangement we find in Myrmecophila, a small degenerate cricket (Orthoptera) inhabiting ants' nests (Fig. 5), the typical nidi (n), with the regular wave-like arrangement of nuclei between them. Here, besides the intima with its pore canals, there are what appear to be cilia, and at their ends are small droplets of secretion.

I have described the appearance of the epithelial cells in one beetle larva, Dendroctonus. Another larva which I have sectioned, that of a Carabid, is entirely different. The cells are arranged in lobe-like groups with a nidus (n) at the base between each two groups, from each side of which the cells arise and gradually grow and migrate until they become full-sized, when the contents is discharged and others replace them. The larger cells are extremely vacuolate, and irregularly granular basally and distally. The nuclei are fairly large and deeply staining.

The Diptera have been studied by various investigators. Van Gehuchten, in his complete work on Ptychoptera, a Tipulid, was one of the first to point out the method of digestive secretion in insects. Haseman's recent paper on Psychoda describes the conditions occurring in another group, with habits not unlike the Tipulids. It is apparent that in larvæ such as these which live practically submerged in their food, the merocrine type of secretion prevails, and the arrangement of the cells secreting in this manner is manifestly entirely different from that representing the holocrine type. This latter, which we have seen in the Carabid larva, and elsewhere, demands cells capable of storing up the digestive fluids until such time as food may be taken into the canal, for predatory insects necessarily get their food irregularly.

The silkworm is distinctly a continuous feeder. Hence we should expect to find no nidi or nuclei present. At first glance it seems otherwise (Fig. 7) but a closer scrutiny reveals the fact that these apparent groups of nuclei are quite different. In the first place there are fewer nuclei in a group than is usual, and then they are strictly not groups of mere nuclei, but groups of small cells. When we realize, too, that this particular insect was just upon the point of molting, we conclude, as I have previously shown, that these are the new cells which form to replace the old ones sloughed off at the molting period.

But let us examine a just-hatched larva, which has taken no food except the portions of the egg-shell devoured in hatching. The cells are exceedingly regular, and none of the small basal cells to be observed. Most of the cells are deeply staining, granular, with an elongate, central, granular nucleus, and distally containing a few small vacuoles. Frequently another type occurs, lighter, more homogeneous, with basal, rounded nuclei.

These I believe are the absorptive cells and correspond to the cells marked ab. in Fig. 7. Of course this larva has had no plant food yet, but we must suppose that these cells contain something besides food products. As a matter of fact they are much leaner than in older larvæ except for the basal part containing the nucleus, being scarcely distinguishable between the secretory cells. These are beginning to form the secretion, though none of them has any protruding droplets. Larvæ sectioned twenty-four hours after beginning to feed, show some food in the alimentary canal, and some of the secretory cells are giving off small drops of fluid. As the larva grows these droplets increase in size until they appear as in Fig. 10 or 11. The contents of the absorptive cells is homogeneous, and takes the Orange G stain precisely as does the contents of the silk glands, which indicates that it is a product of digestion, as the liquid silk is merely this same product somewhat transformed. The changes in the cells during molting I have already described.

As a killing fluid I found nothing superior to Carnoy's fluid, which is a mixture of 6 parts of absolute alcohol, 3 parts of glacial acetic acid, and one part of chloroform. For general insect work it is entirely satisfactory. The chloroform very quickly dissolves any wax or grease, and allows the insect to sink. It acts quickly, and is very simple to use. The specimens are merely dropped into it, left for a couple of hours, and transferred to alcohol, first 70% and then 85%. There was some distortion and occasionally shrinkage, but I am inclined to believe that this latter was due to some fault in the subsequent treatment. Tower's, Gilson's, hot water, etc., gave no better results, and are not so easily handled. I tried injecting a number of silkworms with the killing fluid, just after dropping them into it, but could see no difference between these and those not injected. The specimens were run through alcohol and imbedded in the ordinary way. Sections were cut as thin as possible. I tried a variety of stains and found combinations either of Ehrlich's acid hæmatoxylin or iron hæmatoxylin with Orange G to be the most satisfactory. Occasional preparations stained with carmine and Orange G brought out points not observable in others. The Orange G is a very desirable secondary stain, as it stains tissues which otherwise would remain almost colorless.

The work here recorded was done and the paper prepared in the Entomological Laboratory of Stanford University by me as holder of the Bernard Scholarship for 1913-1914 in Insect Histology.

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EXPLANATION OF PLATE XLI.

(All are camera lucida drawings except Figs. 3, 4 and 5).

Fig. 1. Epithelial cells of mid-intestine of Japyx. Longitudinal section. X 1160.

Fig. 2. Epithelial cells of mid-intestine of Lepisma. Longitudinal section. X 1160.

Fig. 3. One lobe of mid-intestine of termite. Cross section.

Fig. 4. Portion of mid-intestine of Lecanium. Cross section.

Fig. 5. Epithelial cells of Myrmecophila. Cross section. X 760.

Fig. 6. Epithelial cells of Carabid larva. Longitudinal section. X 760.

Fig. 7. Portion of mid-intestine of silkworm, just molting. Longitudinal section. X 740.

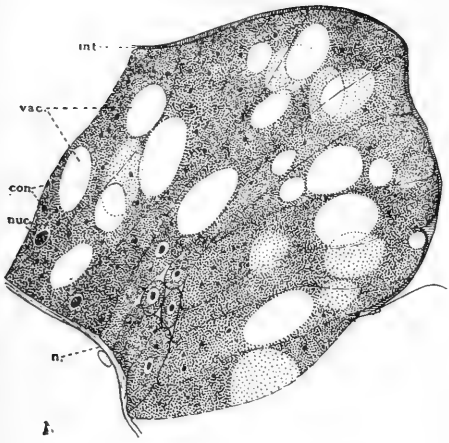
Fig. 8. Cross section through same on line A-B, Fig. 7. X 740.

Figs. 9 and 10. Epithelial cells of silkworm. X 720.

Fig. 11. Portion of mid-intestine of silkworm just after molting. Longitudinal section. X 720.

ABBREVIATIONS.

ab., absorptive cells.
b. m., basement membrane.
c. m., circular muscles.
con., concretions.
d. c., degenerating cells.
int., intima.
l. m., longitudinal muscles.
n., nidi.
nuc., nuclei.
r. c., regenerating cells.
s. c., secreting cells.
sec., secretion.
vac., vacuoles.
y. c., young cells.



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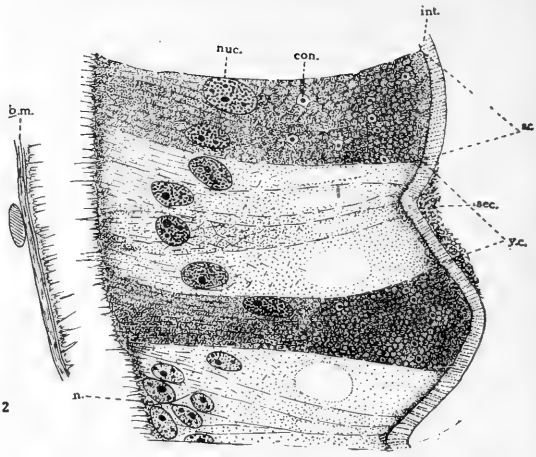

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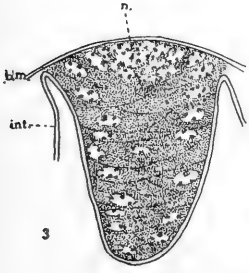

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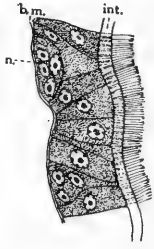

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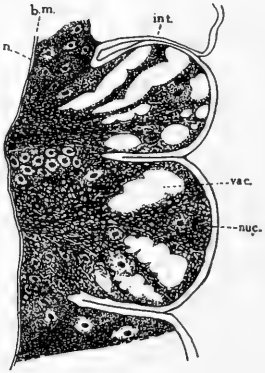

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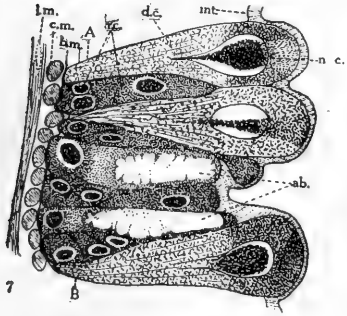

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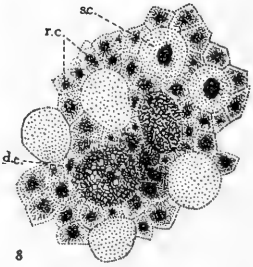

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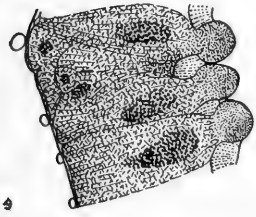

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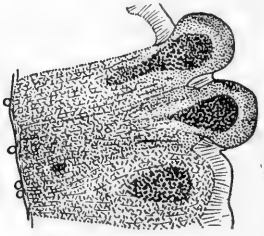

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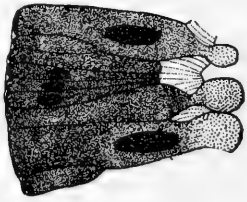

11

E. J. Newcomer

STUDIES IN THE LONGEVITY OF INSECTS.

J. Percy Baumberger.

The investigation of the effect of temperature upon insects discussed below was undertaken at the suggestion of Professor C. W. Woodworth of the Entomological Department of the University of California in the fall of 1911. The purpose of the original problem was to obtain data on the length of the imago stage of the different orders of insects without food and under different temperature conditions.

The present article represents the extension of the original simple experiment to a more comprehensive study of the effects of temperature. The specific problems studied and the conclusions arrived at are as follows:

Part 1. Longevity as affected by different constant temperatures:

(a) is not correlated with systematic groups,
(b) differs inversely with these temperatures,
(c) is approximately proportional with these temperatures, and
(d) is primarily dependent upon physiological factors.

Part 2. Longevity as affected by exposure to two different temperatures:

(a) is increased when the temperature of first treatment is high or low, and
(b) is decreased when the temperature of first treatment is normal.

Part 3. Hibernation as affected by exposure to two different temperatures:

(a) is not brought to a close when the temperature of first treatment is normal and the temperature of second treatment is high,
(b) is brought to a close when the temperature of first treatment is low; is continued for from ten to twenty-one days and is followed by a second treatment at a high temperature, and
(c) is not brought to a close when the first treatment at a low temperature is continued for a period longer than three weeks and then followed by a second treatment at a high temperature.

METHODS.

The collecting of large numbers of insects which were brought alive from the field to the laboratory was greatly facilitated by the use of a net which Professor Woodworth invented some time ago. The advantage of this net is that insects may be procured by sweeping, even in damp weather, without the injuries which are usually the result of such collecting. The making of this net has been previously described by Mr. E. T. Cresson, Jr., who uses it continually for collecting small flies along the sand. Since, however, the net is not as widely known as its advantages deserve, another description will be in place:—

A strong piece of iron wire, three feet, eight inches long, is bent into a circle with a one foot diameter—the ends are then bent at right angles so as to lie adjacent and parallel to each other. These ends are inserted into the small end of a six inch ferrule and soldered fast. A short two foot handle will be found best for sweeping. The net consists of white muslin—a conical bag about eighteen inches deep. The tip is cut off where the circumference of the bag measures about three inches and is replaced by a small cloth bag four by six and a half inches. This small bag is sewed to the point at which the circumference of the large net is four inches, thus leaving a sleeve which hangs down into the small bag—this small bag will just hold a quarter pound paper bag. The sleeve of the large net fits into the paper bag. When filled from a minute's sweeping, the paper bag is pinched at the opening, taken out of the net and placed in a botanical can. Upon the return to the laboratory, the bag is opened at a well lighted window and the contents picked over for specimens.

When insects of one species were found in sufficient number to make it desirable to keep a number of them under observation as a unit, sets of capsules were bound together in tens as devised by Prof. Woodworth for his insecticide experiments. A piece of small iron wire two and a half inches long, sharpened at one end is thrust through the base of a gelatin quinine capsule so that the capsule is on the left of the wire with open end upward—a twist is made in the wire to hold the capsule on—then on the right side with open end in similar position, another

capsule is threaded upon the wire. In like manner, four more pairs of capsules are threaded on. The advantages are that the holes formed by the wire give ventilation and that the similarity of the position of the capsules makes a numbering system possible. The left hand first capsule bears the number of the set of ten written in ink on its face—the other capsules count up to ten in logical sequence from left to right towards the other end.

All insects were placed separately in capsules. If the insects were sufficiently duplicated in collecting, sets of capsules as above described were used. Otherwise the capsules were placed in envelopes, bearing data as to date of collecting, locality, temperature of collecting and temperature of treatment.

The envelopes or sets of capsules were placed on shallow wooden trays at different temperatures, room 62°F.—hot room 72°F or ice room 42°F. Each day the capsules were opened and examined, thus permitting a further change of air. Any insects that had died were removed and a number corresponding to the datum recorded was placed in the capsule. The specimens were generally simply classified to the family. The results are shown in the following table:—

Table 1. Longevity by Families.

Order	Family	Temperature										
		High 72° F.			Medium 62° F.				Low 42° F.			
		Longevity in Days.										
		Max	Ave.	Min.	Diff.	Max	Ave.	Min.	Diff.	Max	Ave.	Min.
Diptera	Mycetophilidæ	1	1	1						3	3	3
	Culicidæ	1	1	1						3	3	3
	Dolichopodidæ	3	3	3	6.0	15	9	3	6	15	15	15
	Syrphidæ					3	3	3				
	Acalyptræ	3	3	3						15	11	7
	Tachinidæ	3	3	3						15	15	15
	Sarcophagidæ					3	3	3				
	Cecidomyidæ	3	3	3		6	6	6				
	Anthomyidæ									3	3	3
	Muscidæ	7	1.6	1	.9	15	2.5	1	1.5	27	4	1
Coleoptera	Carabidæ	10	7	4						10	8	6
	Coccinellidæ	15	15	15						28	21.5	15
	Latridiidæ	15	9	4	5.5	25	14.5	4	7.7	33	22.2	15
	Malachiidæ	3	3	3								
	Tenebrionidæ					2	2	2		5	5	5
	Chrysomelidæ	8	8	8								
Hymenoptera	Curculionidæ	7	5.7	1	1.3	7	7	7	17.6	39	24.6	6
	Cynipidæ	15	5.2	1		8	5	3		15	7.3	1
	Proctotrypidæ					3	3	3		17	17	17
	Chalcididæ	15	5.2	1	.4	7	5.6	1	6.4	17	12	5
	Braconidæ	3	3	3		2	2	2		15	7	3
	Vespidæ	3	1.7	1						3	3	3
	Scoliidæ					3	3	3				
	Myrmicidæ	15	9.5	4						7	5	3
Hemiptera	Lygæidæ									7	7	7
	Anthocoridæ									7	7	7
	Capsidæ	6	2	1						7	7	7
	Membracidæ	3	3	3	.0	3	3	3	1.5	8	4.5	1
	Jassidæ	1	1	1	.0	1	1	1	1	3	2	1
	Aphidæ	3	3	3						15	9	3
	Aleurodidæ									15	15	15
	Coccidæ					15	15	15				
Orthoptera	Tettiginæ					5	5	5				
	Oedipodinæ									5	5	5
	Stenopelmatinæ	1	1	1		7	7	7		7	7	7
Lepidoptera	Nymphalidæ									37	37	37
	Papilionidæ									9	9	9
	Geometridæ									9	9	9
Neuroptera	Hemerobiidæ	3	3	3								

Table 2. Longevity by Orders.

Order	Number of Specimens	Temperature								
		High 72° F.			Medium 62°F.			Low 42° F.		
		Longevity in Days.								
		Max	Ave.	Min.	Max	Ave.	Min.	Max	Ave.	Min.
Diptera	303	15	1.8	1	15	2.5	1	27	4.2	1
Coleoptera	64	15	6.6	1	23	6.5	2	39	20.0	5
Hymenoptera	50	15	5	1	7	4.2	2	17	10.1	3
Hemiptera	24	6	2.5	1	15	5	1	15	6.7	1
Orthoptera	7	1	1	1	7	6	5	7	6.3	5
Lepidoptera	3	.....	.....	.....	.....	.....	.....	37	18	9
Aphaniptera	3	.....	4	.....	.....	3	.....	.....	1	.....
Thysanoptera	3	.....	15	.....	.....	15	.....	.....	15	.....
Neuroptera	2	.....	3	.....	.....	.....	.....	.....	17	.....
Insecta	359	15	4.8	1	23	6	1	39	10.9	1
Arachnida	26	15	8	1	17	13	3	15	8.8	3

In most cases the data are too few to be very significant as to individual groups but are sufficient to draw certain conclusions, viz:

1. That as regards longevity, the taxonomic divisions show little or no comparable variability. That is to say that the amount of variation in an individual species may be as great as the variability of the genus or family or even order making it appear that the average longevity of a large number of insects of one species would give the same results as the average of the same number of many species.

The following table in which the maximum, minimum and average longevity at each of the three temperatures is recorded for the order excluding the family with which it is compared, will show the above statement to be correct.

Table 3. Taxonomic Groups and Longevity.

Order	Family	Temperature.								
		High 72° F.			Medium 62°F.			Low 42° F.		
		Longevity in Days.								
		Max	Ave.	Min.	Max	Ave.	Min.	Max	Ave.	Min.
	Muscidæ...	3	2	1	15	6	3	15	8	3
Other Diptera.....	.....	7	1.6	1	15	2.5	1	27	4	1
	Curculionidæ....	15	9.9	4	25	6.1	2	33	17.3	5
Other Coleoptera...	.....	7	5.8	1	7	7	5	39	24.6	6
	Cynipidæ...	15	5	1	15	5.5	1	17	11.4	3
Other Hymenoptera	.....	15	5.2	1	8	5	3	15	7.3	1
	Chalcididæ	15	5	1	15	5.8	1	17	9.8	3
Other Hymenoptera	.....	15	5.2	1	7	5.6	1	17	12	5

2. That the longevity of insects in general is lengthened by a decrease in temperature and shortened by an increase in temperature (when these temperatures are between 42° and 72° F.)

Table 2 proves this to be true in all except two cases: (a) Coleoptera in general have a slight increase in longevity at high temperatures over that of the medium temperature. (b) Fleas in the three specimens tested show increase in length of life as the temperature increases. (c) (Arachnida have the greatest longevity at medium temperature).

3. That the difference in longevity of a species at different temperatures corresponds roughly to the difference in temperature. Table 4 shows that the greatest difference in length of life is between the longevity at Low and the longevity at Medium temperatures—this corresponds to the greater difference between Low 42° F. and Medium 62°F. as compared with the difference between Medium and High 72°F.

Table 4. Proportion Between Temperature and Length of Life.

Order	Family	Temperature				
		High 72° F.		Med. 62° F.		Low 42°F.
		Longevity in Days				
		Ave.	Diff.	Ave.	Diff.	Ave.
Diptera		1.78	.7	2.5	1.7	4.2
	Muscidæ	1.6	.9	2.5	1.5	4
Coleoptera		6.6	.1	6.5	13.5	20
	Latridiidæ	9	5.5	14.5	7.7	22.2
	Curculionidæ	5.7	1.3	.7	17.6	24.6
Insecta		4.8	1.2	6	4.9	10.9

The most important conclusion arrived at is that longevity is not correlated with systematic groups. Table 3 (Taxonomic Groups and Longevity) upon which this conclusion is based was compiled in each case from the family in which the greatest number of specimens had been included in the experiment. It is not probable that the greater variation in a family than in the average of the other families of that order as is apparent in the table, is due to any greater adaptability to temperature changes in that family than in the others. For a comparison of the maximum and minimum number of days that the representatives of the different families lived will show that individual variation within the family, in the majority of cases where a number of specimens of one species were used in the experiment, is as great as individual variation for the group. This great individual variation is probably due to the physiological conditions of the individual. For example, in the Capsidæ; of the five specimens of one species placed at a high temperature, all died in one day except one which moulted and lived for six days. Apparently the longevity in this case was due to individual physiological conditions and not to any inherent temperature adaptability. Such cases could be multiplied.

We may therefore come to another conclusion, viz:

4. That longevity at different temperatures is due to individual physiological conditions and that any attempt to determine the temperature longevity of the species would be confused by the variability of the results unless these physiological factors were brought into account.

It has been the general belief among entomologists that many insects of the orders Diptera, Lepidoptera and Hymenoptera in the imago stage take no food. Recent experiments (Doten 15) have shown that some parasitic Hymenoptera take food in the adult stage. Closer observations may prove this to be the case with many of the insects which are at present, thought to abstain from food. However, most insects do not feed after the eggs are fully developed. Whether or not, starvation is a factor in this experiment, must therefore be left undecided for the present.

PART 2.

EFFECTS OF EXPOSURE TO TWO DIFFERENT TEMPERATURES ON LONGEVITY.

It was found in Part 1 of these experiments that longevity varied greatly according to the physiological conditions of the individual—in order to obtain further data on the nature of these physiological conditions, the following experiment was performed:

It was thought probable that temperature could produce certain of these physiological conditions—therefore, an attempt was made to find if exposure to a certain temperature for a short time would result in a condition that would be evident in its influence on the longevity of the insect at a secondary and different temperature. The insects used as objects upon which to experiment were the larvæ of the very common oak tree moth (Phryganidia californica). The larvæ were placed separately in capsules, wired together in sets of tens as explained under "Method" in Part 1 of this paper. The sets of capsules were then placed in wooden trays at medium or room temperature at high or the temperature of a bacteriological incubator or at low, the temperature of an ice room, six by twelve by five feet. After two days' preparation at one of these temperatures, the larvæ were transferred to one of the other temperatures where they were kept until starvation resulted in death. The larvæ were examined each day and the date of death recorded.

"Experiment A" represents the results on one hundred young larvæ of the first brood of 1913. "Experiment B" represents the results with eighty-four older larvæ of the second brood of 1912.

Chart I records the results of these two experiments. The abscissa of each of the points marked with circles is the longevity of the larvæ at the constant temperature represented by the ordinate. Each arrow leaving one of these points runs to a point indicating in the same manner the longevity resulting from the treatment at the two temperatures.

Chart I shows that from any change in temperature there results an increased longevity of the larvæ, as follows:

Two Days Treatment at	Followed by	Results in	Longevity at constant
98° F.	58° F.	Same longevity as.....	58° F.
98° F.	68° F.	Increased longevity over.....	68° F.
68° F.	98° F.	Decreased longevity below.....	98° F.
68° F.	58° F.	Decreased longevity below.....	58° F.
58° F.	98° F.	Increased longevity over.....	98° F.
58° F.	68° F.	Increased longevity over.....	68° F.
82° F.	64° F.	Increased longevity over.....	64° F.
64° F.	82° F.	Decreased longevity below.....	82° F.
64° F.	46° F.	Increased longevity over.....	46° F.
46° F.	82° F.	Increased longevity over.....	82° F.
46° F.	64° F.	Increased longevity over.....	64° F.

The exceptions to this rule are in three cases: (a) where 68° F. is the preliminary two day treatment, there is a decrease, (b) where the change is from 98°F. to 58°F. there is no increase and (c) where 64°F. is followed by 82°F. there is a decrease in the longevity.

From the data recorded on Chart I, we may form two conclusions; (1) that the life of the larvæ of Phryganidia californica will be lengthened at any temperature (when starvation is a factor) by placing the insect for two days at either a high or a low temperature; (2) that the life of the larvae of Phryganidia californica will be shortened at any temperature (when starvation is a factor) by placing the insect for two day at a medium temperature.

The temperatures that have been found to have the characteristic effects described are: "High" 98-82°F.

Above 98°F. will probably have other characteristics as 98° F. already shows a transition in that it does not cause an increase in longevity when followed by a low temperature.

"Medium" 68-64°F.

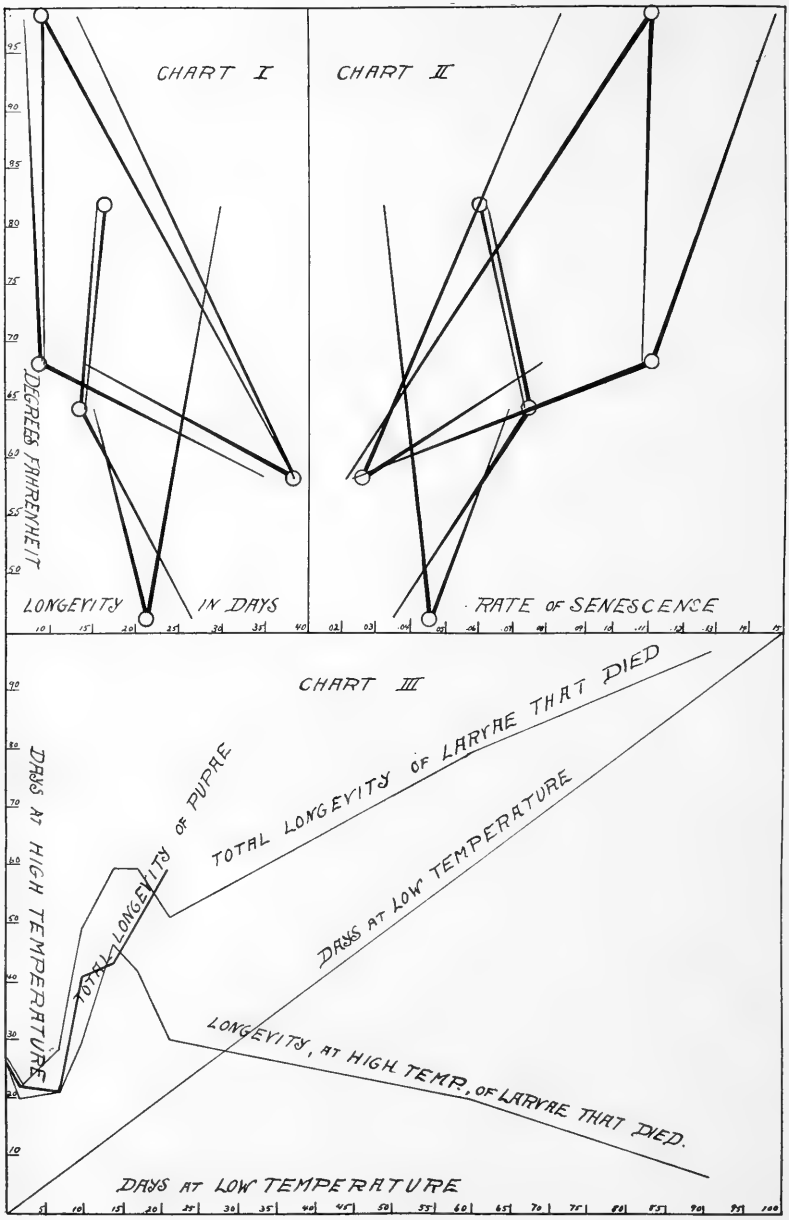
CHART I
CHART II
DEGREES FAHRENHEIT
LONGEVITY IN DAYS
RATE OF SENESCENCE
CHART III
DAYS AT HIGH TEMPERATURE
TOTAL LONGEVITY OF PUPAE
TOTAL LONGEVITY OF LARVAE THAT DIED
DAYS AT LOW TEMPERATURE
LONGEVITY, AT HIGH TEMP., OF LARVAE THAT DIED.
DAYS AT LOW TEMPERATURE

Between 64°F. and 58°F. there must be a temperature with another characteristic for 64°F. holds a transitory position in that it gives an increase in longevity when followed by a low temperature and a decrease in longevity when followed by a high temperature.

"Low" 58-46°F.

These temperatures show the characteristics ascribed to "Low Temperatures."

Since death by starvation is the end of the phase we are studying in this experiment, it was thought that probably a measure of the rate of growth would determine this rate of senescence. Sanderson recommends the following method of obtaining a temperature growth curve, viz: that a "definite valuation" be found "in relation to the accumulation of temperature necessary for any stage of growth" in the following manner: if, at a certain temperature, it requires x days to go through certain phases and this development be considered equal to one unit, then each day's growth at this temperature is equal to $(1 \div x)\%$. Using this method, the following tabulated growth valuations were found:

Table 5. Temperature Growth Valuations per Day.

Exp.	No. Days 1st. Temp	Temp.	Growth Value 1st Temp.	No. Days 2d Temp.	Temp.	Growth Value 2nd Temp.	Growth Value Total
A	9	High	.111 x 9	.....	.....	.....	1.0
	9	Med.	.111 x 9	.....	.....	.....	1.0
	38	Low	.023 x 38	.....	.....	.....	1.0
	2	Med.	.222	5.3	High	.147	1.0
	2	Med.	.222	33.1	Low	.0235	1.0
	2	High	.222	7.2	Med	.108	1.0
	2	High	.222	36	Low	.0216	1.0
	2	Low	.052	11.3	High	.0837	1.0
	2	Low	.052	12	Med.	.079	1.0
B	16.6	High	.0602x16.6	.....	.....	.....	1.0
	13.4	Med.	.0746x13.4	.....	.....	.....	1.0
	22	Low	.0454x22	.....	.....	.....	1.0
	2	Med.	.1492	24.5	Low	.0347	1.0
	2	Med.	.1492	13.6	High	.0625	1.0
	2	High	.1204	12	Med.	.0733	1.0
	2	Low	.0908	13.2	Med.	.0689	1.0
	2	Low	.0908	27.8	High	.0323	1.0

The irregularity of the results given in the next to the last column show that there is some other factor involved in the determination of the longevity of starving larvæ at different temperatures The most probable factor is the rate of metabolic processes for it is the most closely connected with temperature and nutrition, of any of the vital processes. Since the rate of growth and the rate of metabolism will determine how long the insect can live on the reserve material in its body. If the data of Table 5 is plotted in a similar manner to the data of Chart I, the graph on Chart II is obtained.

But if it is true that the rate of growth and of Metabolism determine the longevity it is necessary to bring another factor into consideration before we can explain why a two days treatment at a low temperature will decrease this rate when the insect is placed at a high temperature.

Growth changes in rate with advance in age but is not the process that results in death for while growth is due to the establishment of a constant relation between the nucleus and the cytoplasm and therefore must finally reach a stage where the growth is stopped, senescence always results in a decrease in weight which cannot be accounted for by any theories of growth according to Robertson (43, 44). Still a fall in the rate of metabolism accompanies old age—hence, we must conclude that there is another factor than growth that determines this rate of metabolism. It has been determined that the speed of the metabolic processes decreases with age—therefore, it may be determined by a measure of senescence. The progress of senescence has been defined variously by several investigators. Minot (35) basing his theories on certain truths, which others have used in supporting the theory that a nucleus can control but a limited mass of protoplasm (Sachs and Boveri), has measured the rate of senescence by growth. This has been shown to be improbable as before stated by Robertson and by Loeb (30) and Moore (36) who found that the temperature co-efficient of growth (2.8) is very different from the temperature co-efficient of longevity (1000).

Minot finds that senescence results from a gradual shifting of the ratio between nuclear and cytoplasmic substance (Kernplasma relationship) to the side of the cytoplasm and from the differentiation of the cells which accompany this change. This

differentiation, he claims, is irreversible. He therefore makes no provision for rejuvenation in the Metazoa. C. M. Child (10) has recently constructed a theory, which I will describe shortly, based on certain experiments and upon our present knowledge of the cell activities.

Cells go through two processes—one constructive and beneficial or life-giving, i. e. metabolism—the other destructive, katabolism. Both are necessary to life and a balance is maintained between them—when however, this equilibrium is upset in the direction of the katabolic processes, senescence is the result and finally death. The true measure of senescence then, may be taken to be inversely the rate of metabolism.

In the life processes, many compounds are formed which cannot be made in the laboratory without the use of great heat or chemicals which are incompatible with life. It is believed more and more generally that a study of the physical conditions of the life substance, protoplasm, would throw great light on these processes. Alsberg in his recent paper (2) on the mechanism of cell activities, has given a resumé of present day knowledge and conjecture on the subject.

The nature of protoplasm has been found to be similar to that of colloidal solutions and to emulsions. It is made up of substances that tend to concentrate at surfaces—this concentration and reduction of the size of the phase results in an enormous surface energy, which increases in immense proportion to the smallness or roundness of the surface of that phase or chemical locality. The very general composition of protoplasm, i. e., 80% water, 15-20% solid and 5% fats, would make its rigidity impossible were it not for some emulsified condition. It being a well known fact that emulsions often show great rigidity.

Since these substances have a tendency to form phases or localizations of chemico-physical conditions and since all these phases are in contact and all differ more or less in permeability, it is very possible that they act as a long series of interacting yet separate, semi-porous test tubes. A reaction may go to a certain stage then penetrate into the next phase and while being isolated and going through another reaction, may still influence the first phase—thus making it possible to complete a very complicated and apparently impossible chemical change.

Since the substances of this colloidal or emulsified solution have a tendency to collect at surfaces and when once out of solution (according to Loeb (31) are very difficult to bring into their former condition, permanent, more or less impermeable bars to the process of metabolism may be set up. These may be broken down by a change in the chemical process or a change even in their rate, due to exterior causes of temperature or food quantity.

Childs in some experiments on Planarians finds that the toxicity of alcohol which he uses as a measure of the rate of metabolism varies inversely with the age of the animal, i. e., metabolic processes are being lowered and katabolism is gaining the upper hand. He finds however, that rejuvenation is possible by a change in the rate of these metabolic processes.

Since metabolic processes are carried on through alveolar walls of phases in the protoplasm of the cell and since the longer this process of metabolism is carried on at the same rate and in the same chemical nature, the more permanent these walls become, a lowering of metabolic processes, i. e., senescence due to the establishment of alveolar walls which have through their permanency become bars to the action of metabolism, is the result. He finds however, that a change in these processes will result in an increased rate being possible for them. If an animal is starved for a short time and then fed, its ability to withstand the alcohol is greatly increased—this can be explained by the probability that the processes have gone on in spite of the lack of food and that the actual accumulation of cytoplasmic alveolar walls of obstruction have been destroyed and the cell thus brought into a younger stage of differentiation.

If the animal is starved for only a few days, this increased resistance is very small, upon again refeeding.

The rejuvenation has not gone on to as great an extent, therefore the resistance is less than that of the animal starved for a longer time. A similar result is obtained with animals that have been forced to regenerate parts—the larger the piece is that has been regenerated, the greater the increase in resistance to alcohol. In the case of regeneration, direct visible data has been given by Godlewski (19) showing that regeneration actually leads to a simplification of cells and a reverse process of cytomorphosis that Minot did not take into consideration in

the formulation of his theory. It was also found by Child (11) that the older a Planarian is, the more likely fission i. e., formation of a new individual from a part of the old is to take place. This is probably due to the greater isolation that the tail region of the animal has, because of the clogged condition of the cells as age advances.

An application of these results of Childs, Godlewski and the late experiments of Loeb (32) and Lillie on permeability of membranes will make possible an explanation of all the results of these experiments.

It must be remembered in the first place, and above all that one factor of the experiment was starvation—second, that the insects were placed first for two days at a preliminary temperature and then at a different temperature until they died. Since the result of starvation at a temperature is to clear the cell of cytoplasmic obstacles to a certain degree. The preliminary treatment of an insect with starvation at a temperature will determine to a great extent the results of treatment at a second and different temperature. On the accompanying Chart II, I have therefore plotted, the rates of senescence. They were obtained by finding the value of each day at a certain temperature for completion of a phase but since the end of this period was death, they may serve as the measure of the degree of senescence.

Since death will finally be the result of physiological senescence, due to lack of food, we must bear in mind the distinction between this and natural death which is the result of morphological senescence, the reverse of which is taking place in this case.

Reference to this chart then, will show the degree to which any treatment of temperature will result in combined morphological rejuvenation and physiological senescence. It will be seen:—

1. That preparation at a high or low temperature will result in a combination of physiological oldness and morphological youngness which will make the insect more liable to live, if it be placed in any other temperature, longer than if it had been living constantly at this secondary temperature.

2. That preparation at a medium temperature will render the insect older, both morphologically and physiologically and

therefore less liable to live, if it be placed at any other temperature, longer than if it has been living constantly at this secondary temperature.

The rapid starvation at the high temperature has morphologically rejuvenated the insect but has rendered it physiologically old. This slowing down and probably also change in function has rejuvenated and removed the cytoplasmic obstacles while morphological age, due to destruction of reserve products, has gone on to a less extent than at the high temperature. At medium temperatures, there is no change in rate nor a great enough degree of starvation to remove these inactive substances—therefore the cell is not rejuvenated morphologically and is physiologically old. In other words, the insect is older than the insects prepared by either of the other two methods.

PART 3.

EFFECTS OF EXPOSURE TO TWO DIFFERENT TEMPERATURES ON HIBERNATING INSECTS.

In part 2 of this article, certain studies of the effects of temperature upon the longevity of starving insects were made. In this part, I propose to further substantiate the statements made by the results obtained from certain experiments on the hibernating brood of the Codling moth larvæ (Carpocapsa pomonella L.)

The experiment was started with larvæ collected from windfall apples gathered under the trees and sent by the courtesy of Mr. Frank Perry of Sebastapol, Sonoma County, California, where the insects were collected. These insects were taken in the late part of July, 1913, and many of them pupated. Believing these to be of the earliest second brood, the experiment was abandoned and begun over again with larvæ that were collected in the cocoon—all the two hundred and fifty larvæ of the second experiment were collected in one mass of cocoons under a packing house. There could be no doubt then as to their hibernating condition and as to the similarity of their exposure to temperature, humidity and disease.

The larvæ were handled in the following manner: the cocoons were opened and two larvæ dropped into each clean test tube which was then plugged with cotton. The test tubes

were mixed to avoid the possibility of having a set of larvæ from the same part of the mass of cocoons. The test tubes were placed in round paste board boxes which gave room for seven of them and insured perfect darkness—a long strip of paper was placed in the box upon which was kept a complete record of the temperature treatment.

The insects were kept at three temperatures—room temperature as a check, low temperature in a refrigerator, usually about 43° F., or high temperature 86 to 96° F., maintained by an electric light.

The first experiment performed was to place a set of test tubes at the high temperature—the larvæ of this experiment all died in twenty-six days except one, which pupated, but did not hatch. An attempt was then made to bring the larvæ out of their hibernating condition by first chilling and then heating. Sets were placed in the refrigerator for varying lengths of time —it was found that an exposure to cold of from seven to fourteen days greatly lengthened the life of the larvæ and raised the percentage of pupation and of hatch. This percentage is much higher than that obtained by heat without previous chilling or by exposure to room temperature as in the check.

After fourteen days it will be seen by reference to Chart I that the longevity does not increase and that no pupation occurs. Four conclusions can be drawn from Chart I—

1. That pupation of hibernating Codling moth larvæ is not usually brought about by heat.

2. That exposure of these larvæ to a low temperature for from one to two weeks followed by heat results in pupation, hatch and increase in longevity of those larvæ which do not pupate.

3. That after twenty-one days exposure to low temperature, heat does not result in pupation nor is the longevity increased.

4. The number of days which the larvæ that die, live at the high temperature, is approximately equal to the total number of days, the other larvæ take to pupate.

In order to arrive at some conclusion about these experiments, first, let us consider the nature of hibernation. Hibernation takes place in many forms of insects, fish, Amphibia, Mollusks, birds, Mammals and even in man. Peasants of Russia, according to Cleghorn (12–13) with the approach of

famine, build a fire in a huge stove which serves as a resting place and lying upon this, keep as quiet and warm as possible and thus reduce their need of food. Among the Mammals, the marmot has been the most studied of the hibernating forms. Cleghorn lists a number of animals that hibernate—he states that bats of different species hibernate at different times of the year—that when disturbed for a time, they breathe almost normally and then again, the respiration goes down almost to zero. If awakened suddenly by great heat, death always ensues. He says that bears are as fat after hibernation as when they go into it in the fall and that female bears even raise their young while not obtaining any food and still show very little change in condition. Bears and badgers of the North do not go into any true state of hibernation but sleep lightly through the winter. The black bear, however, is aroused with difficulty from the winter sleep—the woodchuck of Canada, the European hedgehog, chipmunks and ground squirrels, all hibernate. Frogs hibernate in mud at the bottom of pools and if awakened by warmth can remain much longer under water without being drowned than during the active season. Some fish survive long draughts by burial in the mud. Baker (5) states that during some seasons of draught, Lymnæidæ bury themselves and form an epiphragm inside the outer lip as is common with Helix during hibernation and æstivation. Plants have a similar phenomenon also known as hibernation which is closely connected with lowering of temperature and shows itself in the decreased rate of the metabolic processes.

The physiology of hibernation has best been studied by Bellion in the European edible snail (1' escargot). Bellion (6) finds that the moisture content of the air and not temperature is the essential external factor of hibernation—when the moisture content is low, and epiphragm is formed in spite of low or high temperature and the snail is plunged into a condition of lethargy. If moisture content is high, no epiphragm is formed and activity is at its height even at a low temperature. Carbon dioxide content of the tissues increases towards the end of hibernation while the oxygen content diminishes in proportion. Dubois (16) has found in the marmot that when carbon dioxide is present in a certain proportion in the blood, torpor sets in. At moment of awakening, carbon dioxide is high—it is very probable that the carbon dioxide and rehydration

awaken the snail, as the carbon dioxide and dehydration plunges it into sleep. The amount is the essential to sleep or to awakening. Janichen (25) believes that the theory of autonarcosis of carbon dioxide should be held for all cold blooded animals.

The histological changes of hibernation have been studied in the hedgehog by Carlier (9). Plasma cells with deeply staining granules and with lightly staining nuclei are present in great numbers in the base of the tongue—they have the appearance of overfed cells although the fact that they are not found far into the digestive tract, seems, he states, to contradict this appearance. During hibernation the granulations disappear and the tissues of the tongue are less stainable. Numbers of the wandering white blood corpuscles are destroyed by macrophags and their number is recuperated all during hibernation by karyokenetic division in the lymph glands. During this period, some liver cells increase in size followed by an enlargement of the nucleus until the latter, having overstretched the nuclear network, ruptures and disappears—this Carlier believes to be the natural death of the cell.

Insects usually hibernate towards the end of summer when the temperature is falling but they are also known to go into this condition even though placed at a high temperature. Tower (53) found in his experiments with the potato beetle that he was unable under any laboratory conditions of high temperature to bring the beetles into hibernation at an unusual time. Sanderson (47) found that tent caterpillar eggs will not hatch if placed in a green house before being exposed to low temperature, while those which stay out of doors until the temperature falls will hatch rapidly at green house temperature. Merrifield (34) concluded from his experiments with seasonal dimorphism that there is probably a strong tendency for individuals to take either the winter or the summer form in spite of all temperature treatments.

Weismann found that summer forms could be obtained in winter (55), by chilling a pupa and then subjecting it to heat, while on the other hand, if the pupæ were put immediately at a high temperature, they did not hatch until summer. There is further data to show that low temperature is in many cases not the only factor in hibernation. Foster (*) states that of seven-

* Life History of the Codling Moth, U. S. D. A. Bur. Ent. Bul. 97, Part 2, Foster.

ty-eight Codling moth larvæ collected on July 17, at Walnut Creek, Cal., thirty-eight pupated, twenty hibernated as larvae and twenty-eight died. The temperature at Walnut Creek during July in 1909 actually increased three degrees over the mean temperature of June. Most larvæ of the second brood leave the fruit by the first of September and ninety-five per cent. hibernate as larvæ—yet the temperature in September is 3.3° F. higher than the temperature of June. According to Simpson (52), at Grand Junction, Colo., of 33 Codling moth larvæ collected July 16-23, 1900, but one hibernated while of 192 collected from August 30 to September 4, 192 hibernated. The mean temperature of June was 63.3°F. of August 67.8°F. and of September 61.7°. Yet the percentage of larvæ that hibernated had gradually increased from June to September.

Sanderson (47) finds that some Lepidoptera of the North when introduced into the South, do not have an increased number of broods as would be expected nor do southern forms have more than the one hibernating period, which is common to them in their warmer clime when introduced into the North. He bases this statement on the fact that the following insects have but one generation in the South: tent caterpillar, peach borer, plum curculio, canker-worm, gypsy-moth, brown tail moth, and insects effecting native trees, all of which are indigenous to the North. Newell (39) claims that the cotton-boll weavil enters hibernation after the first hard freeze and not due to a mean average temperature of 60° F. or even of 43° F. This is contradicted by Sanderson (46) who claims that weevils hibernate when the average temperature falls below 60° F. Hunter and Hinds (24) agree with Newell in saying that hibernation begins after the first hard frost—though if the insect be deprived of food, it will go into hibernation when the mean average temperature is below 60° F.; at a temperature of 60 to 65° F. however the adults will starve.

Moisture may also be a controlling factor of hibernation as has been shown in the case of the snail in æstivation and hibernation and also in the case of æstivation in the fish and in the Lymnæidæ.

Frogs also go into æstivation during summer as do plants and probably all animal life in arid countries. Loeb (31) points out that lack of water may act similarly to a low temperature—this may account, he says, for the fact that seeds can be kept

alive for so long. The effect of ether on plants is similar to hibernation and since the action of ether is probably a drying, one, this may throw light on the importance of moisture in hibernation. Hunter (24) has found that dryness is desirable for hibernation—he finds that more weevils die during hibernation from exposure to moisture than from cold, on the other hand, high temperature and moisture are the best conditions for weevil larvæ to develop. Sanderson quotes Tower as keeping potato beetles in hibernation for eighteen months in a dry atmosphere. Immediately when placed at a normal humidity, they immerge from hibernation. Donaldson (14) finds that frogs differ in the rate of reabsorbing water during summer and hibernation—it being more rapid in the former—he also finds that the water content of the spinal cord varies with the season—during the growth period (May 30 to July 1) it is high and gradually diminishes towards the end of the season. Rulot (45) has found that during hibernation, the production of metabolic water sometimes falls to zero in the bat. Hatai (21) has found that the effect of partial starvation on the nervous system is to decrease the percentage of water by 24 per cent. upon returning to normal diet, the water content is found to be higher than in the check. Abbe (1) has found that soaking seeds in water before planting accelerates germination but that germination is greatest in dry soil.

Tower states that during hibernation, the cells take on a definite appearance due to loss of water, being shrunken and flattened. In all cells, the protoplasm takes on a colloidal granular appearance which is retained throughout the whole period. The nuclei have an extremely vegetative appearance—it often being impossible to show the presence of chromatin in cells which later will have abundant and active chromatic conditions. There is a twenty-seven per cent. loss of weight due to the emptying of the malphigian tubules of a red fluid and a three per cent. loss of weight due to the emptying of the alimentary canal that takes place just before hibernation in the potato beetle.

Tower believes that this lowering in water content makes the maximum and minimum at which protoplasm can survive change in temperature in either direction, greater. Upon emergence from hibernation the reverse of the process of preparation for hibernation takes place—there is a rapid gain of

water—the cytoplasm becomes more watery, vacuoles appear, the cells become larger and more turgid and the chromatic elements stain deeply and increase in size, thus presenting all the signs of intense activity. The preparation in the potato beetle for æstivation is similar to that of hibernation—the animal remaining underground until first rains. Tower states here that the reduction of water gives an increased capability of meeting higher temperatures.

Hibernation usually follows a period of great feeding—whether this is what makes hibernation possible or whether it is the controlling factor of hibernation or not is unknown. In the marmot, there is a definite storage gland called the hibernation gland and Cleghorn includes in his definition of hibernation, the formation of reserve fat to be used during that period. In the potato beetle, the great period of feeding takes place before hibernation and æstivation (a little less in the latter) this oversupply of food is stored up in the fat body and is used to a certain extent during hibernation for there is a decrease in weight of the insect during that period. The spermophile and the marmot according to Cleghorn go into hibernation immediately after having laid up the last layer of fat. This occurs at a period when their food is most plentiful. The frog according to Holmes (23) goes into hibernation immediately after a period of great feeding. There is some evidence that overfeeding takes place just before hibernation, in the Codling moth for example: Hammar (20) has found that the feeding period of the larvæ of the first brood (transforming directly into pupæ) lasted 24.7 days while that of the first brood which hibernated lasted 28.9 days and the whole second brood (hibernating) 34.2 days. In the next year (1911) he found that the first brood which was to transform had a feeding period of 21.2 days while that part of the first brood that was to over-winter as larvæ fed for 28.2 days. Jones and Davidson (28) find that the second brood feeds twenty days longer than the first and at a higher mean temperature. Jenne (26) finds in like manner that the over-wintering brood of larvæ fed a longer time (.8 of a day) than the transforming brood.

Morgulis (38) has found that during hibernation, the nucleus is nourished by the cell—during starvation on the contrary, the nucleus at first loses volume rapidly though it remains more or less unaffected after it has attained a certain

minimum size. It is possible that by diminishing the volumne it increases its absorbing capacity. Hibernation is also unlike starvation in its characteristic quiescence, for animals when starved are very active. In hibernation also,there is no regeneration of tissues while in starvation this often occurs.

Hibernation seems to have a close connection with the maturation of the reproductive organs. Tower has found that those potato beetles that have gained sexual maturity, do not succeed in passing through the hibernating period successfully. Sexual maturity is seldom gained before hibernation in the second brood of this insect. This activity is greatest immediately following hibernation. He finds that the germ cells remain in the female as oocytes during hibernation and develop rapidly after hibernation. There are two generations in all climates—it would be supposed, Tower says that at high temperatures, breeding would go on continually but every alternating brood has a rest period before breeding goes on—this rest period is æstivation or hibernation depending on climate. All grape leafhoppers that have reached sexual maturity are unable to pass through the period of hibernation successfully—only the very immature males and females live through the winter to produce the next brood (according to Johnson 27).

Morgulis quotes the case of the Rhein salmon which makes a sojourn of from six to nine and a half months in the Rhein, remaining without food, developing in the meanwhile, its sexual elements at the expense of fat and proteids accumulated before hand. Holmes states that the period of great feeding preceding hibernation supplies food for that period and for the development of the reproductive organs which are to come into full activity immediately after hibernation. Hibernating insects seldom arrive at sexual maturity before this period is over. Newell found that the female cotton boll weevils which have hibernated continue to deposit eggs for a much longer time than the others. Morgulis claims that insufficient feeding effects the ovaries the most; since these organs seem to often develop during hibernation, it is very improbable that inanition takes place during this period. Loeb quotes Giard and Caullery as having found that a regressive metamorphosis occurs in Synascidians and that the animals hibernate in this condition. The muscles of the gills of these animals are decomposed in their

individual cells. The result is a formation of a parenchyma which consists of single cells and of cell aggregates resembling a morula. It is probable that a similar disintegration of parts takes place during hibernation and it is certain that it takes place during pupation. According to Sharp, when the larva of an insect has attained its full growth, many internal tissues disintegrate and rudimentary sex organs reabsorb the products of disintegration and with the other regenerative buds produce the perfect imago. On the contrary Jordan claims that the longer duration of the period of oviposition in the newt as compared with many other Amphibia may perhaps be correlated with the absence of the "fasting habit" (29).

The foremost essential factors of hibernation judging from the above observations seem to be temperature and moisture conditions, over-feeding and maturation of the reproductive organs. It is often stated that the loss of water makes it possible for the cell to withstand freezing temperature—for otherwise, as is claimed to be the case in plants (Vines 54) the ice crystals formed would rupture the cells. It is a known fact however that if cooled very slowly cells in which ice crystals have been formed, will again become normal. Tower and Sanderson state that the loss in water of the protoplasm makes it possible for this substance to stand greater variation in temperature for the concentration of salts makes the freezing point lower. But it is a known fact that the freezing point of sols is but sl ghtly lowered by an increase in the concentration of a salt dissolved. They also believe that it makes the protoplasm more able to withstand the high temperature but Loeb and Bachmetjew (3 and 4) have found that the point of coagulation of colloidal substances varies inversely with water content. This may account for the great killing of hibernating insects which Wright (56) ascribes to a rather warm winter.

Most animals that hibernate do so at a period just following great feeding and often at a time when their food is at its greatest abundance, as for example the cotton boll weevil, according to Sanderson (46). In some cases there is cytological evidence of overfeeding—for example, the overfed plasma cells in the hedgehog and the vegetative staining quality of the cells in the potato beetle and as I have found in the Codling moth larvæ. Overfeeding leads to increased number of molts or to hypermetamorphosis according to Sharp (51) who claims that

ecdysis is an extra excretory process. Quaintance and Brues (42) found that highly nutritive foods caused less molts but insufficient and disagreeable food resulted in more molts.

Sharp says that many hibernating larvæ have an extra molt. This may be either a sign of over-feeding or of feeding on some less nutritive substance in larger quantities.

I found in my first experiments with Codling moth larvæ in windfall apples that those larvæ which were about to hibernate remained inactive in the apple for some time (two days to a week) without eating before leaving the fruit to form a cocoon.

If it is granted that there is a condition of over-feeding in the larvæ before hibernating, it will be seen that there are many similarities between this stage and the condition before and during the molt. Before the molt, there is a period of great feeding—then a short period of quiescence, then the histolysis begins.

The process of histolysis is one of rejuvenation—in the second part of this paper, a résumé of the present day knowledge of the process of senescence was given—the most up-to-date and I think the best of these theories is the one advanced by Child. Child, basing his theory on the alveolar nature of protoplasm and on the nature of the metabolic processes and their tendency to lead to structural differentiation in the establishment of cytoplasmic alveolar walls, formulates the following law: "Senescence in nature consists physiologically in a decrease in the rate of metabolism and this is determined morphologically by the accumulation in the cell of structural obstacles to metabolism, e. g., decrease in the permeability, increase in density, accumulation of relatively inactive substances, etc. Rejuvenescence consists physiologically in an increase in the rate of metabolism and is brought about in nature by the removal in one way or another of the structural obstacles to metabolism." Since in the process of pupation, the tissues pass through a more or less complete process of histolysis which is aided by phagocytes, and new tissues often arising from germinal buds absorb this old material (Sharp, Packard (41) and Ganin (18), the cells of these tissues are probably less complex in their cytoplasm. Sharp says that the physiological conditions of the later larval life are different from those of the earlier

life, possibly as the direct result of a mere aggregation of matter—such a histolysis as above described, would reabsorb and redistribute this extra matter in such a way as to clear the cells of all inactive substances. During hibernation in the frog (Morgulis quotes Leonard) a similar process of histolysis and shifting of the nucleocytoplasmic relation in favor of the nucleus takes place. Without doubt, the cells are rejuvenated in the frog during hibernation—the case of Synascidians has already been stated. Lillie has found that fresh water Planarians if exposed to starvation, ultimately return to an embryonic form. These experiments have been confirmed by Schultz (50).

Childs found in his experiments on Planaria that starvation and regeneration both lead to rejuvenation—starvation differs from hibernation in that the life processes go on at a high rate in the former while they are sunk almost to zero in the latter. Starvation does not lead to the lowering of the water content as hibernation does, except in the nervous system. The conditions of the cells in the hibernating or in the starving insect are quite different. In the hibernating animal, the condition is one of overfeeding and probably of old age—that is, the accumulation of inactive substances in the cell is very great. In the starving animal on the other hand, the conditions are morphologically extremely young and physiologically old (underfed). Child compares cells in the overloaded condition to an ovum and the starved young cell to a spermatozoan. Loeb (32) has found that fertilization increases the permeability of membranes. The action of fertilization is the same as rejuvenation. A similar rejuvenation may take place by change in feeding as Calkins (8) has found to be true in his experiments with Paramœcium—where no conjugation took place if a change in feeding were made at the proper time. This agrees with Child's theory that rejuvenation can be brought about by a change in the chemical process of metabolism.

One characteristic of overfed Planarians according to Child is the physiological isolation of parts due to the overloaded condition of the cells with inactive bars to metabolism in the cytoplasm. This isolation leads to fission or to a senescence, i. e., a lowering of the rate of the metabolic processes. In Codling moth larvæ that are about to hibernate, I have found very similar conditions to exist—first, the vital processes are

at a low ebb—second, there is apparently a physiologically isolation of parts—this isolation is evident in the following ways: the larvæ often become entangled or bound by a thread of a spinning larva close by. The bonds which are thus tied about them become so tight that the insect is almost cut in two. I have often observed that the posterior half of the insect may have died from the effect of this isolation and decay set in while the anterior part may remain unaffected for many days. Disease also has been observed in these experiments to spread very slowly through the insect—this also can be accepted as evidence of the overfed and senescent condition of the larva which is about to hibernate. This has generally been found to be the case in hibernating mammals on exposure to disease. (Carlier and Dubois (17).

It seems probable then, that the overfed condition of the insect and the "old" state of the cell has reduced the permeability to a great degree and as a result, the rate of metabolic processes is greatly lowered. The loss of water probably results in the alveolar walls going out of solution and being cast out. In starving Planarians and in those which have undergone regeneration according to Nussbaum and Oxner (40), granules are present throughout the tissues. These granules are absorbed by phagocytes from the body wall—a similar process takes place in the potato beetle during hibernation, according to Tower and is characteristic of the process of histolysis, according to Henneguy (22).

During the molt, pupal period, and apparently in hibernating Codling moth larvæ (as I have observed in my experiments) these granules are very abundant.

From these considerations, it is possible to formulate certain working hypotheses which will serve as guides for further experimentation and consideration of which may throw further light on the nature of the processes of hibernation. These hypotheses are:

1. That temperature is but a single factor and not necessarily the controlling one in hibernation.
2. That hibernation is usually concomitant with overfeeding and may be a result of that condition or the result of accumulation of inactive substances in the cytoplasm of the cell due to feeding on innutritive food.

3. That the loss of water which is general in hibernation probably results in a discharge of insoluble alveolar cytoplasmic structures which have accumulated and produced this premature senility with an accompanying lowering of the rate of the metabolic processes.
4. That starvation during hibernation together with this loss of water may result in rejuvenation, when aided by histolysis, and in increased permeability.
5. That this rejuvenated condition and increased permeability will, if stimulated to activity by heat, permit pupation in Codling moth larvæ, which in this case is the termination of the hibernating condition.

If we remember that the temperature at which colloidal substances coagulate lowers with decrease in water content and that long exposure to cold may result in this decrease in water as well as exposure to high temperature and also the following observations of Bachmetjew, we can explain that the result of a long exposure to cold is the same as the result of a short exposure to heat and that the intensity of the cold, shortens the length of the period (Henneguy):

(a). The relation of the point of coagulation varies with the water content and the point of protoplasmic rigor is also lowered by hunger.

(b). Hunger lowers the critical point in direct proportion to the number of days of its duration.

(c). The intensity of cold shortens the time necessary for cold rigor.

The use of the hypotheses just outlined makes possible an explanation of the results of this experiment. If hibernating insects are placed at a high temperature directly, before being exposed to a low temperature, the characteristics of starvation rather than those of hibernation will set in—in other words, the nuclear material will decrease in greater proportion than the cytoplasmic material. On the other hand, if the insect is placed at a low temperature the characteristic enlargement in the nucleus at the expense of the cytoplasm and due to the low temperature, according to Boring (7), will take place.

With the lowering in the rate of metabolism, due to low temperature, the inactive conditions of the cells and their

enlargement in nuclear material is the ideal condition for disintegration. This has been shown to be the case in the liver cells of the hedgehog by Carlier.

In my experiments, I have found that the tissues of hibernating Codling moth larvæ show the presence of granular substances, immediately after the larvæ have been exposed to the low temperature. Probably these granules indicate cytoplasmic obstructions which due to the disintegration and inactivity of cells have been thus disposed of, leaving the cell in a rejuvenated condition. Tower found in the potato beetle these same granules present in hibernation and immediately after hibernation, a resumption of the activities of the cell, a loss of the vegetative unstaining quality and a more watery and less differentiated appearing condition of the cell. If the insects that are hibernating are exposed for increasing lengths of time to a low temperature and then placed at a high temperature, the tissues will have become rejuvenated and therefore with an increase in temperature, acceleration of the metabolic processes and of growth can take place.

However, if this exposure to cold is of too long a duration, either too much of the water content will have been lost and coagulation corresponding with permanent heat rigor, will set in at a lower temperature than after but a short exposure to cold or disintegration of tissues will have gone on to too great an extent.

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FOUR NEW TETRANYCHIDS.

By E. A. McGregor, Bureau of Entomology.

The following species of phytophagus mites from the Southeast are of considerable economic importance and are herein described for the first time.

Tenuipalpus bioculatus sp. nov.

Female. Body crimson, with two rather well-defined eye-like spots on cephalothorax. Widest at posterior corners of cephalothorax, two-thirds as wide as long. The cephalothorax is narrowed considerably anteriorly, and the abdomen tapers to a rounded tip. The body is armed with a pair of weak spines on the anterior body margin medially, similar spines immediately before and behind the emarginate eyes, six at the posterior tip of the abdomen, a few along the body margin, and scattered ones dorsally. The cephalothorax is hardly half as long as broad, with the anterior margin convex; the palpi greatly resembles the *Tetranychus* type, the penultimate joint bears a strong claw, and the terminal joint (thumb) bears a "finger". The legs are relatively

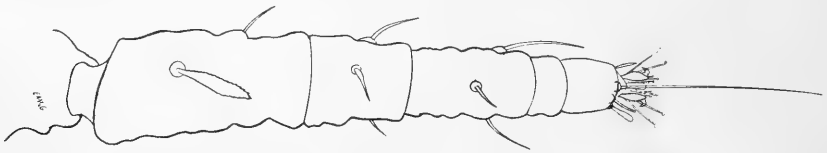


Fig. 1.

Tenuipalpus bioculalus. Right leg I, dorsal view (enlarged 650 times).

stout, crenulated; forelegs in length three-quarters the width of cephalothorax; four anterior tarsi blood-red in life; all legs bearing several lateral hairs, and a terminal bristle in length equalling the three distal segments; the trochanter of the four anterior legs with a lamellate hair placed dorsally; the tarsi with several terminal appendages including a pair of closely appressed claws, a very long bristle, and the four capitate hairs, so frequently seen in *Tetranychus.*

Length, 0.235 mm.; width (hind margin of cephalothorax), 0.149 mm.

The egg is thickly elliptical in linear outline, and measures .096 mm. by .067 mm. It is blood red in color from the first. The eggs are deposited with the long axis perpendicular to the leaf, closely packed (like those of Coccinellids), often comprising clusters of several hundred.

Type No. 19090, U. S. Nat. Mus.

NOTES.

The six posterior spines are much more conspicuous in the younger stages of the larva than in the adult. The molt takes place through a transverse rupture (at the suture between the

cephalothorax and abdomen) quite similar to that of the red-spiders. The male is decidedly smaller than the female, and the abdomen is suddenly constricted behind the cephalothorax and decidedly more attenuate than is the case with the female. The legs of the male are relatively longer, colorless, and the hairs and bristles are more conspicuous.

From Batesburg, South Carolina, on privet (*Ligustrum amurense*), *Rumex acetosella*, *Oxalis stricta* and garden mint (*Mentha spicata*), collected by Mr. F. L. McDonough and the writer, and from Baton Rouge, La., on privet and strawberry, collected by Prof. E. S. Tucker. At Batesburg this pest has been observed frequently to inflict severe damage to privet hedges. Several adjacent bushes are often entirely defoliated which may result in the death of several yards of hedge. The pest attains its greatest abundance and destructiveness during the fall months. Several insecticides were thoroughly tested during the present (1914) season against this species. Schnarr's Insecticide gave complete mortality, with lime-sulphur practically as good. Following are the results of the test.

SPRAYS	MORTALITY
Schnarr's Insecticide	100%
Lime-sulphur (Thomsen Chem. Co.)	99%
Potassium sulphid	90%
"Blackleaf 40"	Less than 5%

Tetranychus yothersi sp. nov.

Predominating color a rusty-red, arising mainly from large internal structures occurring on each side and connected centrally by a narrow isthmus, a shield- or saddle-shaped pale pinkish-amber area includes most of the cephalothorax; a narrow clear or translucent area extends medially from behind almost to the thoracic suture. Eyes crimson, each set at inner border of a groove overlying coxæ I and II. Coxæ and femora of a greenish hue; tibiæ I and tarsi I salmon-color. Palpi salmon-color. Dorsal bristles colorless, not arising from tubercles. Body of female sphero-elliptical, widest equatorially: male subcuneate, widest across cephalothorax which is somewhat truncate in front, abdomen tapering to acute point posteriorly: bristles in four rows, averaging in length two-fifths the width of the body. Mandibular plate less than twice as long as broad, somewhat tapering anteriorly with a distinct emargination. "Thumb" of palpus much reduced longitudinally, bearing at its tip a relatively large, slightly clavate "finger" whose base is almost as wide as the tip of the "thumb"; on its upper distal corner are two pseudo-fingers, not greatly thicker than hairs, on upper side about midway to base is a small "finger" and

between this and base are two short stout hairs; the claw on the penultimate joint reaches to the middle of the "thumb"; a hair arises laterally from the center of the "thumb", and another from a similar position on the penultimate joint. The legs are relatively short, barely as long as width of body; femur only half again as long as wide—exactly equalling tarsus, tibia a trifle longer than patella which equals the trochanter: tip of tarsus bears a claw which is nearly straight for two-thirds its length and then bent to nearly a right angle; a second claw, arising from the other at its point of origin from the onychium, is almost straight and forms with the first an obtuse angle; four strong spurs (corresponding to the usual 4-cleft claw) have their origin in common with the claws; the usual series of four capitate hairs arise by the sides of the claws from the tip of the onychium.

The egg is globose-lenticular and bears a stalk which varies in development from a length equalling the height of the egg to a mere rudimentary papilla; guy fibrils are occasionally seen connecting the egg with the leaf; the color is smoky-amber.

Type No. 19088, U. S. Nat. Mus.

The type material is from Orlando, Florida, August 28, 1914, from the upper surface of camphor leaves, collected by W. W. Yothers. The species is evidently nearest *T. mytilaspidis*, Riley, from which it is easily distinguished through its lack of dorsal tubercles, marked difference in the detail of the palpal characters, emarginate mandibular plate, entirely different proportion one to the other of the leg joints, and through the novel arrangement of the tarsal appendages.

An extensive series of measurements of material on Eucalyptus and camphor from Florida, and on oak, elm and pecan from South Carolina have yielded the following averages:

ADULTS

	LENGTH (not including palpi)	WIDTH	FORELEG
Female	.307 mm.	.237 mm.	.232 mm.
Male	.225 mm.	.152 mm.	.222 mm.

EGG

DIAMETER	HEIGHT	STALK (when well developed
.127 mm.	.082 mm.	.077 mm.

NOTES.

It is of interest to record that, whereas the common red-spiders have long been known to feed almost exclusively on the under surface of the leaf, this species confines its activities entirely to the top of the leaves.

To date, the species has been recorded upon camphor (*Camphora officinale*) and *Eucalyptus* sp. at Orlanda, Florida, and upon two varieties of elm, the willow oak (*Quercus phellos*), the white oak (*Quercus alba*), and the pecan at Batesburg, South Carolina. Mr. Yothers states that at cetrain times it is everywhere present on the camphor tree causing a reddening of the leaves and a reduced vitality of the tree.

The species has been exceedingly abundant the past season (1914) on the foliage of the small-leaved elm (*Ulmus Americana*) to which as early as late June, it imparted a rusty appearance. Trees thus injured have been observed at Batesburg and Columbia, South Carolina, and Laurinburg, North Carolina. During the seasons of 1911, 1912 and 1913 of the Batesburg investigations no evidence of the occurence of this species had been seen. This indicates that the operation of certain factors of natural control must have been suspended during or just prior to the present season. Another observation of interest, is that in spite of the exposure of this species on the top of the foliage very little control seems to be exerted through rains.

Tetranychus banksi sp. nov.

Color rusty-red, from underlying paired organs which occupy all of the dorsal region excepting a median abdominal area and a clear area containg the mandibular plate. Eyes (in mounted material) translucent, directly over suture between coxæ I and II. The usual series of dorsal bristles is lacking, but a series of 18 spatulate-serrate hair-like appendages are distributed on the dorsal aspect of the body as follows: One at either side of mandibular plate anteriorly, one just mediad of each eye, one just overlying each coxa II, six forming a fringe at hind margin of body and three along each side of abdomen. Body of female rhombic-ovate, widest across cephalothorax, exceedingly obese for the size of the legs; cephalothorax rounded generally anteriorly with a slight concave border overlying the palpi: male almost sagitate in outline, conspicuously reduced in proportion to the legs. Mandibular plate about half again as long as wide, tapering somewhat anteriorly, with a distinct emargination and with a superimposed chitinized ridge anteriorly. "Thumb" of palpus subconical, upper surface twice transversely depressed with an intervening dilation, bearing at its tip a long

slender "finger" which is over four times as long as thick; on its upper side arising between middle and tip are two stout hairs, and near the base of upper side arise a reduced "finger" and two stout hairs; the claw of the penultimate joint reaches only to the basal "finger"; a hair arises ventrally from the "thumb", and another laterally from the penultimate joint. Legs of female are of average length barely equalling length of body; those of male are about twice as long as body: femur between four and five times as long as thick—three-quarters again as long as tarsus, tibia somewhat longer than patella which is over twice as long as trochanter: relative length of joints as follows: coxa 9, trochanter 3.75, femur 14, patella 8.75, tibia 10.9, tarsus 8: tip of tarsus not provided with a claw—it being reduced to a vestigial protruberance; the customary series of four capitate hairs arise from the usual point.

Type No. 19089, U. S. Nat. Mus.

The type material from Orlando, Florida, August 16, 1913, from the under surface of castor beans (*Ricinus communis*) and velvet bean leaves. Collected by W. W. Yothers. Evidently allied to *T. latus* of Europe.

NOTES.

Mr. Yothers states that the species is an important pest of the castor bean plant in Florida but that at times it is controlled by a predaceous mite (*Sciulus* sp.) and by the Coccinellid *Stethorus* sp. Larvæ and pupæ of *Arthrocnodax carolina* have been observed on infested castor bean leaves from Orlando, Florida.

An ample series of measurements of material on castor bean from Orlando, Florida, have yielded the following averages:

	LENGTH (exclusive of palpi)	WIDTH	FORELEG
Female	.305 mm.	.267 mm.	.295 mm.
Male	.220 mm.	.197 mm.	.407 mm.

Tetranychus quinquenychus, sp. nov.

There are a number of types of coloration but the general ground-color is reddish-chestnut with the cephalothorax decidedly paler; the prevailing design consists of a large lung-shaped blackish area on each side toward base of abdomen which coalesce medially toward the front, a similar but smaller spot on each side near posterior end of abdomen: legs and mouthparts pale. Body broadest midway between legs II

and III, tapering sharply forward to the narrow, slightly convex frontal margin, also tapering considerably behind, twice as long as broad: bristles rather long and fine, seven each in the dorsal rows and six each in the sublateral rows, frontal pair half as long as subfrontal pair which are placed just in front of the eyes. "Thumb" of palpus very short and stout, on its tip is a blunt "finger" the basal width of which exceeds its length, midway on the upper side is a "finger" equalling the terminal "finger" in length but very slender, at the upper distal corner are two short hairs and two others occur at the upper proximal corner. Mandibular plate of average length with subparallel sides and convex at tip with no emargination. Legs of moderate length; femur I two and one half times as long as broad; tibia I somewhat longer than patella I; tarsus in length equalling tibia and patella together, the tarsal appendages consisting of the usual series of four capitate hairs and a claw which is sharply bent at middle at which point arises distally a strong spur and proximally the usual four claw divisions. There is but a single eye on each side which is set in a shallow submarginal socket directly over coxa II.

Type No. 19087, U. S. Nat. Mus.

Collected at Orlando, Florida, September 28, 1914, on castor bean (*Ricinus communis*), by Mr. W. W. Yothers. This species appears to resemble somewhat *T. tumidus* Banks in the character of the palpus but differs substantially as follows: *T. tumidus*,—body moderately broad: subfrontal bristles not twice as long as frontal pair: only 1 hair on palpal "thumb": sides of mandibular plate narrowed toward tip and concave, tip emarginated: terminal tarsal claw four-cleft. *T. quinquenychus*, body unusually narrow: subfrontal bristles twice as long as frontal pair: four hairs on palpal "thumb": sides of mandibular plate subparallel, tip not emarginated: terminal tarsal claw five-cleft.

MEASUREMENTS OF FEMALE.

Length	.455 mm.
Width	228 mm.
Foreleg	.332 mm.

The relative lengths of the leg joints are as follows: trochanter 10, femur 25, patella 18, tibia 19, tarsus 37.

EXPLANATION OF PLATES.

Plate XLII.

Tenuipalpus bioculatus:

Fig. 1. Front margin of cephalothorax: O, ocular spines; m, median spines; e, eyes (greatly enlarged).
Fig. 2. Female, dorsal view (enlarged 130 times).
Fig. 3. Mouth parts showing left palpus (greatly enlarged).
Fig. 4. Lateral outline of female (enlarged 130 times).
Fig. 5. Tarsal appendages of left leg I, lateral view (greatly enlarged).
Fig. 6. Hind margin of body, dorsal, showing series of 6 spines (greatly enlarged).

All figures were drawn with aid of camera lucida, and figures 3 and 5 were drawn with oil-immersion lens.

Plate XLIII.

Tetranychus yothersi:

Fig. 1. Adult female (from Florida), dorsal view, enlarged 183 times.
Fig. 2. Egg (lateral view) with stalk (from Florida), enlarged 196 times.
Fig. 3. Extremity of left palpus (viewed from outside) showing "thumb", "fingers", claw, and other appendages, greatly enlarged.
Fig. 4. Outline and dorsal pattern of female (from Batesburg), enlarged 151 times.
Fig. 5. Egg (lateral view) without stalk (Batesburg extreme form), enlarged 196 times.
Fig. 6. Tarsal appendages (lateral view) showing onychium, claws, spurs and capitate hairs, greatly enlarged.
Fig. 7. Tarsal appendages (dorsal view), greatly enlarged.
Fig. 8. Adult male (Batesburg form), outline and dorsal pattern, enlarged 129 times.

Figures 3, 6 and 7 were drawn with oil-immersion lens and camera lucida.

Plate XLIV.

Tetranychus banksi:

Fig. 1. Tarsal appendages, a, dorsal view; b, lateral view; greatly enlarged.
Fig. 2. Extremity of right palpus (viewed from outside) showing "thumb", "fingers", claw and other appendages, greatly enlarged.
Fig. 3. Adult male, dorsal view, enlarged 156 times.
Fig. 4. Adult female, dorsal view, enlarged 138 times.
Fig. 5. Front margin of cephalothorax.

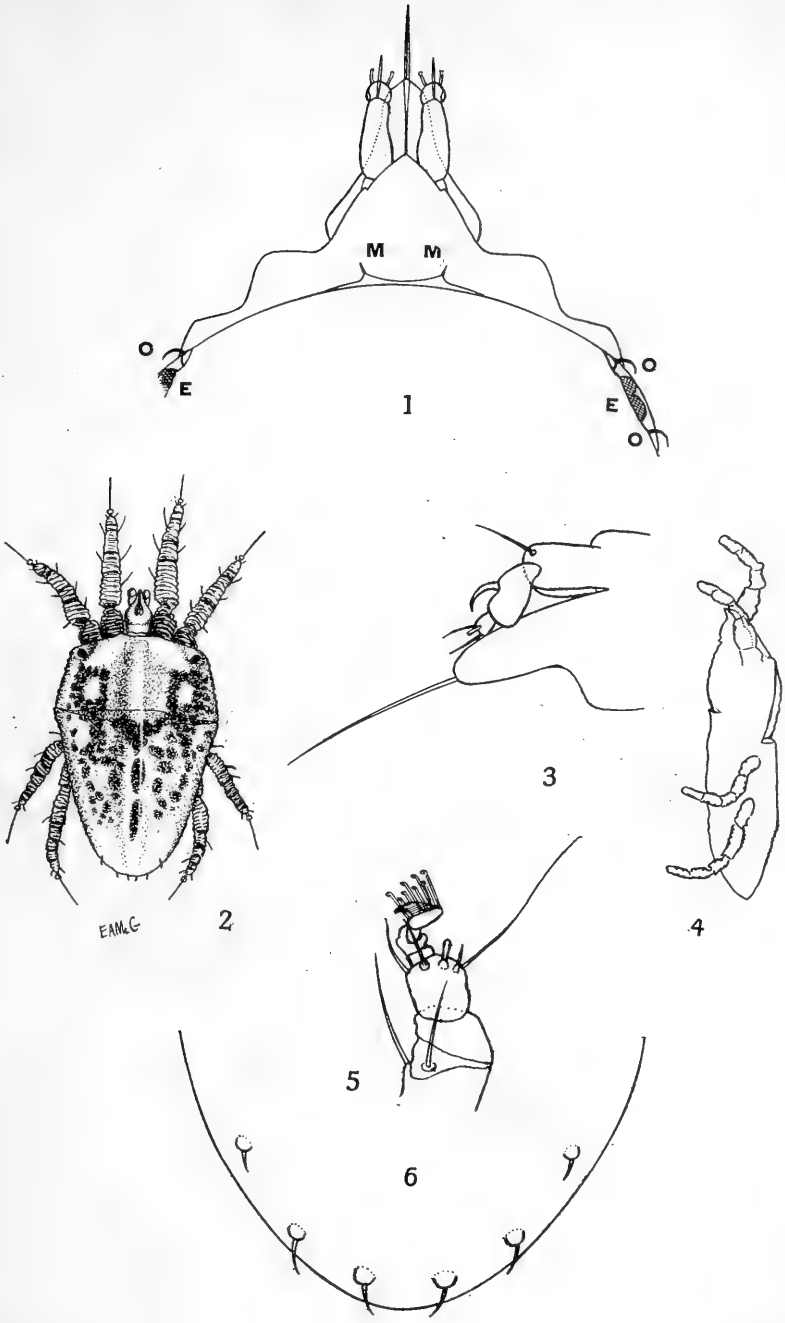
All figures drawn with the camera lucida; figs. 1 and 2 drawn with oil-immersion lens.

Plate XLV.

Tetranychus quinquenychus:

Fig. 1. Tarsal appendages, ventral view.
Fig. 2. Extremity of palpus showing "thumb", terminal "finger", dorsal "finger", "thumb" hairs and penultimate claw.
Fig. 3. Tarsal appendages, lateral view.
Fig. 4. Left eye, seen from above.
Fig. 5. Right foreleg, dorsal view.
Fig. 6. Female, dorsal view (leg bristles not shown).

(Figs. 1, 2, 3 and 4 drawn with oil-immersion lens and camera lucida. Fig. 6 enlarged 150 times.)



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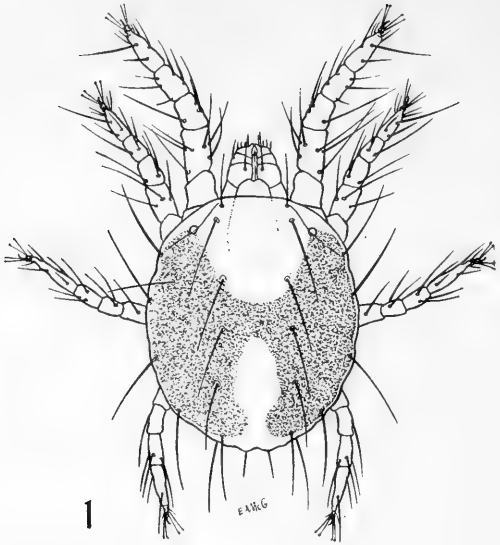

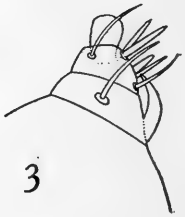

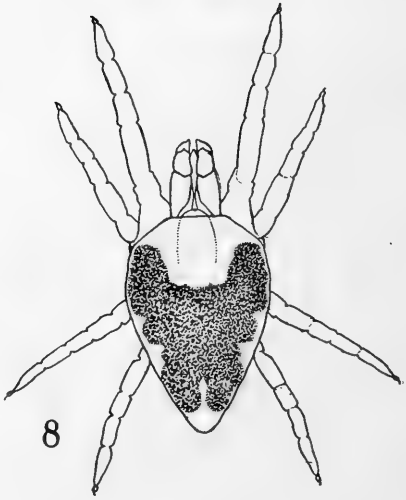

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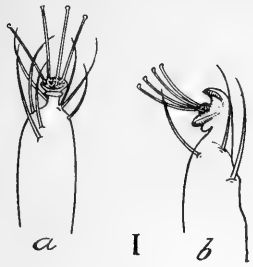

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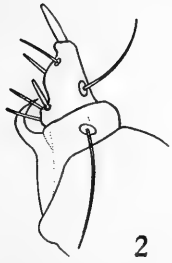

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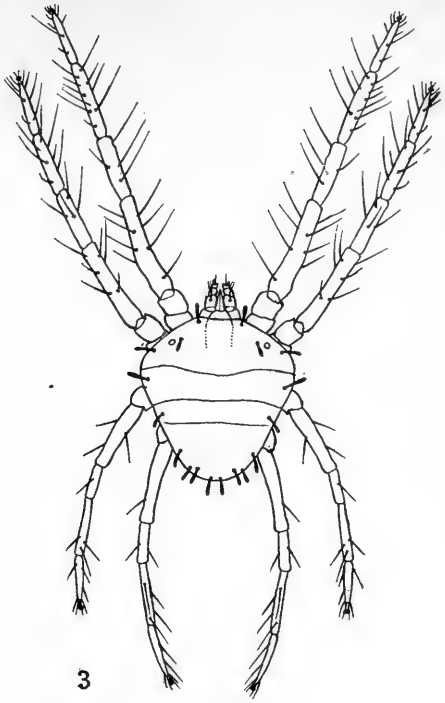

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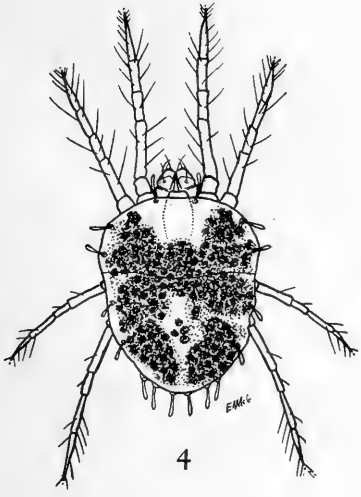

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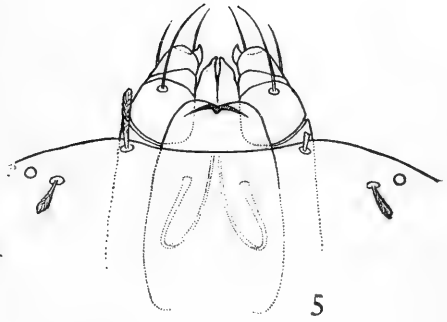

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