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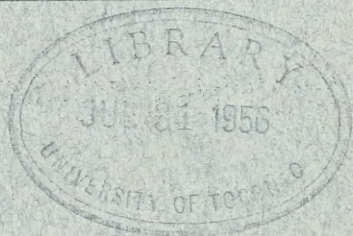
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The Entomological Society of America



DECEMBER, 1914

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CONTENTS OF VOLUME VII.

	PAGE
TRIGGERSON, C. J.—A Study of <i>Dryophanta Erinacei</i> (Mayr) and its Gall....	1
CHILDS, LEROY—The Anatomy of the Diaspinine Scale Insect <i>Epidiaspis Piricola</i> (Del Guer).....	47
GILLETTE, C. P.—Some Pemphiginae Attacking Species of <i>Populus</i> in Colorado	61
ZETEK, J.—Dispersal of <i>Musca Domestica</i> Linne.....	70
HOUSER, J. S.— <i>Conwentzia Hageni</i> Banks.....	73
MOORE, WM.—A Comparison of Natural Control of <i>Toxoptera Granimum</i> in South Africa and United States.....	77
HOWARD, L. O.—Report on Parasites.....	86
FERNALD, H. T.—Notes on Some Old European Collections.....	89
MACGILLIVRAY—Proceedings of the Atlanta Meeting.....	97
FORBES, WM. T.—A Structural Study of the Caterpillars; III, The Somatic Muscles.....	109
WELCH, PAUL S.—Observations on the Life History and Habits of <i>Hydromyza Confluens</i> Loew, (Diptera).....	135
CRAWFORD, J. C.—Some Species of the Bee Genus <i>Coelioxys</i>	148
TOWNSEND, CHAS. H. T.—Connectant Forms Between the Muscoid and Anthomyioid Flies.....	160
PETRUNKEVITCH, ALEXANDER—Spiders Collected by Mr. C. William Beebe in Burma and Borneo.....	169
SEVERIN, HENRY H. P., SEVERIN, HARRY C., HARTUNG, WM. J.—The Ravages, Life History, Weights of Stages, Natural Enemies and Methods of Control of the Melon Fly (<i>Dacus Cucurbitae</i> Coq.).....	177
PALMER, MIRIAM A.—Some Notes on the Life History of Ladybeetles.....	213
ALEXANDER, CHAS. PAUL—On a Collection of Crane Flies (<i>Tipulidae</i> Diptera) from the Fiji Islands.....	239
GAHAN, A. B.—A New Species of <i>Cheiloneurtus</i> with a Key to the Described Species from the U. S.....	247
TOWER, DANIEL G.—Note on the Number of Spiracles in Mature Chalcid Larvae.....	249
NOYES, ALICE AYR—The Biology of the Net-Spinning Trichoptera of Cascadilla Creek.....	251
MOSHER, EDNA—The Classification of the Pupae of the <i>Ceratocampidae</i> and <i>Hemileucidae</i>	277
BLOESER, WM.—Notes on the Life History and Anatomy of <i>Siphona Plusiae</i> ..	301
NEWCOMER, E. J.—Some Notes on Digestion and the Cell Structure of the Digestive Epithelium in Insects.....	311
BAUMBERGER, J. P.—Studies in the Longevity of Insects.....	323
MCGREGOR, E. A.—Four New Tetranychids.....	354

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Volume VII

DECEMBER, 1914

Number 4

THE BIOLOGY OF THE NET-SPINNING TRICHOPTERA
OF CASCADILLA CREEK.*

MISS ALICE AYR NOYES.

CONTENTS.

	PAGE
I. Introduction.....	251
II. Catching-nets of the Families Hydropsychidæ, Philopotamidæ, Polycentropidæ.	
Family Hydropsychidæ.....	252
Family Philopotamidæ.....	259
Family Polycentropidæ.....	260
III. The Aquatic Situation.....	265
IV. Food.....	266
V. Experimental work on Hydropsyche Nets.....	268
VI. Bibliography.....	271

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 HYDROPSYCHIDÆ, PHILOPOTAMIDÆ, POLYCENTROPIDÆ.

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 diagrammatic 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 $1\frac{1}{2}$ 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 *Chimarra*. The nets of *Chimarra 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 leads 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 fascinating 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, seize 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 $5\frac{1}{2}$ 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*, *Chironetes* 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 *Simulium* 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. *Diffugia* 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 *Chimarra* *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 *Protococcales*; 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 ($\frac{1}{4}$ in. by $\frac{1}{4}$ 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.

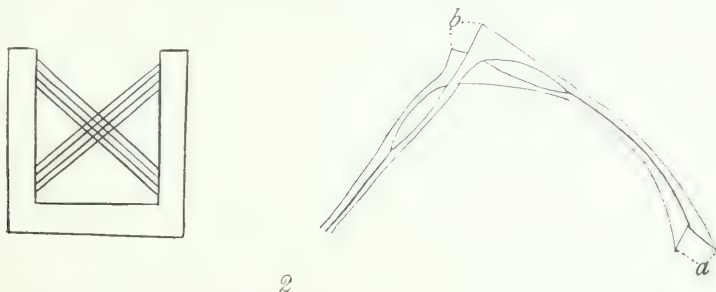
By the above methods, the following results have been obtained.

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.



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.

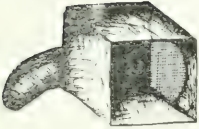
PLATE XXXVII.

- 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 mesh-work 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.

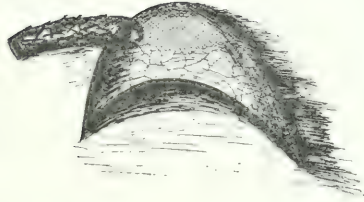
PLATE XXXVIII.

- Fig. 1. Catching-net of *Chimarra 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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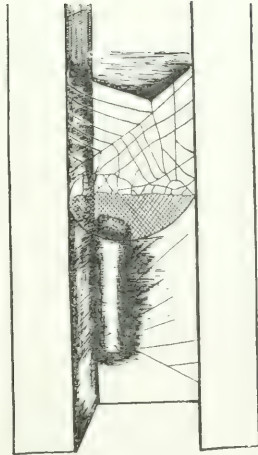
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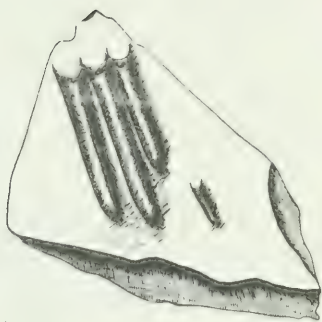


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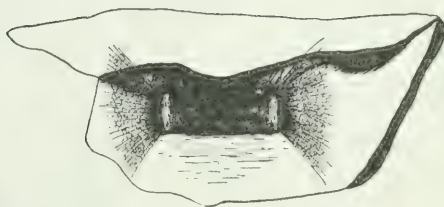


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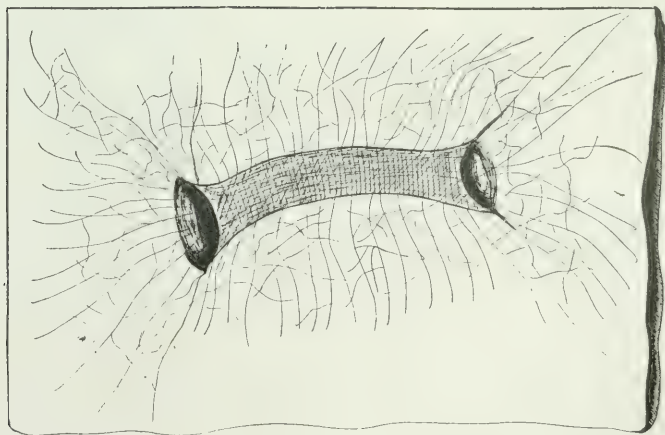




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2



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 tubercle 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.

* 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 tubercles; 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 tubercles 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; antennæ with the central axis bearing a row of prominent spines curved caudad; if without prominent spines on the thoracic segments and antennæ, then the maxillæ, 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; antennæ with the central axis never bearing prominent spines, the spines never curving caudad; maxillæ, 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 tubercles at the bases of the wings; metathorax with a prominent oblong tubercle 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 tubercle on each side the meson on the caudal half of the segment, a tubercle scar laterad of each tubercle and in line with it, and a smaller tubercle 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 tubercle 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 tubercle 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 proximo-lateral 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 $1\frac{3}{4}$ " 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 tubercle 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 tubercle; 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 $1\frac{1}{2}$ " to $1\frac{3}{4}$ ", 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 $1\frac{1}{2}$ " to $1\frac{3}{4}$ ", 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 lacinate 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; meta-thorax with a prominent oblong tubercle 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 lacinate 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 lacinate 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 tubercle 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 tubercle 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 tubercles 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 tubercle scars on each side the meson, sometimes spine-like, seldom all prominent; metathoracic tubercles 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 proximo-lateral 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 tubercles 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 tubercles 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 tubercles, 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 tubercle scar on each side the meson indicated by a small polished area; mesothorax without prominent spines; metathorax with the tubercles 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"—1 1/4"; 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 lacinate spine on the face parts near the proximal end of each antenna; epicranial area with a long lacinate 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 tubercles 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 tubercles irregular, somewhat diamond-shaped, black and polished, irregularly impressed or punctate, each tubercle 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 tubercles; 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 tubercles on each side the meson. maia
- AA. Suture between the seventh and eighth abdominal segments not very deep, the edges without distinct crenulations. olivæ

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 $1\frac{1}{4}$ ".

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 $\frac{3}{4}$ " 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 tubercle 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 $1\frac{1}{4}$ ".

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 $1\frac{1}{2}$ ".

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 cocoons. 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 tubercle each side the meson on the metathorax and first three abdominal segments. *pamina*
- CC. Mesothorax tuberculate with blunt conical projections; never with small tubercles 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 1 1/4"; girth about 1 3/4".

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"—1 $\frac{1}{4}$ ", expanded, 1"—1 3-8"; girth 1 $\frac{3}{4}$ "—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, $1\frac{1}{4}$ "— $1\ 5\text{-}8$ "; girth about $1\frac{3}{4}$ ".

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 $1\ 1\text{-}8$ "; girth about $1\frac{1}{2}$ ".

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 Coquillett 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 posterior 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 allowed 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).

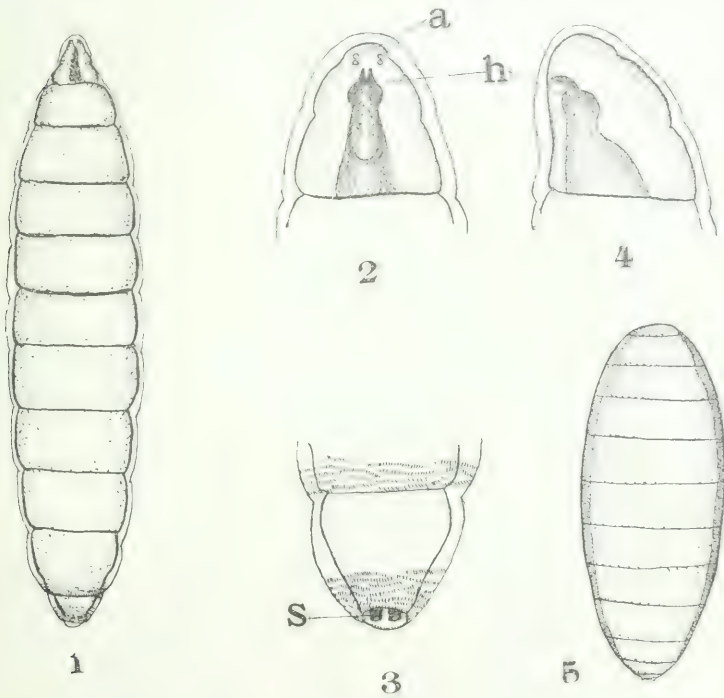


Fig. 1.

1. Dorsal view of full grown larvæ.
2. Ventral view of first segment; a, antennæ (?); 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.

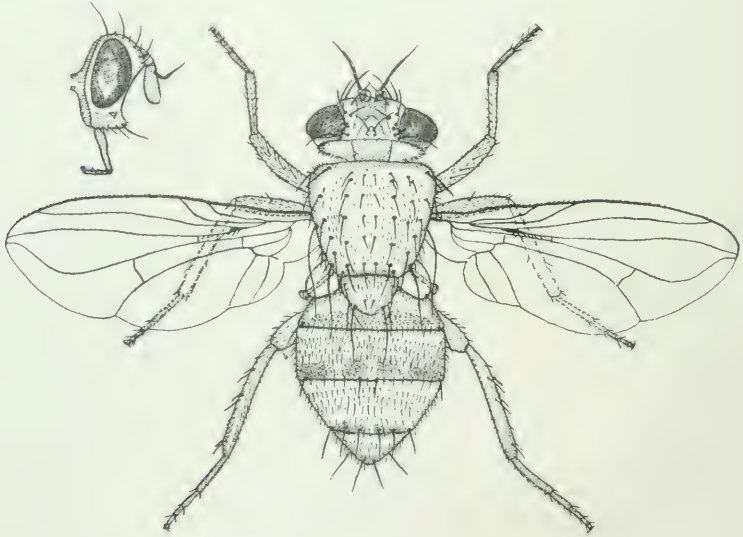


Fig. 2.

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 supracerebral 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 Ganglion.....	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		

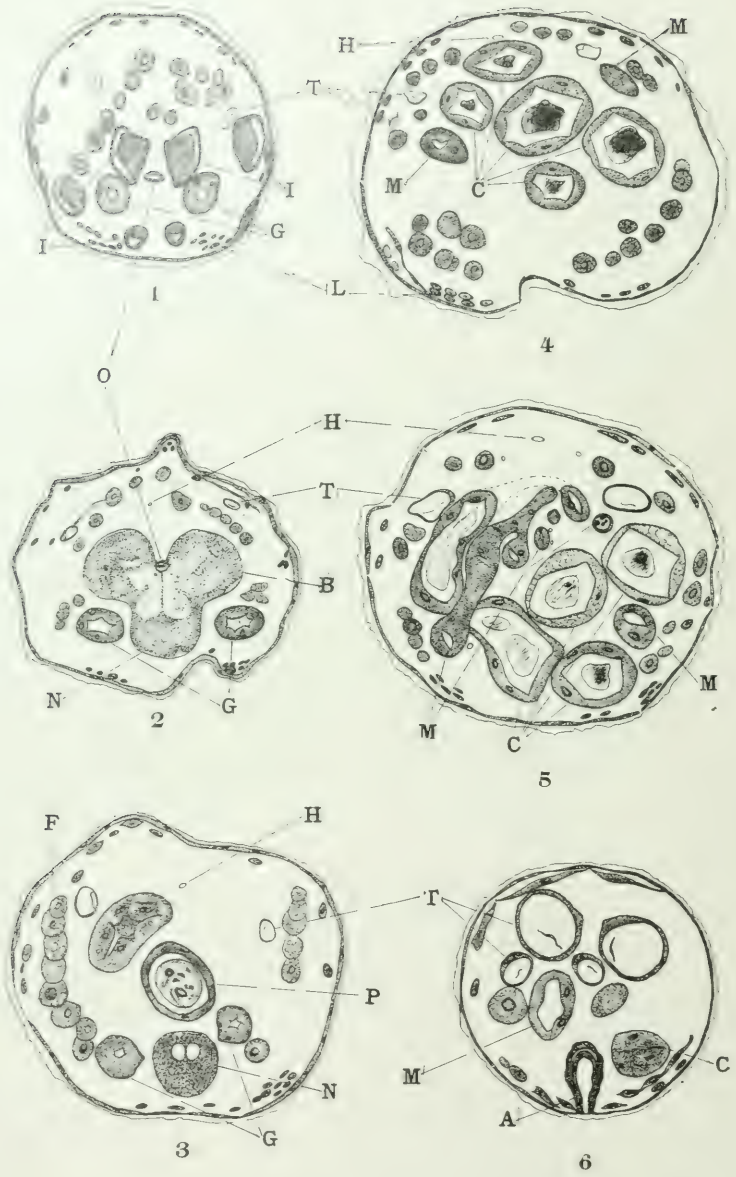
PLATE XXXIX.

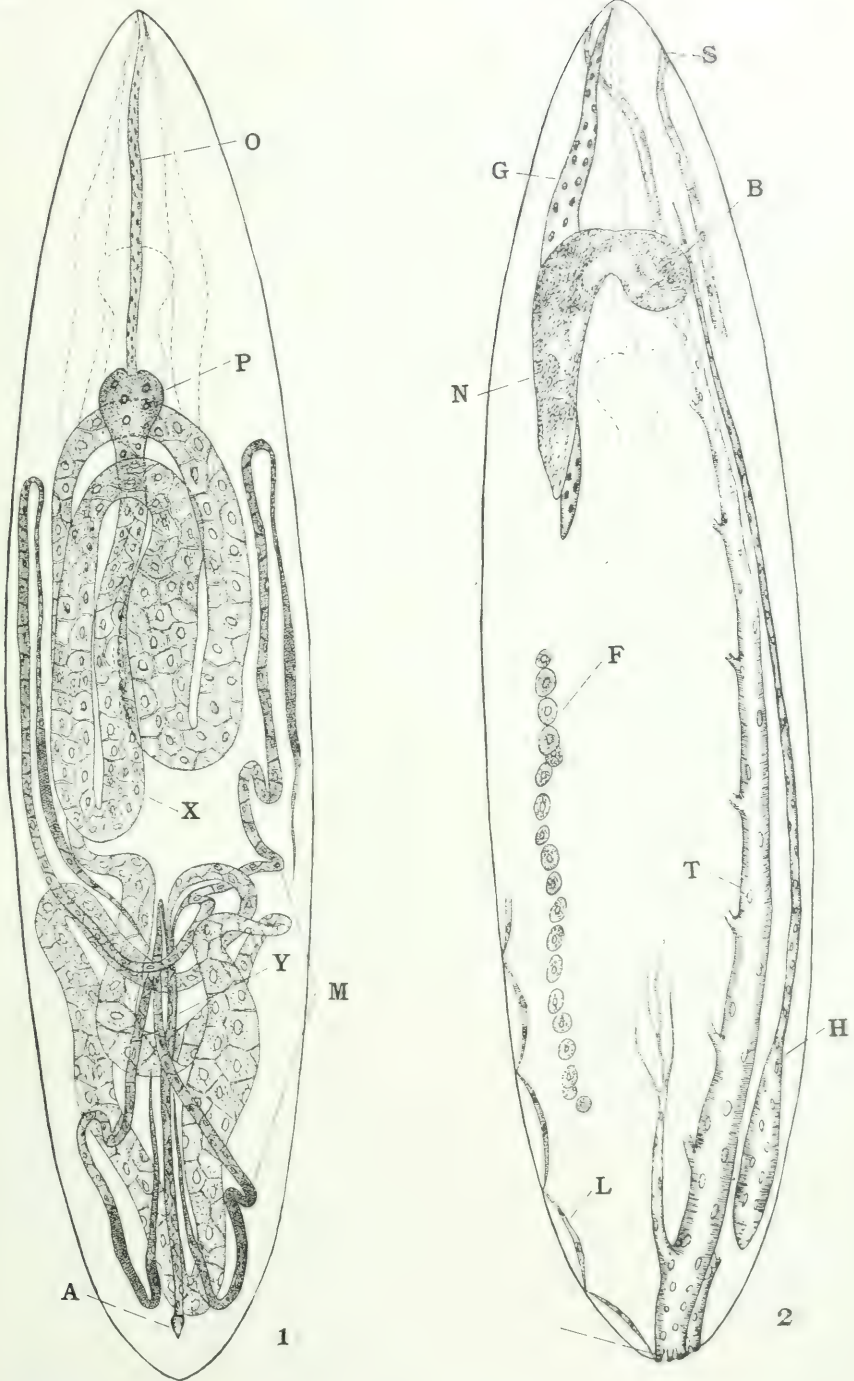
Cross sections through larvae.

- 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.





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 discharged 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 boundary 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 appearance 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—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 continuously, 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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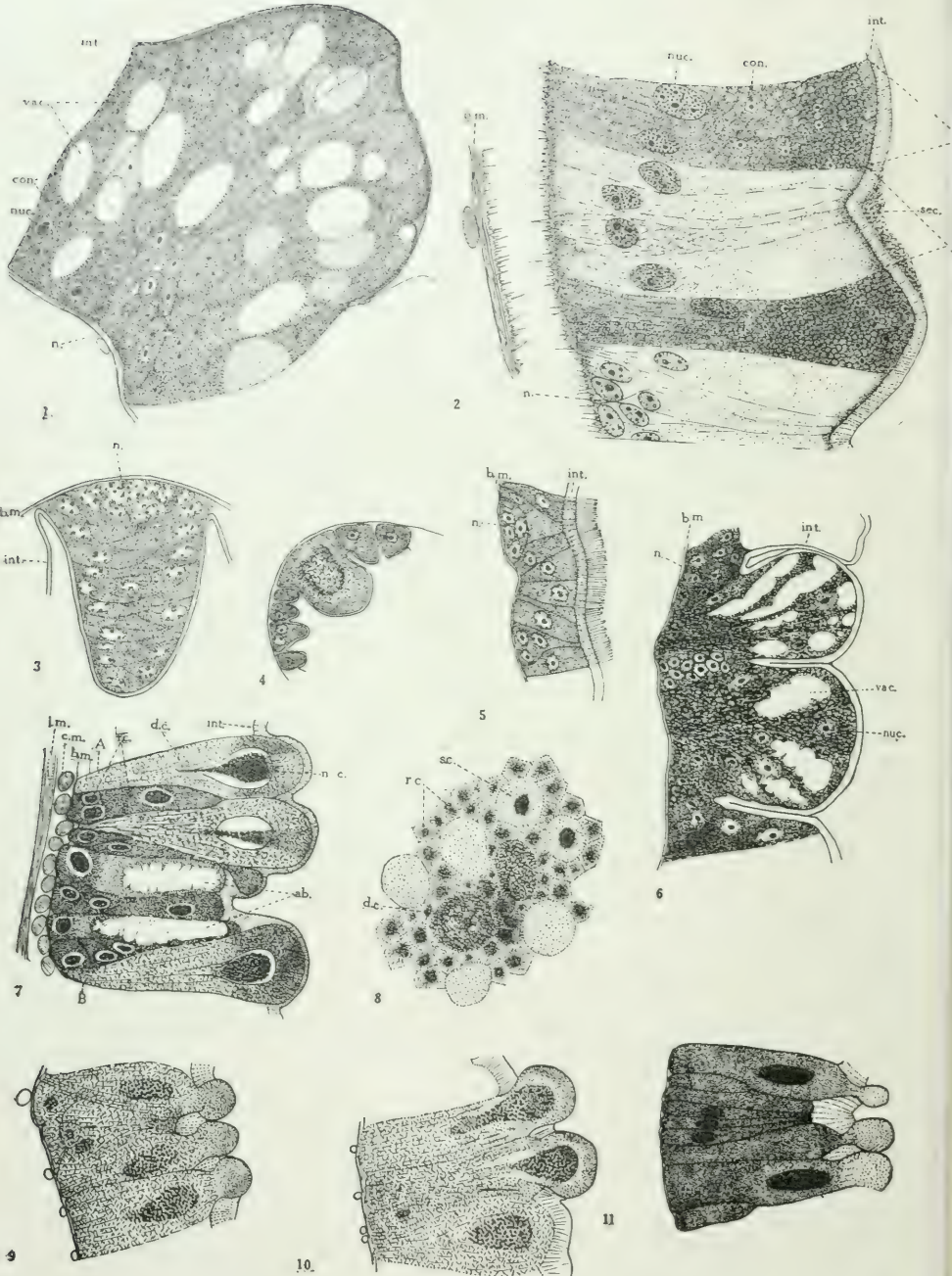
EXPLANATION OF PLATE XLI.

(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. | n., nidi. |
| b. m., basement membrane. | nuc., nuclei. |
| c. m., circular muscles. | r. c., regenerating cells. |
| con., concretions. | s. c., secreting cells. |
| d. c., degenerating cells. | sec., secretion. |
| int., intima. | vac., vacuoles. |
| l. m., longitudinal muscles. | y. c., young cells. |



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 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	.....			.....			.....
Thysanoptera.....	3	.....			.....			.....
Neuroptera.....	2	.....			.....			.....
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.
Other Diptera.....	Muscidæ...	3	2	1	15	6	3	15	8	3
	.....	7	1.6	1	15	2.5	1	27	4	1
Other Coleoptera...	Curcu- lionidæ...	15	9.9	4	25	6.1	2	33	17.3	5
	.....	7	5.8	1	7	7	5	39	24.6	6
Other Hymenoptera	Cynipidæ...	15	5	1	15	5.5	1	17	11.4	3
	.....	15	5.2	1	8	5	3	15	7.3	1
Other Hymenoptera	Chalcididæ	15	5	1	15	5.8	1	17	9.8	3
	.....	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.

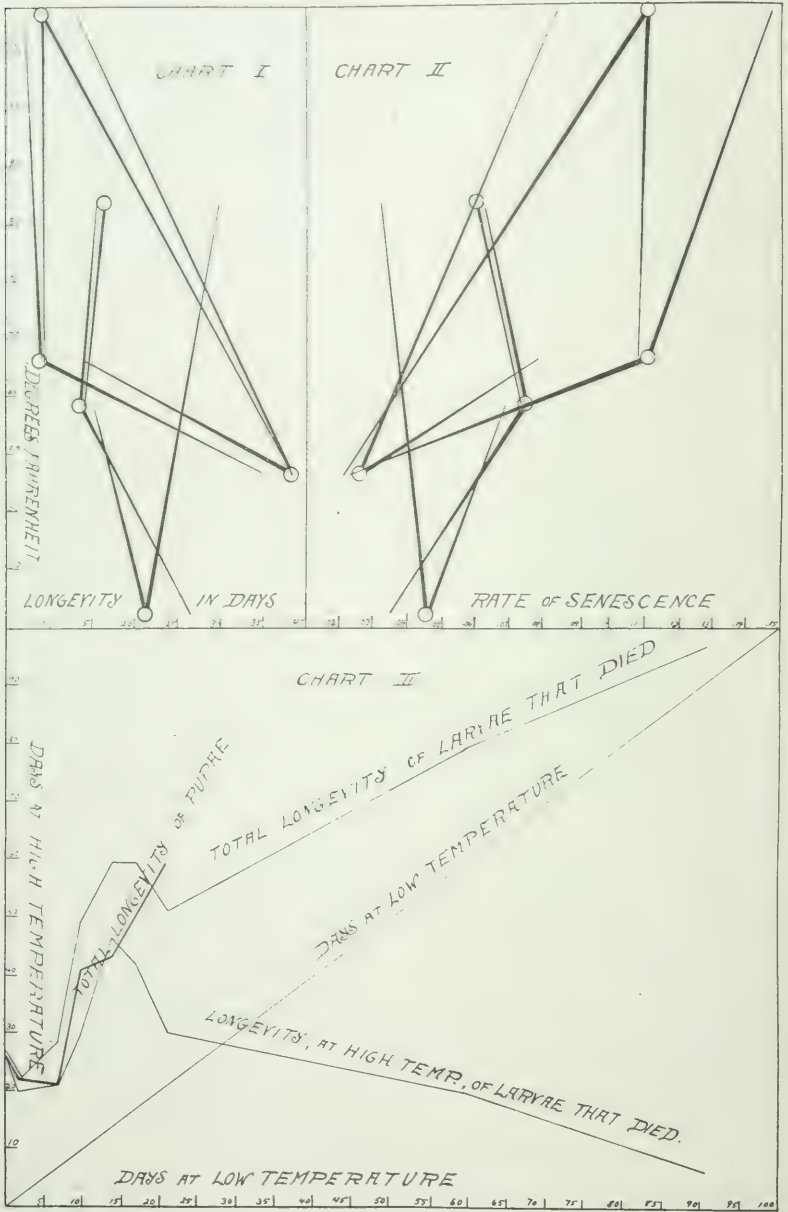
The exceptions to this rule are in three cases: (a) where 68° F. is the preliminary two day treatment, there is a decrease, (b) where the change is from 98° F. to 58° F. there is no increase and (c) where 64° F. is followed by 82° F. there is a decrease in the longevity.

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.



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			
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 (Kern-plasma 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 wind-fall 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 larvae 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 weevil 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 over-feeding 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 volume 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 slightly 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 physiological 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.

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The following species of phytophagous 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 bioculatus. 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 amirensense*), *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 spherio-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; gey 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 certain 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 occurrence 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 containing 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 equaling 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 protuberance; 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.

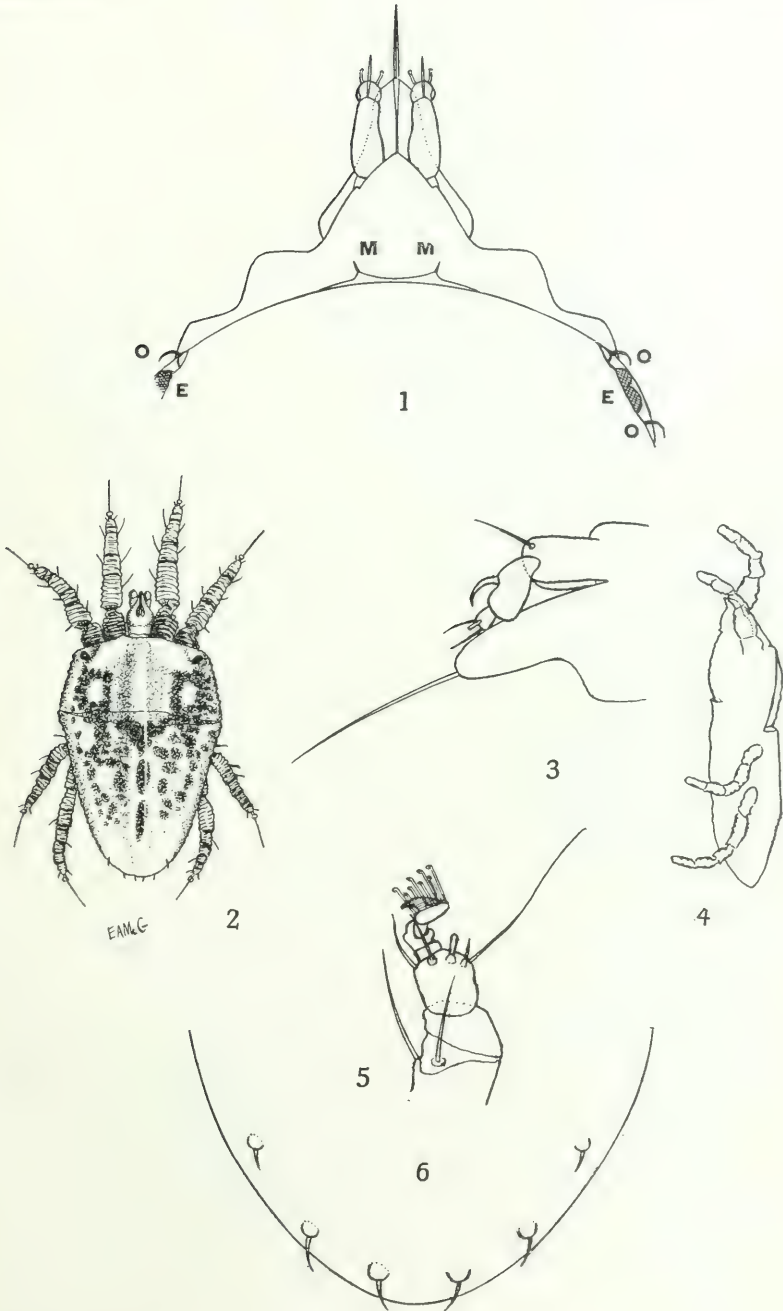
All figures drawn with the camera lucida; figs. 1 and 2 drawn with oil-immersion lens.

PLATE XLV.

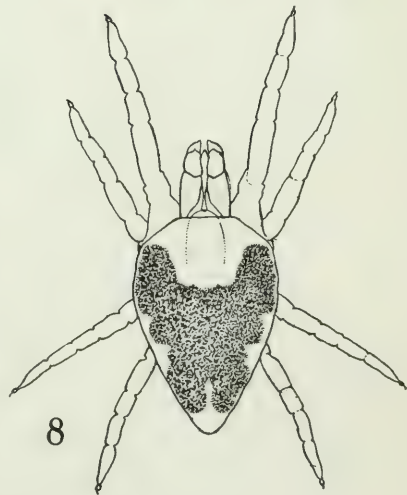
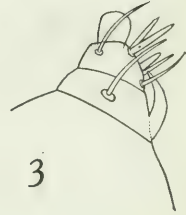
Tetranychus quinquenychus:

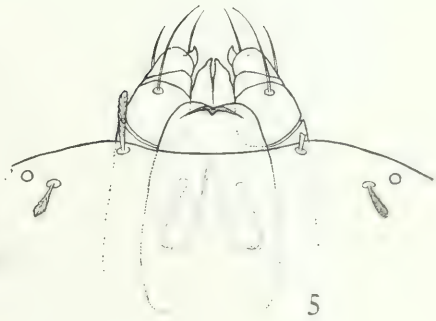
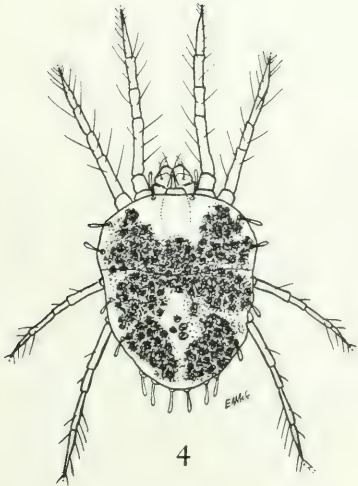
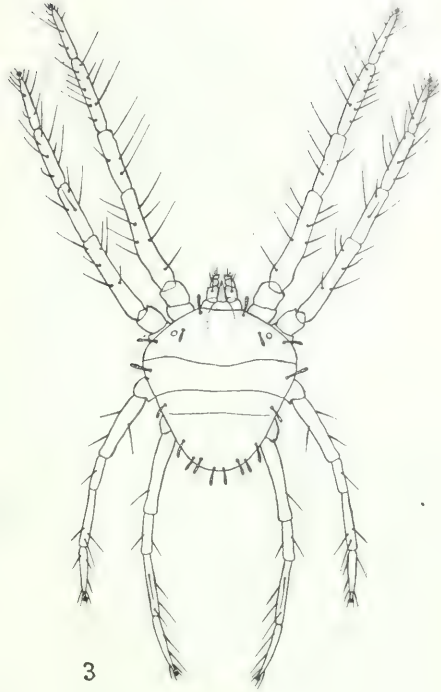
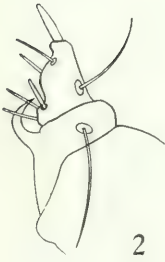
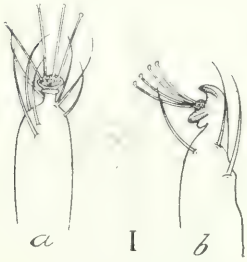
- Fig. 1. Tarsal appendages, ventral view.
 Fig. 2. Extremity of palpus showing "thumb", terminal "finger", dorsal "finger", "thumb" hairs and penultimate claw.
 Fig. 3. Tarsal appendages, lateral view.
 Fig. 4. Left eye, seen from above.
 Fig. 5. Right foreleg, dorsal view.
 Fig. 6. Female, dorsal view (leg bristles not shown).

(Figs. 1, 2, 3 and 4 drawn with oil-immersion lens and camera lucida. Fig. 6 enlarged 150 times.)



E.A. McGregor.







E. A. McGregor.

INDEX OF VOLUME VII.

- Adalia annectans*, 213, 228, 229.
coloradensis, 213, 228.
flavomaculata, 84.
humeralis, 213, 228, 229.
melanopleura, 213, 228.
- Adelocephala*, 279, 282.
bicolor, 283.
bisecta, 283, 284.
- Alexander, Chas. P. Article by, 239.
- Anastatus bifasciatus*, 86.
- Anastrepha ludens*, 202.
- Anatomy of *Siphona Plusiae*, 301.
- Anatomy of the Diaspinine Scale Insect
Epidiaspis Piricola (Del Guer), 47.
- Anisota*, 279, 286.
consularis, 286, 291.
senatoria, 286, 289.
skinneri, 286, 290.
stigma, 286, 287.
virginiensis, 286, 287.
- Antochini*, 240.
- Anthomyia*, 162, 164, 166, 167.
pluvialis, 162.
- Anthomyiden*, 160.
- Anthomyioid Flies, Connectant Forms
 Between the Muscoid and, 160.
- Apanteles*, 87.
lacteicolor, 87.
- Aphidius testaceipes*, 83, 84.
- Aphidoletes marina*, 216.
- Aphis*
atriplicis, 217.
brassicae, 217, 236.
carbicolor, 216, 236.
cerasifolii, 217, 236.
cornifolii, 218.
gossypii, 216, 224, 236.
heraclei, 218, 231, 233.
helianthi, 215, 216, 221, 224, 231, 236.
medicaginis, 127, 236.
oenotherae, 217, 236.
oxybaphi, 216, 236.
pomi, 217, 224.
setariae, 215, 223, 224, 231, 233, 236.
taraxici, 236.
torticauda, 215, 216, 223, 236.
- Apomecyna pertigera*, 183.
- Aptera*, 316.
- Araneus beebei*, 170, 172.
microtuberculatus, 170, 172.
- Aspihium sacculi*, 65.
- Aspidiotus perniciosus*, 54, 55, 249.
piricola, 55.
- Atlanta Meeting, Proceedings of, 97.
- Attulus*, 170.
- Auchmeromyia*, 162.
- Automeris*, 293.
incarnata, 297, 298, 300.
io, 297, 298, 299.
leucaca, 297, 298, 299.
pamina, 297, 298.
- Ballus tabupumensis*, 170, 174.
- Basilona*, 279, 281.
imperialis, 281.
- Baumberger, J. P., Article by, 323.
- Bee Genus *Coelioxys*, Some Species of
 the, 148.
- Beebe, Wm. C., Spiders collected by,
 169.
- Bellura melanopyga*, 140.
- Biology of the Net-Spinning Tri-
 choptera of Cascadilla Creek, 251.
- Bloeser, Wm., article by, 301.
- Bomis*, 170.
- Bryobia pratensis*, 73.
- Byrsocrypta vagabunda*, 67.
- Calliphora*, 160, 167.
erythrocephala, 162.
- Calliphorinae*, 166.
- Calosoma sycophanta*, 88.
- Campodea*, 316.
- Carex*, 218.
- Castalia odorata*, 136.
- Caterpillars*, Structural Study of
 the, 109.
- Cell Structure of the Digestive Epithe-
 lium in Insects, 311.
- Ceratitidis*, 202.
- Ceratocampidae*, Classification of the
 Pupae of the, 277.
- Chalcid Larvae*, Note on the Number
 of Spiracles in Mature, 249.
- Cheiloneurus amplicornis*, 248.
- Childs, Leroy, article by, 47.
- Chaitophorus negundinis*, 215, 217, 221,
 223, 231, 232, 236.
populicola, 217, 218, 223, 224, 231, 236.
populifolii, 215, 217, 231, 236.
- Cheiloneurus*, A New Species of, 247.
- Chilomenes-lunatus*, 84.
- Chimarra*, 259.
aterrima, 259, 267.
- Choeromyia*, 162.
- Citheronia*, 279, 280.
regalis, 280.
sepulchralis, 280.
- Classification of the Pupae of the
Ceratocampidae and *Hemileucidae*,
 277.
- Clinopera*, 164.
- Clubiona tabupumensis*, 169, 171.

- Cobanus Beebei, 170, 173.
 Coccidae, 315.
 Coccinella
 5-notata, 213, 219, 222, 224, 227, 234, 235.
 9-notata, 213, 224, 226, 234, 235.
 monticola, 213, 222, 224, 225, 227, 234, 235.
 sanguinea, 213, 232.
 Coccinellid, 217.
 Coelioxys, 148, 166.
 alternata, 150, 152.
 atilis, 154.
 asteris, 156.
 banksi, 155.
 comstockii, 148.
 coquilletti, 157.
 edita, 153.
 hunteri, 151, 152.
 insita, 158.
 lucrosa, 148.
 moesta, 148.
 obtusiventris, 150.
 octodentata, 154.
 piercei, 152.
 pratti, 159.
 rhois, 159.
 rufitarsis, 148.
 rufitarsis varribois, 159.
 sayi, 154.
 sculptifrons, 153.
 slossoni, 156.
 slossoni arenicola, 156.
 texana, 151, 152.
 Coenosia, 161, 166.
 irrorata, 244.
 Connectant Forms Between the Muscoid and Anthomyioid Flies, 160.
 Collembola, 315, 316.
 Compsilura concinnata, 86.
 Conwentzia Hageni, Banks, 73.
 Cordyluridae, 135.
 Cossidae, 119.
 Cossus, 121.
 Crane-flies, On a Collection of, 239.
 Crawford, J. C., article by, 148.
 Cycloneda
 rubripennis, 232.
 sanguinea, 232, 234.
 Cynus, 262.
 flavidus, 263.
 pallidus, 263.
 Dacus
 cucurbitae, 177.
 oleae, 202.
 tryoni, 202.
 Decatoma flava, 9.
 Deilephila, 122.
 Deilephila lineata, 119.
 Dendroctonus, 315, 318.
 Diaspinine Scale Insect, Anatomy of the, 47.
 Dibrachys boucheanus, 249.
 Dicranomyia illingworthi, 239.
 saltens, 239.
 Digestion of Insects, 311.
 Dipoenia tristis, 169, 171.
 Diptera, 318.
 Dispersal of Musca Domestica Linne, 70.
 Drassodes Drydeni, 169, 170.
 ignobilis, 169, 171.
 Drymeia, 161.
 Dryocampa rubicunda, 279, 284, 285.
 Dryophanta Erinacei and Its Gall, A Study of, 1.
 Enoplognatha marmorata, 169.
 Epidiaspis Piricola, Anatomy of the Diaspinine Scale Insect, 47.
 Epithelium, Digestive, in Insects, 311.
 Epochara canadensis, 203.
 Erigone longipalpus, 169.
 Eriococcus, 248.
 Erioptera oceanica, 243.
 Eriopterini, 241.
 Eumusca, 166.
 European Collection, Notes on Some Old, 89.
 Eurytoma auriceps, 9.
 studiosa, 9.
 Evophris albopatella, 170, 173.
 Exochomus nigro-fasciatus, 84.
 Fernald, H. T., article by, 89.
 Fannia, 161, 162, 166.
 Forbes, Wm. T. M., article by, 109.
 Fundatrigenia ramulorum, 63.
 Gahan, A. B., article by, 247.
 Gasteracantha arcuata, 170.
 frontata, 170.
 Gillette, C. P., article by, 61.
 Glossina, 161, 164.
 Gonomyia fijiensis, 241.
 varipes, 242.
 Graphomyia, 166.
 Haematobia, 162.
 Haploelma doriae, 169.
 Hemileuca, 292, 293.
 burnsi, 293, 294.
 maia, 293, 294.
 maia var. lucina, 294.
 oliviae, 293, 295.
 Hemileucidae, Classification of the Pupae of the, 277.
 Hemiptera, 317.
 Hermetia illucens, 70, 71.
 Hippodamia convergens, 213, 217, 219, 220, 221, 222, 224, 235, 236.
 sinuata, 213, 217, 218, 219, 234.
 parenthesis, 213, 218, 234.
 Holocentropus, 262.
 dubius, 262.

- Houser, J. S., article by, 73.
 Howard, Dr. L. O., article by, 86.
 Hyalopterus arundinis, 217, 236.
 Hydromyza Confluens, Life History and Habits of, 135.
 Hydropsyche instabilis, 255.
 Hydropsychidae, 252.
 Hypodermodes, 162.
 Hypodermodes, 166.
 Insects, Longevity of, 323.
 Inquiline Life in the Gall of *Dryophanta erinacei*, 7, 11.
 Isopods, 316.
 Lachnus, 217, 236.
 Ladybeetles, Some Notes on Life History of, 213.
Lasiocampa americana, 120.
 disstria, 120.
 Lasiocampidae, 119, 120.
 Lecaniums, 315.
Lepisma, 316.
Leucauge tessellata, 170.
Leucomelina, 162, 163, 164, 165, 166.
 squamopleura, 163.
Libnotes strigivena, 240.
 Life History and Habits of *Hydromyza Confluens*, 135.
 Life History of *Dryophanta Erinacei*, 2.
 Life History of Ladybeetles, Some Notes on, 213.
 Life History, Notes and Variations in Wing Venation of *Conwentzia Hageni* Banks, 73.
 Life History of *Siphona Plusiae*, 301.
Limmerium disparidis, 87.
 Linnobiinae, 239.
 Linnobini, 239.
 Linnophora, 162, 163, 165, 166.
 Linyphia, 169.
 Longevity of Insects, 323.
 McGregor, E. A., article by, 354.
Macrosiphum ambrosiae, 216, 217, 223, 228, 236.
 cerasi, 215.
 cynosbati, 217, 236.
 gaurae, 215, 221, 232, 236.
 psi, 217, 236.
 rosae, 215, 217, 221.
 rudbeckiae, 215, 216, 217, 218, 224, 236.
Malacosoma americana, 119.
 disstria, 119.
Melanoxantherium amithiae, 236.
 bicolor, 236.
Melanoxantherium bicolor, 217.
 fraxinifolii, 217, 221.
 smithiae, 233.
 Melon Fly, The Ravages, Life History, Weights of Stages, Natural Enemies and Methods of Control of the, 177.
Mesembrina, 160.
Mongoma fijensis, 243.
Monodontomerus aereus, 88.
 Moore, William, article by, 77.
Mordwilkoja oestlundii, 67.
 vagabunda, 67.
Morellia, 162.
 Mosher, Edna, article by, 277.
Musca Domestica Linne, Dispersal of, 70.
Musciden, 160.
Muscina, 160, 162, 163, 166.
 Muscoid and Anthomyioid Flies, Con- nectant Forms Between the, 160.
Myospila, 166.
Myrmecophila, 317.
Myzus cerasi, 217, 224, 236.
 persicae, 231.
Nephila clavata, 170.
 maculata, 170.
 Net-Spinning Trichoptera of Cascadilla Creek, Biology of, 251.
 Newcomer, E. J., article by, 311.
 Noctuidae, 120.
 Notodontidae, 119.
 Natural Control of Toxoptera Grami- num in South Africa and the United States, 77.
Nephelodes, 119.
Neureclipsis, 260.
 bimaculata, 260.
 Noyes, Alice Ayr, article by, 251.
Nymphaea, 135.
 advena, 135, 146.
 advena variegata, 136.
 americana, 135, 136, 140, 143, 144, 146, 147.
 Observations on the Life History and Habits of *Hydromyza Confluens* Loew., (Diptera), 135.
 Odonata, 316.
 Officers, 1914, Entomological Society of America, 95.
Olla abdominalis, 213, 232, 234.
Othellia, 162.
Orthellia, 166.
Oxyopes, 170.
 Palmer, Miriam A., article by, 213.
Palystes, 169.
Panatala flavescens, 197.
Paralimna, 165.
Paralucilia macellaria, 70.
Pararicia, 164.
 Parasites, Report on, 86.
 Parasitic Life in the Gall of *Dryophanta erinacei*, 7, 11.
 Pemphiginae Attacking Species of *Populus* in Colorado, Some, 61.
Pemphigus californicus, 61.
 oestlundii, 67.
 populiconduplifolius, 61, 63.
 ranunculi, 61.
 vagabundus, 67.

- Petrunkevitch, Alexander, article by, 169.
 Phaeocyma, 119, 121.
 Philodromus tabupumensis, 170, 173.
 Philopotamidae, 259.
 Philopotamus ludificatus, 259.
 montanus, 259.
 Pholcus phalangioides, 169.
 Phorodon humuli, 217, 236.
 Phryganidia californica, 301.
 Plagiolepis dustodiens, 78.
 Plectrocnemia, 261.
 conspersa, 261.
 Polycantropus flavomaculatus, 262, 264.
 Pocyntropidae, 250.
 Populus in Colorado, Some Pemphiginae
 Attacking Species of, 61.
 Populus balsamifera, 61, 62.
 occidentalis, 63.
 tremuloides, 65.
 trichocarpa, 61.
 Porrhopis, 170.
 Proceedings of the Atlanta Meeting, 97.
 Prociphilus fraxinifolii, 215, 221, 231,
 236.
 Prospaltella perniciosi, 249.
 Pseudohazis, 292, 296.
 eglanterina, 296.
 Pteromalus egregius, 88.
 Pupae of the Ceratocampidae and
 Hemileucidae, 277.
 Pygaera bucephala, 119, 122.
 Pyrellia, 166.
 Ranunculus californicus, 61.
 Ravages, Life History, Weights of
 Stages, Natural Enemies and
 Methods of Control of the Melon
 Fly (*Dacus Cucurbitae* Coq.), 177.
 Report on Parasites, 86.
 Resolutions on Death of P. R. Uhler, 96.
 Rhagoletis cingulata, 203.
 fausta, 203.
 pomonella, 203.
 Rhopholosphum braggii, 219.
 pastinaceae, 219, 231, 233.
 Rhyacophylax, 252.
 Samia cecropia, 297.
 Saturniidae, 278.
 Saturnioidea, 277.
 Schedius kuvanae, 86.
 Schizonerura lanigera, 215, 236.
 Severin, Henry H. P., article by, 177.
 Siphona Plusiae, Notes on the Life
 History and Anatomy of, 301.
 Somatic Muscles, Caterpillars, 109.
 Some Old European Collections, Notes
 on, 89.
 Some Species of the Bee Genus
 Coelioxys, 148.
 Spalangia hirta, 197.
 Species of the Bee Genus Coelioxys,
 Some, 148.
 Sphecidae, 92.
 Sphecodina abbotii, 119.
 Spheg fumpennis, 91.
 pensylvanicus, 91.
 Spingidae, 119.
 Spiders Collected by Mr. C. William
 Beebe in Burma and Borneo, 169.
 Spilogaster, 163, 166.
 Spirogyra, 262.
 Stimulus to Gall Production, 12.
 Stomoxys, 160, 162, 163, 164, 166.
 Structural Study of the Caterpillars, 109.
 Synergus erinacei, 10.
 Synthesiomyia, 162, 163, 166.
 Tachiniden, 160.
 Tenuipalpus bioculatus, 254.
 Tetrachyids, Four new, 354.
 Tetranychus banksi, 557.
 mytilaspidis, 73.
 quinquenychus, 358.
 yotheri, 355.
 Teucholabis fijensis, 240.
 Thecabius patchii populiconduplifolius,
 61.
 Theridion sarapus, 169.
 Theridiosoma, 170.
 Thiania, 170.
 Tipulidae, 239.
 Toxoptera Graminum in South Africa,
 Comparison of Natural Control
 of, 77.
 Tower, D. G., article by, 249.
 Townsend, Chas. H. T., article by, 160.
 Treasurer's Report, 101.
 Trichoptera of Cascadilla Creek, Bio-
 logy of the Net-Spinning, 251.
 Triggerson, C. J., article by, 1.
 Tropaea luna, 297.
 Uhler, P. R., Resolutions on Death
 of, 96.
 Volucella obesa, 70.
 Welch, Paul S., article by, 135.
 Xanthogramma scutellare, 84.
 Zelus peregrinus Kirkaldy, 197.
 Zetek, James, article by, 70.

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CONTENTS OF THIS NUMBER.

NOYES, MISS ALICE AYR—The Biology of the Net-Spinning Trichoptera of Cascadilla Creek.....	251
MOSHER, EDNA—The Classification of the Pupae of the Ceratocampidæ and Hemileucidæ.....	277
BLOESER, WILLIAM—Notes on the Life History and Anatomy of Siphona Plusiæ Coq.....	301
NEWCOMER, E. J.—Some Notes on Digestion and the Cell Structure of the Digestive Epithelium in Insects. (Plate XLI.).....	311
BAUMBERGER, J. PERCY—Studies in the Longevity of Insects.....	323
MCGREGOR, E. A.—Four New Tetranychids.....	354

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