Minnesota. State Entomologist.

Nineteenth Report

State Entomologist of Minnesota

To the GOVERNOR

By A. G. RUGGLES

Agricultural Experiment Station
University Farm, St. Paul, Minn.
December 1, 1922

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Agricultural Experiment Station
University Farm, St. Paul, Minn.
December 1, 1922

LETTER OF TRANSMITTAL

December 22, 1922

Honorable J. A. O. Preus,
Governor, State of Minnesota,
St. Paul, Minn.

Dear Sir:

In compliance with the law I have the honor to present herewith a report on the experimental and extension activities of the entomologist for the years ending December 1, 1921 and December 1, 1922.

Very truly yours,

W. C. Coffey,
Dean

Published November 1, 1923

December 1, 1922

Dean W. C. Coffey,
University Department of Agriculture,
University Farm, St. Paul, Minnesota.

Dear Sir:

In compliance with the law I have the honor to present herewith a report on the activities of the entomologist for the years ending December 1, 1921 and December 1, 1922. A typewritten report was given you December 1, 1921, for the year preceding, but as this (1922) is the year for the report to be printed I am making the report to cover the two-year period.

The law mentioned states that the entomologist shall make a report to the governor. As the legislature of 1921 divided my work, placing the regulatory part under the State Commissioner of Agriculture and the experimental and extension part under the University Department of Agriculture, I have made two reports, that covering the regulatory phase of the work being incorporated in the biennial report of the Commissioner of Agriculture; and the attached report, to be printed as the nineteenth report of the entomologist, to the governor. These reports have been the outlet for publishing some very valuable data on Minnesota insects, and it is believed that the value of the series is increasing. Many favorable comments have been received from workers in entomology throughout the country as well as from those within the state.

The legislature of 1894 and every legislature since, appropriated money for the work of the entomologist directly. Up to the fiscal year 1921-22 this money has been spent directly by the entomologist. As the law of 1921 places the responsibility of the work in the two channels mentioned, the funds are now distributed through the State Department of Agriculture and the University Department of Agriculture, respectively.

A discussion of the principal insect problems of the biennium and the financial statement follows:

Insect problems of the biennium

The first year of the biennium 1920-21 was very unusual. The winter was very mild and consequently more insects than usual were able to pass comfortably through the dormant period. This mild winter was followed by a very early spring and a long warm summer. As far as insects were concerned conditions were comparable to those of states much farther south. The usual rigors of our northern winters and the shortness of our summers prevent many insects from becoming very serious pests. If 1921-22 had been similar to 1920-21 the great increase of virulence noted in the summer of 1921 would have reached serious proportions in 1922. Fortunately the last season returned to normal and no unusual outbreak occurred.

Corn Ear Worm (*Heliothis obsoleta* Fabr.)

In 1921 the damage done by the corn ear worm was very severe. Ordinarily this insect is not a bad pest in Minnesota. In our experimental plot where corn has been grown in some part each year for seven years, the ears infested have rarely been more than 10 per cent and usually 5 per cent or less. In 1921 the injury reached 20 per cent and in some parts of the state much more. Field corn, altho normally not injured, was seriously damaged. In some cases even the tassels were attacked before they opened.

The reason for this marked increase in 1921 was probably as follows: The insect passes the winter as a pupa in the soil and according to our experiments, comparatively few survive in Minnesota. Our infestation comes from moths which fly in from states to the south. Whether in the winter of 1920-21 more of these pupae survived the winter or whether more survived the winter in neighboring states, or whether the moths, on account of the warm spring, were able to start operations earlier, there was a decided increase which may be accounted for in one of the ways mentioned. In the summer of 1922 the corn ear worm infestation was only slightly higher than normal and was less than 10 per cent in Golden Bantam. The insect will probably not be serious in 1923.

Unfortunately, no good method for controlling this insect in field corn has yet been found. Cultivating the soil as much as possible after harvest, particularly fall plowing, will help. In small fields of sweet corn we have controlled the pest by dusting arsenate of lead directly on the fresh silks, at short intervals over a period of two weeks. Experimenters in other states have obtained similar results.

Granary Weevil (*Calendra granaria* Linn.)

The insects which attack stored grain were unusually destructive in 1921. The granary weevil, which hitherto had been unknown in Minnesota spring wheat, was prevalent throughout the southwestern part of the state. Its general distribution in elevators and granaries can be accounted for only by the mild winter followed by a long warm summer. The damage done by the granary weevil was added to by other insects. The so-called "bran bugs" which are often present in the state in small numbers were particularly abundant in 1921.

This unusual situation became more complex because recent rulings by insurance underwriters, railroads, and others have prohibited the use of carbon disulphide. Carbon disulphide has been universally recommended by entomologists for fumigating infested grain. Much time has been devoted to the study of fumigants in an effort to provide the grain growers and dealers with some adequate means of protecting their grain from these pests.

In 1922 the superabundance of these granary pests decreased, but the experimental work on fumigants is still being carried on vigorously under the direction of Dr. R. N. Chapman. Preliminary work indicates that in normal years elevators and granaries can be kept free from granary weevils and bran bugs by so handling the grain that the temperature is kept at or below the freezing point. If the grower would grade and clean his grain during the first cold snap of the fall it would seem that he would have very little trouble from these pests.

Potato Leaf Hopper (*Empoasca mali* Le B.)

Probably the insect about which the most complaints were made in 1921 was the potato leaf hopper. It has been in the state for many years, but it is only in particularly dry seasons that it seems to do serious damage in Minnesota. In 1916 a very bad outbreak occurred, but at that time the seriousness of the pest was not thoroly realized and its connection with "hopper burn" not fully recognized. S. Marcovitch, working with this insect here at that time, was convinced of its seriousness and its relation to hopper burn, and published his conclusions in the local press. Between 1916 and 1921 there were no serious outbreaks in this state, but in 1921, taking the state as a whole, this leaf hopper was responsible for a 25 per cent damage. In 1922 this damage was equally severe.

In our experimental plots where different liquids and dusts were tried, liquid bordeaux mixture (4-4-50) applied at 175 pounds pressure, three nozzles to the row, and applied three times during the season gave good control. No other spraying compound was nearly as effective. This again bears out our recommendations of several years ago, advocating high pressure and better sprayers.

Grasshoppers

In 1921, Minnesota was threatened with a grasshopper outbreak. Fortunately a wet June in the infested areas caused the death of most of the young hoppers. In Kittson County one large area was infested but the prompt action of the county agent in organizing the farmers and getting them to spread the poison bait of bran and arsenic stopped the invasion at the outset. Grasshoppers were reported doing damage around Grand Rapids on the edge of the Iron Range, but the injury did not prove serious. From specimens obtained the principal depredator here was *Melanoplus bruneri* Scudder, a species never previously reported as doing damage in Minnesota.

In 1922 no reports were received of damage done in the state by grasshoppers.

Hessian fly (*Mayetiola destructor* Say)

For some unknown reason the hessian fly has done no serious damage in Minnesota for many years. In 1922, a field of winter wheat near Waconia was badly injured by this pest. It is too early to say whether the insect has obtained sufficient foothold to continue its depredations.

The best preventive remedies are plowing under stubble as soon after harvest as possible, keeping down volunteer wheat, rotation of crops, and in the case of winter wheat, sowing as late as possible, not before September 20.

Chinch Bug (*Blissus leucopterus* Say)

In Minnesota fifteen and twenty years ago innumerable chinch bugs destroyed the grains and corn. Since 1908 there has been no authentic record of this insect being present in the state. In 1922 some specimens were sent in from the northern part of the state. We were unable to find, however, that they had done any damage. The last two seasons have been very favorable for their reproduction, being hot and dry, and therefore this insect may again become a serious pest in the near future.

Apple Maggot (*Rhagoletis pomonella* Walsh)

One of the pests that has given much trouble is the apple maggot or railroad worm. This was first found in Minnesota orchards in 1919. At picking time very little notice is taken of the work of the insect, but soon after the apples are placed in storage complaints begin to come in. The real orchard grower is awake to the difficulty but the small grower and the farmer with a small orchard do not appreciate the damage until they begin to use the stored fruit. One small grower in 1922 harvested his fruit and put it away in the cellar. A few weeks afterward he was unable to find a sound apple in his crop of 60 bushels.

Our experimental work has shown that spraying with arsenate of lead at the usual rate about the middle of July and again the first week in August, if the insect is abundant, will control the pest. These sprayings of course are in addition to the regular sprayings, the last of which is usually given the third or fourth week of June.

Oyster Shell Scale (*Lepidosaphes ulmi* Linn.)

The oyster shell scale is becoming more and more abundant in southern Minnesota. Several orchards were studied in 1922 which were badly injured by this pest. Some owners are taking vigorous steps to control the insect. The dormant lime-sulphur spray applied as late as possible in the spring, or a miscible oil, will soon put the insect under control.

Asparagus Beetle (*Crioceris asparagi* Linn.)

The asparagus beetle, found for the first time in the state in 1919, continued to spread. In 1922 it was found in the valley of the Mississippi, having spread from the St. Croix where it was first found.

Several other insects were unusually abundant in 1922. The American sawfly (*Cimbex americana* Leach) and the red-necked cane borer (*Agrilus ruficollis* Fab.) were plentiful at Lakeland. The phlox bug (*Lopidea davisi* Knight) is proving a serious pest in two different localities, Mantorville and Winona, in southern Minnesota, and the plum gouger (*Anthonomus scutellaris* Lec.) was reported very common at La Crescent. A new record for the dark apple red bug (*Heterocordylus malinus* Reut. was obtained in 1922. It is possible that this may prove one of the serious recent introductions.

Spruce Budworm (*Harmologa fumiferana* Clem.)

The spruce budworm has continued its destructive work in the coniferous forests north of Lake Superior. Investigations concerning its activities were carried on and an extension bulletin on the subject was published.

Forest Tent Caterpillar (*Malacosoma disstria* Hbn.)

The forest tent caterpillar has been responsible for considerable damage in several districts of the state. It was particularly abundant in the Lake Park region where considerable areas of hardwoods were defoliated. In this region the caterpillars were heavily parasitized and the outbreak appears to be on the wane. Apparently this insect is becoming increasingly abundant in the aspen forests of the north and promises to be an important factor in the forest economy of that region

Jack Pine Sawfly (*Diprion abietis* Harris)

Many reports of injury to Jack pine by sawfly larvae were received during the season of 1922. The species responsible was not the common pine sawfly but the fir sawfly *(Diprion abietis)*. Several localities were examined where the trees were completely defoliated by this insect, and judging from reports received from other places not visited, injury occurred locally throughout the Jack pine region. Owners of summer hotels and cottages are urged to plant other species of trees and develop mixed woods about their property. This will tend to reduce the likelihood of a sawfly outbreak in these places, where the esthetic value of the trees is paramount.

Birch Skeletonizer (*Bucculatrix canadensisella* Cham.)

In August and early September of 1922, the birch skeletonizer destroyed the leaves in practically all the birch woods in the northern part of the state. This defoliation came after the trees had completed the season's growth and did comparatively little permanent injury. In some cases, however, owing to the early loss of leaves and the late fall, the buds of the birches began to swell before cold weather set in. This will probably mean a considerable amount of winter injury. The larvae of this insect were so abundant that there was not sufficient green foliage to carry them all to maturity. A very large proportion of the caterpillars starved to death and many others spun cocoons in an under-nourished condition. As a result it is probable that the skeletonizer will not be very abundant in 1923.

Many other insects were reported and many letters were written answering inquiries, but these mentioned were the most important.

Spraying

Experimental work in spraying orchards, comparing the regular formula of arsenate of lead and lime-sulphur with dusts, has been continued. Dust versus liquid sprays is a very live question with the orchardist as well as with the potato grower. The importance of spraying is being more and more recognized by the grower in this state and it is necessary that the different formulae be tried under Minnesota conditions. So far the dusts have not proved, either in results or costs, any better than the liquid formulae advised for several years, viz., arsenate of lead and lime-sulphur for orchard spraying, and arsenate of lead or calcium arsenate plus bordeaux mixture for potato spraying.

Except where the oyster shell scale or an abundance of plant lice eggs are present, a dormant spray of lime-sulphur is not advised.

The financial statements for July 1, 1920 to July 1, 1921, and July 1, 1921 to July 1, 1922, are appended.

Respectfully submitted,
A. G. Ruggles,
Entomologist.

FINANCIAL STATEMENT

Fiscal Year, July 1, 1920, to June 30, 1921

Appropriation		$6,300.00
Old balance		404.19
		$6,704.19

Expenditures

Salaries	$3,720.95	
Traveling expenses	530.61	
Printing and publishing	812.35	
Office supplies	19.80	
Freight and express	27.56	
Miscellaneous	440.56	
Photos, cuts, and equipment	108.23	
Furniture and equipment	1,040.64	6,700.70
Balance		$3.49

Fiscal Year, July 1, 1921, to June 30, 1922

Appropriation		$5,000.00

Expenditures

Salaries	$4,342.11	
Traveling expenses	408.96	
Freight and express	8.36	
Miscellaneous	53.88	
Furniture and equipment	18.75	4,832.06
Balance		$167.94

PRELIMINARY NOTES ON THE LIFE HISTORY AND CONTROL OF THE POTATO LEAF-HOPPER,

Empoasca mali LeB.[1]

by

A. G. Ruggles and J. R. Eyer

Life History

Food plants.—The food plants of the potato leaf-hopper as determined from observation at University Farm in 1922 are potato, apple, box elder, blackberry, raspberry, curly dock (*Rumex crispus* L.), rhubarb, and dahlia. Development of the first brood takes place almost exclusively on potato, while the second brood may develop on any of these plants, altho potato is preferred. The adults feed indiscriminately on all these food plants when potato is not available.

Overwintering adults.—Observations on the overwintering habits of the potato leaf-hopper in Minnesota showed that only the adult stage survived the winter. In 1922, following a heavy frost on October 12, adults began to leave their food plants to hunt for hibernating quarters. They had completely disappeared from the fields by November 15. Individuals feeding on potato in the greenhouse left the plants at approximately the same date and hibernated beneath dead vegetation and flower pots. In 1922, adults began to come out of hibernation the latter part of May and to feed on box elder and blackberry. They were first observed on early potatoes June 7 and became quite abundant about the middle of the month.

First generation.—Small numbers of eggs were found in the stems and midribs of potato leaves about June 12, increasing in abundance toward the latter part of the month. The nymphs hatching from these eggs required an average of twenty days for development, changing to adults late in July.

Second generation.—The adults of the first generation became most abundant in August and lived from 25 to 50 days. The egg laying of these adults was continued from the latter part of July until early October.

The nymphs hatching from these eggs required about 30 days for development. Those hatching late in September did not develop

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[1] Published with the approval of the director as Paper No. 390 of the Journal Series of the Agricultural Experiment Station.

so rapidly, however, and were killed by freezing weather before maturity. The adults of this generation fed on potato until the plants were killed by frost and then migrated to other food plants, where they fed until hibernation.

Control

Experiments were conducted during 1922 to determine the value of spraying and dusting with various compounds for the control of this insect. Tenth-acre and one-acre plots of Bliss Triumph and Green Mountain potatoes were used in order to test the same materials on an early-maturing and a late-maturing variety. These fields were planted in duplicate, each set receiving applications of the following materials:

Liquid bordeaux mixture
Liquid bordeaux mixture and Black Leaf 40
Black Leaf 40 alone
Dosch copper calcium arsenate dust
Dosch copper calcium arsenate and nicotine dust
Nicotine dust alone

When no arsenical was in the mixture an application with an arsenical was made when needed to take care of the Colorado potato beetle. All sprays were applied with a Friend power sprayer using a four-row, 3-nozzle-per-row boom, and dusting was done with a Niagara power duster.

Times of spraying.—All plots received four applications of liquid or dust material at intervals of about two weeks. The tenth-acre plots were first sprayed and dusted on June 24, when the potato plants were about six inches high. Subsequent applications were made on July 7, July 25, and August 10. The Bliss Triumph plants were mature at the time of this last spray and died soon after; the Green Mountain plants remained green until frost. The acre plots were sprayed on June 29, July 14, July 27, and August 18, and remained green until the first of September. The tables show the results of these tests.

During the course of these spraying experiments accurate counts were made in the various plots of the percentage of foliage injury, and the average number of hoppers per plant. The results gave some idea of the relation of the hoppers to the percentage of injury and of the efficiency of the spray materials used.

On the early maturing variety, leaf-hoppers occurred in greater abundance over a shorter period of time. The percentage of injury during their maximum feeding period was approximately the same on both varieties.

TABLE I. FIELD PLAN AND RESULTS OF POTATO SPRAYING EXPERIMENT, AT UNIVERSITY FARM, ST. PAUL

Variety	Acres in plot	No. & date of applications	Materials	Per cent of hopper burn on foliage	Av. No. of leaf-hoppers per plant	Yield in bushels per acre
Green Mt.* . . .	1/10	1-June 24 2-July 7 3-July 25 4-Aug. 10	Liquid bordeaux mixture 4-4-50 Lead arsenate 2-50	45	40	249
Green Mt.	1/10	As above	Liquid bordeaux mixture 4-4-50 Black Leaf 40, 1-800; Lead arsenate 2-50	43	29	236
Green Mt.	1/10	As above	Black Leaf 40, 1-800, Fish oil soap 2-50, Lead arsenate 2-50	53	48	205
Green Mt.	1/10	1-June 26 2-July 7 3-July 25 4-Aug. 10	Dosch 13-8-79, Copper calcium arsenate dust	41	42	177
Green Mt.	1/10	As above	Dosch 13-8-79; Copper calcium arsenate dust and Dosch 2-8 per cent nicotine dust	43	60	207
Green Mt.	1/10	As above	Inter-series check (i.e., between Green Mt. and Bliss Triumph) Lead arsenate 2-50			177
Green Mt.	1/10	As above	Isolated check, Lead arsenate 2-50	67	203	150
Bliss Triumph†	1/10	1-June 24 2-July 7 3-July 25 4-Aug. 10	Liquid bordeaux mixture 4-4-50 and lead arsenate 2-50	33	98	226
Bliss Triumph	1/10	As above	Liquid bordeaux mixture 4-4-50 and black leaf 40, 1-800, and lead arsenate 2-50	18	87	202
Bliss Triumph	1/10	1-June 26 2-July 7 3-July 25 4-Aug. 10	Dosch 13-8-79, copper calcium arsenate dust	35	106	204
Bliss Triumph	1/10	As above	Dosch 13-8-79, copper calcium arsenate dust and Dosch 2-8 per cent nicotine dust	27	199	200
Bliss Triumph	1/10	As above	Dosch 2-8 per cent nicotine dust	30	230	132‡
Bliss Triumph	1/10	As above	Inter-series check (between sprayed and dusted series) Lead arsenate dust	36	181	175
Bliss Triumph	1/10	As above	Isolated check; Lead arsenate dust	55	305	158

* Hopper burn and leaf-hopper counts made August 19, after fourth application of materials.

† Hopper burn and leaf-hopper counts made August 2, after third application of materials. Most of Triumph plants matured and died by August 16, and no further data could be obtained.

‡ Yield influenced by loss of foliage due to outbreak of Colorado potato beetle.

TABLE II. FIELD PLAN AND RESULTS OF POTATO SPRAYING EXPERIMENTS ON ONE-ACRE PLOTS AT GRISWOLD FARM, MINNESOTA

Variety	No. and date of applications	Materials	Yield in bu. per acre
Bliss Triumph	1-June 29 2-July 14 3-July 27 4-Aug. 18	Liquid bordeaux mixture 4-4-50 and lead arsenate 2-50..........	273
Bliss Triumph	As above	Liquid bordeaux mixture 4-4-50 and Black Leaf 40, 1-800 and lead arsenate 2-50..............	337
Bliss Triumph	1-June 30 2-July 14 3-July 27 4-Aug. 18	Dosch 13-8-79; copper calcium arsenate dust..................	185*
Bliss Triumph	As above	Dosch 13-8-79; copper calcium arsenate dust and Dosch 2-4% nicotine filler dust.............	201*
Bliss Triumph	1-June 29 2-July 14 3-July 27 4-Aug. 18	Inter-series check, between dusted and sprayed series, lead arsenate 2-50	193
Bliss Triumph	1-June 30 2-July 14 3-July 27 4-Aug. 18	Isolated check, lead arsenate, paris green, lime 7-1-40..............	152*

* Yields slightly influenced by outbreaks of Colorado Potato Beetle.

Liquid bordeaux mixture markedly decreased the number of leaf-hoppers and the percentage of foliage injury in both varieties. The addition of nicotine was followed by a greater decrease in the number of hoppers, but additional lessening of foliage injury was only noticeable in the early variety. In the dusted plots, the number of hoppers and the injury were lessened, but these decreases were not so consistent as in sprayed plots and require further experimental evidence. Nicotine used alone, in dust or liquid form, produced small decreases in both number of insects and injury.

It will be seen that liquid bordeaux mixture gave good control against the leaf-hopper in every plot where it was applied, the yield being decidedly better than in the check and dust applications. In the tenth-acre plots no advantage was gained by adding the nicotine solution to the bordeaux mixture, but in the acre plots a decidedly better yield was obtained. Further experimental evidence should be obtained in 1923.

It will be seen from the tables that bordeaux dust, whether applied alone or in combination with a nicotine dust, gave no appreciable results, in each case the difference between the yield in check plots and in those where the dusts were used being approximately the same, or at least within experimental error.

THE RED TURPENTINE BEETLE IN ITASCA PARK[1]

By S. A. Graham

Injury to trees by the red turpentine beetle, *Dendroctonus valens* Lec., has usually been considered of secondary importance and reports of outbreaks in standing timber are very rare. These occasional outbreaks have usually followed immediately after the conclusion of logging operations. In Itasca Park, however, this beetle has been very abundant and was apparently responsible for a considerable amount of injury to green trees. Norway pine, *Pinus resinosa* Aiton, was the species attacked most frequently. It was not at all uncommon to find groups of apparently healthy trees with from one to a dozen Dendroctonus pitch tubes about their bases. A large percentage of dead trees showed signs of Dendroctonus work and from general observation it might easily have been assumed that many trees were being killed by this insect. In the course of an improvement cutting carried on during the winters of 1920-21 and 1921-22 the work of these beetles was very apparent. In one area 30 per cent of the trees removed were infested.

Many apparently healthy trees showed signs of Dendroctonus work. In many cases these trees were of particularly great esthetic value and their cutting meant a considerable loss. This situation gave rise to two very pertinent questions: (1) Would these infested trees succumb to the attack of the beetles? (2) Was their presence a menace to the adjacent timber? The future policy to be followed in handling the standing timber in Itasca Park hinged to a considerable degree upon the answers to these questions.

Therefore, with the aid of the State Forest Service, the Division of Entomology undertook the task of investigating the activities of the red turpentine beetle in Itasca Park. The problem resolved into an ecological study of the beetle and was naturally divided according to the locations in which the beetle might be found as follows:

1. Breeding in living trees
2. Breeding in fresh stumps
3. Breeding in freshly cut logs
4. Breeding in slash

The Red Turpentine Beetle in Living Trees

In studying the effect of the beetle upon living trees the sample plot method was used in collecting data. Forty-five plots were laid

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[1] Published with the approval of the director as Paper No. 392 of the Journal Series of the Agricultural Experiment Station.

out in different parts of the Park in stands representing as wide a range of site conditions as could be found in the region under observation. The plots were almost all two-tenths acre in area, but in a few cases it was found advisable to make them smaller, and then one-tenth acre was adopted as the unit area.

Each tree in every plot was carefully examined for evidence of beetle attack. The litter was scraped away from the base of each tree, exposing the mineral soil, so that the location of all tunnels, both old and new, could easily be determined. Records for each plot were kept, showing in addition to the amount of infestation, the exposure, the size of trees, the condition of undergrowth, the number of trees per acre, and the presence of old or new cuttings near the plot.

Considering Itasca Park as a whole, the infestation as indicated by these plots was much lighter than the data gathered in connection with the improvement cutting of 1920-22 would lead one to suppose. Of the 45 plots, 8 showed no sign of infestation. On more than two-thirds of the plots the infestation was 10 per cent or less. On only four plots did the infestation exceed 25 per cent. On only one plot did every tree show signs of beetle work. In every instance where the infestation exceeded 25 per cent, freshly cut logs had been held over the summer season in the immediate vicinity of the plot.

Table I. Percentage of Infestation in Standing Norway Pine

Location	Distance from logs		
	Less than 100 yds.	200 yds.	400 yds.
Old mill site............	100	52	8
Nicollet cabin	66	21	7
SW¼ of SW¼ Sec. 3...	23	12	9

The distribution of beetles as shown by sample plot studies proved without doubt that the infestation of green trees is correlated with the presence of green logs, fresh stumps, lightning-killed trees, or windfalls in the immediate vicinity. Apparently the beetles are also attracted to freshly burned areas, and as a result uninjured trees along the edge of a burn are likely to be more heavily infested than trees farther away.

The abundance of infested trees immediately around the old mill site southeast of Mary Lake illustrates well the conditions usually found where freshly cut logs are piled near green trees during the growing season. On the plot nearest the mill 100 per cent of the trees showed evidence of beetle work. The amount of infestation diminished rapidly as the distance from the mill site increased. At two hundred yards the infestation dropped to 52 per cent and at four hundred yards to 8 per cent. Similar conditions existed at Douglas Lodge, where unpeeled green logs for cabin construction were left piled in a Norway pine grove during the summer.

In the SW¼ of the SW¼ of Section 3, where logs were cut for cabin construction in 1920 and left piled for some time, 23 per cent of the trees near the piles were infested. Other plots in the area from which the logs were cut showed an infestation of 9 per cent. Within 500 yards from the cutting, the infestation was reduced to zero. At Nicollet cabin the infestation next to the cabin was 66 per cent, at two hundred yards 21 per cent, and at four hundred yards 7 per cent.

The greatest infestation was always found about spots where logs had been piled, but a very decided relation was also observed between the presence of stumps and beetle infestation. Where there were stumps the trees in the vicinity were always more or less infested. The time of greatest beetle infestation appeared to be the second season after the trees were cut. As a rule the infestation near stumps did not exceed 10 per cent.

TABLE II. INFESTATION IN DIFFERENT PARTS OF ITASCA PARK

Location	No. plots	Stumps	Percentage Norway pine infested
La Salle Trail	2	Present	14
Cabin Log Trail Sec. 3	6	Present	12
Cabin Log Trail Sec. 3	3	None	0 (No recent cutting near)
Old mill site	3	Present	53 (Beetles attracted by green logs)
East of Mary Lake	3	Present	8
Nicollet cabin	3	Present	31 (Beetles attracted by green logs)
Kelley Trail	2	Near	3
Bohall Lake	2	Present	10
NE¼ Sec. 15	1	Present	30
Garrison Pt.	2	Present	11 (All tunnels very old)
Forestry School	2	Near	6
Pritchett's Grove	2	None	5 (All tunnels in burned trees)
Preacher's Grove	3	None	6
Near Peace Pipe Springs	1	None	0
De Sota Cabin	2	None	3 (In path of 1913 fire)
Ockerson Heights	3	Near	6
Budd Lake	1	Near	6
East of S.W. cabin	4	None	9 (Edge of burn)

Windfalls and trees injured by fire also appeared to attract the beetles. When a windfall lay against the base of a standing Norway pine the standing tree was almost always infested. Wherever the forest was undisturbed by cutting, windfall, lightning, or fire, beetle infestation was seldom found. Without exception all of the nine uninfested plots were so located.

Before this study was undertaken, it was suspected that site conditions, density and composition of stand, age and size of trees, density of underbrush, and other such factors might have some influence in determining the extent of beetle infestation, but no such relation is apparent. The examination of the sample plots, however, does demonstrate conclusively a specific relationship between infestation of standing trees by the red turpentine beetle and the presence in the immediate vicinity of green logs, fresh stumps, windfalls, or injured trees. Doubtless the beetles are attracted by this freshly cut or injured material.

Naturally, where so many trees were infested, as indicated by the data gathered on the sample plots, one might expect a considerable number of trees to succumb to the beetle attack. Such an assumption, however, did not prove to be true. Strange to say, not a single tree was killed by the beetles on any of the plots examined. In one case a tree was attacked so heavily that its death was probably only a question of time, but it was still alive when examined. The only tree observed that was without doubt killed by this beetle was a large Norway pine, standing alone near the mill site referred to above. This tree had been attacked at fifty-three separate spots about the base. Brood had been reared in only three of these tunnels. Another large tree near was spotted about the base with forty-five pitch tubes. No brood had been reared in any of the tunnels, and the tree was apparently perfectly healthy and growing normally.

It was exceedingly rare to find any brood emerging from infested living trees. Usually the adult beetles tunnelled into the tree and, after a longer or shorter battle with the flow of resin, they were either overwhelmed and drowned or were forced to leave. From this it would appear that the beetles attacking living trees are either misguided individuals whose instinct leads them to impossible breeding grounds, or they are the overflow which can not be accommodated in the available material suitable for breeding.

In this connection it must be remembered that all the dead trees on much of the area studied were taken out in the course of the improvement cutting mentioned. Much of the evidence of past beetle work had been removed before this study was undertaken. Therefore this report describes conditions only as they exist at present. It is certain that with the passing of logging operations in and about the

Park the number of turpentine beetles has been much reduced. A few years ago, during their flight, these beetles were so abundant that hundreds could easily be collected as they rested on the screens of porches, doors, and windows. Last year very few were observed on the screens.

Red Turpentine Beetle in Green Logs and Slash

From the considerable infestation in living trees standing near green logs it might naturally be assumed that such logs would provide a favorite breeding place for the beetles, but this did not prove true. In the course of the work many logs, broken butts, and slash piles were carefully examined. Never was any sign of turpentine beetle work seen in slash piles or in any part of the tree which came from a point higher than six or eight feet above the ground. Only butt cuts were found infested, and in these the stump end was always most heavily attacked.

Usually the infestation even in butt ends was light, but occasionally a log was found that was particularly attractive to the beetles. In one such instance the bark was entirely loosened from the wood and when stripped off a mass of almost full grown larvae was disclosed. Even with a mortality of 50 per cent during the pupal stage, at least five thousand beetles would have come to maturity in this log. But for this one heavily infested log, dozens were examined containing few or no beetles.

In connection with other experiments in Itasca Park where hundreds of green logs have been used, it has been extremely unusual to find these logs attacked by the turpentine beetle. Therefore, in spite of an occasional heavy infestation such as that mentioned above we are forced to conclude that logs as a general rule do not furnish the best breeding place for these beetles. It seems probable that the infestation of trees standing near green logs is not due to beetles emerging from these logs but to beetles attracted to the spot by the presence of freshly cut material. Once there they attack the trees.

A comparable instance of this sort of attraction may be cited in the case of *Hylurgops pinifex* Fitch. This species is strongly attracted to freshly cut pine either with or without bark. It is not at all uncommon in the spring to find bundles of green pine lath filled with beetles of this species. Sometimes more than one hundred individuals have been found in a single bundle.

The favorite breeding place of the red turpentine beetle proved to be freshly cut Norway pine stumps. Fresh stumps were almost always found infested, sometimes heavily infested, and it is beyond question that a large proportion of the turpentine beetles in Itasca Park breed in them. Examination of a series of stumps cut in the winter of 1921-22 showed an average of 1.6 tunnels per stump for White pine and 13.5 for Norway pine. Summer-cut stumps of Norway pine averaged 6.8 tunnels. Brood was reared successfully from the majority of these tunnels.

In connection with the 1921-22 improvement cutting, an experiment was carried on to determine the effect upon insect infestation of barking and scorching stumps. One set was barked down to the ground line; one set was scorched by burning either slash or dry wood over the stump; and a third set, kept as a check, was untreated. The results of this experiment are shown in Table III.

TABLE III. INFESTATION OF NORWAY PINE STUMPS

		No. of new tunnels per stump		
Time cut	Treatment	Maximum	Minimum	Average
Winter	Untreated	27	0	13.5
Summer	Untreated	15	0	6.8
Winter	Barked when cut	34	0	12.7
Winter	Burned when cut	6	0	2.5

The barking and burning operations were both carried out carefully and a much better job was done than could be expected under ordinary woods conditions. Owing to the frozen condition of the ground it was impossible to bark below the surface of the litter. As the beetles tend to concentrate in the lower portions of a stump and frequently enter below the litter, barking did not have any material effect upon the number attacking the stumps. Therefore, if barking is to be effective, it should be done during the summer following logging. Thoro barking could be cheaply accomplished at that time and the broods of beetles in the stumps completely destroyed. Even winter burning did not entirely prevent infestation. However, the number of beetles per stump was very materially reduced by the treatment. It was found that burning must be thoroly done to be effective. Little good resulted when the slash was piled over the stump and burned. It was necessary to get a good fire all around the stump with dry material and then pile on the slash a little at a time, keeping the fire against all parts of the stump. Slash burned over a stump did little but scorch the upper parts. The cost of barking was not excessive, being approximately 3½ cents per stump. Burning was slower and the cost therefore ran up much higher, being over 26 cents per stump. These figures are on the basis of $3 a day.

Conclusions

Altho the red turpentine beetle is abundant in Itasca Park and is attacking many living trees, it is responsible for the death of very few. Almost never is brood successfully brought to maturity in living trees. The infested trees are always found associated with fresh stumps, green logs, windfalls, or burned areas, the beetles being attracted by the freshly injured wood just as *Hylurgops pinifex* is attracted to freshly cut pine lath. With the reduction in the logging operations in Itasca Park the number of beetles and consequently the amount of infestation will gradually be reduced.

The beetles breed abundantly in fresh stumps and to a lesser extent in logs. They are never found in slash, as they apparently confine their activities to the parts of the tree near the ground. Experiments in barking and scorching stumps were effective only when the treatment was carried down to mineral soil. When the ground was frozen, it was difficult if not impossible to bark low enough on the stump for effective results, therefore the early summer months following logging appear to be the ideal time for this work. Burning, when thoroly performed, was more effective but expensive.

This study opens up the general question of the treatment of stumps and waste materials for preventing the breeding of injurious insects. It is evident from the results obtained that even tho stumps are barked at the time of cutting they may still be a menace. Further work should be carried on to detemine conclusively what methods can be most economically employed in handling logging debris, including stumps, slash, broken logs, and butts.

EFFECT OF PHYSICAL FACTORS IN THE ECOLOGY OF CERTAIN INSECTS IN LOGS*

By S. A. Graham

The study of forest entomology, like that of almost every branch of the biological sciences, was first based upon purely empirical knowledge of the insects concerned. The forester learned by experience and superficial experimentation how the pests of trees lived and reproduced, and how they could be controlled.

In Europe, where labor was cheap, there were developed many mechanical methods of forest insect control such as trapping and other devices for collecting injurious species, poisoning, and banding. In America such means as these have proved too expensive and difficult of application for general use, since the margin of profit in growing trees for market is small and requires that the expense of all the operations involved in producing a crop of timber be reduced to the minimum.

For this reason we must turn our attention to the development of natural methods, where the elements of the environment are so balanced as to reduce the probability of extensive outbreaks of injurious pests. The working out of natural control methods is much more difficult than the more obvious artificial methods, but it has the decided advantage of reducing the danger of insect loss to a minimum without materially increasing the cost of producing timber. The insect control plan will, under this system, be included in the silvicultural procedure set forth in the working plan.

When we come to formulate satisfactory methods for the silvicultural control of forest insects, we soon find that empirical knowledge, superficial experimentation, and general observation do not form an adequate foundation upon which to build. We can not construct a substantial superstructure upon a foundation not based upon the fundamental laws which govern insects activities. We must not only know the life cycle of the insects, as it is ordinarily determined by cage experiments, but we must also know how they react to the varying conditions of their environment and how they are affected by the other living organisms with which they come in contact. Thus the

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development of methods for forest insect control resolves itself into a study of the ecological relationship of insects in the forest envirnoment.

The first single factor of the environment to attract the attention of entomologists was temperature. Several more or less successful attempts were made to correlate variations in the length of the developmental period and the geographic distribution of animals on the basis of this factor alone. Judeich and Nitsche (1895) report a rather unsuccessful attempt of Forester Uhlig-Therand to correlate the length of the life cycle of *Ips typographus* Linn. with temperature by comparing with the length of the insect's life cycle, the total midday temperature and the total mean daily temperature, as computed from three readings a day. Merriam (1898) established life zones on the basis of the sum of positive temperatures (above 43 degrees Fahrenheit for the entire season of growth and reproduction) which, he believed, limited the northward distribution of terrestrial animals. The southern limits of distribution he believed to be governed by the mean temperature during the hottest part of the year. Sanderson (1908) points out that low winter temperatures limit the northward distribution of many insects, since many species do not occur in every locality where the sum of positive temperatures is sufficient for their development. He also points out that the effective temperature may vary with different insects. Later, Sanderson (1910), in a paper treating of the effect of temperature on the growth of insects, recognizes the importance of humidity in influencing the rate of development.

More recently Sanderson and Peairs (1913) published results showing that the variation in velocity of development at different constant temperatures within normal limits was, other things being equal, increased directly as the temperature, the curve for the increase being a true mathematical hyperbole. "The factor, or index of development, for any point on this curve is the reciprocal for the point. Thus the reciprocal, . . . takes by definition the form of a straight line; the inclination of this line to the axes of the curve being governed by the rapidity of development of the insect and stage." In this way it is possible to compute the complete development curve by establishing any two points on the curve and plotting the reciprocals.

The first extensive investigation of temperature and humidity as applied to forest insects was that of Hennings (1907-10), who published a series of articles on the biology of certain bark beetles. His results were based upon experiments under controlled conditions of air temperature and humidity. His work has materially contributed toward the clearing up of some of the controversies arising from conflicting observations of authorities. He shows conclusively that the activities of insects are not governed by temperature alone but that humidity plays a very important modifying role.

More recently the work of Pierce, Shelford and his students, Headlee, and others has further emphasized the importance of humidity. Huntington in his recent book has attempted to show the effect of temperature and humidity upon man. In the United States very little has been produced which bears directly upon the effect of physical factors of the environment upon forest insects. Hopkins (1919-20) in his attempt to formulate and apply the so-called "bioclimatic law" to the activities of forest insects has taken a step in the right direction.

Craighead (1920) working primarily with ash logs in several localities in the South, found that the temperature beneath the bark of logs lying in full sunlight frequently reached a point above the fatal temperature for wood-boring insects. On the basis of his findings he recommends the weekly turning of logs to protect them from injury by wood-borers. Even more recently Craighead (1921) has published the results of a series of experiments concerning the fatal temperature of the red-headed ash borer with special reference to the effectiveness of dry kiln temperatures in destroying these insects. He shows that the fatal temperature varies with the amount of moisture present.

Studies of the nutritional requirements of insects have opened up a field of investigation. The food factor appears to be extremely important in regulating the activities of all insects, and particularly those that live upon such materials as wood. Baumberger (1919) has shown that Drosophila is very largely dependent for its successful development upon the microörganisms working in its food. In sterile media the development is very slow or even impossible, whereas in the presence of microörganisms normal development takes place. He refers to the work of Haberland (1915), who has shown that the protein content of trees is very low except in the cambium and phloem, while the carbohydrate content is high. As a result of this condition we find in sound green logs that the rapidly developing insects work in the cambium or in the outer sap wood, whereas the insects which penetrate the heart wood are usually much slower in their development. Some wood-boring species are unable to live in wood in the absence of the organisms producing decay.

For the sake of brevity no attempt has been made in the above review to mention all the literature contributing to our knowledge of this subject. The only aim has been to give a general idea of the status of those problems dealing with the effect of the external factors upon insect activity, and it will therefore be necessary from time to time to refer to other works not previously mentioned.

Most of the data included in this thesis were collected during the summer of 1920 at the field station of the University of Minnesota Forest School. The prosecution of the work has been materially aided by the laboratory and other facilities provided by the School of Forestry and the helpful suggestions and criticisms by members of the University staff, particularly Dr. R. N. Chapman, under whose direction the work was carried on.

The study of insects in their natural environment calls for a careful study of the environmental factors as they exist in nature. Under controlled experimental conditions it is possible to study very accurately the influence of a single factor upon insect activity by keeping uniform all but one of a series of factors. By varying this factor its influence upon the insects under experimentation may be determined. Such a study under natural conditions, however, involves the accurate measurement of individual factors or groups of factors such as light, temperature, humidity, and evaporating power of the air, and the condition of the nutritive medium.

Experimental Method

In this investigation five species of logs were used. These were White pine, *Pinus strobus*, Linn.; Norway pine, *Pinus resinosa* Aiton; Jack pine, *Pinus banksiana* Lambe; Black spruce, *Picea mariana* Britton Stearns & Poggenberg; and balsam fir, *Abies balsamea* Miller. The logs were cut into four-foot lengths and placed in a north and south direction with the north end slightly raised. Representative logs of each species were placed under lath shades so constructed as to cut off three-fourths, one-half, and one-third of the direct solar radiation. One set of logs was left in full sunlight. The methods employed in supplementary experiments will be described as the results are presented. The principal factors considered in this work were light, temperature, evaporation, and relative humidity.

The measurement of light is always attended with considerable difficulty. Really accurate methods of light measurement are too complex and difficult for general field use, so it was necessary to adopt some simple means of measuring this factor even at the expense of exactness. The various methods used for measuring light in terms of chemical activity were considered as a possibility, but finally rejected. The instrument finally adopted was based upon the principle of the black body and measured the light in terms of heat units. It consisted of two mercury thermometers mounted side by side in a white box. The bulb of one was white and of the other, black. The readings were recorded as the percentage of the maximum difference observed during the season of 1920, this maximum being taken arbitrarily as 100 per cent.

Temperature measurements were made by means of mercury thermometers. A white bulb mercury thermometer was used for measuring air temperature in the sun. An interesting comparison of uncovered mercury, white, black, and red spirit thermometers is shown in Table I.

Table I. Comparative Readings of Thermometers with Differently Colored Bulbs Taken at 1 p.m.

Color of bulb	Light intensity 52% Aug. 31	Light intensity 20% Sept. 1	Light intensity 75% Sept. 2	Light intensity 72% Sept. 6	Light intensity 55% Sept. 7
Black	42.5°C	28 °C	40 °C	46 °C	40 °C
Red	39 °C	28.5°C	38.5°C	41 °C	36.5°C
Mercury	35 °C	26.5°C	27 °C	33 °C	33.5°C
White	33 °C	24 °C	27 °C	33 °C	30 °C

Subcortical temperatures in the logs were measured by mercury thermometers inserted in a hole bored into the end of the log just beneath the bark.

The evaporating power of the air for each 24-hour period was measured by means of Livingston porous cup atmometers. The white spherical type was used. An average of readings from three cups was taken for each set of logs. Since these instruments were left in position during the entire season, it was necessary to equip them with check valves to prevent the absorption of water during rains. A single mercury valve mounting proved very satisfactory and caused little trouble. A special mounting was designed for measuring the rate of evaporation at any particular time. In this mounting the evaporation during one minute was measured in a graduated capillary tube and the rate per hour calculated.

Relative humidity was measured by the use of the cog psychrometer (Clements 1905). This instrument has proved very satisfactory, as it is accurate and easily operated in a limited space.

Measurements of the moisture content of the cambium and outer sapwood regions were attempted by running moisture analyses of samples taken from the logs. The method was too slow and cumbersome to give satisfactory results.

Influence of the Character of Food

Food is one of the important factors limiting insect development in logs. Some forms are very exacting in their food requirements and their development is only possible within narrow limits. Others are not so exacting and are therefore found under a wider range of conditions. Insects working in freshly cut logs may be divided into several ecological units on the basis of food.

1. Insects requiring fresh cambium. These forms are living in a highly nutritious medium and are therefore not greatly dependent upon the aid of microörganisms. Examples of this group are many Ipidae.
2. Insects requiring fresh cambium for early development and which are later able to complete their growth and development in the outer sap wood. Many Cerambycidae and Buprestidae come under this head.
3. Insects requiring fresh cambium during their early stages, but later capable of entering both sap wood and heart wood to complete their development. Examples are Monochammus and Chalcophora.
4. Insects which live in the wood during the entire development period, such as the Siricidae.
5. Insects which do not depend directly upon the wood for food, but live upon organisms growing in the wood. This group may be exemplified by Gnathotricus.

The maximum length of the insect's developmental period is limited by the time that its food remains in a usable condition. Insects of the first group must complete their development while the cambium is still fresh and green. Thus their developmental period must be short. The second and third groups require green cambium for only a comparatively small portion of the entire developmental period, therefore their cycle may be almost indefinitely lengthened.

Influnce of Light and Heat

Insects react in much the same way to both light and heat. Since as a rule these factors are closely associated with one another and, under outdoor conditions, usually vary synchronously, it is often impossible to determine whether the effects are produced by the one or by the other. For this reason it seems logical that they should be considered together.

TABLE II. Interval of Time Between the Developmental Stage of *Ips typographus* Linn. at Various Temperatures and Humidities After Hennings (1908)

	Beginning of larval period		Beginning of pupal period			Beginning of young adult period				Emergence of adults					
	From entrance	From oviposition	From entrance	From oviposition	From hatching	From entrance	From oviposition	From hatching	From pupation	From entrance	From oviposition	From hatching	From pupation	From trans. to young adult
24° dry	6½	5½	12	11	5½	17½	16½	11	5½	27	26	20½	15	9½
24° damp	8	6½	15	3½	7	21	19½	13	6	33½	32	25½	18½	12½
20° dry	9½	8½	17	16	7½	28	27	18½	11	42	41	32½	25	14
20° damp	10½	8½	22½	20½	12	35	33	24½	12½	50	48	39½	27½	15
20° to 17° dry	14½	11	25½	22	11	38½	35	24	13	65	61½	50½	39½	26½
17° dry	15	11½	28	24½	13	42½	39	27½	14½	69	65½	54	41	26½
20° to 17° damp	16	11½	33½	20	17½	49	44½	33	15½	76	71½	60	42½	25
17° damp	17	12½	34½	30	17½	50	45½	33	15½	77	72½	60	42½	27
20° to 14° dry	19½	16	60	56½	40½	76½	73	57	16½	103½	100	84	43½	27
14° dry	21	16	61½	56½	40½	78	73	57	16½	105	100	84	43½	27
20° to 14° damp	24½	18	74½	68	50	91½	85	67	17	119½	113	95	45	28
14° damp	25	18	75	68	50	92	85	67	17	120	113	95	45	28

Both these factors are exceedingly important in their influence upon insect activities. Insects vary both within the species and between species as to their reactions to these factors, but in each case temperature and probably light also can be divided into optimum, effective, high and low dormant, and high and low fatal zones. It seems probable, however, that light under natural conditions seldom goes beyond the limits of toleration for most insects. It does, however, have a stimulating effect as shown by Hennings (1907) who noted that *Ips typographus* Linn failed to develop normally in the absence of light, and by the fact that Chrysobothris adults remain inactive on cloudy days at temperatures equal to or higher than the temperature at which they are active on sunny days.

The influence of heat and of light converted into heat may be observed in all stages of insects from egg to adult. Hennings (1908) has shown the effect of different degrees of temperature and humidity upon each step in the life history of *Ips typographus* Linn. Some of his results are set forth in Table II.

In correlating the period of activity of Chrysobothris adults, our experiments show that of the factors which influence the activity of these insects, temperature ranks first and light next, while relative humidity appears to have little influence. Under bright conditions activity begins at 26°C. and full activity is reached at 30°C. Under cloudy conditions they remain inactive until 29°C. With these insects there seems to be a marked daily periodicity which appears to be independent of both light and temperature. Regardless of conditions they are seldom active before 8:30 a.m. or after 4:30 p.m.

Some other Buprestids appear to have a somewhat lower active temperature, since Chalcophora and Dicerca were observed flying when conditions were not favorable for Chrysobothris. In contrast to the narrow range of activity of Chrysobothris, Monochammus was observed actively feeding and flying from early morning to sunset.

The rate of larval development of wood-boring insects varies greatly, owing not only to quality of food, but also to temperature difference. Monochammus will frequently come to maturity in a single season under favorable conditions, whereas under cool, shady conditions three years or even longer are required to complete development.

Factors Influencing Subcortical Temperature

The recent work of Craighead (1920) calls attention of entomologists to the high temperatures which occur under the bark of logs lying in the sun. That this is not the first time this phenomenon has been noted is evidenced by the repeated reference in bark-beetle literature to heat paralysis, or estivation. Craighead's article emphasizes the fact that solar radiation may raise the subcortical temperature above a point fatal to the insect inhabitants of the logs. He observed subcortical temperatures exceeding air temperature by 60°F. depending upon locality, condition of sky, and angle of sun's rays.

The present experiments have shown that the chief factors influencing subcortical temperatures may be summarized as follows:

1. Solar radiation
   a. Light intensity
   b. Solar altitude
   c. Angle of incidence
2. Character of bark
   a. Color
   b. Surface
   c. Structure
   d. Thickness
3. Air temperature
4. Air movement
5. Evaporation from bark surface
6. Proximity to other radiating or absorbing surfaces.

The highest temperatures recorded were observed beneath the dark colored bark of White pine. Frequently the noon temperature exceeded a point fatal to insects and several times reached 60°C. Under the bark of Norway pine, however, the temperature never was observed to exceed 44°C., which is several degrees below the fatal point of most subcortical insects. The fatal temperature for most insects is about 48°C., altho there is evidence that some bark beetles die at a somewhat lower temperature, whereas Chrysobothris is able to endure slightly over 50°C. Tables III and IV show the effect of degree of shade and the character of the bark upon subcortical temperature for three species of pine during June, July, and August. From these tables it is evident that the bark characteristics of the different species and the amount of shading the logs receive have a very decided influence upon the subcortical temperature.

As a result of these experiments it appears that in many instances, even in northern latitudes, the weekly turning of logs as recommended by Craighead would be effective in destroying wood-boring insects. This is particularly true of logs with moderately thin dark colored bark. It is equally evident that the method can not be applied to all cases since some logs will remain below the fatal temperature of insects even on very bright days.

Table III. Effect of Shade Upon Subcortical Temperature*

Expressed in percentage of the days of the month in which the subcortical temperature exceeded varying degrees C.

Noonday subcortical temperature in deg. C.	Percentage of days in June, 1920 — Amount of shade				Percentage of days in July, 1920 — Amount of shade				Percentage of days in August, 1920 — Amount of shade			
	0	1/3	1/2	3/4	0	1/3	1/2	3/4	0	1/3	1/2	3/4
15	95	95	95	95	100	96	100	92	94	95	95	89
20	92	87	83	40	96	92	92	58	89	92	89	92
25	90	80	70	5	94	85	85	15	87	87	84	45
30	75	70	65	2	92	81	69	4	84	84	78	0
35	71	68	57	0	91	76.5	65	2	82	81	76	..
37	70	67	55	..	89	75	59	0	81	78	73	..
38	69	66	45	..	88	74	54	..	80	75	71	..
39	67	65.5	15	..	87	73	42	..	79.5	72	63	..
40	66	65	10	..	86.5	67	38	..	79	66	56	..
41	65	60	5	..	86	58	35	..	78.5	61	45	..
42	61	55	2	..	85	56	19	..	78	57	28	..
43	52	40	0	..	83	54	12	..	76	53	22	..
44	45	30	..	..	81	52	8	..	73	50	17	..
45	40	23	..	..	77	50	6	..	69.5	45	11	..
46	30	15	..	..	73	42	4	..	67	39	0	..
47	25	10	..	..	65	39	2	..	64	28	..	..
48	15	7	..	..	62	31	1	..	62	26	..	..
49	12	5	..	..	61	25	0	..	56	23	..	..
50	10	3	..	..	59	19	..	..	50	17	..	..
51	5	1	..	..	58	17	..	..	47	12	..	..
52	0	0	..	..	42	16	..	..	44	0	..	..
53	..	..	..	..	8	0	..	..	23	..	..	..
55	..	..	..	..	0	..	..	..	0	..	..	..
60	..	..	..	..	..	..	..	..	..	..	..	..

* Temperatures taken in White pine logs with bark 5 mm. thick.

Table IV. Effect of Bark Character upon Subcortical Temperature*

Expressed in percentage of the days of the month in which the subcortical temperature exceeded varying degrees C.

Noonday subcortical temperature in degs. C.	Percentage of days in June, 1920			Percentage of days in July, 1920			Percentage of days in August, 1920		
	White pine	Norway pine	Norway pine	White pine	Norway pine	Norway pine	White pine	Norway pine	Norway pine
	5mm.	2mm.	10mm.	5mm.	2mm.	10mm.	5mm.	2mm.	10mm.
15	95	100	100	100	100	100	94	100	100
20	92	95	90	96	92	89	89	98	83
25	90	80	50	94	85	81	87	96	72
30	75	65	50	92	77	54	84	94	69
35	71	62	0	91	73	50	82	92	66
37	70	60	..	89	69	45	81	90	62
38	69	35	..	88	62	32	80	80	59
39	67	10	..	87	58	20	79	77	56
40	66	9	..	86	54	8	79	73	39
41	65	7	..	86	47	4	78	69	28
42	61	5	..	85	42	0	78	65	17
43	52	0	..	83	39	..	76	60	6
44	45	..	..	81	19	..	73	50	3
45	40	..	..	77	12	..	69	40	1
46	30	..	..	73	4	..	67	20	0
47	25	..	..	65	2	..	64	10	..
48	15	..	..	62	0	..	62	5	..
49	12	..	..	61	..	..	56	0	..
50	10	..	..	59	..	..	50	..	..
51	5	..	..	58	..	..	47	..	..
52	0	..	..	42	..	..	44	..	..
53	..	..	..	8	..	..	23	..	..
55	..	..	..	0	..	..	0	..	..

* Logs lying in full sun.

Fatal Temperature of Insects in Logs

A consideration of temperatures fatal to insects in logs is essential if we are fully to appreciate the significance of subcortical temperature. The fatal temperature varies with the species and also with the individuals within the species. As a rule, however, a large proportion (about eighty per cent) of the individuals of a species will succumb at approximately the same temperature, and those dying above or below this point must be regarded as erratic. The presence of about twenty per cent of these erratic individuals makes it necessary to use a sufficiently large number of specimens in each set of experiments to make clear the distinction between normal and erratic.

In these experiments *Pityokteines sparsus* Lec. served as a representative of the bark beetles and *Chrysobothris dentipes* as a representative of the Buprestids. It must not be assumed, however, that the other species necessarily have the same fatal temperature as these, but it is reasonable to assume from the results of these experiments that *Pityokteines sparsus* represents a group having a fairly low fatal temperature, whereas Chrysobothris represents a group having a high fatal temperature.

The experiments with *Pityokteines sparsus* were conducted without removing the insects from the logs. The logs containing the insects were exposed to full sunlight and the temperatures within the logs were recorded every fifteen minutes. As the various degrees of temperature were attained some of the pieces were removed to a cool place and the condition of the insects was noted. These experiments show that 43°C. marks the upper limit of activity, and 47°C. the fatal temperature for this species. Between 43°C. and 47°C. the insects are in a state of estivation. The fatal temperature for adult specimens of Chrysobothris is about 52°C. No disturbance of the ability of these insects to control their movements was noticed until a temperature of 51°C. was attained. From this it appears that the zone of estivation is very narrow with Chrysobothris. That larvae of Chrysobothris are able to endure extremely high temperature is indicated by their occurrence on the upper side of logs lying in full sunlight.

Cerambycid larvae are as a whole less able to endure high temperatures than Chrysobothris. They are seldom found developing normally on the upper side of logs exposed to full sunlight, but usually confine their activities to the sides and bottom of such logs. Under partial shade, however, they are active on the upper side.

The Influence of Moisture upon Insect Activity Within the Log

The effect of moisture upon insect activity has been shown to be important. Shelford, Pierce, and others have shown that the optimum temperature and the limits of effective temperature are greatly influenced by humidity. By analogy it is reasonable to suppose that this factor, the importance of which has been demonstrated for other insects, is also of great importance to insects working in logs. The work of Henning (1907) demonstrates that *Ips typographus* is influenced in every stage of its development by this factor.

The influence of the relative humidity of the air is probably not of such great importance to insects living within the log as is the moisture content of the wood and inner bark. It does, however, have an influence upon rate of evaporation and therefore upon the rate of drying of the log.

Distribution of Insects Under Different Conditions

An examination of the distribution of the different insects under the four environmental conditions studied shows that these insects may be grouped according to their ecological requirements. Under one set of conditions certain species develop at the optimum rate. Under other conditions development is slow, and under still others it is impossible. Unfortunately the habits of different groups of insects are so variable that it seems almost hopeless to find any method of handling and storing logs that will prevent all insect infestation. Nevertheless when we remember that not all insects working in a log are injurious, as some do not enter the wood, we realize that our problem is not quite so difficult as it first appears. When we can check the development of the true wood-boring forms, our chief aim has been attained.

The study of the distribution of insects under different environmental conditions illustrates how the species are grouped according to their ecological requirements. The results may be outlined as follows:

Group I. Insects requiring high temperatures for development—represented by Chrysobothris.

Group II. Insects unable to endure extremes of temperature or moisture—represented by bark beetles such as *Ips pini*, and by Monochammus.

Group III. Insects requiring cool moist conditions—represented by Hylurgops and some Cerambycidae.

The insects of Group I are found on the upper side of logs in full sun, one-third shade, and to a lesser extent in one-half shade. They are usually most abundant in full sun altho this varies with the character of the log. They occur rarely on the sides of logs and almost never in heavy shade.

The insects of Group II are more generally distributed. In full sun they occur most commonly on the side of the logs, whereas in three quarters shade they find optimum conditions on the top surfaces. They are not usually abundant on the lower surfaces.

The insects of Group III are confined for the most part to the lower side of the logs where moist conditions maintain. Few of them are injurious.

The results so far obtained seem to indicate that logs in heavy shade are less subject to insect injury than logs in more exposed situations. This appears to be due primarily to the reduced rate of development under cool, shady conditions.

Effect of Relative Humidity and the Evaporating Power of the Air

When this problem was undertaken it was thought probable that relative humidity and the evaporating power of the air would be found to have a marked effect upon the activity of insects in logs. For this reason careful observations of these factors were made using the instruments already described, i.e., the Livingston porous cup atmometer and the cog psychrometer. The daily records of these factors were plotted in graphic form on profile paper together with the daily records of light, air temperatures, and subcortical temperature of typical logs. The graphs, however, failed to prove any definite effect of either the evaporating power of the air or relative humidity. Altho from this experiment no conclusions can be drawn as to the effect of relative humidity and evaporating power of the air, it still appears possible that both these factors have a decided influence upon the activity of xylophagous insects.

Conclusions

These experiments have shown that the activities of insects working in logs are greatly influenced by the environmental conditions to which they are exposed. These conditions are in many cases controlled or modified by the action of external physical factors such as light, heat, and moisture. The effect of these factors upon the conditions within the log to which the insects are exposed varies according to the characteristics of the species and the characteristics of the individual log within the species.

The food value of logs is determined primarily by the chemical composition, which is in turn dependent upon the species of tree and the part of the log under consideration. The cambium and phloem regions are comparatively high in protein, whereas the other parts of the tree contain little protein, but are high in carbohydrates. The differences in food value of the different parts of a log result in the definite localization of certain insects within the log. These differences also lead to variation in the rate of insect development, depending upon nutritional conditions. Thus we find the rapidly developing insects localized in the areas in which the wood is most nourishing, i.e., the cambium and phloem. The insects in the heart wood develop, as a rule, quite slowly. In some cases development is made possible or the rate of development is hastened by the presence of microörganisms in the wood. These organisms, having the ability to convert cellulose into proteins, sugars, and starches, increase the nutritive value of the wood. It has been shown that many insects are unable to develop in the absence of these organisms. In logs, the process of decay depends largely upon the the character of infection and the time at which the organisms gain entrance into the log. Insect infection often determines to a very marked degree the time and the extent of fungous infection in the log.

One of the factors which is obviously of the greatest importance in regulating insect activity within the log, is heat. Since a large proportion of the light which strikes upon the log is converted into heat units, it is very difficult, in the effect upon insects, to distinguish between these two factors. Heat may be divided into optimum, active, dormant, and fatal zones, and theoretically light may also be thus divided. The effect of temperature has been shown to vary according to humidity conditions. There is evidence that variations of light intensity also influence the effect of temperature upon insects. It has been shown by experiments and observations with Chrysobothris adults that changes of temperature may bring about changes in the reaction of insects to light. Differences in temperature conditions as they occur in nature are sufficient to account for the great differences in the length of life cycles of insects which have been observed. This is well illustrated in Monochammus which may, under favorable conditions, complete its development in a single season, whereas under less favorable conditions two or even three years are required.

The correlation of temperature, light, and relative humidity readings with the active periods of the insects living under natural conditions has shown that conditions favorable for the activity of one group are not necessarily favorable for the activity of another group. Monochammus adults appear to have an extremely wide range of active temperature, and for this reason fly at almost any time during the day. Chrysobothris, however, requires high temperature and bright sunlight before it reaches its maximum state of activity. Other buprestids, such as Dicera and Chalcophora, are active at lower temperatures than Chrysobothris.

Subcortical temperature was found to be very variable in the same log. Also there was considerable difference between logs of the same species and still more between logs of different species. The subcortical temperature on the upper side of certain logs exposed to full sunlight often reached a temperature far above that fatal to insects. Craighead also found this to be true, and recommended that advantage be taken of solar radiation in the control of wood-boring insects. The present series of experiments has shown, however, that the application of this method is limited in its scope, and can not be applied to all logs under all conditions. Many heat resistant insects, such as Chrysobothris larvae, are able to withstand extremely high temperatures for short periods of time, and are thus able to survive and develop normally on the upper side of many logs lying in the sun. It is true that most insects succumb to such conditions. On the other hand, some logs, such as those of Norway pine, which have scaly bark, highly efficient as an insulator, never reach extremely high temperatures.

Solar radiation, the character of the bark, air temperature, air movement, evaporation from the bark surfaces, and proximity to other radiating or absorbing surfaces, are the most important factors controlling the subcortical temperature of logs.

The fatal temperature of insects, like their effective temperature, varies under different conditions. There is considerable variation within a single species and even greater differences between different species. From the series of experiments described in this paper it appears that Chrysobothris has a much higher fatal temperature than any other of the insects studied. The adults were able to endure temperatures up to 52°C., while the larvae apparently were still more resistant to heat. Cerambycid larvae have a much lower fatal temperature than Chrysobothris. The only bark beetle for which the fatal temperature was determined was *Pityokteines sparsus* Lec. It was shown to be comparatively low for this species of beetle, as they passed into a state of estivation at about 43°C. and were practically all killed by a temperature of 47°C. This is about the point at which the majority of insects succumb.

That moisture conditions within the log have an important effect upon the activities of xylophagous insects can not be doubted. This is shown by the distribution of beetles in logs under different conditions.

It was found that some insects are very exacting in their requirements and occur only in narrowly limited areas. For example, *Hylurgops pinifex* is always found in cool moist locations. Unfortunately, the attempt to measure the moisture content of logs was not attended with much success because of the few observations which could be made during the season. For this reason a direct experimental correlation of this factor with insect activity was impossible.

The effect of the physical factors of the environment upon insects in logs is well illustrated by the distribution of these insects under different conditions. The effect of high temperature is clearly shown in logs in the open. On the upper side of these logs are found only insects which are most resistant to heat, such as Chrysobothris. In the cooler portions, however, other species make their appearance. Under the shade where cooler conditions obtain, the heat loving insects disappear, whereas the insects which develop best under cool conditions become more and more abundant with increasing shade. Three quarters shade was the heaviest used in these experiments. Under this condition no Chrysobothris was present and there appeared to be some indications of a reduction in abundance of Monochammus. Under these conditions there was a distinct reduction in the developmental rate of all species represented. From this it seems probable that still greater shading would check Monochammus as well as Chrysobothris. If this is true, the shading of logs which must be left in the woods over the summer season by covering them with brush or in some other way, may prove the most satisfactory method for controlling wood-boring insects.

From this series of experiments no attempt has been made to formulate definite recommendations for controlling wood-boring insects. Rather than to present a solution of an immediate problem the aim of this work is to lay a foundation for further investigations of a more immediate practical nature. These experiments, however, have shown conclusively that the activities of wood-boring insects are controlled very decidedly by the action of external factors, and that the zone of their optimum development is often very narrow. These results indicate that further investigations may make possible the formulation of simple, inexpensive, and practical control measures. It will, in all probability, be possible to control wood borers by very slightly modifying the present-day methods of handling logs. If this work can form the basis for further development in the control of injurious wood borers, it will have justified the expenditure of all the time and energy required in its prosecution.

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DERRIS AS A PARASITICIDE*

By Paul M. Gilmer

Derris, as at present produced commercially, is the product obtained by grinding the dried roots of certain tropical plants belonging to the genus Deguelia. It has long been known that in the tropics the macerated roots of these plants are used by the natives for stupifying fish, a fact which has recently led to investigations as to its possible value as an insecticide.

In 1919, McIndoo, Sievers, and Abbot called the attention of entomologists to the insecticidal properties of derris. Independently, work was also done by E. Mathieu, 1920, in the Straits Settlements, and by C. J. J. Van Hall, 1920, in the Netherlands' East Indies, upon its properties as a controller of certain insect pests. All found it to possess marked insecticidal properties.

In view of the desirability of developing satisfactory powders for the control of external parasites on animals, and because of the paucity of data concerning the properties of derris, it seemed desirable to extend these experiments with the following questions especially in mind:

1. Is derris a practical and economical insecticide?

2. Is it advantageous to mix the powder with tobacco dust, and if so in what proportions is it most effective?

3. What, if any, is the effect upon experimental animals?

4. What is the most practical method of applying it?

5. Against what type of insects is it most effective?

6. Are the powder and liquid extract equally effective and desirable?

The actual material used in the following experiments is made from a South American species of Deguelia by an English corporation. It is prepared both as a powder and as a liquid extract. The powder is produced by grinding the dried roots, while the liquid derris is the result of the extraction by certain liquid solvents of the fibrous residue from the ground roots used in the production of the powder. It was furnished by the American Tobacco By-Products and Chemical Corporation, of Louisville, Ky., which at present holds a monopoly of the supply of the manufactured material for this country.

The active principle is a resinous material, with a rather high toxic property so far as the higher invertebrates are concerned. It

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seems to act both as a stomach poison and as a contact insecticide. Results obtained in the following experiments seem to indicate that it also possesses considerable toxicity for vertebrates.

The liquid derris used was said to contain 16 per cent active derris and 84 per cent inert substances, the latter being for the greater part apparently pyridine, which is probably used as the solvent for the derris resin.

No analyses were made of the composition of the powder, largely because of the technical difficulties involved and because it would unquestionably vary considerably in different samples, owing to the manner of its manufacture. It is suspected, however, that it contains on the average between 10 and 20 per cent of the active resin, the residue being cellulose, the debris of ground roots, etc. The powders were used as furnished by the By-products corporation and had the following compositions:

Powder No. 1.	Derris powder 10 %	—Tobacco dust 90 %	
No. 2.	Derris powder 7½%	—Tobacco dust 92½%	
No. 3.	Derris powder 100 %	—Tobacco dust 00 %	
No. 4.	Derris powder 20 %	—Tobacco dust 80 %	
No. 5.	Derris powder 7½%	—Tobacco dust 67½%	
			Powdered sulphur 25%

The experiments were of two general types; those performed with the derris powder as furnished, and those with the liquid derris extract. The experimental animals were cats, dogs, white rats, and chickens; the insects being fleas, lice, chicken lice, and to some extent cockroaches. The fleas included the rat flea *Ceratophyllus fasciatus* Bosc., and the cat and dog fleas, *Ctenophalus canis* Curt. and *C. felis* Rothsc.. The chicken lice included both the body louse, *Menopon biseriatum* Paiget, and the head louse, *Lipeurus heterographus* Nitzsch., but especially the latter. The rat louse was the common louse of these animals, *Polyplax spinulosus* Burm. The cockroaches included the American roach, *Periplaneta americana* Linn., and the croton bug, *Blatta germanica* Linn.

The experiments began with the use of white rats which were infested with the rat louse. It was found at once that a very slight amount of the powder was effective against the insects. It was ordinarily applied by small pinches rubbed into the fur, usually two on the back, one on the belly, and two small pinches on the flanks—five in all.

When used pure the powder (No. 3) acted with surprising rapidity, the animal usually being practically free of lice within a few hours (usually from three to five hours). In every case, however, where the pure powder was used the rats were sick on the following day; a profuse, watery diarrhea was noted, the nose was dry, respiration rapid, and the animal gave every symptom of high fever. Thirst seemed insatiable, the animal lying by the water container and drinking repeatedly. In all cases but one, death ensued within three or four days, the body being exceedingly emaciated. The surviving case had been given a rather smaller dosage (three pinches only, one applied to the belly and two to the back). This animal recovered from the effects of the derris but never again became vigorous. It died about a month later from a pulmonary infection with which it had previously suffered. There can be little doubt that the severe illness due to derris poisoning considerably hastened its death. The powder acts as an internal poison, being licked off the fur by the animals in grooming their coats.

The pure powder was used rather sparingly on a full grown cat for the flea, *C. felis*. The animal was completely rid of the insects, and seemed to suffer but slight inconvenience. There was no sign of the diarrhea so pronounced in the rats, but some symptoms of a feverish condition in its dry nose and a desire to drink. The cat was fully recovered in forty-eight hours and suffered no further inconvenience. The amount of powder used per unit of body weight was considerably less than with the rats, approximately one fourth to one third, it is estimated. No attempt was made to weigh the powder, as the inevitable wastage in applying it made such a procedure seem a useless check.

With a small puppy, about the same size as the cat used, so far as could be noted, the powder produced no ill effects, and was certainly effectual in removing the fleas, *C. canis,* with which the animal was heavily infested. On both the cat and the dog, the powder was applied in generous pinches on the back, belly, and flanks, and rubbed in by stroking the animal against the "lay" of the fur. On both the cat and the dog the insects were quickly stunned, dropping to the paper upon which the animal was placed and, so far as noted, never recovered more than enough to crawl weakly for a short time.

Following this series of tests with the pure derris powder, similar experiments were made with the various diluted powders. All were found more or less effective, but there was considerable variation in their efficiency and time of reaction. Rats were again largely used as experimental animals, both because they were easier to handle and to keep, and because they were more easily reinfected after having once been cleared of parasites. The insects tested against were again the rat louse and the rat flea. The general results are discussed in the following paragraphs.

A rat, heavily infested with lice, was isolated and dusted as previously mentioned with five pinches of powder No. 2 (derris 7½% —tobacco dust 92½%). Twenty-four hours later there were still a considerable number of live lice present, altho the number was very considerably reduced. Forty-eight hours after treatment the number was still further reduced. A second and a third dusting produced like results, the third practically removing all lice.

A rat with a light flea infestation and a fairly heavy louse infestation was isolated and treated with powder No. 2 as above. Results were very similar to those obtained in the former experiment. No fleas were observed after the second application. It was noted, however, that the fleas that dropped from this rat very shortly after dusting seemed only stunned. Many of them recovered and were used to infect clean rats. It appears that the fleas endeavor to leave the treated rat to a certain extent. This may account for the fact that the dusting is not quite so effective in killing them as in killing the lice, and for the further fact that the second treatment completely cleared the treated rat. No attempt was made to trap the fleas.

These two experiments are fair samples of all those made with powder of this strength. The powder is moderately effective in this dilution but not so much so as are the slightly higher concentrations.

Powder No. 5 is similar to No. 2 in derris content but contains 62½% tobacco dust and in addition contains 25% sulfur in a very fine state. The results of the trial were slightly more satisfactory than with the No. 2 powder, owing doubtless to the action of the sulfur. The following typical experiments show the usual results.

A rat, infested with lice, was powdered as usual with five pinches of No. 5 powder. Twenty-four hours later the number of lice was very much reduced, the infestation remaining practically constant again after forty-eight hours. Twenty-four hours after the second treatment no lice were noted after a careful search. This rat was kept isolated and in a few weeks again developed lousiness, probably from the hatching of the numerous eggs contained in the fur.

A second rat, lousy, and with a slight flea infestation, was treated as usual. Most of the fleas left the animal at once, dropping on the paper a few minutes after the powder was applied. These fleas seemed badly affected by the powder, but a fair percentage (approximately one fourth) recovered after a few hours. This rat was given no second treatment, as the first completely removed the fleas by either killing the insects or causing their migration. It was noticed, however, that the louse infestation was again very much reduced. There is no doubt that the No. 5 mixture is considerably more efficient than the No. 2 containing the same percentage of derris.

A rat heavily infested with lice was treated with the No. 1 powder (containing 10% derris and 90% tobacco dust). The effectiveness of this powder was about equal to that of No. 5 so far as lice were concerned, possibly a little more efficient, but two treatments were necessary to clear the infested animal. Upon continued isolation infection again appeared in about the same time (two to three weeks) as in the animals treated with the No. 2 powder, due again probably to the hatching of the eggs in the fur.

A rat lightly infested with fleas was treated. This treatment was apparently more efficacious than the No. 5 treatment, the fleas leaving the animal but very few surviving after doing so. One treatment completely cleared the animal of fleas, and it is calculated that about 90% of those found on the paper did not survive. No count was made, the paper containing the fleas being placed over a rat cage in order to save the live fleas for further use.

The best results were obtained with powder No. 4. This powder contains 20% derris and 80% tobacco dust. A lousy rat treated with this powder showed no appreciable number of live lice after twenty-four hours. A second, examined after twenty-four hours, showed a few exceedingly sluggish lice. An isolated animal did not show reinfestation within two weeks and a half, when it was returned to the general hutch for reinfestation. This animal, the same that had been treated about a month previously with No. 2 powder, did not carry a large number of eggs, altho a few were noticeable on the fur at the time of treatment with the No. 4 powder.

A flea-infested rat was treated, and again the rat was flea-free within twenty-four hours. Apparently none of the fleas that dropped off this rat within the first five minutes recovered. Upon making a second test on another rat, of the seventeen fleas dropped off in the first five minutes none had recovered twenty-four hours later. These fleas were placed under a bell jar after being counted. This rat was given a rather heavy treatment, the pinches being generous, and since the animal was a large one, seven pinches were applied. It was accidentally returned to the flea-infested hutch immediately after treatment. This hutch had a moderate infestation with fleas, and a growing crop of larvae. Three days later a rat was removed for examination and no fleas were found. Altho it is not certain, it is probable from the results of later experiments that the powder retained in this rat's fur was distributed to the other three rats in the hutch as they lay sleeping together, and was finally scattered over the floor litter. Examination of the litter showed a remarkable reduction in the number of live larvae present. This same accident happened twice during the experiments, the second one completely destroying the flea infestation.

As a new flea culture was not obtainable, the experiments with fleas on rats were discontinued. However, some further work was done on stray cats and one experiment was made on a dog, all of which showed the 20% derris—80% tobacco dust mixture was very effective against fleas on these animals. The dog was treated by heavily dusting the rags in the box in which it slept. The method seemed completely effective against the fleas and also killed the few larvae contained in the old cloths. The work on cats was less satisfactory, as it was difficult to apply the powder effectively to them since they were all rather wild and objected strenuously to being handled.

Of the series of powders used, the No. 4 powder (derris 20%–tobacco dust 80%) seemed to be the best combination. When used on rats pure derris proved fatal to the experimental animal in all but one case, in which it was used very lightly. While all the powders produced slight symptoms of illness in rats, none except the pure derris produced any permanent ill effects. The 20% derris completely removed both the louse and flea infestations in one treatment, and the fleas did not revive after dropping off the animal. From the results obtained by placing the treated rats immediately in the flea-infested cages it seemed evident that direct treatment of the infested animals was not absolutely necessary. A series of tests was made, therefore, to determine if treatment of the nests or bedding was a practical method of eliminating the insects.

Three rats heavily infested with lice were put in a clean cage with chip litter. Excelsior was used for nesting material and a small teaspoonful of derris powder No. 4 was shaken loosely into the excelsior. The rats quickly worked this over into a nest, spending most of their time beneath it. Examination two days later showed no appreciable infestation with lice. The rats were left in the cage about a month and showed no reinfestation until again placed with infested rats for reinfestation. The experiment was repeated several times with from one to three rats with essentially similar results.

A similar experiment was tried with a small kitten harboring the cat flea, *C. felis*. Derris powder No. 4 was scattered over the old coat used as a bed for the kitten. This coat had a fair number of flea larvae in it, and the kitten showed a moderate infestation. Three days later no live larvae were found, altho the kitten still harbored some fleas. The kitten was not completely cleared, altho the number of fleas was very considerably reduced. She had the run of a small room with dusty earth as a part of its floor. She was accustomed to lie in this dust a considerable part of the time, and this probably served as a flea breeding ground which was untouched by the powder. It seems reasonable to believe from the gradual reduction in the number of fleas found upon her, together with the non-appearance of live larvae in the bedding box, that under the usual conditions, where the cat has free run and sleeps largely in the usual bedding box, this method will effectually clear the animal of fleas.

Since this same method had already been shown to be successful in the puppy experiment, no further work was done with dogs.

This latter phase of the work was not undertaken until late in the summer and during the winter, and the possibility of its application to sitting hens was not worked out. There is, however, more than an even probability that it may be of value in the treatment of nesting material for sitting hens for the purpose of destroying lice and mites. There are no data on its effect upon the viability of incubating eggs, but since the effective agent is a non-volatile resin, and tobacco dust is known to be non-injurious, there is no reason to anticipate any ill effects from its use. The fact, furthermore, that it retains its efficiency upon exposure to air without deterioration would add very considerably to its value for this purpose. It is intended to carry out investigations upon this phase of its use.

The work which was done in testing the efficiency of the powder as a louse remover with chickens showed it to be effective, but no more so than the familiar sodium fluoride. Its action is slower but equally certain. In the dry form it has certain advantages. It is not so irritating to the eyes, nose, and lungs of either the operator or the fowl as is the dry fluoride. It has no advantage over the fluoride dip treatment, is not so rapid in its action, requires more time to apply, and in all probability will never be as inexpensive as the fluoride treatment. There is no doubt, however, of its efficiency so far as louse removal is concerned.

A series of experiments with cockroaches was also undertaken. Here the 20% derris–80% tobacco dust mixture was also found to be effective, altho somewhat slow in action. Roaches forced to run through the powder and then confined in cages or small glass jars all died within twenty-four hours. These roaches were forced to run over a considerable depth of the powder and were thoroly coated with it. The powder was also mixed with flour and a little sugar and roaches were allowed to feed upon it. It proved an effective stomach poison, killing all the roaches experimented upon.

It was found fairly effective under the average conditions in which such an insecticide would be used. The rat cages and the cracks in the rough board tables were fairly heavily infested with cockroaches *(B. germanica)* which fed upon the grain, etc., found in the litter of the cages and upon the tables about them. The usual harbor was beneath the cages. Derris powder No. 4 was scattered fairly thickly about the cages and dusted into the cracks of the rough pine tables. There was a very considerable reduction in the number of roaches and with continued treatment they practically disappeared for some weeks after the treatment was discontinued.

In comparison with sodium fluoride for this purpose, derris has no advantage except that it is considerably less irritating to the mucous membrane of the nose, eyes, and respiratory passages; being, in fact, practically nonirritant unless inhaled in considerable quantities, when the tobacco dust will cause sneezing and coughing.

It is believed that derris is not quite so efficient as fluoride, and undoubtedly is much slower in action, as well as more expensive. Compared with a goodly number of the patented roach powders, however, it is both much more efficient and much less expensive, besides having the added feature of being non-deteriorating, a glaring fault of most roach powders having pyrethrum as the insecticidal base. Derris should be ranked second to sodium floride as a roach exterminator.

Some work was done with liquid derris. Its use upon animals is not to be recommended. The odor is very strong and repugnant to both animals and man, while the liquid is almost non-miscible and must be used with some sort of emulsifying agent such as soap, which makes it unhandy to prepare and use. As a spray for fruits and vegetables it seems to have no properties to recommend it above the ordinary insecticides. Its efficiency is a little below the better nicotine preparations, while its cost is no less and its preparation is more difficult. It does not mix well with sprays containing lime. It is, however, fairly effective and sticks well. Its effect if eaten with cabbage, lettuce, etc., is not known. It is very slightly toxic, altho probably not to a sufficient extent to cause illness in human beings in the quantities likely to be consumed.

Conclusions

From the experiments undertaken it is evident that derris furnishes a very efficient insecticide, particularly when used as a powder against ecto-parasites. It is effective, easily applied, not repugnant to the animal or man, and retains its insecticidal properties unaltered in the open air. It should be used about the same as pyrethrum powder, and in the 20% derris–80% tobacco dust mixture affords a killing powder about as great as commercial pyrethrum. Its stability in insecticidal power recommends it above pyrethrum even at a slightly higher price. It seems, however, to lack the instantaneous effect of the latter, and is not effective against flies when blown into the air. As a check against roaches, ants, and insect ecto-parasites, it is fully the equal of pyrethrum as ordinarily purchased.

The powder is not now obtainable commercially. When finally placed on the market it will probably cost about the same as pyrethrum, possibly a little less, and should make a very desirable addition to the means of combating household insects and external animal parasites.

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STUDIES ON THE LIFE HISTORY AND BIOLOGY OF *PERILLUS BIOCULATUS* FABRICIUS, INCLUDING OBSERVATIONS ON THE NATURE OF THE COLOR PATTERN[1]

(Heteroptera, Pentatomidae)

By Harry H. Knight

The writer's attention was first directed to *Perillus bioculatus* when specimens were found feeding upon the Colorado potato beetle, during July, 1913, in Genesee county, N. Y. Upon finding a red and black bug mating with a white and black individual, the idea immediately occurred that here was a fine opportunity to study color inheritance in an insect. Studies on the life history were at once begun, and the writer has given more or less time each year since to the rearing of this Pentatomid, except for the years 1917 and 1918. After the close of the war, and with the writer's removal to Minnesota in 1919, the study of Perillus was begun anew when the species was found fairly abundant in the vicinity of St. Paul. The first three years, or from 1913 to 1915 inclusive, were given over to breeding experiments and the study of color inheritance in the bugs. By the close of 1915 it became quite evident that the color forms could not be segregated by ordinary methods of breeding, but that individual colors were more dependent on the external conditions under which the bugs were reared. The season of 1916 was given over to a study of the factors influencing the color pattern of the bugs. The work on Perillus at Minnesota during the last three years has been chiefly on the nature of color, as well as a continuation of study on the factors influencing the color in individual bugs.

Since the double-eyed soldier-bug is of economic importance in the control of the Colorado potato beetle, the present paper is given over largely to an account of the life history and biology of the species with data on its importance as a beneficial insect.

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The following topics are discussed:

Classification and synonomy of *Perillus bioculatus*
History and distribution
Methods of rearing
- Life history
- Life cycle
- Egg cluster
- Oviposition
- Fecundity of females
- Incubation
- Hatching
- Nymphal instars
- Feeding habits of nymphs
- Habits of adults
- Mating habits
- Length of life
- Hibernation

Determining the fatal minimum temperature by the thermoelectric method
Economic importance of Perillus
Kinds of insects fed upon by Perillus
Technical descriptions
- The egg
- Nymphal instars
- The adult

Color varieties
Nature of the color pattern
Change of color in adult
Relation of temperature to color forms
Relation of color to sex
Conclusion
Perillus circumcinctus Stal
Notes on the life history of *Perillus circumcinctus*
Literature cited

Classification and Synonomy

The double-eyed soldier-bug was first described by Fabricius (1775) as *Cimex bioculatus,* from specimens which had been collected in America by Drury. The same author in his later works (1781, 1787, 1794, and 1803) records the species by repeating the original description but without adding additional information. Goeze (1778) and Gmelin (1788), both record *Cimex bioculatus,* but merely transcribe the original description by Fabricius.

Thomas Say (1825) described this species as new, under the name *Pentatoma clanda,* and recorded it as inhabiting "Missouri." Say states that the species is very variable and describes varieties *a, b,* and *c*. Stal (1872) placed *bioculatus* in his genus *Perillus,* which in 1862 he had described as a subgenus of *Oplomus* for the reception of *confluens* H. S., and his new species *virgatus* and *circumcinctus*. In the opinion of the present writer, *virgatus* Stal is nothing more than one of the many color forms exhibited by *Perillus bioculatus*. Distant (1880), under the name *virgatus* Stal, gives a good figure of a pale color phase of *bioculatus*. In a majority of specimens of this white color form, the black bar on the anterior portion of the pronotum is separated by a white median line, but not always, for the writer has a few specimens in which the black is united to form a transverse bar, as shown by Distant.

Uhler (1872), under the name *Perillus claudus*, records *bioculatus* from the western territories of the United States, and in subsequent papers records the species from various western localities. Under the name *Perillus splendidus*, Osborn (1894) recorded from Colorado what was undoubtedly a dark red form of *bioculatus*.

Schoutedon (1907) made *bioculatus* Fabricius the type of a new genus, *Perilloides*, but later workers have rejected this name, believing that *confluens* H. S., genotype of Perillus, is really congeneric with *bioculatus* Fabricius.

The present synonomy of the species is as follows:

1775 *Cimex bioculatus* Fabricius, Syst. Ent., p. 715.
1778 *Cimex bioculatus* Goeze, Ent. Beytr., ii, p. 248.
1781 *Cimex bioculatus* Fabricius, Spec. Ins., ii, p. 358.
1787 *Cimex bioculatus* Fabricius, Mantissa Ins., ii, p. 295.
1788 *Cimex bioculatus* Gmelin, *in* Linnaeus, Syst. Nat., Edn. 13, i, pt. 4, p. 2157.
1794 *Cimex bioculatus* Fabricius, Ent. Syst., iv, p. 120.
1803 *Cimex bioculatus* Fabricius, Syst. Rhyng., p. 175.
1825 *Pentatoma clanda* Say, Jl. Acad. Nat. Sci. Phil., iv, p. 312.
1859 *Pentatoma clanda* Say, Compl. Writ., ii, p. 240.
1862 *Oplomus (Perillus) virgatus* Stal, Stett. Ent. Zeit., xxiii, p. 89.
1870 *Perillus virgatus* Stal, Enum. Hem., i, p. 32.
1872 *Perillus bioculatus* Stal, Enum. Hem., ii, p. 129.
1872 *Perillus claudus* Uhler, Hayden's Surv. Terr., Rept. for 1871, p. 395.
1875 *Perillus claudus* Uhler, U. S. Geog. Surv. w. 100th mer., V, chap. xii, p. 830.
1876 *Perillus claudus* Uhler, Bul. U. S. Geol. Geog. Surv., i, p. 281.
1877 *Perillus claudus* Uhler, Bul. U. S. Geol. Geog. Surv., iii, p. 398.
1877 *Perillus claudus* Uhler, Wheeler's Rept. Chief. Eng., for 1877, p. 1323.
1878 *Perillus claudus* Uhler, Bul. U. S. Geol. Geog. Surv., iv, p. 504.
1880 *Perillus virgatus* Distant, Biol. Cen.-Amer., Rhyn., i, p. 34, pl. 3, fig. 22.
1886 *Perillus claudus* Uhler, Check List Hemip., p. 4.
1893 *Perillus bioculatus* Lethierry and Severin, Cat. Genl. Hemip., i, p. 206.
1894 *Perillus claudus* Uhler, Proc. Calif. Acad. Sci., ser. 2, iv, p. 228.
1895 *Mineus bioculatus* Gillette and Baker, Hemip. Colo., p. 12.
1895 *Perillus claudus* Gillette and Baker, Hemip. Colo., p. 12.
1904 *Perillus bioculatus* Van Duzee, Trans. Am. Ent. Soc., xxx, p. 66.

1907 *Perilloides bioculatus* Schoutedon, Genera Ins., Fasc. 52, p. 37.
1909 *Perilloides bioculatus* Kirkaldy, Cat. Hemip. Heterop., i, p. 6.
1910 *Perillus bioculatus* Banks, Cat. Hemip., p. 95.
1912 *Perilloides bioculatus* Zimmer, Univ. Nebr. Studies, xi, p. 234.
1917 *Perillus bioculatus* Van Duzee, Cat. Hemip., p. 73.
1917 *Perillus bioculatus* var. *clauda* Van Duzee, Cat. Hemip., p. 74.
1919 *Perillus bioculatus* Hart, Bul. Ill. Nat. Hist. Surv., viii, p. 198.
1920 *Perillus bioculatus* Stoner, Univ. Iowa Stud. Nat. Hist., viii, No. 4, p. 117.

History and Distribution

The original home of *Perillus bioculatus* appears to have been the eastern slopes of the Rocky Mountain region. From there it has migrated eastward, apparently following the movement of the Colorado potato beetle, which forms its natural food. Thomas Say (1825) described this species from material collected during the expedition of Major Long to the Rocky Mountains, and altho the author states that the species "inhabits Missouri," the specimens described were probably collected in the western part of that territory.

What appears to be the first published account of *Perillus bioculatus* as a beneficial insect feeding on the Colorado potato beetle, is given in a bulletin by Howard (1900). This record is in the form of a letter, which was accompanied by specimens, from Mr. J. A. Green, Waynoka, Oklahoma. The letter, dated September 16, 1899, describes the feeding habits of Perillus on the Colorado potato beetle, with notes on the life history and relative abundance of the species.

An unpublished account of observations on *Perillus bioculatus* was recently related to the writer by Dr. H. B. Hungerford. He states that as a small boy, during the summer of 1896, when living near Fairbury, Neb., it was his task to rid the potato vines of the Colorado potato beetle. Then it was that he became acquainted with a conspicuous stink-bug, black in color and varied with white, yellow, or red, which was present in some numbers feeding on the potato beetle. The predaceous habits of these bugs proved of such interest that specimens were placed in cages where he fed them daily with grubs and adults of the potato beetle.

The eastward movement of *Perillus bioculatus* is reflected to a certain extent in the writings of various entomologists who have noticed the predaceous habits of the bug in its relation to the Colorado potato beetle.

Osborn (1892) listed *Perillus bioculatus* from Iowa, and indicated that it occurred rarely in the state. Stoner (1920), in a comprehensive account of the Scutelleroidea of Iowa, records only three specimens from the state. This would indicate that the species is still rather scarce, or perhaps the collectors have neglected to look in potato fields.

In his annotated list of the Pentatomidae, Van Duzee (1904) recorded *Perillus bioculatus* from New Mexico, Colorado, Kansas, Nevada, Idaho, and Montana.

Pettit (1908) reported *Perillus bioculatus* from Michigan and gave the following note: A predaceous bug "appeared during the summer of 1907 in potato fields all over the state and did noble service in killing off the potato beetles. These bugs were seen to be repeatedly piercing the larvae of the beetles and sucking them dry. Indeed, we were told by some farmers that this work was so effective on certain farms as to make it unnecessary to spray for the [potato] bugs."

Chittenden (1911) published a note in which he states: "*Perillus bioculatus,* a predaceous bug, was reported by Mr. D. H. Shannon, Appleton, Wisconsin, as having been noted killing the Colorado potato beetle in August, 1908."

Bethune (1911) reports as follows: "A very remarkable occurrence of predaceous bugs has taken place in Southwestern Ontario during the last few weeks. Correspondents in the counties of Dufferin, Norfolk, Oxford, and Middlesex have sent in specimens of *Perillus bioculatus* Fabr., and of its variety, *claudus* Say. The latter form was described and figured in the Second Annual Report of the Entomological Society of Ontario, published in 1871, under the name of *Perillus circumcinctus.* These bugs, both in the imago and nymphal forms, are destroying the Colorado potato beetles, both eggs, larvae, and mature beetles, to such an extent that in some fields it is reported that hardly any of the beetles are to be found, though the plants have not been sprayed. They are quite abundant also at the College in Guelph and other parts of the County of Wellington. The specimens have been kindly identified by Mr. E. P. Van Duzee. He expresses surprise at the species being found in this part of Ontario, as he considers it a southern form, and is rarely known to be found as far north as the State of Illinois." The present writer is inclined to believe that the early record mentioned above (1871) really applied to *Perillus cicumcinctus* as we know it now, a species which is sometimes found feeding on the potato beetle but never in abundance.

Yothers (1911), in speaking of the article by Dr. Bethune, reports as follows: "I also am glad to report the good work of this insect in Michigan during the years 1908 and 1909. In 1908 it was sent in to the Michigan Agricultural College several times, and each time mentioned as killing the potato beetle. In 1909 it was sent in quite frequently, and from many localities. Several of the correspondents claimed that it was becoming so beneficial that spraying was hardly necessary. . . . . There seems to have been a northward spread of this insect, as it was not formerly known to occur as far north as Illinois, and here we have it in 1908 and 1909 in Michigan, and in Ontario in 1911."

Caesar (1912) publishes concerning *Perillus bioculatus* in Ontario, as follows: "*Perillus bioculatus* var. *claudus* has been found in many counties this year [1911]. Evidently it ranged almost all over the southern and western part of the province, and, at least, as far east as Toronto. In some fields it was present in large numbers and destroyed many of the adult Colorado potato beetles and also the larvae."

Nash (1912) published the following: "One of the Soldier Bugs, *Perilloides claudus,* appeared in considerable numbers this year [1911] in the potato fields, where it fed upon larvae of the potato beetle. Early in August I found several of these bugs in the nymph stage feeding on Tussock moth larvae. *Claudus* has never been a common insect in Ontario, and why it should have become abundant and so generally distributed this year is a mystery."

In 1913 the writer found *Perillus bioculatus* abundant in Genesee County, N. Y., at which time the present studies were begun. They were carried on for four years in that locality. On making inquiries, one farmer reported having noticed the bugs at work in his potato field, at least two years earlier, or in 1911. As yet the species has not been recorded from the New England states but there seems to be no good reason why it should not move as far eastward as the Colorado potato beetle has gone. At the present time the eastern limit of distribution for the species must extend well into the eastern half of New York, altho the most easterly record known to the writer is that of a specimen taken at Ithaca, in 1915.

In Minnesota, since the summer of 1919, the writer has found *bioculatus* fairly abundant in potato fields in the vicinity of University Farm. Specimens have also been received from Mendota, Northfield, St. Peter, Jordan, Center City, and St. Cloud, which would indicate that the species is well distributed in the central eastern half of the state. During the present year, 1923, Mr. C. E. Mickel has found *bioculatus* present in potato fields at Quamba, Kanabec County; Meadowlands, St. Louis County; and Thief River Falls, Pennington County.

Methods of Rearing

For rearing Perillus, the ordinary type of jelly glass was found to be a very convenient kind of cage. Holes punched in the lid furnish plenty of ventilation and at the same time prevent the potato leaves from drying out too rapidly. One pair of bugs in a glass will take very kindly to this arrangement, and when fed daily will produce eggs quite as freely as in the field. After the bugs have been confined in the jars for two or three weeks they become very tame, rarely try to fly when handled, and show little fear as they walk about on the hand or table. The female bug will lay her eggs on the potato leaves when provided, but in the absence of these, will lay eggs readily on the sides of the jar or on cheesecloth when it is supplied. The bugs should be fed once or twice each day, altho they will get along if neglected for a day. As fast as the eggs are laid they may be removed to new jars for rearing. After the nymphs attain the third instar it was found best not to keep more than six or eight in one jar. Unless plenty of food is available at all times the bugs may develop cannibalism. The unfortunate victim is usually attacked when in the act of molting. However, when the bugs are not overcrowded this difficulty rarely occurs. It was found necessary to clean the breeding jars frequently, especially when rearing nymphs on larvae of the potato beetle. For the purpose of keeping records, labels were pasted on the sides of the jars, or attached to the lids.

Life History

Life cycle.—The adults of Perillus come forth from hibernation as soon as the ground thaws out in the spring. By the time the potato plants show above ground, and the first potato beetles appear, Perillus may be found congregating in the potato fields. Their first meal in the spring is sap from the potato plant, but after that their food is almost, if not exclusively, the body fluids of potato beetles, their eggs and larvae.

Perillus lays its eggs in masses on the leaves of the potato plant. These hatch within five or six days, according to the temperature. In the second instar the nymphs begin feeding on eggs or small larvae of the potato beetle and as the bugs grow in size, large grubs and even beetles fall as prey. The nymphs pass through five stages or instars before attaining the adult stage; the average length of nymphal life being 19 days during July and August, and 22 to 24 days during September. Upon reaching the adult stage the bugs begin mating, and the females may start laying eggs six or seven days thereafter.

In New York, the first brood adults were found mating in the field July 9 and 10, 1914. One pair of these laid eggs on July 16, and from this lot adults matured August 9. This lot of bugs, or the second brood, laid eggs that matured the third brood during September. Thus three broods of Perillus matured when the first brood eggs were laid about June 10. But one of the females that laid eggs early in June also laid eggs as late as July 12. Thus the last eggs laid could not be expected to produce adults of the first brood before August 6, and the second generation adults by September 8 or 9. In western New York, during 1914, three broods of Perillus were reared when the overwintering females deposited their eggs before June 25, but the same females continued to lay eggs after that date, and these later eggs produced only two broods of bugs before the fall frosts drove beetle and bug into hibernation.

In the latter part of September and early October, depending much on the arrival of killing frosts, Perillus begins to seek hibernation quarters. The bugs usually hide away under piles of leaves or rubbish, altho many of them are found entering buildings. In fact, the habit of entering buildings appears to be an important factor in the preservation of the species in northern localities.

Egg cluster. The eggs are normally deposited in a compact double row (Pl. I) on the upper surface of the potato leaf. Two egg masses have been found on squash leaves, but on vines that were growing by the side of a potato patch, thus they were probably accidental. It is unusual to find eggs arranged in other than a double row, but when disturbed the female bug may at times deposit an irregular mass. In such case a partial third row of eggs is usually formed. Irregular egg masses usually occur where the female has been forced to lay on small, newly formed potato leaves. The average number of eggs laid in one mass is estimated at 14, altho 24 and 26 eggs have been found in single clusters, and one mass that was certainly unusual contained 33 eggs. The large egg masses are usually laid following times when the female goes three or four days without laying.

Oviposition. The overwintering bugs begin laying eggs in June, very soon after the potato beetles make their appearance on the potato leaves. The writer has observed the process of egg laying many times, both in the field and in the breeding jars. When the female deposits an egg, the tip of the abdomen first feels for the proper place, and while the valves of the ovipositor are pressed close to the leaf surface, they may be observed to swell and spread as the egg moves into position. With the end of the egg placed firmly against the leaf surface, the valves are moved upward and away, thus uncovering the egg and leaving it standing on end in the desired position. The actual movement of laying an egg requires only ten or twelve seconds. The interval between deposition of eggs is usually from one and one-half to two minutes, but the time for an individual bug rarely varies but a few seconds between eggs. The eggs are deposited in a double row, the sides of the eggs in contact and glued together. In placing the eggs the female alternates in such a way that one row never has but one egg more than the other. The eggs are yellow when first laid but begin turning brown almost immediately; within ten minutes they are blackish and by the end of an hour have attained their permanent, deep black color. The average female lays a cluster of eggs each day for the first five to seven days of egg production, following which she usually begins to skip alternate days, while the last egg masses deposited may be separated by periods of four or five days. Egg masses of from 24 to 30 eggs are produced as the result of a female going more than three days without laying.

Females that are kept segregated from the males frequently deposit infertile eggs. Invariably such eggs are pale in color when laid and never change to black. Females that are isolated from the males will continue laying fertile eggs for several days, but in the case of several such bugs it has been observed that after about two weeks, and the deposition of several egg masses, the last eggs to be laid remain pale, and in most cases never hatch. From this it would seem that the spermatozoa had all been used, and the unfertilized eggs without such stimulus remain pale in color. This observation has been made so many times that it appears quite certain that the act of fertilization produces changes in the egg which result in the black color. Of perhaps three dozen pale egg masses observed, only one was found to hatch part of the eggs. This particular egg mass is discussed below under incubation.

Fecundity of the females. In Table 1 is recorded the egg laying performance of nine female bugs selected as the most successful layers among fourteen that were started during August, 1913. The number of eggs laid in a mass is shown under the different dates as deposited, and where two or three egg masses were laid on a single day, the number of eggs in each mass is indicated. The death of a female is indicated with "D" under the date when found dead. The bugs were selected from reared lots, and isolated as pairs in cages, the records showing the total number of eggs laid by each female. The males lived as long as the females except in pair No. 5, of which the male died August 29, while male No. 8 died August 16. The highest number of eggs produced was 264 by female No. 8, while the lowest was 62 by bug No. 1, the latter dying somewhat prematurely. Averaging the total number of eggs laid by these nine female bugs, it is found that the average per individual is 144 eggs.

TABLE 1

Egg-Laying Record of Nine Females During August and September, 1913

The figures indicate the number of eggs in each mass as laid, and where two or three egg masses were laid on the same day these are indicated by separate figures. The death of each female is marked "D" on the date when it occurred.

Bug	August																			September						Total
No.	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	1	2	3	4	5		eggs
1	..	14	..	..	16	12	..	15	..	..	5	..	..	..	D	..	..	..	..	..	..	..	..	..		62
2	22	..	16	7	14	14	10	..	10	18	..	..	..	..	11	..	D	..	..	..	..	..	..	..		122
3	..	..	..	..	14	..	..	..	18	14	..	13	..	..	..	..	29	..	..	6	6	..	3	..	D 6th	87
5	..	..	..	10	18 12	3	16	..	..	..	15	..	..	..	..	..	..	..	..	10	15	..	..	..	D 12th	91
7	13	..	18 24	..	18 20	22	14	13	13	13	..	16	..	12	9	..	..	..	..	..	..	..	10	..	D 12th	215
8	..	18	16 16	11 21	6 14 13	10	18	..	11	..	20	15	..	14	11	22	..	..	17	11	D	..	..	..		264
9	..	16	14 25	18 7	18 23	18	23	15	..	18	..	*	..	..	..	..	..	..	..	..	..	..	..	..		172
11	..	..	..	..	7	16	13	8	..	17	..	11	..	..	10	12	..	..	8	10	10	..	5	6	D 16th	156
14	..	..	..	8 20	16	11	21	..	14	..	16	..	..	..	5	..	..	..	21	..	..	D	..	..		132

* Data on the death of female No. 9 are not shown in the records, altho it must have occurred shortly after the deposition of the last egg mass.

Incubation. The period of incubation normally is five or six days. In temperatures of 80°F. or above, five days were sufficient; with lower temperatures, or from 70°F. to 78°F., six days elapsed before the eggs hatched. One egg mass laid June 15 hatched on June 22, making a period of seven days for June. Since the normal color of the egg is black, one can not observe changes in the egg just prior to hatching. In one instance at least, where abnormally pale eggs were observed, it was possible to see changes of color in the eggs such as may be observed in Pentatomid eggs that are normally pale in color. This particular mass of 17 eggs, pale yellowish in color, was thought to be infertile when laid on August 5. It was observed on August 10 that certain eggs in this mass had turned dark orange red, and the following day these hatched in a normal manner. The egg shells left after hatching were pale in color, whereas the normal color of Perillus eggs is black before and after hatching. The nymphs from these particular eggs grew to maturity, and later two females from the lot laid eggs which were of the usual black color.

Hatching. The process of hatching requires about 10 or 12 minutes from the time that the nymph can be observed cutting the lid at the top of the egg. This is accomplished by means of the egg-burster or hatching spine, a T-shaped chitinous structure which rests on the anterior part of the head. By rotating within the egg, the emerging nymph gradually cuts out a lid at the top of the egg, and this hangs by a slender portion as if by a hinge, the hatching spine usually remaining attached to the lid. This lid is almost immediately forced up by the head of the hatching nymph, and the act of emergence is accomplished by a series of pulsating movements of the body fluids. The antennae and legs first appear closely appressed to the ventral surface, but as soon as released the legs take an active part in freeing the abdomen from the egg shell. Very shortly the newly emerged nymph moves to one side of the egg mass and remains quietly huddled with other newly hatched members. The gregarious habit is very pronounced among nymphs in the first three instars, but in the later stages the individuals become more or less scattered among the potato vines.

Nymphal Instars

The length of the nymphal instars varies according to the temperature under which the bugs are reared, even when an abundance of food is always at hand. Table 2 gives data on three lots of eggs reared in glass jars under natural conditions of temperature prevailing at that particular time of year. The 1913 and 1914 lots were reared at Batavia, N. Y., while the 1921 lot was reared at St. Paul, Minn. The data are arranged in a table similar to that given by Drake (1920) for *Nezara viridula* Linnaeus.

Owing to higher average temperatures prevailing during July and August, the average time from egg to adult in New York was found to be 24 or 25 days. This time was duplicated by other lots reared, but for which the exact time for individual instars was not always kept. During September the period of development for nymphs is more extended, some not completing their transformations before the potato beetles enter the ground. From eggs which hatched September 2, 1913, and were reared in the laboratory, two individuals attained the fifth instar during October. These were kept for hibernation but both were found dead on November 1.

In Minnesota, where eggs were laid on June 15, 1921, adults did not emerge until July 20, a period of 35 days. In this lot it is possible that growth was somewhat retarded because of irregular feeding, still it is doubtful if the bugs would have found more food in the potato patch during their early stages. From eggs deposited July 17, 1921, adults emerged August 15, a period of 28 days. Another lot of eggs deposited July 18 developed adults on August 16, taking the same number of days for development. From this it may be seen that during the most favorable growing period of 1921 three or four days more were required to mature adults at St. Paul than was the case at Batavia, N. Y., in 1913 and 1914.

The minimum time observed for an individual bug to pass from egg to adult stage was found to be 21 days, in 1914, at Batavia, N. Y.

TABLE 2

Length of Instars of *Perillus bioculatus* as shown by Individuals in Three Lots

Bug No.	Eggs		Period of incubation	Date of Molting and Number of Days in Each Instar										Total time from egg to adult
				First		Second		Third		Fourth		Fifth		
	Laid	Hatched		Molt	Instar	Molt	Instar	Molt	Instar	Molt	Instar	Molt	Instar	
	1913		Days		Hours		Days		Days		Days		Days	Days
1	Aug. 10	Aug. 15	5	Aug. 16	33	Aug. 18	2	Aug. 22	4	Aug. 27	5	Sept. 3	7	24
2	Aug. 10	Aug. 15	5	Aug. 16	33	Aug. 18	2	Aug. 22	4	Aug. 27	5	Sept. 3	7	24
3	Aug. 10	Aug. 15	5	Aug. 16	33	Aug. 18	2	Aug. 22	4	Aug. 27	5	Sept. 3	7	24
4	Aug. 10	Aug. 15	5	Aug. 16	33	Aug. 18	2	Aug. 22	4	Aug. 27	5	Sept. 3	7	24
5	Aug. 10	Aug. 15	5	Aug. 16	33	Aug. 18	2	Aug. 22	4	Aug. 27	5	Sept. 3	7	24
6	Aug. 10	Aug. 15	5	Aug. 16	34	Aug. 19	3	Aug. 22	4	Aug. 27	5	Sept. 3	7	24
7	Aug. 10	Aug. 15	5	Aug. 16	34	Aug. 19	3	Aug. 22	4	Aug. 27	5	Sept. 4	8	25
8	Aug. 10	Aug. 15	5	Aug. 16	34	Aug. 19	3	Aug. 22	4	Aug. 27	5	Sept. 4	8	25
	1914													
A	Aug. 5	Aug. 10	5	Aug. 11	32	Aug. 13	2	Aug. 16	3	Aug. 19	3	Aug. 26	7	21
	1921				Days									
a	June 15	June 22	7	June 25	3	June 30	5	July 7	7	July 14	7	July 20	6	35
b	June 15	June 22	7	June 25	3	June 30	5	July 7	7	July 14	7	July 21	7	36
c	June 15	June 22	7	June 25	3	June 30	5	July 7	7	July 13	6	July 20	7	35
d	June 15	June 22	7	June 25	3	July 1	6	July 9	8	July 16	7	July 21	5	36
e	June 15	June 22	7	June 25	3	July 1	6	July 8	7	July 15	7	July 21	6	36
f	June 15	June 22	7	June 25	3	July 1	6	July 9	8	July 16	7	July 21	5	36
g	June 15	June 22	7	June 25	3	July 1	6	July 8	7	July 16	8	July 21	5	36

Feeding Habits of Nymphs

During the first nymphal instar the bugs do not require animal food. Several groups of newly hatched nymphs have been watched, yet it seems rather doubtful if they even take sap from the leaf where they remain quietly huddled. In this stage the nymphs rarely move about, but spend the whole time in a closely formed group, apparently awaiting the second day, when they molt and start in search of food. During the second instar the nymphs feed largely on eggs or newly hatched larvae of the potato beetle; but when these are not available they may be observed attacking larger grubs, or joining in the feast provided by an older nymph or adult bug. When a nymph successfully attacks a grub, it is usually joined by two or three of its brothers, for increased numbers help materially in rendering the prey helpless. Beginning with the third instar, individual nymphs will attack all stages of the potato beetle grubs, and during the fourth and fifth instars the same nymphs will attack mature beetles when the grubs are not available.

The writer has reared Perillus from egg to adult on nothing but mature beetles, but in this case the beetles were always rendered helpless for the benefit of nymphs in the second and third instars. More labor is necessary in rearing Perillus on beetles alone that when grubs are available, yet it has been done in order to rear a fall generation of bugs after the potato beetle grubs have disappeared. By this method of rearing, Perillus could no doubt be kept active and breeding during the winter months if proper greenhouse facilities were available.

To determine the amount of food consumed by individual bugs, and thereby to estimate the economic value of Perillus, a good series of bugs has been reared singly in jars and a record kept of the food consumed. The following is an average for the food consumed during the different stages of development: Stage I: no food, or possibly sap from potato leaf; Stage II: 36 eggs of potato beetle; Stage III: 8 large grubs; Stage IV: 12 grubs or beetles; Stage V: 14 grubs or beetles. This gives a total of 36 eggs and 34 grubs or beetles, consumed by one Perillus nymph during its immature stages. Within six weeks one adult Perillus consumed 84 beetles and grubs, which combined with the average amount of food taken by a nymph during its development, gives a total of 36 eggs and 118 grubs and beetles destroyed by one Perillus. Under field conditions both nymphs and adults undoubtedly destroy many more eggs than were fed in the above experiments.

Habits of the Adults

When the adult Perillus comes forth from hibernation in the spring, it has first of all a thirst for sap from the potato vine. This is well illustrated by describing the actions of two males and six females which were observed in one lot confined in breeding cages. These bugs were kept fairly inactive until May 20 when they were placed in jars with potato beetles and exposed to outdoor temperatures. These bugs showed no great desire to attack the potato beetles provided, and fed only sparingly when mutilated beetles were offered them. On June 2, potato leaves containing eggs of the potato beetles were introduced into the cages. Immediately all the bugs became active, extending their beaks and probing around on the leaf surface, very quickly inserting the rostrum in veinlets of the leaf in preference to feeding on eggs of the potato beetle. Two of the bugs actually probed at the egg masses of the beetle, then without paying further attention to them, turned to feed on the leaf. Following a period of thirty minutes all six bugs were still drawing sap from the potato leaves. After thirty-five minutes, one of the males began paying attention to a female, whereupon copulation soon took place but without the female removing her rostrum from the leaf. Shortly after the thirty-five minute period of feeding, two female bugs turned to feed on eggs of the potato beetle. Following forty-five minutes of sucking sap from potato leaves, the last of the six bugs turned to feed on eggs of the potato beetle. Having finished their first meal on sap of potato leaves, these bugs were never again observed to probe at leaves for sap, altho they were watched closely each time fresh leaves were placed in the cages. Among hundreds of bugs confined in breeding jars during summer months, only two were ever observed in a feeding position on a leaf, and it seemed doubtful if these bugs were actually drawing sap. One of these bugs stood with rostrum extended to the leaf for nine minutes, but the movements were not such as usually occur with feeding, and the conclusion reached was that the bug merely chanced to remain resting in that position. Why these bugs should desire to draw sap from potato leaves only once, and that the first chance they get after emerging from hibernation, is a mystery. One can only guess that following hibernation sap is required for some physiological function in the process of bringing the body fluids back to normal from the condition of great density that obtained in hibernation.

Adults of Perillus feed on eggs, larvae, and mature potato beetles, apparently taking the stage that is most convenient. Beetles are frequently attacked even when the more easily managed lavae are abundant. When advancing to the attack, Perillus approaches with rostrum extended to the front, ready to insert the mandibles and maxillae the moment a soft part of its prey is touched. To make the insertion it seems necessary for the bug to place its front feet on the victim, thus gaining leverage to make the puncture, following which the bug retires as far as the rostrum will permit. Once the insertion is made the prey is securely held by barbs at the tips of the mandibles. When attacking beetles the bug usually approaches from the rear, inserting its rostrum near the tip of the abdomen or between sclerites at the side of the venter. However, Perillus has occasionally been observed standing on top of a beetle with tip of rostrum inserted at a point where the head fits into the thorax. Having attained this position it is difficult for the beetle to dislodge the predator.

In the potato field, the encounters between potato beetle and predator are not without interest. If the potato beetle feigns death when attacked, and tries to drop to the ground, the victim merely becomes suspended from the tip of the bug's rostrum. However, the beetle usually tries to pull away by scrambling rapidly over the leaves of the potato plant, dragging along the predator, who clings and pulls back at every opportunity. When these tactics fail the potato beetle may at times turn upon the enemy with mandibles snapping, trying desperately to snip antennae or legs, when they can be reached; but Perillus is very agile and usually manages to keep at rostrum's length, except at times when caged in small glass jars for breeding purposes.

In these encounters, all efforts of Perillus, following the insertion of mandibles in the soft integument of the beetle, are directed toward dislodging the feet of its prey and trying to keep the victim suspended in mid air, where scrambling feet avail nothing. These encounters in the potato field invariably result with Perillus the victor, while the beetle or grub, following loss of blood, remains suspended over the edge of a leaf and the predator finishes the meal undisturbed (Plate III, fig. 4).

In restricted quarters, such as glass breeding jars, Perillus is at a disadvantage and is not always able to keep the beetle at a safe distance. Therefore when confining Perillus for breeding purposes, and using adult beetles for food, it was found best to snip the mandibles of the beetle to prevent accidents to the bug, such as the loss of antenna or leg, which eventually would result in premature death of the bug.

Mating habits. Following hibernation, and after both sexes have had their first spring meal on sap of the potato vine, the bugs begin mating almost immediately. The males are polygamous and the females polyandric, thus it is necessary to keep the sexes isolated from the time they emerge, if one wishes to control the mating of individuals. The female will mate within a few hours following the molt to the adult stage. The male usually approaches from in front, applies the antennae with a vibrating motion upon head and antennae of the female. This is followed by the male pushing with head beneath that of female, very soon turning to one side and applying the head to basal part of the female's abdomen, raising her up from the normal standing position; whereupon the male turns quickly, extending the oedeagus to clasp with female, and if successful settles in a position of end to end, the bugs facing in opposite directions. The sexes will remain quietly in this position for hours at a time, and in the cages the isolated pairs were found to remain *in coitu* from early evening until late the next morning, and for successive nights during the period when the female was producing eggs.

When the female is deprived of the male during a period of active egg production, she will, after a period of about two weeks, begin laying infertile eggs. In the field it has been observed that the sexes continue mating during the warm days of fall, just prior to the time when frosts drive them into hibernation. This raised the question whether it is necessary, in the preservation of the species, that the males hibernate and copulate with the females in the spring. Accordingly, during the latter part of September, 1921, six pairs of copulating bugs were isolated in jars and kept for hibernation. Two of these females were found alive the following spring altho the males had perished. Without further contact with a male, one of these females produced a mass of 30 eggs on June 15, 1922, which were normal in color and hatched on June 22. This female also laid 6 eggs on June 20, 15 eggs on June 21, and 10 eggs on June 26, all of which hatched. It therefore becomes apparent that the female may occasionally carry the fertile eggs in her body during hibernation and deposit them the following spring.

Length of life. Under favorable conditions, the adults which mature during August and September of one year may be expected to hibernate and live until the first part of June the following year. The longest lived individual of which the writer has record was a white female bug which emerged July 29, 1921, and lived until June 18, 1922; making a period of 10 months and 21 days as an adult, to which may be added 23 days of nymphal development. The usual length of life is illustrated by a female that hatched on July 23, 1921, became an adult on August 14, and lived until June 13, 1922, also a female that hatched on August 28, 1921, and lived until June 25, 1922.

Ordinarily the male does not live as long as the female but of two males which hatched from the same egg mass on July 18, 1921, one lived until June 4, 1922, and the second until June 28. In New York, among the bugs that matured during September, 1914, at least six females were alive in the cages as late as July 8, 1915. One of these lived until July 13, and a second until July 15. The longest lived individual laid eggs on July 12 (which hatched), was alive on July 15, but was found dead on July 18.

Hibernation

With the coming of cool days in September, and the disappearance of the Colorado potato beetle, *Perillus bioculatus* begins to seek hibernation quarters for the winter. After the potato vines have been killed by frost, many bugs have been found in depressions of the ground beneath piles of the dead plants. Others leave the patch entirely and fly in search of more suitable hibernation quarters. Individual bugs are frequently found entering buildings, and such situations appear to be most favorable as places for passing the winter successfully. In northern regions, as in Minnesota and New York, a greater relative abundance of Perillus may be correlated with nearness to cities and villages where large numbers of bugs probably pass the winter safely within buildings of various kinds. This statement is borne out by the capture of a considerable number of specimens in buildings late in the fall and then again in the spring as the bugs become active and try to get out by way of windows. One bug has been found in hibernation beneath a burlap band which was wound around the trunk of an apple tree for the purpose of collecting larvae of the codling moth.

A survey of potato fields and egg plants at University Farm, St. Paul, was made on September 23, 1921, to learn what activities the bugs displayed following frost and the drying up of the potato vines. On that date the sun was shining and the temperature stood at 75°F. Bugs were scarce in the dead and dried up potato fields, altho six specimens of *bioculatus* were taken from spots where groups of potato beetles were feeding on potato tubers. From egg plants which were still largely green, 35 bugs were collected, of which two pairs were taken in copulation. Bugs were found among the dead leaves at bases of plants, others were active in the sunshine on the upper surface of leaves. Several of the active specimens were found feeding on potato beetles. Of the inactive specimens, five were found in one group under dead leaves at the base of an egg plant. Others were found two or three in a spot. Judging by these as well as other observations, the gregarious instinct in Perillus is sometimes apparent in their hibernation habits.

Under natural conditions the bugs come forth from hibernation during the first warm days of spring, or very shortly after the frost leaves the ground. At St. Paul, the earliest capture in the field was that of a red male taken on the sidewalk on May 7, 1920. In New York, the earliest field record was the capture of a female specimen, on April 17, 1915, at Batavia. Several specimens have been taken in buildings in April, and one bug was found active in February at the window of a heated room.

The condition of the bugs when they go into hibernation has much to do with the chance they have of passing the winter successfully. This condition depends on the activities of the bug, the amount of food taken, and the temperatures to which the bug has been subjected just previous to the time when it becomes inactive for hibernation. In handling various lots of bugs for hibernation it was noticed that some were much more successful in passing the winter than others. This may best be shown by giving actual figures on three lots of bugs selected from a large series kept for hibernation.

Lot A contained 27 bugs, 10 males and 17 females, all of which had matured in August. Beginning with September 1, these bugs, confined in jars without food, were kept in a cool situation which during September averaged between 60° and 68°F. On October 1 they were placed in cold storage where the temperature was gradually lowered until by October 15 it had reached 41°F. The temperature of the hibernating chamber ranged between 41°F. and the freezing point until the following May. Upon examining the jars on October 19, it was found that all were alive except 4 males and 3 females. An examination of this lot of bugs on May 19, 1922, revealed the fact that 3 males and one female had died since October 19, thus leaving 4 males and 12 females that had passed the winter successfully. These figures show that 59 per cent of the bugs passed the period of hibernation and came forth alive.

Lot 207 was composed of 15 bugs, 7 males and 8 females, which were kept active and given all the food desired as late as September 10. The bugs were then placed under similar conditions with Lot A. An examination of these specimens on October 19 showed that 6 males and 3 females were dead. When examined on May 19, 1922, only one male and one female were left alive. In this case only 13 per cent of the bugs survived the period of hibernation.

Lot 218 numbered 86 miscellaneous bugs collected in the field on September 1 and 2. These bugs were kept alive in jars with plenty of food all through September. By September 24, only 55 bugs were left alive. It was found on September 28 that 11 more were dead. Some of this number doubtless were bugs of the first brood which had matured in July, while the remaining 44 must have been of the second brood and of similar age to the preceding lots. On October 1 this lot of bugs was placed in cold storage beside Lot A and Lot 207. An examination on October 19 showed that only 3 males and 6 females were left alive. These figures indicate that 79 per cent of the bugs died between September 2 and October 19. On May 19, 1922, only one female was found alive.

On the basis of these observations it would seem that when the bugs are kept active thoughout September, and with plenty of food available, they are not in fit condition to go immediately into hibernation when cold weather overtakes them. The bugs that were kept inactive and without food during September, in a temperature of from 60° to 68°F., were in the best condition by October to pass into the hibernating stage.

Under natural conditions of hibernation the mortality of the bugs must be very high during most years. It has been the writer's experience during six or seven years' observation in potato fields in New York and Minnesota, that very few bugs appear in the fields the following spring, where the preceding fall they were very abundant.

Under natural conditions it appears that probably not more than 5 per cent of the bugs which go into hibernation come out safely in the spring. In New York and Minnesota this may well be due to the fact that many of the bugs seek hibernation in situations where their fatal minimum temperature is reached during the cold winters. In the spring of 1921 the largest number of bugs appeared in the field that the writer has ever observed. The fall of 1920 was very favorable for the bugs that went into hibernation, and following this the winter was unusually mild. The mild winter probably allowed many bugs to hibernate safely in situations where during ordinary cold winters their fatal temperature would have been reached. Such conditions would seem to account for the greater abundance of the bugs in the spring of 1921.

Determining the Fatal Minimum Temperature by the Thermoelectric Method[2]

To determine the fatal minimum temperature of a hibernating Perillus, experiments were performed utilizing the thermoelectric

[2] The writer is indebted to Dr. R. B. Harvey, of the Botany Department, University of Minnesota, for the use of certain apparatus as well as for helpful suggestions in the matter of taking temperatures by the thermoelectric method.

method for measuring temperatures. Using needle-type thermocouples with potentiometer that records temperature in millivolts, it was possible to follow the internal temperature of individual bugs, as well as the temperature of the surrounding air; to note the amount of undercooling which each could withstand, and finally the point at which actual freezing took place. For details of this method see White (1910), Harvey (1919), and Taylor (1920).

The bugs used in these experiments were all kept in the same hibernating chamber at a temperature averaging very close to 4°C., from October 15, 1921, until the hour of the experiment. The first attempt to freeze hibernating bugs was made on March 28, 1922, when ether was used to lower the temperature of the freezing chamber. This was accomplished by drawing air through the ether which surrounds the freezing chamber. With this particular apparatus the lowest temperature which could be obtained was —17°C. Four different bugs were reduced to this temperature and kept there for periods of fifteen to thirty minutes, but without attaining actual freezing. The freezing of undercooled tissue or liquids is always indicated by a rebound in temperature to the actual freezing point. One of these bugs was placed in the freezing chamber three different times, the periods totaling 45 minutes, during which the internal temperature was read at points between —15 and —17°C. This bug revived when warmed to room temperature and was alive and crawling about the next day in spite of the fact that it had been pierced with a thermocouple. The thermocouple, which had been reduced to the thickness of an ordinary pin, was always inserted through the anus and extended to a point near the base of the abdomen. The ether freezing chamber was discarded at this point since it was evident that lower temperatures must be reached in order to freeze the hibernating insects.

On the following day, March 29, carbon dioxide gas was used to reduce the temperature in the freezing chamber. With this arrangement one bug was cooled to a point where the internal temperature was read at —26°C. but without freezing taking place. Unfortunately, at this point the gas supply gave out, so it was not possible on that date to find the limit of undercooling which Perillus could withstand. It was two weeks before a new tank of carbon dioxide gas could be obtained, so the next attempt to freeze the bugs was not made until April 15. On this date some more of the hibernating bugs were taken from cold storage, where they had remained all winter undisturbed, at a temperature near 4°C. The first bug selected was undercooled to an internal temperature of —9.2°C., when a rebound occurred to —2.08°C., thereby indicating the actual freezing point. The second specimen undercooled was reduced to —9.74°C. when the rebound occurred and indicated —2.24°C. as the freezing point. Four more individuals were frozen but not one could withstand undercooling to a point lower than —9.18°C. It might be added that all these specimens were undercooled carefully to prevent shaking, which might cause inoculation prematurely, thus to determine so far as possible the limit of undercooling in an undisturbed insect. All bugs that were actually frozen, that is, in which a rebound in temperature took place, indicating crystallization, were killed even tho removed immediately from the freezing chamber.

Table 3 summarizes the data obtained from freezing ten specimens of Perillus, the first six on April 15 and the last four on April 17.

TABLE 3

Bug No.	Freeze (trial)	Undercooled to: °C.	Rebound to: (freezing point) °C.
1	1st	—9.20	—2.08
	2nd	—7.80	—2.01
2	1st	—9.74	—2.24
3	1st	—8.17	—1.79
4	1st	—9.18	—2.08
5	1st	—7.90	—1.70
	2nd	—7.70	—1.79
6	1st	—8.13	—1.88
	2nd	—8.62	—1.61
7	1st	—7.60	—1.52
	2nd	—7.60	—1.56
	3rd	—6.79	—1.48
	4th	—8.13	—1.50
8	1st	—8.40	—1.13
	2nd	—7.86	—1.15
	3rd	—5.50	—1.34
9	1st	—9.45	—2.30
	2nd	—9.03	—2.13
	3rd	—8.50	—1.90
	4th	—7.40	—1.90
	5th	—3.70	—1.90
	6th	—3.70	—1.70
10	1st	—7.16	—1.74
	2nd	—7.57	—1.88
	3rd	—7.25	—1.77

In Figure 1, temperature curves are plotted for the freezing of bugs Nos. 1 and 2, and since the temperature curves for the remaining bugs are very similar, these latter are omitted to prevent a confusion of lines on the graph. The dotted line shows the temperature of the air as recorded by a thermocouple placed at about three-sixteenths of an inch to one side of No. 1. This curve indicates that sufficient heat is given off during crystallization to raise the temperature of the air in the immediate vicinity of the bug. Similar changes in temperature at the moment of freezing, as recorded by the air couple, were noted in the freezing of other bugs, the amount depending on the dis-

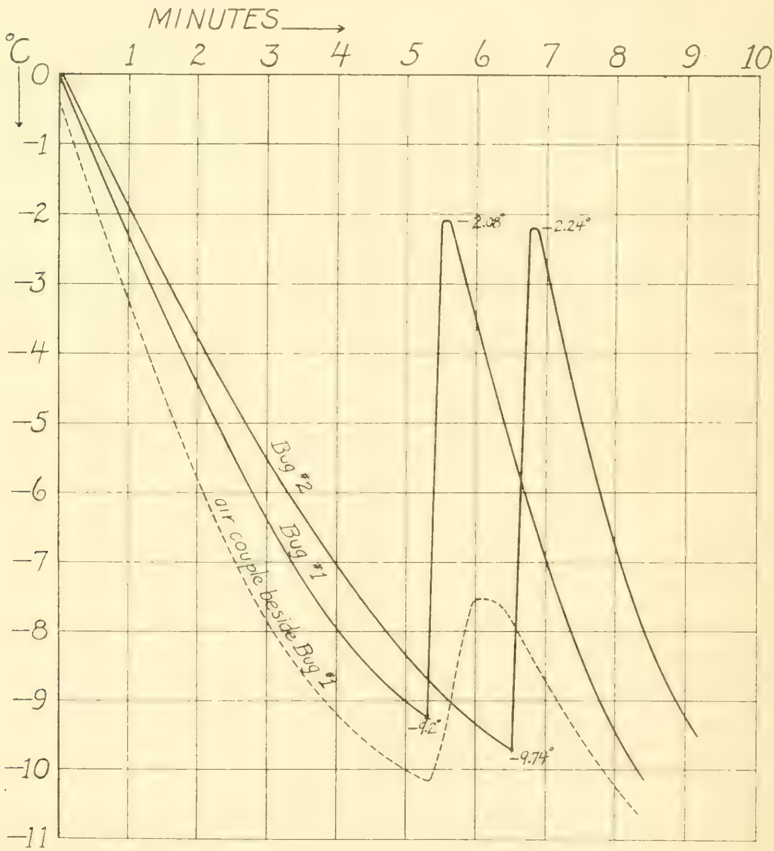

Fig. 1. The heavy lines are temperature curves for the freezing of bugs Nos. 1 and 2. The dotted line gives temperature of the air as recorded by a thermocouple placed at about three-sixteenths of an inch to one side of bug No. 1. This curve indicates that heat was given off by the bug at the moment of freezing which was sufficient to raise the temperature somewhat in the immediate vicinity of the bug.

tance of the couple from the bug. When lowering the temperature of the freezing chamber at the rate shown on the graph, the temperature of the bug showed a lag of about 1°C. This lag was more pronounced when the temperature of the freezing chamber was lowered more rapidly.

The surprising result of freezing the bugs on April 15 and April 17 was that not a single specimen could be undercooled to —10°C. without actual freezing taking place, followed by the death of the insect. As indicated above, it was not possible to freeze specimens at —17°C. on March 28, and one individual was reduced to —26°C. on March 29 without actual freezing taking place. From this it is apparent that certain changes took place in the hibernating bugs between March 29 and April 15, altho the latter lot had been kept inactive at a temperature near 8°C. It also would appear that there must be a periodicity in that physiological condition which enables the bugs to withstand low temperatures. Whatever the change in the resistance of the insects to low temperatures, it was not due to physical activity or warming up of the insect. It seems more likely that this change in resistance must be related to time or age.

As yet, Perillus has not been frozen at intervals during the fall as it goes into hibernation. Such experiments would indicate the rate of change and adaptation to lower temperatures. But from data presented above it is shown that if the bugs are to live through the winter they must undergo changes in the fall and adapt themselves to lower temperatures, something quite analogous to the well known hardening of plant tissue in the fall. Certainly the bugs undergo a drying out process, for examination of specimens during the winter and early spring shows that the body fluids have been practically eliminated. No doubt this concentration of body fluids and apparent elimination of free water, is largely responsible for the ability of these insects to withstand low temperatures during hibernation. This physical condition, coupled with results obtained in freezing the bugs, bears out the theory that the phenomenon of hibernation, which permits undercooling to temperatures much below the freezing point, is possible only because of the high water-holding capacity of the body substance; and this in its last analysis can be explained only on a colloidal basis.

In the tabulated data above, it will be observed that some of the bugs were frozen from three to six times, altho the bug was in each case killed by the first freezing. Bug No. 9 shows rather clearly that with successive freezing and thawing the freezing point is raised and approaches that of water. Each time the bug is frozen a certain amount of bound water is liberated, and a small amount of free water will prevent much undercooling, for the presence of water causes early inoculation and freezing. Then it would appear that the amount of undercooling possible in an insect will depend (1) on the amount of free water present and (2) on the density of the body fluids, or the colloidal content.

Economic Importance of Perillus

From time to time enthusiastic reports have come from potato growers in Michigan, Ontario, and New York, stating that Perillus was becoming so abundant that spraying for the potato beetle seemed unnecessary. In Genesee County, New York, the writer had opportunity to observe the result in a potato patch where the owner was depending on Perillus to control the potato beetle. The first brood of potato beetles had undoubtedly done considerable damage to the potato vines before Perillus had developed to the point of abundance. By the time the second brood of potato beetles had made their appearance the predatory bugs were quite abundant and apparently destroyed the eggs and young larvae of the beetle nearly as fast as they developed. However, a considerable number of potato beetle larvae were able to reach maturity, and meanwhile these had caused some damage to the vines. There was no doubt about Perillus doing good work in checking the damage caused by potato beetles, yet the bugs were not sufficiently numerous as to cause a scarcity of the beetles. Had Perillus been as abundant at the beginning of the season as was the case by September 1, very likely this predaceous bug could have been relied upon to control the potato beetle.

Unfortunately there are certain factors in the life history of Perillus which work against the increase of the species from one year to the next. As brought out under the subject of hibernation, it was estimated that not more than 5 per cent of the bugs present in the field in September, hibernate successfully. Thus we find each spring that Perillus is decimated in numbers, and not until the second generation has developed do they appear in numbers which would suggest control of the potato beetle. Some years they appear more abundant than others, and such seasons apparently follow a mild winter, as that of 1920-21 in Minnesota.

Another factor which enters to prevent the increase of Perillus is the fact that the bugs become poisoned by feeding on larvae and adults of the potato beetle which have previously fed on sprayed potato vines. Very early in the breeding work the writer learned that one must be very careful about the selection of food for Perillus, and never select grubs or beetles from vines which have been sprayed with arsenicals. Perillus is apparently more sensitive to arsenic poisoning than are the potato beetles, for one can go among the sprayed vines and select grubs which appear healthy, but when fed to Perillus the bugs die very shortly. This has been tested so many times that there is no doubt in the writer's mind that spraying for potato beetles will also result in the death of nearly all Perillus in the field sprayed. It is unfortunate that this is true, for otherwise Perillus might be able to destroy all the beetles not killed by the spray. From this it may be concluded that spraying for the potato beetle is also one of the factors which serves to check the increase of Perillus in commercial potato fields.

Perillus would prove more beneficial in the potato fields if they were not so economical in their feeding habits. Unfortunately they rarely waste food by giving up a victim that has been sucked to the point of death. Once the potato grub or beetle has been overpowered, Perillus feeds on the victim until it is sucked dry. Then again, when one Perillus seizes a victim in the vicinity of other bugs, the latter will join in sharing the food rather than each taking the trouble to kill a different victim. Were Perillus as bloodthirsty as *Podisus maculiventris* Say, the species would be more efficient as a beneficial insect in the control of the potato beetle.

The average amount of food consumed by an individual Perillus has been indicated above under a discussion of the nymphs. It was found that one nymph consumed 36 eggs and 34 grubs or beetles before attaining the adult stage. One adult Perillus destroyed 84 beetles and grubs during a life of six weeks, which is not an uncommon period of activity. Under field conditions the bugs would doubtless destroy many more eggs of the potato beetle than were fed in the above experiments.

Kinds of Insects Fed Upon by Perillus

There are a few records of *Perillus bioculatus* feeding on insects other than the potato beetle. Nash (1912) in speaking of this predaceous bug says: "Early in August I found several of these bugs in the nymph stage feeding on Tussock moth larvae." Marsh (1913) says that "*Perilloides bioculata* Fab. a pentatomid, was frequently found stabbing the partly grown Mamestra larvae." The writer has placed a larva of *Mamestra picta* in a cage with several hungry specimens of *Perillus bioculatus* and both nymphs and adults fed upon it. In 1913 and 1914, while breeding for color inheritance in Perillus, the writer made tests to find if insects other than the potato beetle could not be used as food for rearing the bugs. Among the insects that were tried as food were larvae of *Calligrapha* from willow, the army worm (*Cirphis unipuncta* Haw.), and *Melanoplus femur-rubrum*. In these tests it was found that the young nymphs of *bioculatus* failed to feed readily on the insects provided. Upon finding that the bugs would not feed on the larvae of *Calligrapha*, a genus of beetles closely related to *Leptinotarsa*, the idea of substituting food was given up.

During the present year, 1923, while collecting on the high prairie at Fort Snelling, Minn., the writer found both *P. bioculatus* and *P. circumcinctus* feeding on the goldenrod beetle (*Trirhabda canadensis* Kirby). Only one adult *bioculatus* was found in the field feeding on this beetle, but three nymphs were collected and reared along with a dozen nymphs of *P. circumcinctus*, all of which fed entirely upon *T. canadensis*. Specimens of the goldenrod beetle were then placed in jars with fifth-stage nymphs of *P. bioculatus* which had previously fed only upon potato beetle grubs, and several bugs fed upon the beetles provided. In the writer's experience only two insects, the potato beetle and *T. canadensis*, have been observed in nature to serve as food for *Perillus bioculatus*. Altho this Pentatomid has been found to feed on certain Lepidopterous larvae, such choice of food appears to be unusual for the species.

Technical Descriptions

The egg. The eggs are keg-shaped, but rounded off above and below, an average egg being 1.2 mm. high and 0.88 mm. at its greatest diameter. The upper portion of the barrel is distinctly marked with irregular reticulations but these become invisible as the lines approach the middle of the egg. The dorsal portion of the egg is encircled by a row of semi-erect chorial processes, clubbed at their apices and bent inward toward the micropyle. Within this ring is a smaller one surmounting the top of the egg, a circular carina of nodular structure, which on its outer circumference has a few supporting ridges that radiate from it. (Plate I.) The chorial processes vary slightly in number, and of several eggs examined, the number varied from 13 to 15. The color of a normal egg is deep black, but at times fertile eggs may be found which are dark brown to blackish. Infertile eggs are invariably pale, altho one pale egg mass was observed in which several of the eggs hatched.

Nymphal instars. The immature stages are represented by five nymphal instars, and upon molting for the fifth time the adult stage is attained. The first two instars are very similar, the chief difference being in size. During the third instar a difference in the red coloration may be noted, for in some individuals the original tomato red color is retained while in others the color may become orange red. In the fourth instar the margins of the meso- and metathorax become sinuated; in the fifth instar distinct wing pads are developed. (Plate I.)

First nymphal instar. Length 1.5 mm., greatest width 0.97 mm.; black; abdomen tomato red, with five dark patches on median line, lateral margins of segments with heavily chitinized black spots which join with similar spots on the ventral surface. The line formed by posterior margin of metathorax practically transverse. Antennae four-segmented; tarsi two-segmented.

Second nymphal instar. Length 3 mm., greatest width 2.3 mm.; similar to the first stage except in size.

Third nymphal instar. Length 5.2 mm., greatest width 4.3 mm.; very similar to the preceding stage but in some individuals the tomato red color may become orange red. The black color of the thorax may frequently show distinct greenish reflections; also the sclerites of the metathorax show a slight change in outline. (Plate I.) Tergites of the abdomen finely punctate.

Fourth nymphal instar. Length 6.5 mm. to 7.5 mm., greatest width 4.5 to 5 mm. Distinguished from the preceding instar by the sinuated outline of meso- and metathorax. The red coloration exhibits two distinct phases; the tomato red color may be replaced by reddish yellow but the dark markings remain much the same. The thorax is usually blackish with a greenish luster. Punctures on abdomen more distinct.

Fifth nymphal instar. Length 8 to 9 mm., width 5.5 to 7 mm. In this instar there are two distinct forms, the dark form in which the corium of the adult will be black, and the light form in which the embolium and inner half (or margin) of corium will be white or yellowish.

Dark form: Black, shining, with greenish luster, lateral margins of prothorax and frequently the outer margins of wing pads at base, yellowish to red; abdomen orange to red as in the preceding instar but with the dark chitinized areas larger and more prominent. Punctures of abdomen becoming fuscous or black. Wing pads strongly developed, attaining hind margin of second abdominal tergite.

Pale form: Head, antennae, and legs black to greenish, tibiae more or less pale on middle third; thorax and abdomen chiefly white or yellowish, abdomen with dark spots similar to the preceding stage but much reduced in size. Prothorax with a pair of black spots on anterior half but smaller than the corresponding spots in the adult; basal margin of pronotum blackish but not extending to lateral angles, also broken at median line by pale. Wing pads greenish black, outer margins broadly pale; mesonotum with a large pale area which separates the wing pads at base. (Plate I.)

The males are usually smaller than the females and can be separated by differences found in the genital segments. The greenish black chitinized areas along median line of the tergites, the mediodorsal plates of Hart (1919), each contain a transverse, curved suture connecting laterally with the orifice of a scent gland. The first suture, near the posterior margin of the third tergite, has at each lateral extremity a minute and perhaps nonfunctional orifice. The fourth and fifth tergites have more prominent sutures and the lateral extremity of each bears a well developed orifice, apparently connected with a functional scent gland. The fourth mediodorsal plate bears a suture but this is probably without functional glands.

The adult. Male, length 8.6 to 10 mm., width at base of pronotum 5 to 5.5 mm. *Female,* length 10.5 to 11.5 mm., width at base of pronotum 6.4 to 6.7 mm.

Subelongate, somewhat broadly ovate; lateral margins of abdomen visible from above, broad at middle and rounding sharply to apex. Dorsum glabrous, smooth except for punctures. *Head* rather densely, irregularly, and coarsely punctate; tylus and juga of equal length, the former with a prominent subapical concavity, outer margins of juga moderately elevated. Rostrum reaching upon intermediate coxae.

Antennae: Segment I, length 0.41 mm., thickness 0.166 mm.; II, 1.05 mm., distinctly compressed and uniform in thickness, greatest diameter 0.111 mm.; III, 0.83 mm., apex 0.17 mm. thick, slender at base and gradually thickened to apex; IV, 1.11 mm., 0.166 mm. thick, nearly cylindrical, slightly more slender at base and apex; V, 1.22 mm., 0.166 mm. thick, cylindrical, tapering to slightly more slender at base and apex.

Pronotum deeply, irregularly, and in places sparsely punctate; transversely across middle of disk and between calli, sparsely punctate. Lateral margins slightly sinuate, rather distinctly concave at middle, anterior angles with small but apparent tubercle; basal angles bluntly angulate, nearly forming right angles. *Scutellum* more nearly flat than in *circumcinctus;* basal half sparsely punctate except on black area each side of median line, apical half rather closely and more finely punctate. Pleurites of thorax coarsely, deeply, and irregularly punctate. *Ostiolar peritreme* slightly elevated, shining, narrowly surrounded by opaque, nearly crescent shaped in outline but the anterior margin rectilinear, inner half with a shallow sulcus which deepens and leads into the ostiole; ostiole situated slightly laterad of a line drawn through lateral extremities of adjacent coxae. In *circumcinctus* the ostiolar peritreme is narrower, its length equal to a little more than three times the width. *Hemelytra* rather closely and finely punctate; membrane extending slightly beyond tip of abdomen, dark fuscous to black.

Venter rather deeply but finely punctate, the punctures becoming obsolete near median line. Ventral spine reaching to middle of posterior coxae. Spiracles surrounded by black which forms a spot equal to at least three times the diameter of spiracle. Males with a quadrate area of dense, closely appressed, silvery pubescence each side of median line on segments five to seven but limited to anterior margin on seventh segment. Male genital claspers nearly triangular but the dorsal margin distinctly sulcate in outline. In *circumcinctus* the dorsal margin of genital clasper is practically rectilinear, the apex being rather broadly rounded while in *bioculatus* the apex is acute.

Legs typical for the genus; the anterior femora with a prominent tubercle or blunt spine situated on ventral surface, distant from the apex a space equal to diameter of femur. Rarely a specimen may be noted in which the tubercle is scarcely apparent.

Color Varieties

White color form. In this form the background is white with markings of black and brown. *Head* brown, becoming black at base. *Antennae* black, segments I, II, and base of III, brown to reddish. *Pronotum* with basal one-third brown, frequently black, basal angles not obscured; callosities covered by black, each with a nearly quadrate spot, separated by white on median line of disk; occasionally specimens occur in which the black spots join, thus forming a transverse black bar. Pleura black, usually showing ivory white irregularly on disk of each sclerite. *Scutellum* with black longitudinally along middle, becoming wider toward base and usually notched with white at middle of base; the roughly punctate and depressed basal half of lateral margins also black. *Clavus* except basal angle, and outer half of corium except apex, black; thus with embolium, inner half and apex of corium white; inner half of corium frequently with white area much reduced; membrane always dark fuscous or black. *Legs* dark brown, tibia becoming white on middle one-third, tarsi blackish. *Venter* black each side of ventral spine but not extending laterally to the spiracle on third segment; lateral submargins white, a prominent black spot surrounding each spiracle; ventral portion of fifth and sixth segments black or only narrowly pale along median line, in the male partly covered by dense silvery pubescence, seventh segment black on basal half; genital segment black.

The white areas described for this form may with age become red; the red color appearing first at basal angles of pronotum, tip of scutellum, apex of corium, and ventral areas of abdomen. Adults may at time of emergence have the pale areas partly red but in such specimens the corium is always black. The white color form here described always emerges from a fifth stage nymph which has the mesonotum pale, as is shown on Plate I.

Yellow color form. All the brown areas described for the white form are here deep black, while the white areas are reduced somewhat and replaced by yellow except on the tibiae. The corium is entirely black; embolium yellow but becoming black apically. The black on scutellum usually expanded, sometimes extending to base, and in dark forms spreading laterally so that only the apex remains yellow. In dark specimens the quadrate spots on pronotum may unite to form a transverse black bar. In the female the black on venter unites to form a lateral line, but situated somewhat beneath the black spots enclosing the spiracles.

Red color form. The pattern of this form is similar to the preceding except that the yellow color is replaced by red. Red forms occur in which the inner half of corium is red but in this case the bug was a white form to begin with and the red color has been attained during the adult stage.

The three color forms here described will include a high percentage of those which one may expect to find. In a series of several hundred specimens, however, it is possible to pick out specimens which show a gradual transition from one form to another. (Plate III, fig. 3.) The line of demarkation between the yellow and the red forms is not always clear, for in many specimens the yellow gradually becomes orange, and in fact that change actually takes place in living adults. However, the colors never change once the adult has been killed and properly dried. In a large amount of material collected ten years ago, the yellow and red colors have not faded in the least.

During the breeding experiments, in which the writer was trying to establish pure lines of color, both yellow and red color forms were reared from parents which were of the typical white color pattern. Likewise, white color forms have been reared from both red and yellow parents.

Nature of the Color Pattern

As stated briefly in the introduction, the writer began his studies on Perillus with the idea of working on color inheritance in this insect. After three seasons of breeding work trying to establish pure lines of the white color form, and of a red color form, it became perfectly clear that the color pattern of individual bugs was influenced more by conditions under which they were reared than by characters inherited from the parents. Since that time breeding experiments have been carried on with the purpose of determining those factors which produce the white color form, as well as the other extreme, the red color form. It is hoped to publish elsewhere a more detailed account of these experiments, but at the present time it is desired to make a few preliminary statements of the results which will better explain the nature of color varieties in Perillus and other Heteroptera.

The principal types of coloration found in insects have been dealt with in a comprehensive paper by Hagen (1883). Hagen reviews all the published statements regarding the nature of color in insects and then contributes much from his own researches. This author divides insect colors into: (1) dermal or cuticula colors; (2) hypodermal colors. Tower (1903) published additional data, especially through morphological studies on the hypodermis and cuticular layers. The present writer has made morphological studies on the body wall of Perillus and finds much in common with the figures published by Tower, exhibiting details of the hypodermis and cuticula of Coleoptera.

The present studies on Perillus show that the black and brown colors are located in the cuticula and are not subject to change, once the adult stage has been attained. The white, yellow, and red colors are located in the hypodermis and show through where black coloring matter is not present in the cuticula. The white color occurs in the absence of pigment granules in the hypodermal cells, while in the yellow and red varieties the hypodermal cells are filled to a greater or less degree with minute colored granules. The writer's breeding experiments with Perillus show that the accumulation of pigment granules in the hypodermis is influenced largely if not entirely by the physiological activities of the bug. And the physiological activities of the bug are governed very largely by the temperatures to which it is subjected. With some insects the kind of food taken would be expected to influence the color, but in the case of Perillus the food uniformly consists of body fluids of potato beetles and their larvae.

Explanation of Plate I

Plate I. *Perillus bioculatus* Fabricius, showing the five nymphal stages; also dorsal aspect of eggs, and one egg in lateral aspect greatly enlarged; photograph from colored chart. Two figures represent stage V, with yellow or red color form above and white form below.

Explanation of Plate II

Fig. 1. Three fifth stage nymphs feeding on a large grub of the potato beetle.

Figs. 2-5. Showing the actions of two fifth stage nymphs as they struggle for control of a potato beetle grub. In figure 5 one nymph has placed all its weight on the other bug.

Figs. 6-7. A fifth stage nymph of the white color form is shown in feeding attitudes, suspended largely by the hind legs.

Fig. 8. Three nymphs of the fifth instar attacking two large potato beetle grubs.

Fig. 9. Seven fourth and fifth stage nymphs attacking a large potato beetle grub.

Fig. 10. Adult Perillus, of pedigree stock, feeding on a potato beetle from which the elytra have been removed.

Fig. 11. Second stage nymphs feeding on eggs of the potato beetle, enlarged (X3).

Fig. 12. Nymphs of the second and third instars feeding on newly hatched grubs of the potato beetle.

Explanation of Plate III

Fig. 1. *Perillus bioculatus,* white color form, enlarged ($\times 4\frac{1}{2}$).

Fig. 2. *Perillus bioculatus,* showing four color forms, enlarged ($\times 2$); *a,* female, white color form; *b,* female, red color form; *c,* female, yellow color form; *d,* male, dark red color form.

Fig. 3. A series of *Perillus bioculatus* illustrating the range of color pattern and size (slightly reduced).

Fig. 4. *Perillus bioculatus,* red female, shown in characteristic feeding position with potato beetle grub suspended in mid-air.

Figs. 5-6. *Perillus bioculatus,* male and female ($\times 1\frac{1}{2}$), shown for comparison with a pair of *Perillus circumcinctus* (Stal) in figure 10.

Figs. 7-8. *Perillus circumcinctus* (Stal) attacking potato beetle grub; (fig. 7) the grub grasps the plant stem and succeeds in throwing Perillus off its feet; (fig. 8) Perillus is shown retaining its hold with rostrum after losing all foot-holds.

Fig. 9. *Podisus maculiventris* (Say) in characteristic feeding position, with rostrum inserted on the ventral side of a potato beetle grub.

Fig. 10. *Perillus circumcinctus,* male and female ($\times 1\frac{1}{2}$).

Fig. 11. *Perillus circumcinctus* feeding on grub of potato beetle (natural size).

PLATE I

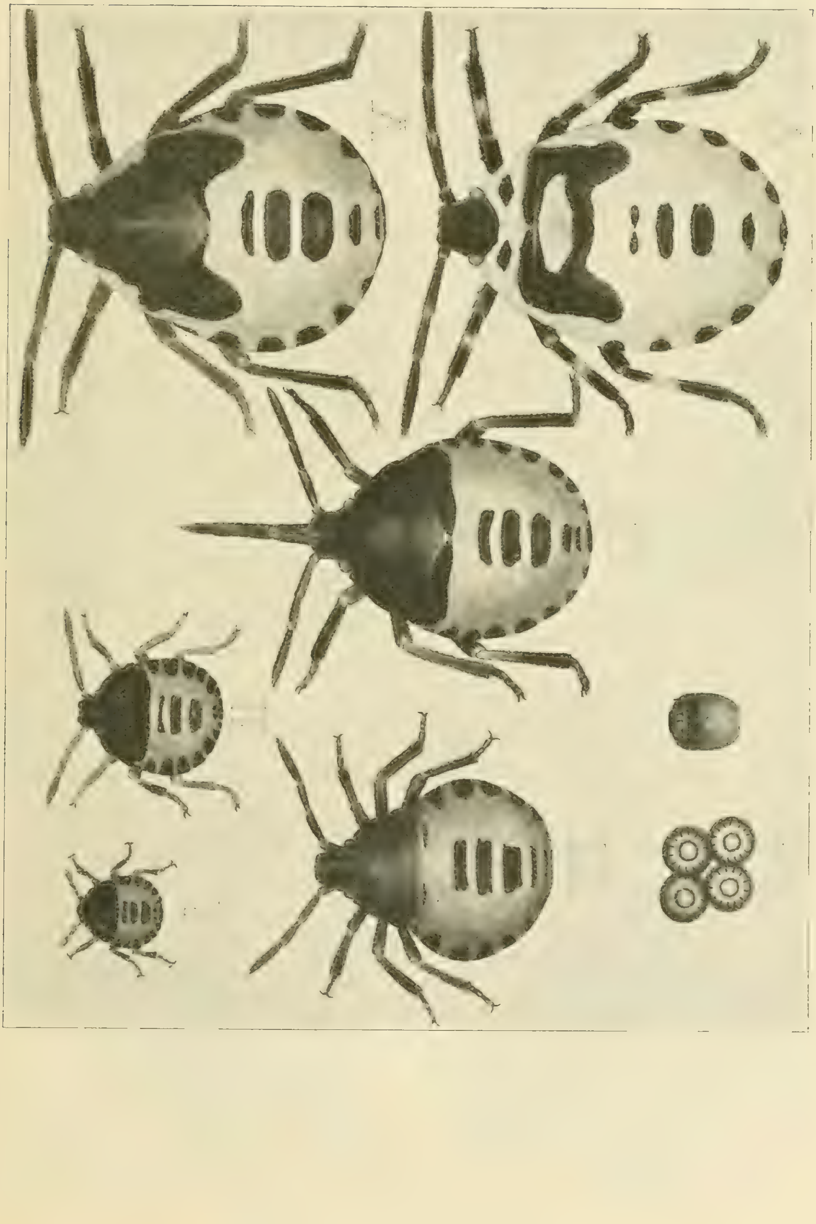

PLATE II

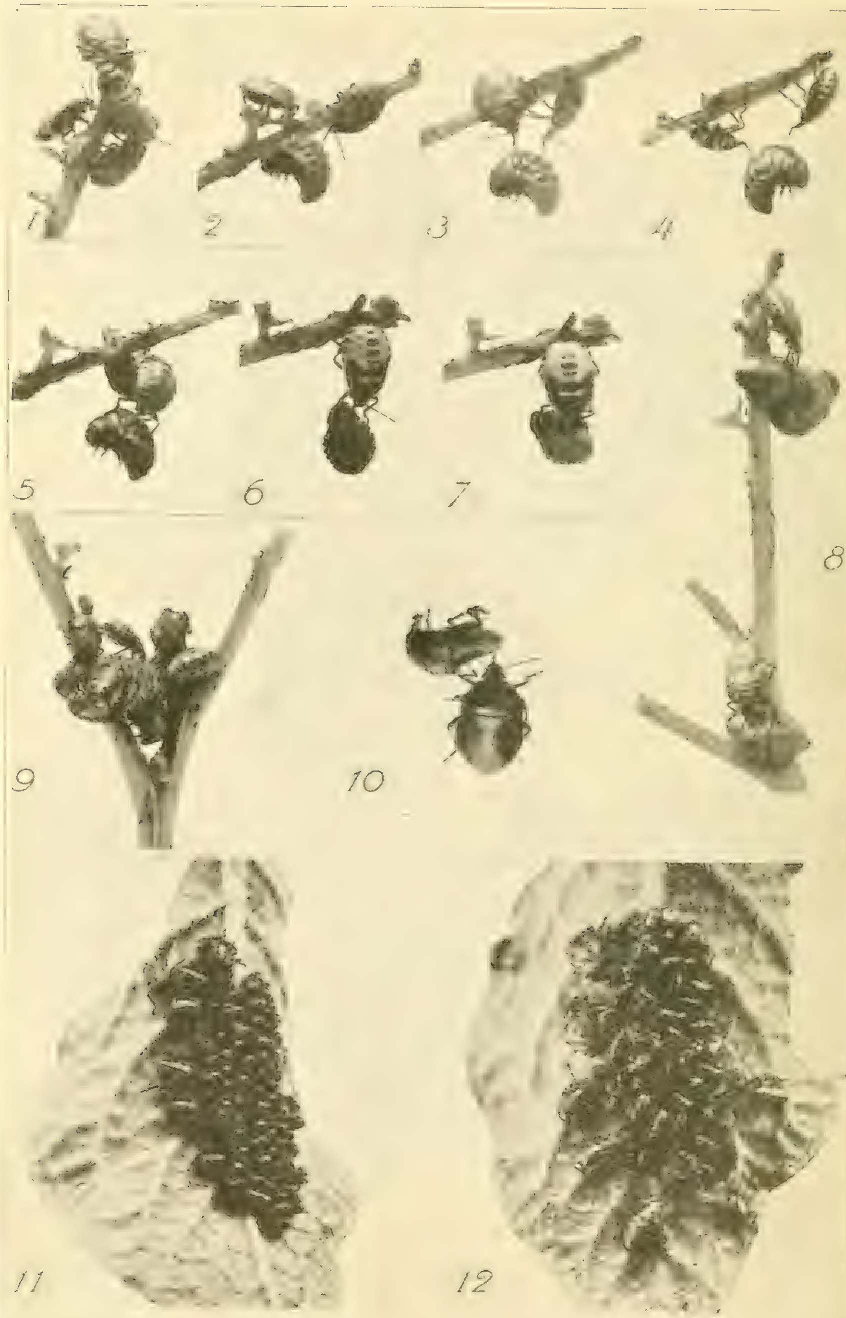

PLATE III

The hypodermal colors are subject to change during the active life of the insect. But the change of color in adult bugs is always in one direction, from white to red, or from yellow to red. Once the yellow or red color has been attained in the hypodermis of the adult, it remains throughout the life of the bug. Large numbers of adult bugs have been kept under observation, at both high and low temperatures, but in no case has the red color been reduced. The case is different with growing nymphs. During the last three nymphal instars the yellow color may change to red, or under other conditions, notably high temperatures, the red of a fourth stage nymph may change to yellow, and from that to white in the fifth instar. Thus the color pattern of an adult is determined largely by conditions under which the nymph has developed; for once having attained the adult stage, the cuticular, or black color pattern, can not be changed, while the hypodermal colors can change only in one direction, white to red, or yellow to red as the case may be.

Change of Color in Adult

As brought out above, the change in hypodermal colors of the adult Perillus is always in one direction, from white to red, or from yellow to red. The change of color in the typical white color form is of particular interest. In this form a yellow stage can scarcely be detected, for the appearance of color in the white pattern is almost immediately that of red. It is also noticed that the red color appears first at basal angles of pronotum, tip of scutellum, apex of corium, and ventral areas of the abdomen. From these points it progresses outward until in the final stages all the white areas may appear deep red. Male specimens turn red much more rapidly than do females, and in fact it is difficult to keep white males as long as two weeks without the red color developing. An examination of the hypodermis at points where the red color is just appearing, shows that the granules in the hypodermal cells are yellow at first but change very soon to red, or at least by the time the cell is well filled with granules. It appears that once these pigment granules have formed in the adult hypodermis, reduction never takes place.

The typical yellow color form has the hypodermal cells filled with yellow granules. Under certain conditions, notably temperatures of 78°F., or above, this color may be maintained unchanged. When the temperature goes below 75°F. for a few days, the yellow color begins to take on an orange-red cast, and if the bug lives six or seven weeks it may become deep red in color. During hibernation there appears to be no change in color of the bugs, and this is just as might be expected, since the physiological processes are at a standstill. It also shows that temperature of itself can not affect changes in color but only influences physiological processes during the active life of the insect. However, rapid changes of color have been observed in the two or three weeks prior to entering the state of hibernation, and again during the period when the bug becomes active in the spring.

Relation of Temperature to Color Forms

Rather early in the breeding work, the rearing of a high percentage of white color forms was correlated with high temperatures, both in the laboratory and in field collections. This was rather forcibly impressed on the writer during August, 1914, at Batavia, N. Y., while breeding for pure lines of color in Perillus. The progeny of pair No. 27 (yellow forms) began maturing August 3, and by August 10 twenty-one adults had emerged, all of which were yellow forms except one, which was white. From August 5 to 10, inclusive, the weather turned unusually hot, the temperature ranging between 83°F. and 95°F., the minimum temperature not going below 76°F. in the laboratory, and that only early in the morning. Of thirteen specimens that matured on August 14 and 15, two males were yellow, while three males and eight females were white. The appearance of white forms in other breeding jars was also conspicuous. From August 12 to 21 inclusive, the temperature remained much cooler, not going above 78°F. Between August 16 and 21, a total of thirty-nine yellow forms and only four white bugs matured in a group of nine breeding jars, which also included the progeny of pair No. 27. To the writer this was rather convincing evidence that external conditions, notably temperature, were having much to do with the color of the maturing bugs. However, breeding for pure lines of color was not discontinued at that time, but was kept up through the following year. Eventually, all progeny of the white parents became yellow or red forms, this occurring in the fall generation or in the spring. The progeny of red parents all became yellow or white during the hot weeks of July or August, and thus the parent type could not be maintained. Again in 1921 an effort was made to breed for a pure line of white color forms, but all the progeny from three pairs of white bugs became either yellow or red during the second or early-fall generation.

The influence of humidity on color varieties of Perillus has not been tested under conditions with absolute control, yet bugs have been reared under two extremes of humidity where the temperature was kept the same for both lots. This was accomplished by rearing bugs in glass jars, one lot in which the humidity was kept near the saturation point by supplying fresh potato leaves regularly. These created enough moisture to condense on the sides of the glass. The other lot of jars contained only cheese-cloth for the bugs to crawl over and thus was kept at the same humidity as the outside air. The bugs used in these experiments were in each case selected from one egg mass, part placed in the humid jars and part in the low humidity jars. Both lots of jars, when kept at a temperature of 85°F. or higher, matured a high percentage of white color forms, an occasional yellow male, but never a red one. The results from these two extremes indicate that humidity has little, if any, influence on the coloration of the bugs. These experiments were carried on during two different years but always with similar results.

Sunlight can scarcely be said to have a direct influence on the color pattern, for the above experiments have been carried out in the laboratory where the bugs were never exposed to direct rays of the sun. However, if the deposit of pigment granules in the hypodermis has a direct relation to physiological processes in the bug, it is very probable that sunshine indirectly speeds up these processes. Many observations show that sunshine stimulates an insect to greater activity, as do high temperatures even without sunshine. But at a given temperature, sunlight probably speeds up the physiological processes and produces what otherwise would be attained only at a higher temperature in the absence of the sun's rays.

Relation of Color to Sex

It was observed rather early in these studies that the male sex averaged darker in color than the female, altho it is possible to find white males as well as red females. An average population of 341 bugs, collected during August and September, 1913, gives the following results:

White form	Yellow form	Red form
16 ♂ 85 ♀	101 ♂ 50 ♀	72 ♂ 17 ♀

From this it is observed that in a given population of bugs, reared under the same average conditions, the male sex tends to be dark in color while the females tend to be light. This difference in color may very well be accounted for on a physiological basis. Since the females must mature large numbers of eggs it seems reasonable to suppose that the physiological processes go on at a higher rate than is the case in the male. Male specimens of the white color form have never been reared except with temperatures averaging above 82°F.

In the male sex, then, the only way of raising the physiological activity to a point where white color forms appear, is by rearing the bugs under high temperatures.

In Conclusion

It appears to the writer that *Perillus bioculatus* is, even among the Hemiptera, an exceptionally good form for the study of color in an insect. Bearing in mind that the food of this species is nothing but the body fluids of the potato beetle or its immature stages, and the quantity all that the bug desires, certain food factors that might influence changes in color are here reduced to a minimum.

Experiments show that low temperatures cause a greater deposit of coloring matter in the hypodermal layer, and with this condition a lower rate of physiological activity can be correlated, namely, longer periods of growth for nymphs to reach the adult stage. Apparently it is not temperature directly that affects the deposit of coloring matter in the hypodermal cells, but the influence of temperature on the physiological processes of the insect. With the ceasing of physiological activity, as in hibernation, no changes in color can be observed.

Since a maximum amount of pigment is deposited in the body wall under low temperatures (65°-75°F.), and the minimum amount deposited under high temperatures (85°-95°F.), it appears that increased metabolism does not produce pigment, but on the contrary must consume or otherwise dispose of the materials which under lower temperatures are laid down as pigment in the body wall. In this connection it is interesting to note that the most frequently found yellow and red pigments, in both plants and animals, belong to the group known as Carotinoids (Palmer, 1922). Furthermore, it has been shown by several workers that the carotinoid pigments oxidize readily in animals having a high rate of metabolism. Palmer (1922, p. 136) states: "The normal cause of the disappearance of carotinoids from both plants and animals is an oxidation. This is undoubtedly their ultimate fate in animals unless they are secreted in the milk fat or egg yolk (in fowls) or stored up as adipose tissue and thus protected from oxidation. Where the oxidative tone of the body is low, as in diabetes, coupled in many cases with abnormally large intake of carotinoids, it is not surprising that the pigments should appear in the tissues in abnormally large amounts. This is especially likely to be true of the epidermal tissues inasmuch as the effect of eating carotinoid-rich diets in normal persons shows that the subcutaneous glands can serve as an excretory medium for these pigments."

Palmer (1922) also calls attention to the work of Physalix (1894) who made chemical tests of the red pigment in one of the Heteroptera: "Red coloration in the integument among some species of bugs is unquestionably carotinoid at times, perhaps carotin itself. Thus, Physalix (1894) extracted the red pigment [undoubtedly from the hypodermal layer] of the hemipter, *Phyrrhocoris apterus,* from two liters of the insects. The pigment was deep red in carbon disulfide, yellow in alcohol and ether, gave the lipochrome reaction with concentrated H_2SO_4, and showed the absorption spectra of carotin. Physalix asserted that the pigment was carotin or a very closely related substance."

In the case of Perillus, it is interesting to note that once the red pigment is laid down in the hypodermis of the adult, it is never diminished, thus it must be protected from oxidation. The case is different in growing nymphs, for the yellow and red nymphs may at times (under high temperatures) become distinctly paler even between molts, altho the most rapid changes occur at the time of molting. Adults and nymphs placed in alcohol (70 to 95 per cent) remain for years (10 years) without losing their characteristic red and yellow colors, while dried specimens preserved on pins and kept for the same period retain the bright red and yellow colors nearly as in life.

The type of coloration manifested in *Perillus bioculatus* is exhibited in some degree throughout the order Hemiptera. In numerous forms examined, the yellow and red colors are all located in the hypodermis. Correlating the prevailing temperatures with extensive collecting of *Neoborus amoenus* (Reuter) and *Horcias dislocatus* (Say), indicates that the color varieties of these species are influenced by temperature in a manner similar to Perillus.

In the present work no attempt has been made to determine the chemical nature of the pigments involved, but rather to arrive at some understanding of the ecological factors which influence or govern the production of color in the body wall of Hemiptera. To the biologist it is worth something to know when and how the color pattern manifests itself. It is left to the chemist to say *what it is.*

In 1923 the writer interested Dr. L. S. Palmer, chemist and an authority on carotinoid pigments, in making chemical tests on the nature of the red and yellow pigment found in the hypodermis of *Perillus bioculatus.* Results of these experiments will be published elsewhere, but it may not be out of place to state that all the tests show the pigment to be nothing but carotin, the yellow or red color depending on the concentration of this pigment. Furthermore, chemical analysis of the blood of the potato beetle grub shows that the reddish color is due entirely to carotin and, strangely enough, not a trace of xanthophyll could be detected.

Perillus circumcinctus Stal

Another species, *Perillus circumcinctus* Stal, is sometimes found in potato fields feeding on *Leptinotarsa decemlineata* (Say). This species of Perillus has been the subject of some confusion as regarding its identity and relation to *bioculatus* Fabricius.

Van Duzee (1904), in speaking of *circumcinctus* Stal, says: "I have observed but little tendency to vary in this species." The writer is entirely in accord with this statement, and believes that all the variation mentioned by Zimmer (1912) was to be found only in specimens of *bioculatus* Fabricius. Distant (1880, Biol. Centr. Am., Heter. I, pl. 4, fig. 6) has figured an insect which he took to be a black form of *cicumcinctus* Stal, but judging from the colored figure, the present writer is satisfied that it represents an entirely different species. The outline of the drawing as well as the coloration is not that of *circumcinctus* Stal.

Because of a long acquaintance with *bioculatus* Fabricius, the writer desires to point out some of the differences between this species and *circumcinctus* Stal. In *Perillus circumcinctus* the pronotum is slightly longer and more convex, and this has been pointed out by Van Duzee (1904) and Stoner (1920). The coloration of the antennae can not be used for distinguishing the species, for in some pale forms of *bioculatus*, segments I, II, and base of III, are brownish to reddish. However, certain color aspects of *circumcinctus* appear to be distinctive, and since the species is not variable in this respect, those points are mentioned here. The spiracles appear black but are never surrounded by a distinct black spot having a diameter greater than the spiracle itself. In *bioculatus* the spiracles are inclosed in a black spot which in diameter is at least equal to three times that of the spiracle. In *circumcinctus* the pronotal disk is rarely transversely pale across middle, that is, just behind the callosities, but instead there are two broad dark brownish rays extending from the callosities to basal margin of disk, thus leaving the lateral margins and a distinct longitudinal median ray, pale. The dark color on dorsum is always more brown than black, also shines with a bronze luster, while the pale areas never become red. It is rare to find specimens of *bioculatus* so dark that the black color on base of disk extends to join that covering the calli. There are at hand three specimens of *bioculatus*, selected from perhaps one thousand examined, where the black on base of pronotal disk has joined with that on calli, but in these specimens the longitudinal median red ray has likewise been eradicated, or does not extend beyond middle of disk. Differences in the male genital claspers have already been described under the technical description of *Perillus bioculatus*.

Notes on the Life History of Perillus circumcinctus

On June 28, 1923, the writer found *Perillus circumcinctus* in some numbers on the high prairie at Fort Snelling, Minn. On that date several nymphs and two adults were taken. These specimens were all found on goldenrod where they were feeding on the goldenrod beetle (*Trirhabda canadensis* Kirby). This beetle was very abundant on certain large clumps of goldenrod and *Perillus circumcinctus* was concentrated in these places. Upon visiting the same locality on July 3, twelve nymphs and five adults were taken. The nymphs were kept for rearing and the last one matured July 10. All specimens collected were kept in cages and supplied with fresh goldenrod to which was added numbers of *Trirhabda canadensis*, their favorite food. However, it soon became apparent that *P. circumcinctus* would not rear a second brood, for no mating was observed among the several pairs. By the end of July several individuals showed distinct indications that they were preparing for hibernation. Fewer of the beetles were fed upon and the bugs began to crawl under dead leaves and cellu-cotton with which the cages were provided. One or two of the bugs were active until August 10, on which date they were last observed to feed on the goldenrod beetles. A collecting trip to the high prairie was made August 3, and while the goldenrod beetle was abundant, not a single specimen of *P. circumcinctus* could be obtained. No doubt all the bugs had retired preparatory to hibernation, as was noted in the breeding cages. At the present time, August 25, all the bugs, five pairs, remain in a hibernating position, with legs drawn up and antennae closely pressed against rostrum and ventral side of thorax.

These observations indicate that *Perillus circumcinctus* develops only one brood each year. Mating will not take place until next spring. This is very different from *P. bioculatus*, which species may frequently be found mating on the last warm days of September, some days after the last potato beetles have disappeared.

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PRELIMINARY NOTES ON THE MUTILLIDAE OF MINNESOTA WITH DESCRIPTIONS OF THREE NEW SPECIES[1]

By Clarence E. Mickel

During the summer of 1922, in the course of an ecological study of the sand dune area just north of Minneapolis, a large blowout was found to be literally swarming with solitary wasps. In fact, these insects were so numerous that it is doubtful if a square foot of ground could have been found in the whole ten acres that did not harbor several of them. The fauna included a great many species but the most conspicuous, in point of numbers, belonged to the families Bembicidae, Sphecidae, and Mutillidae. The Bembicids were especially numerous, were to be seen everywhere, and the ground was honeycombed with their burrows. The Sphecids were busy everywhere digging their nests, bringing caterpillars for provisions, and putting the finishing touches on their completed nests. Mutillids were universally present, the females running over the ground, and the males flying overhead, a foot or two above the ground. The number of Mutillids was rather remarkable since they are usually seen in small numbers, one or two individuals at a time. It was at once evident from an examination of a few representative specimens that several species of Mutillids were involved in the fauna of this sand dune area. Therefore an attempt was made during the season to collect a large number, hoping thereby to obtain specimens of all the species present. This collection and other specimens taken in other parts of the state during the year and a few collected in previous years, form the basis of this paper.

The blowout mentioned above is located in a sand dune area in the most southern part of Anoka county, about one mile east of the town of Fridley, and about two miles north of the Minneapolis city limits. It is about ten acres in area, and is practically barren except for a few spots which are sparsely covered with short vegetation. There are several other blowouts in the same vicinity but none are so large or have so abundant a fauna of solitary wasps as this one. The soil of the surrounding country is sandy but in most places is covered with vegetation and is not blown about by the wind. The adjacent territory is for the most part virgin prairie, altho on the southeast

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side there is a small area of oak woods, and within a mile there are stands of oak and other trees.

The Bembicids which were found so abundant belonged to the species *Bembix pruinosa* Fox, and *Microbembex monodonta* Say; the Sphecids were mostly *Sphex argentatus* Hart; while there were 17 species of Mutillids. Mutillids were so numerous that 625 specimens were collected in eight hours. About 2500 specimens were taken here during the season. Considering the abundance of the Mutillids, and the enormous number of Bembicids in this situation, it would seem probable that at least some of the species of Mutillids were parasitic in the nests of the Bembicids. While this assumption is entirely hypothetical, no other species of insect appeared to be numerous enough to furnish host material for such a large number of Mutillids. It is hoped that during the season of 1923 some definite information can be obtained regarding the life history and habits of the Mutillids in this sand dune area.

The female Mutillid wasps at once attract attention, when seen, because they are wingless and their bodies are covered with velvety pubescence. The lack of wings gives them much the appearance of ants and they are therefore commonly known as "velvet-ants." The females are usually seen when running around over bare ground and it is seldom that more than one is seen at a time. The males, which are winged, may often be found visiting flowers, from which they secure nectar. Both sexes are fond of sweet liquids and occasionally are found in considerable numbers on plants where aphids are present, where they congregate to partake of the honeydew which the aphids excrete. Under such circumstances as this, and the conditions which existed in the blowout described above, Mutillids may sometimes be collected in large numbers. The female Mutillids have the reputation of possessing very painful and severe stings. One species in the southern states has received the name "cowkiller" on this account. In collecting female Mutillids at the sand dunes it was found that large numbers could be collected only by picking them up with the fingers and placing them in the cyanide bottle. This necessitated getting stung occasionally, but experience demonstrated that their sting was no more painful than the injury caused by pricking one's finger with a sandbur, so that getting stung occasionally came to be regarded as a more or less annoying, but not painful experience.

For the most part, these wasps are parasitic in the nests of solitary wasps and bees, but the actual hosts for the various species of Mutillids are known in only a comparatively few cases. *Pseudomethoca sanbornii*

Blake, which is found in Minnesota, has been reared from the cells of a bee, *Nomia patteni* Cockerell. A species which occurs in Texas has been reared from the nests of the mud dauber, *Chalybion caeruleum* L. A species in Europe is said to be parasitic in the nests of bumble bees. In recent years several species have been found to be parasitic on the tsetse fly, *Glossina morsitans* Westwood, in Africa, and are therefore of considerable economic imporance.

The Mutillidae are to be found in all parts of the world but are much more numerous, both in individuals and species, in the arid and semiarid regions of the tropics and subtropics. In the United States the species are especially numerous in the southwest. As one proceeds northward the number becomes less and less, so that comparatively few species are known from Canada. It has therefore been somewhat remarkable to find 22 species of Mutillids in one year's collecting for Minnesota, and it is probable that other forms yet remain to be found.

Prior to 1918 no species of Mutillidae had been definitely recorded from Minnesota. Washburn (1918) lists eight species of Mutillidae as occurring in Minnesota but gives no definite dates or localities for any of them. Four of these records, *Dasymutilla ferrugata* F., *D. macra* Cresson, *D. vesta* Cresson, and *Mutilla* (*Sphaerophthalma*) *mutata* Blake, are misidentifications. These species, so far as known, do not occur in Minnesota. The specimens of Mutillidae from which the figures in Professor Washburn's paper were made have been examined and their synonymy cited under the correct specific name. The present material included 22 species representing four genera, as follows: *Pseudomethoca,* 3; *Dasymutilla,* 16; *Timulla,* 2; and *Ephuta,* 1. No doubt a number of other species will be found to occur in the state when collecting has been done in other localities. The following notes are intended only as a preliminary survey of the family as it occurs in Minnesota, and as an aid to the further investigation of these interesting wasps.

Two male Mutillids are described here which occur commonly throughout the United States east of the Rocky Mountains, and which have heretofore been confused in collections with other species. A more detailed study of these two species and several related forms which bear a superficial resemblance to them must be made before the average worker will be able to identify any of them with certainty. This is especially true of *castor* Blake, *fenestrata* Lepeletier, *agenor* Fox, and several undescribed species. It is the intention of the writer to treat these in a future paper.

KEY TO THE GENERA OF MINNESOTA MUTILLIDAE

1. Eyes round, strongly convex, usually polished.............................. 2
   Eyes ovate, strongly faceted; in the males deeply emarginate within........ 3
2. First abdominal segment greatly enlarged toward the apex, completely sessile with the second; second abdominal segment at the base scarcely wider than the apex of the first...............................*Pseudomethoca* Ashmead
   First abdominal segment constricted at the apex, before the base of the second; not completely sessile with the second; base of second abdominal segment considerably wider than the apex of the first..*Dasymutilla* Ashmead
3. First abdominal segment completely sessile with the second; tergites of the male without, or only the last one with a longitudinal carina..*Timulla* Ashmead
   First abdominal segment petiolate, not at all sessile, short, nearly cylindrical; third to seventh tergites of male with a longitudinal carina......*Ephuta* Say

Genus PSEUDOMETHOCA Ashmead

Key to the species

Females

1. Head spinose or dentate beneath...........................*canadensis* Blake
   Head not spinose or dentate beneath.. 2
2. Propodeum with the posterior face more or less rounded into the dorsum, not at a distinct right angle with the dorsum; metapleura micropunctate, thinly clothed with silvery pile...........................*sanbornii* Blake
   Propodeum with the posterior face at a distinct right angle with the dorsum; metapleura sometimes very slightly micropunctate, not clothed with silvery pile ....*propinqua* Cresson

Males

1. Postero-lateral angles of head dentate......................*canadensis* Blake
   Postero-lateral angles of head rounded..................................... 2
2. Abdomen ferruginous, with black pubescence.................*sanbornii* Blake
   Abdomen black, with golden pubescence....................*propinqua* Cresson

Pseudomethoca canadensis (Blake)

1871. *Mutilla (Sphaerophthalma) canadensis* Blake, Trans. Amer. Ent. Soc., iii, 252 ♀.

1800. *Photopsis cressonii* Fox, Ent. News, i, 138 ♂ (not *Mutilla cressoni* Blake).

1899. *Mutilla canadensis* Fox, Trans. Amer. Ent. Soc., xxv, 224 ♀ ♂.

Specimens examined: ♀ August 1, 1922, Jordan, Scott county (A. T. Hertig).

Pseudomethoca sanbornii (Blake)

1871. *Mutilla (Sphaerophthalma) sanbornii* Blake, Trans. Amer. Ent. Soc., iii, 248 ♂.

1899. *Mutilla sanbornii* Fox, Trans. Amer. Ent. Soc., xxv, 228 ♂.

1916. *Pseudomethoca (Nomiaephagus) montivaga* Bradley, Trans. Amer. Ent. Soc., xlii, 320 ♀ (not of Cresson).

1918. *Nomiaephagus sanbornii* Washburn, 17th Rept. State Ent. of Minnesota, 209.

Specimens examined: ♀ July 14, 1922, Fridley sand dunes, Anoka county (A. A. Nichol); ♂ August 5, 1896, Gray Cloud Island.

This species, as well as the other two species of Pseudomethoca, seems to be uncommon in this state.

Pseudomethoca propinqua (Cresson)

1865. *Mutilla propinqua* Cresson, Proc. Ent. Soc. Phila., iv, 433 ♂.
1865. *Mutilla montivaga* Cresson, Proc. Ent. Soc. Phila., iv, 436 ♀.
1899. *Mutilla montivaga* Fox, Trans. Amer. Ent. Soc., xxv, 227 ♀ (in part).
1899. *Mutilla propinqua* Fox, Trans. Amer. Ent. Soc., xxv, 228 ♂.

Specimens examined: ♀ August 21, 1911, Fergus Falls (Stoner).

Genus DASYMUTILLA Ashmead

Key to the species

Females

1. Mandibles tridentate..*harmonia* Fox
   Mandibles bidentate, without a third tooth within........................ 2
2. Lateral angles of vertex rounded, neither carinate nor tuberculate........ 3
   Lateral angles of vertex carinate or tuberculate.......................... 7
3. Head and thorax clothed with appressed, silvery pubescence........*caneo* Blake
   Head and thorax with red or yellow pubescence............................ 4
4. Third tergite entirely black pubescent, except the lateral margins; disc of second tergite with sparse, fine, rather indistinct punctures............. *chlamydata* Melander
   Third tergite either with a median spot of silvery pubescence on the apical margin, or the apical margin entirely silvery pubescent.................. 5
5. Thorax with a scutellar scale..................................*zella* Rohwer
   Thorax without a scutellar scale... 6
6. Apical margin of second tergite with black pubescence; no median spot of silvery pubescence ....*champlaini* Rohwer
   Apical margin of second tergite with a median spot of silvery pubescence.. *sparsa* Fox
7. Second abdominal tergite black, with two small basal, and two large, subapical, ivory spots.................................*quadriguttata* Say
   Second abdominal tergite ferruginous...................................... 8
8. Front with a delicate carina extending from the base of the antennae to the margin of the eye....................................*cariniceps* Fox
   Front without such a carina.. 9
9. Second tergite with two small basal, and two large subapical, pale, ferruginous spots, coarsely and closely punctate; posterior face of propodeum rugoso-punctate ....*cypris* Blake
   Second tergite without spots, finely and sparsely punctate; posterior face of propodeum coarsely reticulate..............................*rugulosa* Fox

Males

1. Second sternite with a longitudinal keel, surmounted by a crest of bristles.. *asopus* Cresson
   Second sternite without a longitudinal keel.............................. 2
2. Body entirely black...*gibbosa* Say
   Body not entirely black; at least second abdominal segment reddish........ 3
3. Second sternite with a pit which is filled with bristles........*permista* n. sp.
   Second sternite without such a pit..................................... 4
4. Dorsum of thorax with reddish pubescence................*bioculata* Cresson
   Dorsum of thorax with black pubescence................................ 5
5. Tegulae impunctate 6
   Tegulae punctate ....*agenor* Fox
6. Abdomen black, except second segment ferruginous...........*hirticula* n. sp.
   Abdomen castaneous, with black pubescence..................*Admetus* Blake

Dasymutilla harmonia (Fox)

1899. *Mutilla harmonia* Fox, Trans. Amer. Ent. Soc., xxv, 229 ♀.

Specimens examined: 4 ♀ July 27, 1922, Ft. Snelling (C. E. Mickel); 3 ♀ July 28, 1922, Fridley sand dunes, Anoka county (Paul Gilmer; 4 ♀ July 28, 1922, Fridley sand dunes, Anoka county (C. E. Mickel); 2 ♀ August 8, 1922, Fridley sand dunes, Anoka county (A. T. Hertig); 5 ♀ August 8, 1922, Fridley sand dunes, Anoka county (C. W. Johnson); 2 ♀ Hennepin county; ♀ August 5, 1896, Gray Cloud Island.

This species is comparatively uncommon at the Fridley sand dunes. It doubtless will be found in sandy situations over most of the state.

Dasymutilla asopus (Cresson)

1865. *Mutilla asopus* Cresson, Proc. Ent. Soc. Phila., iv, 435 ♂.
1899. *Mutilla asopus* Fox, Trans. Amer. Ent. Soc., xxv, 230 ♂.
1918. *Dasymutilla (Bruesia) asopus* Washburn, 17th Rept. State Entomologist of Minnesota, 209.

Specimens examined: ♂ July 27, 1922, Ft. Snelling (C. E. Mickel); ♂ August 8, 1922, Fridley sand dunes, Anoka county (A. T. Hertig); ♂ August 8, 1922, Fridley sand dunes, Anoka county (C. W. Johnson); ♂ August 20, 1898, Gray Cloud Island.

This may possibly be the male of *harmonia*.

Dasymutilla caneo (Blake)

1879. *Mutilla caneo* Blake, Trans. Amer. Ent. Soc., vii, 250 ♀.
1899. *Mutilla caneo* Fox, Trans. Amer. Ent. Soc., xxv, 240 ♀.

Specimens examined: 9 ♀ July 21, 1922, Fridley sand dunes, Anoka county (C. E. Mickel); 4 ♀ July 24, 1922, Fridley sand dunes, Anoka county (Paul Gilmer); 6 ♀ July 28, 1922, Fridley sand dunes, Anoka county (Paul Gilmer); 6 ♀ July 28, 1922, Fridley sand dunes, Anoka county (C. E. Mickel); 19 ♀ August 8, 1922, Fridley sand dunes, Anoka county (A. T. Hertig); 13 ♀ August 8, 1922, Fridley sand dunes, Anoka county (C. W. Johnson).

This species is easily recognized by its small size and the appressed, silvery pubescence of the head and thorax.

Dasymutilla chlamydata (Melander)

1903. *Mutilla chlamydata* Melander, Trans. Amer. Ent. Soc., xxix, 299 ♀.
1918. *Dasymutilla ferrugata* Washburn, 17th Rept. State Ent. of Minnesota, 209, fig. 98 (not of Fabricius).

Specimens examined: 9 ♀ August 5, 1896, Gray Cloud Island; 2 ♀ August 20, 1896, Gray Cloud Island; 2 ♀ September 3, 1899, Gray Cloud Island; 5 ♀ August 1, 1922, Jordan, Scott county (A. T. Hertig); ♀ August 25, 1922, Barden, Scott county (C. E. Mickel); ♀ July 17, Ramsey county; 3 ♀ Hennepin county; 3 ♀ July 27, 1922, Ft. Snelling (C. E. Mickel); 63 ♀ July 21, 1922, Fridley sand dunes, Anoka county (C. E. Mickel); 30 ♀ July 24, 1922, Fridley sand dunes, Anoka county (Paul Gilmer); 13 ♀ July 24, 1922, Fridley sand dunes, Anoka county (C. E. Mickel); 123 ♀ July 28, 1922, Fridley sand dunes, Anoka county (Paul Gilmer); 146 ♀ July 28, 1922, Fridley sand dunes, Anoka county (C. E. Mickel); 25 ♀ August 8, 1922, Fridley sand dunes, Anoka county (A. T. Hertig); 31 ♀ August 8, 1922, Fridley sand dunes, Anoka county (C. W. Johnson).

This is the most abundant species at the Fridley sand dunes. It is found in sandy localities over a wide area in the middle west. The individuals vary a great deal in size, the length varying from 7 to 15 mm. They also vary in color from a golden yellow to a deep ferruginous. The series can be separated into two sections: those in which the color is for the most part yellowish and which vary in size from 7 to 10 mm.; and those in which the color is for the most part ferruginous, and which vary in size from 12 to 15 mm. However, I can find no other tangible characters upon which to separate them and for the present have designated all of them as *chlamydata*. If a study of their life history can be made, it may throw some light on this variation. It seems probable that this species is parasitic in the nests of *Bembix pruinosa* Fox, or in those of *Microbembex monodonta* Say, or perhaps in both.

Dasymutilla bioculata (Cresson)

1865. *Mutilla bioculata* Cresson, Proc. Ent. Soc. Phila., iv, 431 ♂.
1899. *Mutilla bioculata* Fox, Trans. Amer. Ent. Soc., xxv, 243 ♂.
1918. *Dasymutilla bioculata* Washburn, 17th Rept. State Entomologist of Minnesota, 209, fig. 97.

Specimens examined: ♂ July 7, 1921, Lake City (A. A. Nichol); ♂ August 1, 1922, Jordan, Scott county (A. T. Hertig); ♂ Hennepin county; ♂ June 30, 1922, Fridley sand dunes, Anoka county (A. T. Hertig); 5 ♂ July 21, 1922, Fridley sand dunes, Anoka county (C. E. Mickel); 16 ♂ July 24, 1922, Fridley sand dunes, Anoka county (Paul Gilmer); 16 ♂ July 24, 1922, Fridley sand dunes, Anoka county (C. E. Mickel); 83 ♂ July 28, 1922, Fridley sand dunes, Anoka county (Paul Gilmer); 78 ♂ July 28, 1922, Fridley sand dunes, Anoka county (C. E. Mickel); ♂ August 8, 1922, Fridley sand dunes, Anoka county (A. T. Hertig); 5 ♂ August 8, 1922, Fridley sand dunes, Anoka county (C. W. Johnson).

This is the most abundant male Mutillid at the Fridley sand dunes. It is probably the male of *chlamydata*. This series may also be separated into two sections on the basis of size; (1) those varying in length between 7 and 10 mm.; and (2) those varying between 12 and 15 mm. Both sections have identically the same genitalia and there is apparently no character other than size upon which they may be separated. I have therefore designated them all as *bioculata*.

Dasymutilla champlaini (Rohwer)

1912. *Dasymutilla champlaini* Rohwer, Proc. U. S. National Museum, xli, 461 ♀.

Specimens examined: ♀ August 5, 1896, Gray Cloud Island; ♀ August 20, 1898, Gray Cloud Island; ♀ August 1, 1922, Jordan, Scott county (A. T. Hertig); ♀ August 25, 1922, Barden, Scott county (C. E. Mickel); 5 ♀ July 21, 1922, Fridley sand dunes, Anoka county (C. E. Mickel); 4 ♀ July 28, 1922, Fridley sand dunes, Anoka county (Paul Gilmer); 11 ♀ July 28, 1922, Fridley sand dunes, Anoka county (C. E. Mickel); 9 ♀ August 8, 1922, Fridley sand dunes, Anoka county (A. T. Hertig); 13 ♀ August 8, 1922, Fridley sand dunes, Anoka county (C. W. Johnson).

This is one of the more uncommon species at the Fridley sand dunes. These specimens have been compared with the type of *champlaini* and found to be identical. This species, together with *sparsa*, is easily distinguished from related forms by the lack of a scutellar scale on the thorax.

Dasymutilla sparsa (Fox)

1899. *Mutilla sparsa* Fox, Trans. Amer. Ent. Soc., xxv, 240 ♀.

Specimens examined: ♀ August 1, 1922, Jordan, Scott county (W. E. Hoffmann). This specimen has been compared with the type of *sparsa* and found to be identical.

Dasymutilla zella (Rohwer)

1910. *Mutilla zella* Rohwer, Proc. Ent. Soc. Wash., xii, 50 ♀.

Specimens examined: 2 ♀ July 27, 1922, Ft. Snelling (C. E. Mickel); 7 ♀ July 21, 1922, Fridley sand dunes, Anoka county (C. E. Mickel); 17 ♀ July 24, 1922, Fridley sand dunes, Anoka county (Paul Gilmer); 14 ♀ July 24, 1922, Fridley sand dunes, Anoka county (C. E. Mickel); 30 ♀ July 28, 1922, Fridley sand dunes, Anoka county (Paul Gilmer); 41 ♀ July 28, 1922, Fridley sand dunes, Anoka county (C. E. Mickel); 42 ♀ August 8, 1922, Fridley sand dunes, Anoka county (A. T. Hertig); 55 ♀ August 8, 1922, Fridley sand dunes, Anoka county (C. W. Johnson).

This is the second most abundant female Mutillid at the Fridley sand dunes. These specimens have been compared with the type and found to be identical. This is not the same species as *vesta* Cresson.

Dasymutilla quadriguttata (Say)

1823. *Mutilla quadriguttata* Say, West. Quart. Rept., ii, 74 ♀.
1899. *Mutilla quadriguttata* Fox, Trans. Amer. Ent. Soc., xxv, 239 ♀.

Specimens examined: 2 ♀ July 13, 1922, La Crescent (C. E. Mickel); ♀ August 5, 1896, Gray Cloud Island.

Dasymutilla cypris (Blake)

1871. *Mutilla (Sphaerophthalma) cypris* Blake, Trans. Amer. Ent. Soc., iii, 246 ♀.
1871. *Mutilla (Sphaerophthalma) mutata* Blake, Trans. Amer. Ent. Soc., iii, 247 ♀.
1899. *Mutilla cypris* Fox, Trans. Amer. Ent. Soc., xxv, 240 ♀.
1916. *Dasymutilla (Dasymutilla) cypris* Bradley, Trans. Amer. Ent. Soc., xlii, 326 ♀.
1918. *Dasymutilla cypris* Washburn, 17th Rept. St. Ent. of Minnesota, 209, fig. 96.
1918. *Mutilla (Sphaerophthalma) mutata* Washburn, 17th Rept. State Ent. of Minnesota, 209.

Specimens examined: ♀ June 14, 1922, Rochester (C. E. Mickel); 4 ♀ August 5, 1896, Gray Cloud Island; 2 ♀ August 20, 1898, Gray Cloud Island; 3 ♀ August 1, 1922, Jordan, Scott county (A. T. Hertig); 2 ♀ July 27, 1922, Ft. Snelling (C. E. Mickel); ♀ June 5, 1911, St. Anthony Park, Ramsey county; ♀ August 7, 1922, St. Anthony Park, Ramsey county (A. T. Hertig); 10 ♀ July 21, 1922, Fridley sand dunes, Anoka county (C. E. Mickel); ♀ July 24, 1922, Fridley sand dunes, Anoka county (Paul Gilmer); 5 ♀ July 28, 1922, Fridley sand dunes, Anoka county (Paul Gilmer); 4 ♀ July 28, 1922, Fridley sand dunes, Anoka county (C. E. Mickel); 14 ♀

August 8, 1922, Fridley sand dunes, Anoka county (A. T. Hertig); 22 ♀ August 8, 1922, Fridley sand dunes, Anoka county (C. W. Johnson).

Dasymutilla cariniceps (Fox)

1899. *Mutilla cariniceps* Fox, Trans. Amer. Ent. Soc., xxv, 241 ♀.
1916. *Dasymutilla (Dasymutilla) cariniceps* Bradley, Trans. Amer. Ent. Soc., xlii, 323 ♀.

Specimens examined: 2 ♀ July 21, 1922, Fridley sand dunes, Anoka county (C. E. Mickel); ♀ August 5, 1922, Ramsey county (A. T. Hertig).

This is one of the rare species of Mutillids at the Fridley sand dunes. Fewer specimens of this species were collected than of any other.

Dasymutilla gibbosa (Say)

1836. *Mutilla gibbosa* Say, Bost. Journ. Nat. Hist., i, 298 ♂.
1899. *Mutilla gibbosa* Fox, Trans. Amer. Ent. Soc., xxv, 246 ♂.
1916. *Dasymutilla (Dasymutilla) gibbosa* Bradley, Trans. Amer. Ent. Soc., xlii, 322 ♂.

Specimens examined: ♂ July 18, 1911, Chisago county.

Dasymutilla rugulosa (Fox)

1899. *Mutilla rugulosa* Fox, Trans. Amer. Ent. Soc., xxv, 240 ♀.
1916. *Dasymutilla (Dasymutilla) rugulosa* Bradley, Trans. Amer. Ent. Soc., xlii, 325 ♀.
1918. *Dasymutilla vesta* Washburn, 17th Rept. State Ent. of Minnesota, 209, fig. 95 (not of Cresson).

Specimens examined: ♀ July 13, 1922, La Crescent (C. E. Mickel); ♀ July 27, 1922, Ft. Snelling (C. E. Mickel); ♀ July 21, 1922, Fridley sand dunes, Anoka county (C. E. Mickel); ♀ July 24, 1922, Fridley sand dunes, Anoka county (C. E. Mickel); 2 ♀ July 28, 1922, Fridley sand dunes, Anoka county (Paul Gilmer); ♀ August 8, 1922, Fridley sand dunes, Anoka county (A. T. Hertig); 2 ♀ August 8, 1922, Fridley sand dunes, Anoka county (C. W. Johnson).

Dasymutilla agenor (Fox)

1899. *Mutilla agenor* Fox, Trans. Amer. Ent. Soc., xxv, 245 ♂.

Specimens examined: ♂ July 27, 1922, Ft. Snelling (C. E. Mickel); ♂ July 13, 1911, Ramsey county; ♂ July 21, 1922, Fridley sand dunes, Anoka county (C. E. Mickel); 13 ♂ July 28, 1922, Fridley sand dunes, Anoka county (Paul Gilmer); 9 ♂ July 28, 1922, Fridley sand dunes, Anoka county (C. E. Mickel); 10 ♂ August 8, 1922, Fridley sand dunes, Anoka county (A. T. Hertig); 10 ♂ August 8, 1922, Fridley sand dunes, Anoka county (C. W. Johnson).

Dasymutilla hirticula n sp.

1899. *Mutilla macra* Fox, Trans. Amer. Ent. Soc., xxv, 245 ♂ (in part).
1916. *Mutilla (Dasymutilla) macra* Bradley, Trans. Amer. Ent. Soc., xlii, 329 ♂ (not of Cresson).
1916. *Dasymutilla macra* Rohwer, Hymen. Conn., Bull. 22, Conn. State Geolog. and Nat. Hist. Surv., 624 (not of Cresson).

♂. Black; second abdominal segment entirely ferruginous; length, 9mm. Head black, about as wide as the thorax, sparsely clothed with long, erect, black, pubescence; mandibles tridentate, i.e. acute at the apex and feebly bidentate within; clypeus feebly bidentate medially at the cephalic margin, finely, confluently punctate; scape closely punctate, with a sharp, longitudinal carina beneath; front with strong, confluent punctures; vertex and genae punctate, but with the punctures more separated than on the front; eyes round, very prominent.

Thorax black, sparsely clothed with long, black pubescence; pronotum, mesonotum, and scutellum with strong, deep, confluent punctures; dorsum and posterior face of propodeum coarsely reticulate; propleura with strong, confluent punctures, cephalic margin rounded; mesepisternum and mesepimeron with large, separated punctures, interspersed with a few very fine punctures; metapleura polished, except the basal one-fourth, which is rugosely punctate; sides of propodeum polished, with a few scattered punctures; tegulae polished, with a few punctures at the base.

Abdomen black, the second abdominal segment entirely ferruginous, clothed with long, shaggy, black pubescence, except that on the apical four-fifths of the second tergite dark orange-colored; first segment strongly petiolate; first tergite with coarse, confluent punctures throughout; second tergite with elongate, separated punctures, the latter finer and closer on the apical margin; tergites 3-6 with fine, close punctures, ultimate tergite longitudinally rugose; second sternite with distinct, well-separated punctures; sternites 3-6 with fine, confluent punctures at the apical margin; ultimate sternite closely, irregularly punctate.

Wings dark; cell R4 indistinct.

Legs black, clothed with black hairs.

Holotype: ♂ July 28, 1922, Fridley sand dunes, Anoka county, Minn. (C. E. Mickel), collection University of Minnesota.

Paratypes: CONNECTICUT: 4♂ August 5, 1915, Lyme. DISTRICT OF COLUMBIA: ♂ August 21, 1898, Washington. GEORGIA: ♂ July 29, 1916, Brinson. ILLINOIS: ♂ July 15, 1894, Algonquin; ♂ July 19, 1895, Algonquin; ♂ July 20, 1895, Algonquin. MASSACHUSETTS: ♂. MINNESOTA: ♂ August 25, 1921, Houston county (J. D. Winter); ♂ July 27, 1922, Ft. Snelling (C. E. Mickel); 2♂ July 28, 1922, Fridley sand dunes, Anoka county (Paul Gilmer); 2♂ July 28, 1922, Fridley sand dunes, Anoka county (C. E. Mickel). NEBRASKA: 20♂ August 16, 1912, Monroe Canyon, Sioux county (R. W. Dawson); 9♂ August 16, 1912, Monroe Canyon, Sioux county (E. J. Taylor); ♂ August 6, 1908, Monroe Canyon, Sioux county (C. H. Gable); ♂ Bad Lands, Sioux county (L. Bruner); ♂ August 13, Glen, Sioux county; ♂ August 9, 1912, Halsey (J. T. Zimmer). NEW JERSEY: 2 ♂ August 16, 1904, Weymouth; ♂ July 16, 1901, Da Costa; ♂ September 6, 1903, Hammonton; ♂ September 10, 1910, Milltown; ♂ June 24, 1906, Brown's Mills Jc.; ♂ July 13, 1912, Ramsey. NEW YORK: ♂ August 7, 1898, Pelham. NORTH CAROLINA: ♂ August 1, 1916, Southern Pines. VIRGINIA: 3 ♂ August 15, 1913, Kearney (Wm. Middleton); ♂ August 4, 1913, Falls Church (S. A. Rohwer); ♂ August 4, 1913, Falls Church (H. B. Kirk); ♂ August 20, 1913, Falls Church (C. T. Greene); ♂ September 4, 1915, Falls Church (C. T. Greene); ♂ August 28, 1913, Wiehle (Wm. Middleton).

Paratypes are deposited in the following collections: U. S. National Museum, American Museum of Natural History, University of Minnesota, University of Nebraska, State Entomologist of Pennsylvania, and the author's.

The paratypes vary in length from 7 to 12 mm. This species has much the same appearance as *macra* Cresson and is confused with the latter in all collections of Mutillidae. It may be distinguished from *macra* by the following characters: the second abdominal segment is entirely ferruginous, while in *macra* only the second tergite is ferruginous; second tergite with the punctures elongate and distinctly separated on the disc, more or less contiguous on the basal third, while in *macra* the punctures are elongate and close on the disc, and confluent on the basal third. The genitalia of this species is distinctly different from that of *macra*. The types of Blake's *macra* and *hispida* have been examined and found to be quite different from this form. The species *macra* Blake, so far as known, does not occur in the eastern part of the United States.

Dasymutilla permista n. sp.

1899. *Mutilla castor* Fox, Trans. Amer. Ent. Soc., xxv, 244 ♂ (in part).
1903. *Mutilla castor* Melander, Trans. Amer. Ent. Soc., xxix, 302 ♂ (in part).
1916. *Dasymutilla (Dasymutilla) castor* Bradley, Trans. Amer. Ent. Soc., xlii, 326 ♂ (in part).

♂ Black, second tergite more or less ferruginous; length, 12 mm. Head black, about as wide as the thorax, sparsely clothed with long, erect, black pubescence; mandibles tridentate; clypeus strongly bidentate medially on the cephalic margin, very closely punctate; scape closely punctate, bicarinate beneath; front closely, confluently punctate; vertex and genae with smaller, separated punctures; eyes round and prominent.

Thorax black, sparsely clothed with long, erect, black pubescence; pronotum and mesonotum with large, close punctures, those on the disc confluent; scutellum rugoso-punctate; dorsum and posterior face of propodeum reticulato-punctate; propleura with a few large punctures, interspersed with very fine punctures, cephalic margin with a weak carina extending about half way from the ventral margin to the humeral tubercle; mesepisternum and mesepimeron with large punctures, separated on the ventral half, confluent on the dorsal half; metapleura polished, with a few large punctures near the ventral margin; sides of propodeum coarsely punctate; tegulae convex, polished, punctate near the basal margin.

Abdomen black, second tergite with two large, ferruginous spots, covering almost the whole of the tergite; abdomen clothed with moderately dense, long, erect, black pubescence, except that on the ferruginous spots the pubescence is more or less yellowish; first abdominal segment strongly petiolate; first tergite coarsely, confluently punctate throughout; disc of second tergite with moderate punctures, separated by about their own width; tergites 3-6 very closely, moderately punctate; pygidial area feebly longitudinally rugose; second sternite with strong, separated punctures, medially with an ovate pit, about three times as long as wide, closely packed with erect bristles; sternites 3-6, punctate at the apical margin; ultimate sternite with strong, separated punctures.

Wings dark; cell R4 indistinct.

Legs black, clothed with black hairs.

Holotype: ♂ July 28, 1922, Fridley sand dunes, Anoka county, Minnesota (C. E. Mickel), collection University of Minnesota.

Paratypes: COLORADO: ♂ August 7, 1899, Durango; ♂ August 19, 1904, Sterling; ♂. CONNECTICUT: ♂ August 25, 1909, Lyme (A. Champlain); ♂ August 28, 1909, Lyme (A. Champlain). ILLINOIS: ♂ July 12, 1895, Algonquin; ♂ July 15, 1894, Algonquin; 2 ♂ July 22, 1894, Algonquin; ♂ July 1, 1901, Belvidere (W. D. Pierce); ♂ 1894, Havana. KANSAS: ♂ July 11, Riley county (Popenoe); 2 ♂ July 17, Riley county (Popenoe); 3 ♂ July 19, Riley county (Popenoe); ♂ July 21, Riley county (Popenoe); 2 ♂ July 22, Riley county (G. A. Dean); ♂ July 25, Riley county (G. A. Dean); ♂ August 9, Riley county (Popenoe); ♂ August 9, Riley county (J. B. Norton); ♂ August 25, Riley county (G. A. Dean); 2 ♂ August 27, Rooks county; 3 ♂ September 1, Riley county (Popenoe); ♂ July 17, 1901, Wellsville. LOUISIANA: ♂. MASSACHUSETTS: ♂ August 18, 1890, Hyannisport (J. L. Zabriskie); ♂ August, 1898, Woods Hole (C. L. Marlatt). MINNESOTA: ♂ July 13, 1922, La Crescent (C. E. Mickel), ♂ August 17, 1900, Gray Cloud Island; ♂ August 20, 1898, Gray Cloud Island; 8 ♂ July 12, 1921, Gray Cloud Island (Wm. A. Riley); ♂ August 9, 1899, St. Anthony Park, Ramsey county; ♂ July 13, 1911, Ramsey county; ♂ July 21, 1911, Washington county; ♂ August 2, 1922, St. Peter (R. R. Holland); ♂ July 6, 1910, Hennepin county; 11 ♂ July 27, 1922, Ft. Snelling (C. E. Mickel); 2 ♂ July 21, 1922, Fridley sand dunes, Anoka county (C. E. Mickel); ♂ July 24, 1922, Fridley sand dunes, Anoka county (Paul Gilmer); 2 ♂ July 28, 1922, Fridley sand dunes, Anoka county (Paul Gilmer); ♂ August 8, 1922, Fridley sand dunes, Anoka county (C. W. Johnson). NEBRASKA: ♂ July, 1903, Meadow; ♂ July 29, 1914, Louisville (E. G. Anderson); ♂ July 30, 1914, Louisville (H. A. Jones); ♂ July 30, 1914, Louisville (E. G. Anderson); ♂ July 31, 1914, Louisville (E. G. Anderson); ♂ July 31, 1914, Louisville (H. A. Jones); 5 ♂ August 1, 1914, Louisville (E. G. Anderson); ♂ August 2, 1914, Louisville (H. A. Jones); 3 ♂ July, Lincoln; ♂ July 4, 1920, Lincoln (R. W. Dawson); ♂ July 11, 1920, Lincoln (C. B. Philip); 17 ♂ July 11, 1920, Lincoln (C. E. Mickel); 5 ♂ July 18, 1920, Lincoln (R. W. Dawson); ♂ July 30, 1909, Lincoln (C. H. Gable); ♂ August 26, 1901, Lincoln (W. D. Pierce); 2 ♂ June, 1887, West Point; 5 ♂ June 24, West Point; ♂ August 20, 1906, Broken Bow (H. S. Smith); ♂ August 8, 1912, Halsey (J. T. Zimmer); 2 ♂ July 22, 1902, Rock county (W. D. Pierce); 8 ♂ July, Pine Ridge. NEW JERSEY: ♂ South Amboy; ♂ September 2, 1901, Lucaston; ♂ July 5, 1901, Manumuskin; ♂ July 30, 1912, Ramsey. NEW YORK: 3 ♂; 2 ♂, Fisher's Island; ♂ Flatbush, Long Island; ♂ July 21, 1900, Cold Spring's Harbor, Long Island; ♂ July 23, 1900, Cold Spring's Harbor, Long Island; 2 ♂ July 24, 1900, Cold Spring's Harbor, Long Island; ♂ July 27, 1900, Cold Spring's Harbor, Long Island. PENNSYLVANIA: 2 ♂ July 24, 1902, Castle Rock (E. Daecke); ♂ July 5, Rockville; ♂ July 29, Rockville; ♂ Mount Hope. TEXAS: ♂ June 21, 1905, Quinlan (F. C. Bishopp); ♂ July 7, 1906, Bryan (J. C. Crawford); ♂ June 28, 1905, Rosser (C. R. Jones); 2 ♂ August 22, 1907, Overton (W. W. Yothers); ♂ Hockley. VIRGINIA: ♂ July 13, 1911, Vienna (C. W. Hooker); ♂ September 1, 1915, Falls Church (C. T. Greene).

Paratypes are deposited in the following collections: U. S. National Museum, American Museum of Natural History, University of Minnesota, University of Nebraska, State Entomologist of Pennsylvania, Kansas Agricultural College, Colorado Agricultural College, and Oregon Agricultural College.

The paratypes vary in length from 8 to 16 mm. In a few the ferruginous color extends on to the second sternite and the first abdominal segment.

The type of *castor* Blake has been examined and found to be a unique from Texas. The specimens designated as *Mutilla castor* Blake in collections consist of several distinct species. This is one of the most common species found in those series. Superficially this is very much like *agenor* Fox, *fenestrata* Lepeletier, and several other species. The relationships of these species will be treated in a future paper.

Dasymutilla admetus (Blake)

1872. *Mutilla (Sphaerophthalma) admetus* Blake, Trans. Amer. Ent. Soc., iv, 74 ♂.

1899. *Mutilla admetus* Fox, Trans. Amer. Ent. Soc., xxv, 245 ♂.

Specimens examined: ♂ July 28, 1922, Fridley sand dunes, Anoka county (C. E. Mickel).

Genus TIMULLA Ashmead

Key to the species

Females

1. Thorax with a distinct scutellar scale; last three abdominal segments blackish .... *briaxus* Blake

   Thorax without a scutellar scale; last three abdominal segments red .... *euterpe* Blake

Timulla briaxus (Blake)

1871. *Mutilla briaxus* Blake, Trans. Amer. Ent. Soc., iii, 227 ♂.

1909. *Mutilla (Timulla) briaxus* Rohwer, Trans. Amer. Ent. Soc., xxxv, 132 ♀.

1916. *Mutilla (Timulla) briaxus* Bradley, Trans. Amer. Ent. Soc., xlii, 207 ♂ ♀.

Specimens examined: ♂ July 7, 1921, Lake City (A. A. Nichol); ♀ July 18, 1922, Newport (A. A. Nichol); ♀ July 18, 1922, Newport (C. E. Mickel); ♂ June 27, 1921, Minneapolis (A. A. Nichol).

Timulla euterpe (Blake)

1879. *Mutilla euterpe* Blake, Trans, Amer. Ent. Soc., vii, 249 ♀.

Specimens examined: ♀ Hennepin county.

A specimen of this species in the University of Minnesota collection bears the above locality label. Whether the data are authentic or not, can not be determined. The species has been known heretofore only from the unique type collected in Florida. There is, therefore, some doubt as to whether this species actually occurs in Minnesota.

Genus EPHUTA Say

Ephuta conchate n. sp.

♂. Entirely black; length 9 mm. Head coarsely, confluently punctate, with appressed and erect, short, whitish pubescence; two low carinae diverge from between the antennae, then are subparallel to a point about half way to the margin of the clypeus, here they flare outward to the margin of the clypeus;

the space thus enclosed finely rugose at the base, polished at the apical margin; first joint of flagellum about three-fourths the length of the second; lateral ocelli a little more than four times their diameter from the inner margin of the eyes.

Pronotum, mesonotum, and scutellum very coarsely, confluently punctate, with semi-erect, short, sparse, whitish pubescence; cephalic surface of pronotum punctate; dorsum of propodeum very coarsely and deeply reticulate, with a subrectangular, median enclosed space, separated from the posterior surface by a sharp ridge; posterior surface of propodeum reticulately punctate; propleura confluently punctate, the cephalic margin sharply carinate; humeral angles prominent, almost dentate; mesepisternum and mesepimeron reticulately punctate, clothed with dense, semi-erect, whitish pubescence; metapleura polished; sides of propodeum coarsely reticulate; tegulae very large, shell-shaped, elongate convex, not ridged longitudinally, irregularly punctate and hirsute, the lateral and apical margins polished and impunctate.

Abdomen clothed with spare, erect, whitish pubescence; first and second tergites with a band of dense, appressed, whitish pubescence at the apical margin; first segment cylindrical, coarsely punctured, with a keel beneath; second segment with large, deep, contiguous punctures above and beneath; remaining segments distinctly and closely punctate; tergites 3-7 with a median longitudinal keel.

Wings subhyaline.

Legs black, clothed with whitish pubescence; calcaria whitish.

Holotype: ♂ July 27, 1922, Ft. Snelling, Minnesota (A. A. Nichol), collection University of Minnesota.

This species is apparently related to *tegulicia* Bradley. It may be distinguished from that species by the form of the carinae on the clypeus and the absence of a longitudinal ridge on the tegulae.

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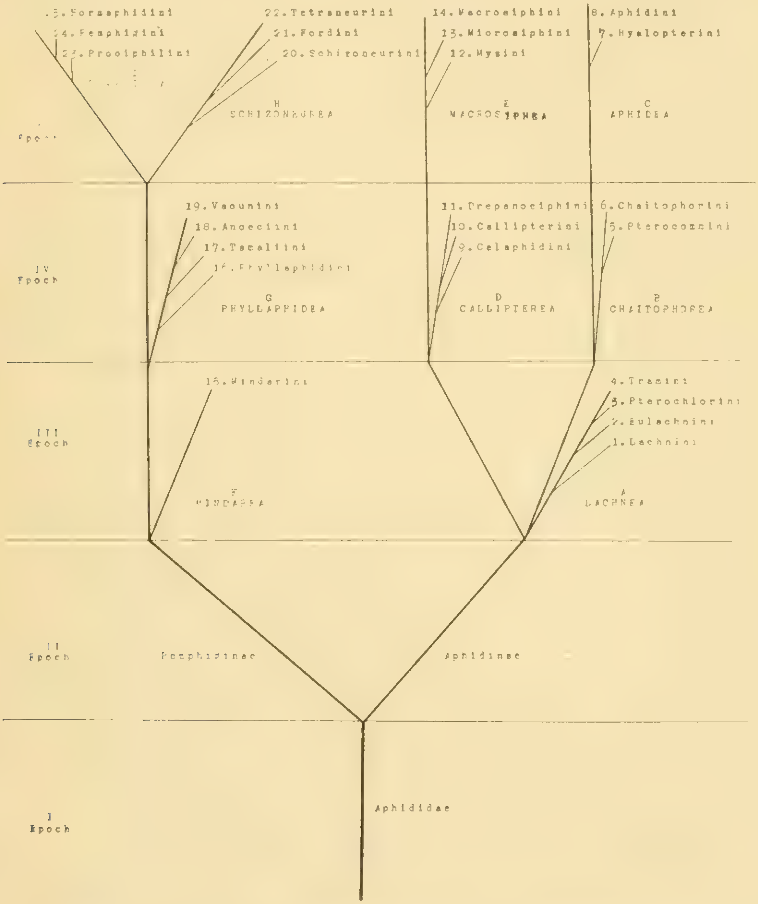
A SYNOPTICAL KEY TO THE APHIDIDAE OF MINNESOTA

By O. W. Oestlund

A synopsis of the Aphididae of Minnesota was published as Bulletin No. 4 of the Geological and Natural History Survey of Minnesota for 1887. This bulletin has long been out of print as well as out of date. The classification of Thomas, Riley, Monell, and Buckton, as then usually accepted, was followed. The classification of the family has undergone great changes since that time, and the author has long had in mind again to present this early effort of his in a more modern form. Limit of time and space will not allow a full account of the various groups and species as now known to occur in the state, but a key is given that will lead the user to the more modern name. The practical entomologist and the student have not the time or the literature at hand to enable them to follow the many changes that have taken place in the names of many of our genera and species leading up to a modern phylogenetic view of the family. The contibutors to this study of the Aphididae for the last thirty years have been many, for America as well as for Europe and other parts of the world. Their publications are scattered over a large number of scientific periodicals and other publications, which only the specialist may be fortunate enough to possess or to know of. They are found in various languages, as English, Latin, French, German, Italian, Dutch, Scandinavian, and Russian. To codify this extensive and varied knowledge, as far as our fauna is concerned, is one of the great needs for the present. In a previous contribution by the author, in which he endeavored to establish the tribes and higher groups of the family as held somewhat differently by Mordwilko, Van der Goot, and the author, the statement was made that the groups of tribes, there recognized and largely suggested by Mordwilko, are not supertribes but would eventually work out as such. Mordwilko in some of his latest works, the Fauna of Russia and Aphids of the Graminaceae, has so regarded them. To be sure he calls them tribes and not supertribes, but this is of minor importance, the important thing is that they represent natural phylogenetic groups which help us to form a conception of the probable order of development of the family. We differ somewhat as to the number and order of these groups, but it is out of place to discuss this here. The differences as well as the similarities can best be expressed by a phylogenetic tree that accompanies this paper. Quite a number of new generic terms have been suggested which may seem to complicate the classification rather than simplify it, but the taxonomist, as he finds new relationships and differences, requires terms to express them, be these specific, generic, or of higher order.



KEY TO THE APHIDIDAE OF MINNESOTA

1. Superfamily APHIDOIDEA. It is now generally conceded that Chermes and Aphis represent distinct families, the Chermesidae and the Aphididae. Together they form the superfamily Aphidoidea or Aphidodea of Mordwilko. Some would prefer the term Phylloxeridae in place of Chermesidae, but there are no good reasons for

discarding the term Chermes that has been current in literature for a century or more. An obvious distinguishing character is the absence of the stigmal vein (radical sector) in the Chemesidae, and the simple media which appears as a stigmal vein. In the Aphididae the radial sector appears as a distinct vein and only very exceptionally is it reduced or wanting; the media is usually once or twice branched. In the following key only the family Aphididae is treated. . . . . 2.

2. Family APHIDIDAE. Tarsi 2-jointed; antennae usually 6-jointed, the terminal segment with a slender prolongation or spur; wings transparent and with characteristic aphidian venation. Abdomen with a pair of dorsal tubes, or cornicles, on the posterior end, sometimes very short or wanting; the last segment of the abdomen with a more or less obvious dorsal projection, the cauda, and usually with a less obvious ventral projection, the anal plate. Passerini divides the family into several subfamilies, but the best writers of the present admit only two:

a. Living exposed on plants. Typical Aphididae in which the antennae, cornicles, and cauda show a tendency to increase in size and complexity; sensoria on the antennae usually circular..............APHIDINAE 3

b. Living concealed under woody secretions, in folded leaves, in galls, or underground on roots; antennae, cornicles, and cauda show a tendency to become reduced or lost; sensoria on antennae usually transverse or annular ....PEMPHIGINAE 106

3. Subfamily APHIDINAE. Antennae always longer than the head and thorax, usually half as long, equal to, or longer than the body; spur of the terminal antennal segment much longer than the basal part, sometimes equal to it or shorter in the more generalized forms. Cornicles obvious as cylindrical tubes; cauda usually well developed. The fifteen or more tribes of the subfamily may be grouped in three series of tribes:

a. Spur short; body and appendages thickly covered with long spreading hairs; found on trunk and limbs of woody plants.....................
............Series LACHNEA PROPER 4

b. Spur long; hairs on the antennae usually short and spinelike; found on leaves of trees, on tender growing twigs, or on herbs..................
..........Series LACHNEA-APHIDEA 19

c. Spur long; hairs on the antennae and usually on the body with enlarged apices or globate (capitate); feeding on leaves of trees or on herbaceous plants....................Series LACHNEA-MACROSIPHEA 62

4. Series LACHNEA PROPER. Antennae about half the length of the body; terminal segment with a very short spur (unguis); body and appendages thickly covered with long, slender hairs and sensilla;

cornicles very short, situated on hairy, cone-shaped tubercles; cauda short and broad, hardly extending beyond the anal plate. Large, spiderlike, dark colored forms living in large colonies on woody parts of trees, or underground on roots or in nests of ants.

a. The three or four tribes of the series are further considered as a supertribe with the same characters as the series.............................. Supertribe LACHNEA 5

5. Supertribe LACHNEA. The distinguishing characters are the same as those already given for the series. Two groups of tribes are recognized:

a. Stigma of fore wings long and narrow, transverse or blunt at distal end; radial sector arising from the lower distal angle of the stigma and running as a straight vein to the margin of the wing. Found exclusively on Conifera......................................Group LACHNINA 6

b. Stigma long and narrow, or short and broad, the distal end truncate or ending as a point in the margin of the wing; radial sector arising from the middle of the stigma, or at least some distance back of the end, and more or less curved. Found on woody parts of deciduous trees and woody plants, or on roots........................Group TRAMINA 13

6. Group LACHNINA. Usually very large forms and in the aptera spiderlike in appearance and in movements; black or brown and hairy; rostrum with five distinct segments; media is faint, indistinct vein in comparison with the other veins, and is usually twice branched. Two tribes are recognized in this group:

a. Large forms with wide and globate abdomen and long legs. Found on trunk and limbs of Conifera.......................Tribe LACHNINI 7

b. Medium to small forms with narrow, elongated abdomen; found on the needles of pines and usually with some green colors.................. Tribe EULACHNINI 10

7. Tribe LACHNINI. Large, hairy, black or brown, often with metallic reflections; legs long, especially the hind pair; found exclusively on woody parts of conifers. Two genera are recognized:

a. The media of the fore wings twice branched..........Genus LACHNUS 8

b. The media of the fore wings with only one branch..................... Genus SCHIZOLACHNUS 9

8. Genus LACHNUS (Illiger) Burmeister, 1835. Type: *Aphis pini* Linnaeus, 1758. Antennae about half the body in length; usually 6-jointed, and terminal segment with a very short spur (unguis). Size large, body and appendages provided with numerous, long, spreading hairs; rostrum distinctly 5-jointed. Wings long and narrow; stigma long and narrow with distal end blunt or truncate; radial sector arising from the lower distal angle of the stigma and running

as a short, straight vein to the margin of the wing; media faint, indistinct vein in comparison with the other veins, and usually twice branched; hind wings with two oblique veins arising nearer the base of the wing than usual in the family. Cornicles very short, on hairy, cone-shaped tubercles; cauda short and broad, extending but slightly or not at all beyond the rounded anal plate. Found on woody parts of conifers. The species found in Minnesota may be arranged in three habitat groups:

a. Abies-Picea group. Very large forms, black or brown, with long oval abdomen. Basal part of terminal antennal segment with at least 10 sensilla besides the 7 or 8 terminal rods.

(1) LACHNUS CURVIPES Patch, 1912
Found on Balsam Fir, *Abies balsamia.*

(2) LACHNUS PICEAE (Panzer) Altum, 1875
Found on Spruce, *Picea canadensis.*

b. Pinus group. Medium large to large, with broad oval or globate abdomen; brown and often mottled with darker spots or with metallic reflections. Basal part of terminal antennal segment with 10 or less hairs besides the terminal rods.

(3) LACHNUS STROBI (Fitch) Fitch, 1858
Found on White pine, *Pinus strobus.*

(4) LACHNUS PINI (Linnaeus) Burmeister, 1835
Found on Scotch pine, *Pinus sylvestris.*

c. Larix-Juniper group. Medium to small, light brown to yellowish; spur somewhat longer, basal part of terminal segment with 5 or 6 hairs besides the terminal rods.

(5) LACHNUS LARICIFEX (Fitch) 1858
Found on Tamarack, *Larix laricina.*

(6) LACHNUS JUNIPERI (DeGeer) Kaltenbach, 1843
Found on Juniper, *Juniperus communis.*

9. Genus SCHIZOLACHNUS Mordwilko, 1908. Type: *Aphis tomentosa* DeGeer, 1773. Similar to Lachnus but with the media of the fore wings with only one branch; found on young twigs and needles of pines.

(7) SCHIZOLACHNUS TOMENTOSUS (DeGeer) Mordwiko, 1908
This widely distributed species has not been taken in the state, but seen from the West and is reported from various places, and should be found in Minnesota.

10. Tribe EULACHNINI. The Eulachnini are closely related to the preceding tribe (Lachnini), but may be distinguished readily by

their smaller size and elongated body; they are found on the needles of pines and not on the bark, and usually with some green or paler colors. They are of much interest as showing the probable line of modifications leading to the two higher series of tribes of the subfamily. Several genera are already recognized in the tribe, of which we have one and probably a second:

a. Antennae 6-jointed; media of fore wings simple, not branched.......... Genus UNILACHNUS 11
b. Antennae 5-jointed; media with one branch.........Genus ESSIGELLA 12

11. Genus UNILACHNUS Wilson, 1919. Type: *Lachnus parvus* Wilson, 1915. Size small; antennae 6-jointed; media simple; found on needles of pines. Only one species is known:

(8) UNILACHNUS PARVUS (Wilson) Wilson, 1919

This species, the smallest known of the Lachnina, has been taken on the needles of White pine in Minnesota.

12. Genus ESSIGELLA Del Guercio, 1909. Type: *Lachnus californicus* Essig, 1909. Antennae 5-jointed; media of fore wings with one branch. Found on needles of pines; colors green or yellowish-green. A genus with only one species known. This may be found in Minnesota as it is reported from both east and west of us.

(—) ESSIGELLA CALIFORNICUS (Essig) Del Guercio, 1909

13. Group TRAMINA. The group is readily separated from the Lachnina by the radial sector arising, not from the distal end of the stigma, but from the middle or some distance back of the tip of the stigma and running as a more or less curved vein to the margin of the wing. None are found on conifers but on woody parts of deciduous trees and other woody plants; some are to be found on roots and underground in nests of ants. While the group contains some of the largest forms known in the family, it also has several medium or smaller sized forms. Two tribes are recognized:

a. Feeding on woody parts of trees; tarsal joints as usual in the family.... Tribe PTEROCHLORINI 14
b. Feeding underground on roots, or found in nests of ants; tarsi of hind legs very long, nearly as long as the tibia..........Tribe TRAMINI 18

14. Tribe PTEROCHLORINI. Size usually large; stigma of fore wings long and narrow, sometimes short and broad as usual in the family; radial sector arising from the middle of the stigma, or at least some distance back of the apex, and running as a more or less curved vein to the margin of the wing. While the stigma may be truncate as in the Lachnini, it is more often rounded and ends

as a point in the margin of the wing; media slender but usually more distinct than in the Lachnini; colors of the body brown or black and wings often with smoky bands or spots. Found on woody parts of trees and other woody plants. The tribe is represented by the following genera in Minnesota:

a. Stigma elongate, extending far in the stigmal cell and truncate at the distal end; no abdominal dorsal tubercle present...................... Genus LONGISTIGMA 15

b. Stigma elongate, pointed distally; radial sector long and curved only basally; abdomen with a median dorsal tubercle or gland.................. Genus TUBEROLACHNUS 16

c. Stigma short; radial sector strongly curved; wings usually with dusky patches ....Genus PTEROCHLORUS 17

15. Genus LONGISTIGMA Wilson, 1909. Type: *Aphis caryae* Harris, 1841. Stigmal vein arising some distance back of the apex of the very long and narrow stigma and only slightly curved near its base, running almost as a straight vein; stigma truncate at apex in the middle of the stigmal cell, and continued as a dusky band to or beyond tip of stigmal vein; found on woody parts, as trunks and limbs, of oak, hickory, basswood, etc. One species is known from Minnesota:

(9) LONGISTIGMA CARYAE (Harris) Wilson, 1909

This very characteristic species is rather abundant in Minnesota. The primary habitat is oak rather than hickory. It has repeatedly been taken on *Tilia*, hickory and other trees, but the sexes are known only from the oak. The species was well described by Monell under the name *Lachnus longistigma* taken on *Tilia*.

16. Genus TUBEROLACHNUS Mordwilko, 1908. Type: *Aphis viminalis* Boyer, 1841. Stigma long, apically rounded and ending in the margin of the wing. Abdomen with a dorsal median tubercle, which is apparently glandular in function. Found in large colonies on woody parts of willow. One species is known from Minnesota:

(10) TUBEROLACHNUS VIMINALIS (Boyer) Mordwilko, 1908

Found on various willows, *Salix*.

17. Genus PTEROCHLORUS Rondani, 1848. Type: *Aphis roboris* Linnaeus, 1758. Stigma short, apically rounded; stigmal vein strongly curved; wings usually with spots. Found on woody parts of oak and rose. One species is known from Minnesota:

(11) PTEROCHLORUS ROSAE (Cholodkovsky)

Found on the stalks of the rose, usually close to the ground or even partly under ground.

18. Tribe TRAMINI. Distinguished by the very long tarsal joint of the hind legs. Found on roots of plants and in nests of ants. No representative of this tribe has been recorded from Minnesota, but probably occurs. They must be looked for on roots of plants (trees and Compositae) and also in nests of ants.

19. Series LACHNEA-APHIDEA. Antennae 6-jointed, rarely only 5-jointed; spur of terminal segment as long as or longer than the basal part; sensilla of the antennae hair-like or spinelike; cornicles short and truncate, or long and cylindrical; cauda usually obvious and projecting beyond the rounded anal plate. The series includes two supertribes:

a. Antennae usually shorter than the body, with numerous long, curved hairs like those in Lachnus; spur usually much longer than the basal part; cornicles short and of the truncated type, not longer than broad, or if longer then swollen..............Supertribe CHAITOPHOREA 20
b. Antennae usually as long as or longer than the body; sensilla on the antennae usually short and spinelike with a pointed apex; cornicles cylindrical and much longer than broad, sometimes very short and small or swollen ....Supertribe APHIDEA 29

20. Supertribe CHAITOPHOREA. The long, spreading, curved hairs of the body and appendages are characteristic of the Chaitophorea. While some are still found on the bark and woody parts of trees, most of them have become adapted to live on the leaves and succulent growth of their host plant. There is an obvious and easy transition fom the Lachnea to the Chaitophorea. Two tribes are represented in Minnesota:

a. Usually large forms found on woody parts of trees; cornicles longer than broad and swollen, rarely cylindrical, and usually pale, yellow or red, contrasting with the darker colors of the body....................
Tribe PTEROCOMMINI 21
b. In size medium to very small and depressed forms found on leaves and succulent growths of trees, rarely on the woody parts; cornicles short and truncate, rarely absent; cauda triangular, extending beyond the anal plate; rostrum short.................Tribe CHAITOPHORINI 25

21. Tribe PTEROCOMMINI. The Pterocommini represent the generalized Chaitophorea which stand nearest to the Lachnea as seen in their large size, shorter antennae, and moderately long spur in comparison with the more highly specialized Chaitophorini; they are all bark feeders on woody plants. Characters in advance over the Lachnea are their shorter legs, enlarged cornicles. The lateral tubercles of the body are also better preserved than in the Lachnea. Representatives of three genera are known from Minnesota:

a. Cornicles cylindrical, pale; habitat *Populus* (*Salix*).................... Genus PTEROCOMMA 22

b. Cornicles more or less distinctly swollen; in color pale yellow or red; habitat *Salix* (*Populus*)............Genus MELANOXANTHERIUM 23

c. Cornicles slightly swollen and abruptly constricted at distal end with a very small opening; body covered with flocculent matter as in the Pemphiginae; habitat *Salix*......................Genus PLOCAMAPHIS 24

22. Genus PTEROCOMMA Buckton, 1879. Type: *Pterocomma pilosa* Buckton, 1879. Cornicles cylindrical. No representative of this genus is known from Minnesota but is likely to be found.

23. Genus MELANOXANTHERIUM (Koch) Schouteden, 1901. Type: *Aphis salicis* Linnaeus, 1758. Size large; cornicles pale, yellow or red and distinctly swollen. The following species are known from Minnesota:

(12) MELANOXANTHERIUM SALICIS (Linnaeus) Schouteden, 1901

Color bluish black with white patches of pulverulent matter on the abdomen; spur of the terminal segment of the antennae shorter than the cornicles; veins of the wings with dusky borders, anal vein especially conspicuous in this respect. Rather common on branches of willow.

(13) MELANOXANTHERIUM BICOLOR (Oestlund)

Color reddish brown, the pulverulent spots less conspicuous; spur of the terminal antennal segment about equal to the cornicles and twice as long as the basal part; veins clear without dusky borders. Much rarer species, sometimes found in small colonies with the above form.

(14) MELANOXANTHERIUM SMITHIAE (Monell)

Color dark brown; terminal segment of the antennae longer than the cornicles; cornicles short, not more than twice as long as broad.

24. Genus PLOCAMAPHIS gen. nov. Type: *Melanoxanthus flocculosus* Weed, 1891. Color dull yellowish brown; body very flocculent; cornicles longer than broad, swollen above the middle and strongly contracted to a very small opening without a flange. The very distinct type of cornicles with the conspicuous flocculent matter would indicate distinct generic differences. One species is recorded:

(15) PLOCAMAPHIS FLOCCULOSUS (Weed)

This peculiar form is not rare on willow

25. Tribe CHAITOPHORINI. The Chaitophorini are medium to small in size in comparison with the preceding tribe, the body is more or less depressed, with shorter legs and rostrum; antennae about

as long as the body, and the spur of the terminal segment longer than the basal part; cornicles short and truncate, not longer than wide; cauda short and broad, triangular or globate, projecting beyond the rounded anal plate. The following genera are represented in Minnesota:

a. Cauda short and broad, like the Pterocommini; veins with dusky borders; found on *Populus*....................Genus NEOTHOMASIA 26
b. Cauda triangular; with dimorphic summer forms; found on maple and box elder ....Genus PERIPHYLLUS 27
c. Cauda triangular or globate; no peculiar summer generations present; found on willow and poplar.........Genus CHAITOPHORUS 28

26. Genus NEOTHOMASIA (Wilson) Baker, 1920. Type: *Chaitophorus populicola* Thomas, 1879. Cauda broad; habitat *Populus*. The generic characters approach the Pterocommini and represent the generalized and transitional forms of the Chaitophorini. Only one species is recorded and rather common in the state:

(16) NEOTHOMASIA POPULICOLA (Thomas) Baker, 1920
Common on cottonwood.

27. Genus PERIPHYLLUS (Thornton) Van der Hoven, 1863. Type: *Phyllophorus testudinatus* Thornton, 1852. The genus is well characterized by the presence of summer generations that are very different from the ordinary spring and fall forms; the dimorphs are very small and greatly depressed, with fanlike setae around the margin of the body, and show no disposition to grow or change for a month or more. The habitat of the genus is maple and box elder.

(17) PERIPHYLLUS NEGUNDINIS (Thomas) Baker, 1920
Rather common and sometimes injurious to box elder.

28. Genus CHAITOPHORUS Koch, 1854. Type: *Aphis populi* Linnaeus, 1758. Cauda usually enlarged at apex or globate. The dimorphic summer forms are never present. The habitat of the genus is willow, poplar, and oak. Several species are known from the state, but the species are difficult to separate and have not been sufficiently studied:

(18) CHAITOPHORUS VIMINALIS Monell, 1879
Surface of the head with broken reticulations or granulations; spur long; color yellowish green.

(19) CHAITOPHORUS NIGRAE Oestlund, 1886
Surface of the head with distinct reticulations, not broken; colors green or black.

(20) CHAITOPHORUS DELICATA Patch, 1913
Color pale with transverse bands on the abdomen; larvae whitish; this small and delicate little species is found on *Populus dentatus* and willow.

(21) CHAITOPHORUS QUERCICOLA Monell, 1879
Veins of wings with dusky bands; larvae with stout brown or black spines; found on the leaves of oak.

29. Supertribe APHIDEA. Abdomen short and broad and abruptly rounded posteriorly, rarely elongated; antennae usually as long as or longer than the body with spur much longer than the basal part; sensilla usually short and spinelike; cornicles rather stout and much longer than broad, sometimes distinctly swollen in the middle, or again very small and inconspicuous; cauda distinct and usually triangular with a clear area near the base. Migration from winter habitat, usually some tree, to more succulent herbs for the summer and again returning to the winter habitat for ovipositing is rather common in the group. Two tribes are represented:

a. Cornicles very short and small, usually shorter than the cauda......... Tribe HYALOPTERINI 30
b. Cornicles longer than the cauda (with some exceptions) and cylindrical or swollen; body short and legs moderately long....Tribe APHIDINI 34

30. Tribe HYALOPTERINI. The Hyalopterini are quite a large assemblage of genera, which should be held distinct from the Aphidini proper, as representing a more primitive line of development in which the cornicles are very short and weak (not reduced). The body is more or less elongated and pulverulent; antennae shorter than the body; rostrum and legs short. Three genera are present in Minnesota:

a. Living exposed or in crumpled leaves; migrating from plum to *Phragmites* .... Genus HYALOPTERUS 31
b. Living in closely folded, pod-like leaves on *Chenopodium albus*.......... Genus HAYHURSTIA 32
c. Living exposed on cruciferous plants and on cabbage; cornicles slightly swollen ....Genus BREVICORYNE 33

31. Genus HYALOPTERUS Koch, 1854. Type: *Aphis pruni* Fabricius, 1775. Secondary sensoria in migrant scattered and present on the third and fourth segments; cornicles short and slender, slightly narrower basally.

(22) HYALOPTERUS PRUNI (Fabricius) Koch, 1854
Found on plum and during the summer on *Phragmites*.

32. Genus HAYHURSTIA Del Guercio, 1909. Type: *Aphis atriplicis* Linnaeus, 1761. Secondary sensoria in migrant in a row on the third segment of the antennae; cauda rather long and slender.

(23) HAYHURSTIA ATRIPLICIS (Linnaeus) Del Guercio, 1909
Found in podlike folds of the leaves on Chenopodium.

33. Genus BREVICORYNE Van der Goot, 1915. Type: *Aphis brassicae* Linnaeus, 1758. Cornicles slightly swollen in the middle and short; secondary sensoria in migrant, numerous and scattered on the third segment of the antennae.

(24) BREVICORYNE BRASSICAE (Linnaeus) Van der Goot, 1915
Found on cruciferous plants and on cabbage.

34. Tribe APHIDINI. The Aphidini have the body usually short and rounded posteriorly; antennae usually about as long as the body, with spinelike sensilla, which rarely are long and hairlike; cornicles cylindrical or swollen, stout and often wider at base and tapering; reticulations on cornicles in broken lines; cauda obvious, triangular, and usually with a clear area at base. Found on leaves of trees or more commonly on herbs. This is the largest tribe in the family, rich in genera and species. Two main divisions may be recognized:

a. Cornicles cylindrical.................... Division CYLINDRICORNIA 35
b. Cornicles swollen.............................Division CLAVICORNIA 55

35. Division CYLINDRICORNIA. Cornicles stout, cylindrical, usually much longer than the cauda; reticulations on the cornicles broken or disconnected lines. The genera of this large division may further be divided into three groups:

a. Antennae provided with long, slender hairs like those found in the Chaitophorea......................The CHAITOPHOROIDES group 36
b. Sensilla on the antennae short, straight and spinelike hairs................ The APHIS group 40
c. Similar to the preceding group but showing some marked aberrant character as reduced venation or antennal segments, tarsal characters, etc. .... The TOXOPTERA Group 51

36. The CHAITOPHOROIDES group. Mordwilko separated a rather large aphis form with the body and appendages provided with long, slender hairs like those of the Chaitophorea under the generic name Chaitophoroides. We have several similar forms in America, not all of which can be placed in Mordwilko's genus. Three genera of the group are at present known from Minnesota:

a. Secondary sensoria in migrant 15-30, rather large; pulverulent glands, when present, in dorsal longitudinal rows; cornicles cylindrical....... Genus CHAITOPHOROIDES 37

b. Secondary sensoria in migrant 50 or more, small and scattered; pulverulent glands massed in large areas on each side of the abdomen; cornicles cylindrical and Aphis-like.................Genus AMPHICERCIDUS 38

c. Secondary sensoria in migrant 40 or more, small and scattered; pulverulent glands along the sides of the abdomen; cornicles very short, not longer than wide .... Genus GYPSOAPHIS 39

37. Genus CHAITOPHOROIDES Mordwilko, 1908. Type: *Aphis lantanae* Koch, 1854. Size large with the aspect of a Pterocommini; antennae with long, slender hairs; cornicles rather long and cylindrical; cauda triangular and Aphis-like with many scattered hairs. Found on tender twigs and leaves of various trees and woody plants. The following species are recorded from Minnesota:

(25) CHAITOPHOROIDES MACULATA (Oestlund)
Found on *Cornus* and *Populus* and sometimes on *Salix*.

(26) A second species found on elm is imperfectly known and undescribed. Forms of this genus have in the past been more or less mixed with the Pterocommini, and will require an extended synonymical study to clear up.

38. Genus AMPHICERCIDUS gen. nov. Type: *Aphis pulverulens Gillette,* 1911. Third joint of the antennae rather long and provided with numerous small sensoria (50 or more) in migrant; body strongly pulverulent, the glands massed along the sides of the abdomen. Found on the stem of wolfberry, close to the ground. The sexes appear late in September. One species is known:

(27) AMPHICERCIDUS PULVERULENS (Gillette)
Brownish; strongly pulverulent; on the stems of *Symphoricarpus occidentalis.*

39. Genus GYPSOAPHIS gen. nov. Type: *Aphis lonicerae* Monell, 1879. The third joint of the antennae in migrant long and provided with many small sensoria; cornicles short, not longer than broad; body strongly pulverulent. Found on stalks and leaves of *Lonicera glauca.* One species is known:

(28) GYPSOAPHIS LONICERAE (Monell)
A large green form found on honeysuckle.

40. The APHIS group. Abdomen broad and short, segments 6-8 usually abruptly narrowed; cornicles cylindrical, or wider at base; reticulation on cornicles broken; sensilla of antennae short and spine-like; cauda short and triangular, or rather long, cylindrical, and pointed, with hairs showing tendency to be arranged in rows; spur of antennae always longer than the base; rostrum moderately long and

stout; lateral tubercles usually present. Found on trees, or migrating to herbs for the summer, or their entire history is passed on herbs. Four genera are found in Minnesota, two of which must be indicated as new:

a. Pleurites on the sides of the body with large glands in place of lateral tubercles. The secondary sensoria of the antennae with wide margins, and crowded so as to be transversely oval; cauda short................ Genus CEDOAPHIS 41
b. Pleurites with lateral tubercles in place of glands; secondary sensoria with wide margins but not crowded so as to be transversely oval; cauda Aphis-like; cornicle narrower at base...........Genus THARGELIA 42
c. Pleurites with lateral tubercles in place of glands; secondary sensoria with narrow border, circular; cornicles short, with spinelike crowded reticulations; cauda short and triangular........Genus ANURAPHIS 43
d. Pleurites with lateral tubercles, sometimes reduced or wanting; secondary sensoria with narrow border and circular; cornicles usually long and cylindrical, with open, loose reticulations; cauda rather long, cone-shaped or cylindrical ....Genus APHIS 44

41. Genus CEDOAPHIS gen. nov. Type: *Aphis symphoricarpi* Thomas, 1878. The pleurites on the sides of the body are provided with very large glands in line with the lateral tubercles and cornicles when present. These glands are not pulverulent or wax glands, but of the same order as the cornicles which are also glandular in function. These glands are apparently very primitive structures and are best seen in the present genus, and again in some of the more generalized Callipterini. Their association with the lateral tubercles and cornicles opens up a very interesting field in connection with the functions and origin of the cornicles so unique and characteristic of the family Aphididae.

(29) CEDOAPHIS SYMPHORICARPI (Thomas)

Found in distorted leaves of Symphoricarpus.

42. Genus THARGELIA gen. nov. Type: *Aphis albipes* Oestlund, 1887. Pleurites with lateral tubercles in place of glands; cornicles narrowed at base and slightly swollen toward the apex; secondary sensoria on the antennae with wide margins, but smaller than in the preceding genus and not crowded. The secondary sensoria of these two genera indicate a distinct form from those found in the rest of the family.

(30) THARGELIA ALBIPES (Oestlund)

Found on Symphoricarpus in twisted leaves, sometimes on the same bush with the much rarer form *Cedoaphis symphoricarpi*.

43. Genus ANURAPHIS Del Guercio, 1907. Type: *Aphis pyri* Koch, 1854. Pleurites with lateral tubercles in place of glands; secondary sensoria of antennae with narrow margins, and of the usual type; cornicles short, cylindrical, with crowded reticulations, which appear as rows of minute spines; cauda short and cone-shaped. The genus as first indicated by Del Guercio, based on the relative length of the cornicles and cauda, is an artificial character and will not hold. Baker has lately restricted the genus, based on the peculiar type of cauda. Tho better, it also is not sufficient to separate it from the genus Aphis. Adding to this the peculiar type of reticulations on the cornicles, we probably have a natural genus. Two species are known from Minnesota:

(31) ANURAPHIS BAKERI (Cowen) Baker, 1920
The short-beaked clover aphis. Found on apple and clover.

(32) ANURAPHIS CRATAEGIFOLIAE (Fitch) Baker, 1920
The long-beaked clover aphis. On Crataegus and clover.

44. Genus APHIS Linnaeus, 1758. Type: *Aphis sambuci* Linnaeus, 1758. Pleurites with lateral tubercles (sometimes reduced in number or wanting); cornicles long and cylindrical (sometimes reduced or wanting), or with a wider base; reticulations on the cornicles open or broken lines; cauda usually long and more or less constricted near the base, and usually with a clear area above. Several attempts have been made of late to further restrict the genus but without satisfactory results. The grouping of the species is still unsatisfactory and more or less artificial, but is probably the best that can at present be given with the incomplete knowledge of their life histories and the sexes. The species may be grouped in two divisions based on the arrangement of the secondary sensoria on the antennae:

a. The secondary sensoria on the antennae are numerous (15-50 or more), scattered, circular, and varying more or less in size.................. Division POLYSENSORIA 45

b. The secondary sensoria on the antennae are found in small numbers (4-15), usually large and subequal, and arranged in a single row, or nearly so.. Division PARVISENSORIA 48

45. Division POLYSENSORIA. The Polysensoria probably represent an early condition of the secondary sensoria, when they were numerous, small, and scattered over the first three segments of the flagellum. With their further development for greater efficiency, they became fewer and larger, allowing more favorable positions for functioning, which gave rise to the second division as the more modern

and specialized. The division may further be divided into two sections based on the number of segments with secondary sensoria:

a. The third segment of the antennae with 12 or more sensoria; the fourth and usually also the fifth with a smaller number............Section A 46
b. Secondary sensoria present only on the third segment..........Section B 47

46. Section A. The third segment of the antennae with 12 or more sensoria more or less scattered; the fourth and usually the fifth with a smaller number. Usually rather large forms. The following species are recorded from Minnesota:

(33) APHIS HELIANTHI Monell, 1879
Found on Helianthus; dark green in color; when numerous cause the leaves to curl.

(34) APHIS MIDDLETONI Thomas, 1878
Found on the roots of *Erigeron canadensis* and other Compositae.

(35) APHIS THASPII Oestlund, 1887
Found on *Thaspium aureum;* abdomen dark green.

(36) APHIS NEILLIAE Oestlund, 1887
Found on Ninebark, *Physocarpus opulifolius;* abdomen black.

(37) APHIS CARDUELLA Walsh, 1862
Found on *Circium;* abdomen dull green.

(38) APHIS NEPETAE Kaltenbach, 1843
Found on *Nepeta catarea;* abdomen green.

(39) APHIS RUMICIS Linnaeus, 1758
Found on Rumex, Chenopodium, and other herbs; abdomen black.

(40) APHIS MAIDIS Fitch, 1856
Found on corn; abdomen green.

(41) APHIS MIMULI Oestlund, 1887
Found on Mimulus; a very small form; abdomen pale green.

47. Section B. Secondary sensoria are found only on the third segment. The following species are known from Minnesota:

(42) APHIS CARDUI Linnaeus, 1758
Found on plum and thistle; rostrum very long for an Aphis.

(43) APHIS RIPARIAE Oestlund, 1886
Found on *Vitis riparia.*

(44) APHIS CORNIFOLIAE Fitch, 1851
Found on Cornus; abdomen dark brown.

(45) APHIS OXYBAPHI Oestlund, 1887
Found on *Oxybaphus angustifolia.*

(46) APHIS ASCLEPIADIS Fitch, 1851
Found on *Asclepias cornutus* and related plants.

48. Division PARVISENSORIA. Secondary sensoria are usually large, equal in size, and fewer in number (4-12), arranged in a single row, or nearly so. This division may also be considered under two sections based on the position of the sensoria on certain segments:

a. Sensoria present on segments 3 to 5........................Section A 49
b. Sensoria restricted to the third segment......................Section B 50

49. Section A. Sensoria or segments 3 and 4 or 3 to 5. The following species occur in Minnesota:

(47) APHIS LUTESCENS Monell, 1879
Found on *Asclepias syriaca.*

(48) APHIS SPIRAEAE Oestlund, 1887
Found on *Spiraea salicifolia.*

(49) APHIS IMPATIENTIS Thomas, 1878
Found on *Impatiens fulva.*

(50) APHIS MONARDAE Oestlund, 1887
Found on *Manarda fistulosa.*

(51) APHIS FRONDOSAE Oestlund, 1886
Found on *Bidens frondosa.*

(52) APHIS EUPATORII Oestlund, 1886
Found on *Eupatorium perfoliatum.*

50. Section B. Sensoria restricted to the third segment.

(53) APHIS POMI DeGeer, 1773
Found on apple and *Graminaceae.*

(54) APHIS SALICICOLA (Thomas) Monell, 1879
Found on the leaves of willow.

(55) APHIS CERASIFOLIAE Fitch, 1855
Found on chokecherry, *Prunus virginiana.*

(56) APHIS FORBESI Weed, 1889
Found on strawberry.

(57) APHIS RUBICOLA Oestlund, 1887
Found on leaves of *Rubus.*

(58) APHIS APARINES Fabricius, 1775
Found on *Galium aparine,* twisting the leaves.

(59) APHIS OENOTHERAE Oestlund, 1887
Found on *Oenothera.*

51. Group TOXOPTERA. In a more strict classification the following genera would be arranged with the preceding group, but it is more practical to consider those genera separately that differ greatly in some one character which at once distinguishes them from the ordinary Aphis. Such aberrant characters are a reduction in venation, antennae, or tarsi. The following genera are known from Minnesota:

a. Media of forewings with only one branch........Genus TOXOPTERA 52
b. Hind wings with only one oblique vein.......Genus HYSTERONEURA 53
c. Tarsi of all the legs reduced and without claws..Genus MASTOPODA 54

52. Genus TOXOPTERA Koch, 1857. Type: *Aphis aurantiae* Boyer, 1841. Media with only one branch in the fore wings; cornicles cylindrical and moderately long; cauda Aphis-like; sensoria on the antennae in small number.

(60) TOXOPTERA GRAMINUM (Rondani) Passerini, 1860
This southern grain aphis is at times quite common.

53. Genus HYSTERONEURA Davis, 1919. Type: *Siphonophora setariae* Thomas, 1878. Aphis-like in characters, but the hind wings have but one oblique vein; sensoria on the antennae in small number.

(61) HYSTERONEURA SETARIAE (Thomas) Davis, 1919
This red-brown species is rather common on plum, migrating to various grasses for the summer.

54. Genus MASTOPODA Oestlund, 1886. Type: *Mastopoda pteridis* Oestlund, 1886. Antennae with only five segments, the third and fourth connate; cauda short and cone-like; tarsi reduced to a small mamma-like joint without claws. Found on fern.

(62) MASTOPODA PTERIDIS Oestlund, 1886
Found on *Pteris aquilina;* a comparatively rare form.

55. Division CLAVICORNIA. Koch placed all aphids with swollen cornicles in the genus *Rhopalosiphum;* it has since been found that swollen cornicles are present in many of the tribes of the family and that the character is more than generic. Koch's *Rhopalosiphum* has therefore been broken up into numerous genera, some of which belong to the division Clavicornia of the tribe Aphidini. The division includes those genera that are Aphis-like, but with distinct swollen cornicles. The following genera are found in Minnesota:

a. Cornicles swollen on the apical half; cauda slender.......................
Genus RHOPALOSIPHUM 56
b. Cornicles slightly swollen in the middle; cauda stout....................
Genus SIPHOCORYNE 57
c. Cornicles strongly swollen in the middle.........Genus LIOSOMAPHIS 58

d. Abdomen with a dorsal tubercle above the cauda...Genus CAVARIELLA 59
e. Cornicles with two swellings, one in the middle and one apical............
Genus CACHRYPHORA 60
f. Cornicles with only the apical swelling.........Genus EPAMEIBAPHIS 61

56. Genus RHOPALOSIPHUM Koch, 1854. Type: *Aphis nymphaeae* Linnaeus, 1761. The characters are those of the genus Aphis, but with the cornicles swollen on the upper half, or club shaped.

(63) RHOPALOSIPHUM NYMPHAEAE (Linnaeus) Koch, 1854
A species common on various water plants.

57. Genus SIPHOCORYNE Passerini, 1863. Type: *Aphis xylostei* Schrank, 1801. Similar to Rhopalosiphum but with a large and stout cauda.

(64) SIPHOCORYNE XYLOSTEI (Schrank) Passerini, 1863
Found on honeysuckle *(Lonicera)*.

58. Genus LIOSOMAPHIS Walker, 1868. Type: *Aphis berberidis* Kaltenbach, 1843. Cornicles distinctly swollen in the middle.

(65) LIOSOMAPHIS BERBERIDIS (Kaltenbach) Walker, 1868
At times abundant on barberry.

59. Genus CAVARIELLA Del Guercio, 1911. Type: *Aphis pastinacae* Linnaeus, 1758. The distinguishing character of this genus is the presence of a tubercle above the cauda, which appears as a cauda above the cauda.

(66) CAVARIELLA PASTINACAE (Linnaeus) Del Guercio, 1911
Found on parsnips and other umbelliferous plants.

(67) CAVARIELLA SALICIS (Monell)
Rather common on *Salix*.

60. Genus CACHRYPHORA gen. nov. Type: *Rhopalosiphum serotinae* Oestlund, 1887. Cornicles with a double swelling, one in the middle and a second as a distinct swelling of the apex, a decided constriction separates the two; cauda conical. The enlarged apices of the sensilla on the head and antennae would indicate a Myzini relationship, but the frontal margin and the head place it in the tribe under consideration.

(68) CACHRYPHORA SEROTINAE (Oestlund)
Cornicles capitate at apex and swollen below
Found on goldenrod, *solidago*.

61. Genus EPAMEIBAPHIS gen nov. Type: *Aphis frigidae* Oestlund, 1886. We may also include this genus with the Clavicornia

based on the swollen, knob-like apex of the cornicles, tho the sensilla show Macrosiphea characters.

(69) EPAMEIBAPHIS FRIGIDAE (Oestlund)
Found on *Artemisia frigida*.

62. Series LACHNEA-MACROSIPHEA. Traced from a common stock with Lachnea and the series Lachnea-Aphidea, we have two other supertribes that have evolved alongside the Aphidea line. The body is usually large and pointed posteriorly; antennae usually longer than the body, with very long spur, and provided with apically enlarged sensilla and hairs on the antennae and other parts of the body. The two supertribes of the series may be separated as follows:

a. The glandular apex of the sensilla globate; cornicles short and truncate... Supertribe CALLIPTEREA 63
b. The glandular apex of the sensilla flattened and spearlike; cornicles usually long and cylindrical.....................Supertribe MACROSIPHEA 83

63. Supertribe CALLIPTEREA. Sensilla on the antennae and on the body, especially in larval forms, glandular and ending in globular apices; cornicles short and truncate, usually not longer than broad; cauda usually ending in an enlarged or globate apex. The supertribe differs from the rest of the family in being sporadic and not gregarious, never found in large colonies, and in the fact that the parthenogenetic generations all acquire wings before reproducing. The following tribes are represented in Minnesota:

a. Large and Macrosiphum-like, front strongly emarginated................ Tribe CALAPHIDINI 64
b. Medium to small, front not strongly emarginated; cauda globate.......... Tribe CALLIPTERINI 68
c. Cornicles longer than broad, widest at base............................. Tribe DREPANOSIPHINI 81

64. Tribe CALAPHIDINI. Size large and front strongly emarginated as in the Macrosiphini; cornicles usually somewhat longer than broad and cylindrical, sometimes swollen at base. Body and appendages often with pulverulence or wax threads. Three genera are recognized:

a. Spur shorter than the very long base; stigmal vein distinct; cornicles swollen or bulged at base.. Genus QUIPPELACHNUS 65
b. Spur shorter than the base; stigmal vein distinct; cornicles cylindrical..... Genus EUCERAPHIS 66
c. Spur longer than the base; stigmal vein indistinct on basal half or more; cornicles cylindrical ....Genus CALLIPTERINELLA 67

65. Genu QUIPPELACHNUS gen. nov. Type: *Euceraphis gillettei* Davidson, 1915. Spur of terminal antennal segment shorter than the base; stigmal vein distinct; cornicles swollen or bulging at base. Habitat Alnus.

(70) QUIPPELACHNUS GILLETTEI (Davidson)
A conspicuous western and northern form with tufts of flocculent strands on body and legs.

66. Genus EUCERAPHIS Walker, 1870. Type: *Aphis betulae* Koch. Spur shorter than the base; stigmal vein distinct; cornicles cylindrical; anal plate usually entire.

(71) EUCERAPHIS BETULAE (Koch)
Sensoria on the third joint, crowded on the enlarged basal part. Found on *Betula*.

(72) EUCERAPHIS ALNIFOLIAE (Fitch)
Sensoria not crowded. Found on *Alnus*.

67. Genus CALLIPTERINELLA Van der Goot, 1913. Type: *Aphis betularius* Kaltenbach, 1843. Spur of the antennae longer than the base; stigmal vein indistinct on the basal half or more; cornicles cylindrical.

(73) CALLIPTERINELLA BETULAECOLENS (Fitch)
Rather common on *Betula*.

68. Tribe CALLIPTERINI. Size moderate to small; cornicles short and truncate; cauda globate at apex; antennae with the spur shorter or much longer than the base. This large and interesting tribe has long been a favorite with aphidologists. Their classification is still unsatisfactory, but of great phylogenetic value as it gives a picture of a very remote condition of the family that has become lost by all the other tribes. The following subtribes are represented in Minnesota:

a. Found on woody parts of trees (*Corticola* group)..Subtribe SYMYDOBII 69
b. Found on leaves of walnut and hickory (*Juglans-Myrica* group).......... Subtribe PANAPHIDII 71
c. Found on leaves of linden and oak (*Tilia-Quercus* group)................ Subtribe CALLIPTERII 76

69. Subtribe SYMYDOBII. Corticola group. Antennae about as long as the body; spur of the terminal segment about equal to the base; cornicles short and truncate and cauda slightly emarginated; abdomen with lateral tubercles and rather hairy; sensilla spine-like. A genus that stands midway between the Chaitophorea and the Callipterea but is usually considered to belong to the latter.

a. With characters of the subtribe..................Genus SYMYDOBIUS 70

70. Genus SYMYDOBIUS Mordwilko, 1894. Type: *Aphis oblonga* Heyden, 1837. Our American representative of this genus has long been considered the same as the type form of Europe, but Baker has lately indicated it as distinct.

(74) SYMYDOBIUS AMERICANUS Baker

Found on shoots and twigs of *Betula papyracea*.

71. Subtribe PANAPHIDII. Juglans-Myrica group. Antennae usually much shorter than the body; spur shorter than the base; anal plate emarginated. Found on walnut and hickory. The following genera may be indicated:

a. Antennae less than half the length of the body.......Genus PANAPHIS 72
b. Antennae about half the length of the body......Genus CHROMAPHIS 73
c. Antennae as long as or longer than the body..........Genus MONELLIA 74
d. Antennae longer than the body; many spine-like tubercles on various parts of the body..............................Genus MELANOCALLIS 75

72. Genus PANAPHIS Kirkaldy, 1904. Type: *Aphis juglandis* (Frisch) Gmelin, 1788. The very short antennae and spur led Passerini to consider *juglandis* the type of his Callipterus which was placed with the Lachnini. Koch considered it a Callipterini.

(75) PANAPHIS JUGLANDIS (Gmelin) Kirkaldy, 1904

On the upper sides of the leaves of walnut. Not known from Minnesota but may be looked for.

73. Genus CHROMAPHIS Walker, 1870. Type: *Lachnus juglandicola* Kaltenbach, 1843. Antennae about half the length of the body.

(76) CHROMAPHIS JUGLANDICOLA (Kaltenbach) Walker, 1870

Found on the underside of the leaves of walnut.

74. Genus MONELLIA Oestlund, 1887. Type: *Aphis caryella* Fitch, 1855. Antennae longer than the body; spur of the terminal segment somewhat shorter than the base; cornicles very short, small and primitive and not far in advance of the lateral tubercle type. The following species are found here:

(77) MONELLIA CARYELLA (Fitch) Oestlund, 1887

This delicate whitish form is rather common on the leaves of hickory.

(78) MONELLIA CARYAE (Monell) Gillette, 1910

Found with the above species; not as depressed and wings held roof-like at rest.

75. Genus MELANOCALLIS gen. nov. (The black beauty). Type: *Callipterus caryaefoliae* Davis, 1910. This very interesting form is found on the leaves of hickory. They are found as minute black specks along the veins and have considerable leaping ability. The body is provided with many spinelike tubecles on various parts:

(79) MELANOCALLIS CARYAEFOLIAE (Davis)

Found on the underside of the leaves of *Carya*.

76. Subtribe CALLIPTERII. (*Tilia-Quercus* group.) The subtribe indicates the maximum of Callipterini development. The North American continent seems to be their center of distribution as attested by the large number of species found in comparison with other parts of the world. The group has a wide habitat on forest trees, besides *Tilia* and *Quercus* they are also found on *Alnus, Corylus, Castania,* etc. The following genera are found in Minnesota:

a. On *Tilia*. Base of terminal antennal segment elongated.................. Genus CALLIPTERUS 77

b. On *Alnus*. Base not elongated.................. Genus PTEROCALLIS 78

c. On *Corylus* and *Quercus*. Stigmal vein often indistinct.................. Genus MYZOCALLIS 79

d. On *Quercus* and *Ulmus*. Body with dorsal tubercles.................... Genus TUBERCULATUS 80

77. Genus CALLIPTERUS Koch, 1855. Type: *Aphis tiliae* Linnaeus, 1758. Stigmal vein distinct; base of terminal antennal segment elongated, spur somewhat shorter. The genus *Callipterus* was established by Koch in 1855 based on all the species included without indicating any one as the type. Some years later Passerini broke up the genus, indicating several additional genera, and restricted Koch's Callipterus to *juglandis* as type and placed with the Lachnini. Koch's description of his *Gaylous*, very obviously does not apply to *juglandis*, but rather to the forms Passerini included in the genus *Myzocallis*. Later writers like Walker, Riley, Monell, Thomas, Buckton, and others, strongly protested the procedure of Passerini and attempted to restore *Callipterus* to its original meaning as given by Koch. *Callipterus* Koch and *Callipterus* Passerini are two very different conceptions, as Passerini misinterpreted Koch. Walker first suggested that *tilia* be the type of Koch's genus *Callipterus* and that *Myzocallis* be restricted to species on *Corylus* and *Quercus*. In place of Passerini's *Callipterus* he proposed the term *Callaphis*, which Buckton later changed to *Ptychodes,* a tem that was still later changed to *Panaphis* by Kirkaldy. It should be noticed that Koch arranged his species in a descending order, placing first the more typical forms, and ending with the lowest,

juglandis, which was followed by the genus Lachnus. Monell aimed to suppress the term *Myzocallis* altogether. There is undoubtedly a place for Myzocallis and it should be retained, but Koch's *Callipterus* should be applied to *tiliae* and not to *juglandis*.

(80) CALLIPTERUS TILAE (Linnaeus) Walker, 1868
Not known from Minnesota but may be looked for on *Tilia*.

78. Genus PTEROCALLIS Passerini, 1860. Type: *Aphis alni* DeGeer, 1773. Antennae about as long as the body; spur of the terminal segment slightly shorter than the base; anal plate slightly emarginated; radial sector indistinct basally, and anal vein with a distinct bulla on the base of the vein.

(81) PTEROCALLIS ALNI (DeGeer) Passerini, 1860
A rather small delicate form found on the leaves of *Alnus*.

79. Genus MYZOCALLIS Passerini, 1860. Type: *Aphis coryli* Goeze, 1778. Antennae usually much longer than the body; basal part of the terminal antennal segment not elongated, and the spur equal to or commonly much longer than the base; stigmal vein usually indistinct on basal part. The following species are known from Minnesota:

(82) MYZOCALLIS DISCOLOR (Monell) Wilson, 1910
Cornicles black; wings mottled with brown areas.

(83) MYZOCALLIS ASCLEPIADIS (Monell) Wilson, 1910
Cornicles yellow; wings with brown areas.

(84) MYZOCALLIS PUNCTATUS (Monell) Wilson, 1910
Wings clear; spur slightly longer than base.

(85) MYZOCALLIS WALSHI (Monell) Baker, 1917
Wings clear; spur nearly twice the base in length.

(86) MYZOCALLIS BELLUS (Walsh) Thomas, 1879
Wings with black border; spur nearly twice the base in length.

80. Genus TUBERCULATUS Mordwilko, 1894. Type: *Aphis quercus* Kaltenbach, 1843. Abdomen with dorsal tubercles; spur shorter than base.

(87) TUBERCULATUS ULMIFOLII (Monell)
Common on leaves of elm; a small, pale, delicate form.

81. Tribe DREPANOSIPHINI. Antennae much longer than the body; cornicles longer than broad, enlarged basally; abdomen with dorsal tubercles. One genus is known from Minnesota:

a. Found on leaves of soft maple.................Genus DREPANAPHIS 82

82. Genus DREPANAPHIS Del Guercio, 1909. Type: *Siphonophora acerifolii* Thomas, 1878. The excessive length of the antennae, conspicuous dorsal tubercles with white flocculent patches, indicate a high development similar to what is found in the Macrosiphni.

(88) DREPANAPHIS ACERIFOLII (Thomas) Del Guercio, 1909

Rather common on the leaves of soft maple.

83. Supertribe MACROSIPHEA. Size large or moderately large, with abdomen more or less pointed posteriorly; antennae usually longer than the body; spur of terminal segment very long; sensilla on antennae and parts of the body with a glandular, globate, or spearshaped apex, sometimes only fingerlike and blunt; cornicles long and cylindrical, rarely short, sometimes swollen; reticulations on cornicles usually continuous and forming closed cells; cauda long and usually curved. The three tribes may be separated as follows:

a. Frontal tubercles enlarged or swollen on the inner side and strongly reticulated; sensilla globate.................................Tribe MYZINI 84

b. Frontal tubercles not swollen on the inner side; cornicles very short..... Tribe MICROSIPHINI 90

c. Cornicles long and cylindrical; sensilla on antennae spear-shaped.......... Tribe MACROSIPHINI 92

84. Tribe MYZINI. Size moderately large to small; frontal tubercles with obvious swelling on the inner side, strongly reticulated and provided with glandular hairs like those on the antennae; cornicles usually long and slender, cylindrical or slightly swollen apically. The Myzini partake in form both of the Aphidini and the Macrosiphini, but their glandular, capitate sensilla appear to be a distinct type that may be directly traced from the Callipterini, while the Macrosiphini are traced from the Calaphidini. The following genera are represented in Minnesota:

a. Antennae usually shorter than the body; sensilla short in the aptera; lateral tubercles present..............................Genus MYZUS 85

b. Antennae longer than the body; sensilla short in aptera; no lateral tubercles present on the abdomen; spurea sometimes with sensoria on the third segment...............................Genus NEOMYZUS 86

c. Antennae usually equal to or shorter than the body; sensilla long in the aptera; no sensoria in spurea...............Genus CAPITOPHORUS 87

d. Antennae much longer than the body; sensilla long in the larval forms; sensoria many and scattered on segments 3-5 in the migrant........... Genus CRYPTOMYZUS 88

e. The swellings on the frontal tubercles are produced into projecting hornlike tubercles, best seen in the spurea............Genus PHORODON 89

85. Genus MYZUS Passerini, 1860. Type: *Aphis cerasi* Fabricius, 1775. Myzus partakes more of the Aphidini than any other genus of the group. The following species are known from Minnesota:

(89) MYZUS CERASI (Fabricius) Passerini, 1860
This black species is rather common on cherry.

(90) MYZUS PERSICAE (Sulzer) Passerini, 1860
A very common species on various field and garden plants.

86. Genus NEOMYZUS Van der Goot, 1916. Type: *Siphonophora circumflexus* Buckton, 1876. This genus partakes somewhat of the Macrosiphini.

(91) NEOMYZUS CIRCUMFLEXUS (Buckton) Van der Goot, 1916
Found on Vinca and other plants.

(92) A species belonging here is also found on the rose.

87. Genus CAPITOPHORUS Van der Goot, 1913. Type: *Aphis carduinus* Walker, 1850. The numerous and long sensilla on the body, especially in the apterous forms, relate this genus to the Callipterini. The following species are found in Minnesota:

(93) CAPITOPHORUS CARDUINUS (Walker) Van der Goot, 1913
Common on Canada thistle.

(94) CAPITOPHORUS XANTHII (Oestlund)
On Xanthium or cocklebur.

(95) CAPITOPHORUS ROSARUM (Walker)
Found on rose

88. Genus CRYPTOMYZUS nomen nov. Type: *Aphis ribis* Linnaeus, 1758. Van der Goot considered this as the type of his genus Myzus, but incorrectly so.

(96) CRYPTOMYZUS RIBIS (Linnaeus)
Common on currant, cupping the leaves.

89. Genus PHORODON Passerini, 1860. Type: *Aphis humuli* Schrank, 1801. One representative of this genus is rather abundant:

(97) PHORODON HUMULI (Schrank) Passerini, 1860
Found mostly on wild hops.

90. Tribe MICROSIPHINI. Cholodkovsky in 1908 erected the genus Microsiphum for a very peculiar form that is not an Aphis, a Myzus, or a Macrosiphum. It is a representative of a characteristic tribe and fauna found on Artemisias and related plants on the great plains. When *Aphis frigidae* was described as new in 1886 from *Artemisa frigida,* it was seen that it did not look o behave like an ordinary Aphis, but would eventually become a distinct genus. A second species was also described at the same time from the same

habitat, as *Siphonophora frigidae.* Williams described several additional species from Artemisias and still later Gillette and Wilson have increased our knowledge of these forms. There is something distinctive about all our Artemisia forms, tho most of them can be associated with the Aphidini and Macrosiphini. There are some that can not so be placed and probably represent a different stock, as indicated by the present tribe. One would not expect the sage-bush areas of the great western plains to be rich for collecting aphids, but a score of species are now known and many remain to be made known. Minnesota is on the border of this area and can be considered to come within it, as several different Artemisias are found over the state, which become infested with these western forms from time to time.

It has long been a puzzle to me to account for this peculiar sage-bush fauna, as most of them can easily be associated with various tribes, the Aphidini, Chaitophorini, Myzini, and Macrosiphini. They may be looked upon as a biological group and not a phylogenetic, with the exception of the Microsiphini. The geology of the great plains may give us the clue as to the origin of the fauna. In the early stage of the North American continent the western plains did not exist, as geologists tell us, but the land was only slightly above the sea level and the flora and fauna were probably the same for both the east and the west. With the gradual elevation of the west, the original flora and fauna would tend to disappear, except for those forms that were able to adapt themselves to the new and changed condition, and a new flora, adapted to the changing conditions, would come in, replacing the old and disappearing one. The Artemisias were some of those new immigrants, and have now become the dominant forms. The various forms of *Aphis, Chaitophorus, Myzus;* and *Macrosiphum* persisted only to the extent that they became adapted to the dominant Artemisias; while *Lachnus, Callipterus,* and *Pemphigus* have disappeared from those areas. One genus of the Microsiphini is well represented in Minnesota:

a. Genus MICROSIPHUM 91

91. Genus MICROSIPHUM Cholodkovsky, 1908. Type: *Microsiphum ptarmicae* Cholodkovsky, 1908. Has the general appearance of a small Macrosiphum with very short cornicles.

(98) MICROSIPHUM ARTEMISIAE (Gillette) Wilson, 1915
Color wine red; found on *Artemisia ludoviciana.*

92. Tribe MACROSIPHINI. Size large and gradually pointed posteriorly; antennae usually much longer than the body; sensilla of

the antennae long and apically enlarged, arrow-shaped, spoon-shaped, or finger-like; sensoria are usually present on the third segment of the spurea; head strongly emarginated in front owing to large antennal tubercles, which are not swollen on the inner side, or very slightly so; cornicles long, stout, and cylindrical or swollen; reticulations on the cornicles continuous and forming cells or closed areas on the upper part; cauda long and usually curved, with the hairs arranged in rows on the sides. This large tribe has usually been considered as the highest development of the family, or more correctly, of the subfamily. The two subtribes may be separated as follows:

a. With typical or normal venation and other characters.................. Subtribe MACROSIPHII 93
b. Venation abnormal, more or less aberrant forms...................... Subtribe PENTALONII 104

93. Subtribe MACROSIPHII. Typical Macrosiphini with normal venation; cornicles cylindrical or swollen. The subtribe may further be considered under two divisions based on the cornicles:

a. Cornicles cylindrical ....Division CYLINDRICORNIA 94
b. Cornicles swollen ....Division CLAVICORNIA 102

94. Division CYLINDRICORNIA. Cornicles cylindrical and usually strongly reticulated; sensoria usually present and restricted to the third segment in both the spurea and the migrant. The genera of this rather large group may again be arranged in two groups:

a. Cornicles short and with aphis-like reticulation; generalized forms...... 95
b. Cornicles long and cylindrical with closed reticulations; typical forms..... 98

95. Group Generalized Cylindricornia. Cornicles comparatively short and the reticulation often indistinct or broken as in the Aphidini. Two genera are represented in Minnesota:

a. Cauda short and conical; cornicles short and not much longer than the cauda ....Genus MACROSIPHONIELLA 96
b. Cauda longer and Aphis-like; cornicles longer than cauda............... Genus CATAMERGUS 97

96. Genus MACROSIPHONIELLA Del Guercio, 1911. Type: *Siphonophora atra* Ferrari, 1872. A genus established by Del Guercio for certain Aphidini-like Macrosiphini, based on the short cone-shaped cauda and cornicles with aphis-like reticulation.

(99) MACROSIPHONIELLA SANBORNI Gillette, 1908
Found on chrysanthemum in greenhouses.

97. Genus CATAMERGUS gen. nov. Type: *Nectarophora fulvae* Oestlund, 1887. The characters of the cornicles are similar to Macrosiphoniella, but the cauda is long and Aphis-like.

(100) CATAMERGUS FULVAE (Oestlund)
Found on *Impatiens fulva;* larval forms pulverulent.

(101) CATAMERGUS PURPURASCENS (Oestlund)
Found on *Thalictrum purpurascens;* pale green.

(102) CATAMERGUS CYNOSBATI (Oestlund)
Found on *Ribes cynosbati.*

98. Group Typical Cylindricornia. Large and typical forms with cornicles long and cylindrical and with an area of closed reticulations on the apical part; sensoria present in the spurea as well as in the migrant and usually restricted to the third segment. The following genera are found in Minnesota:

a. Third segment of the antennae with numerous, scattered sensoria (polysensoria); found on Compositae..........Genus TRITOGENAPHIS 99
b. Sensoria not so numerous and scattered; found on *Rosaceae* and other plants ....Genus MACROSIPHUM 100
c. Sensoria few and arranged in a single row; in the spurea the sensoria are usually 1-4 or wanting...................Genus ACYRTHOSIPHON 101

99. Genus TRITOGENAPHIS gen. nov. Type: *Aphis rudbeckiae* Fitch, 1851. Very large and typical Macrosiphini found on Compositae, and usually brown, red, vermillion, or green in color. A large number of our Macrosiphini belong to this genus:

(103) TRITOGENAPHIS RUDBECKIAE (Fitch)
Found on Rudbeckia, Silphium, and golden glow; bright vermilion red in color.

(104) TRITOGENAPHIS AMBROSIAE (Thomas)
Found on Iva and Ambrosia; color seal-brown or red brown

(105) TRITOGENAPHIS CHRYSANTHEMI (Oestlund)
Found on *Bidens;* color dark red brown.

(106) TRITOGENAPHIS ERIGERONENSIS (Thomas)
Found on *Erigeron canadensis;* color green.

(107) TRITOGENAPHIS LUDOVICIANAE (Oestlund)
Found on *Artemisia ludoviciana;* color green with white pulverulent matter.

100. Genus MACROSIPHUM (Passerini) Schouteden, 1901. Type: *Aphis rosae* Linnaeus, 1758. The sensoria on the antennae are not so numerous as in the foregoing genus, and are less scattered, showing a tendency to be arranged in a row and may be present on segments 3-5. It may be noticed that Passerini never once associated his Macrosiphum with a species altho he published several papers and species since he proposed the new term; Schouteden was the first to associate the term as a genus with a species in 1901, and this association should be ascribed to him and not to Passerini, who only suggested the term and never made use of it.

(108) MACROSIPHUM ROSAE (Linnaeus) Schouteden, 1901
Found on roses; color green.

(109) MACROSIPHUM PALLIDA (Oestlund) Sanborn, 1906
A pink form found also on rose; this species has been redescribed by Patch as *pseudorosae*.

(110) MACROSIPHUM POTENTILLAE (Oestlund) Sanborn, 1906
A pale brown form found on *Potentilla*.

(111) MACROSIPHUM GERANII (Oestlund) Sanborn, 1906
Found on geranium; a pulverulent form.

(112) MACROSIPHUM FRIGIDAE (Oestlund) Sanborn, 1906
Found on *Artemisia frigida;* color dark green.

101. Genus ACYRTHOSIPHON Mordwilko, 1914. Type: *Aphis pisi* Kaltenbach, 1843. Sensoria few, arranged in a row and usually restricted to the third segment; spuria with only a few, 1-4, found on the base of the third segment. Large green or pale forms found on various plants, mostly herbs.

(113) ACYRTHOSIPHON PISI (Kaltenbach) Mordwilko, 1914
Found on various *Legumenosae;* color green.

(114) ACYRTHOSIPHON GRANARIUM (Kirby) Mordwilko, 1914.
Found on *Graminaceae;* color pale brown.

(115) ACYRTHOSIPHON SOLANIFOLII (Ashmead)
Found on cruciferous plants and potato.

102. Division CLAVICORNIA. Cornicles very long and swollen, usually without closed reticulations except a few near the apex of the cornicles. At present a great many different forms are considered under one genus:

a. Cornicles swollen; large Macrosiphum-like forms...................... 103

103. Genus AMPHOROPHORA Buckton, 1876. Type: *Amphorophora ampullata* Buckton, 1876. A number of genera that Mordwilko recognizes for the European fauna have not yet been applied to our American representatives.

(116) AMPHROPHORA NABALI (Oestlund)
Found on *Nabalus albus;* a large and conspicuous form, with numerous small sensoria on segments 3 to 5 in the migrant.

(117) AMPHOROPHORA SONCHI (Oestlund)
Found on *Sonchus oleracea;* similar to *nabali* but with fewer and larger sensoria on the third and the fourth segments.

(119) AMPHOROPHORA RUBICOLA (Oestlund)
Found on growing stalks of *Rubus;* sensoria restricted to the third segment.

(120) AMPHOROPHORA AMPULLATA Buckton, 1876

What is considered to be this species was once taken at Minneapolis on the Ostrich fern, but has not since been seen and may have been an escaped form from some greenhouse; sensilla on antennae short and small.

104. Subtribe PENTALONII. The Pentalonii have certain abnormalities in venation and otherwise that separate them from the typical Macrosiphii. A very interesting biological question is associated with this peculiarity of tropical or subtropical forms. One representative is known from Minnesota:

a. Hind wings much reduced and without oblique veins....................
Genus MICROPARSUS 105

105. Genus MICROPARSUS Patch, 1909. Type: *Microparsus variabilis* Patch, 1909. A peculiar genus characterized by the media of the fore wings with only one branch, and by the reduced hind wings with only a stump of an oblique vein or altogether wanting.

(121) MICROPARSUS VARIABILIS Patch, 1909

Found on tick trefoil or *Desmodium*.

106. Subfamily PEMPHIGINAE. Specialized Aphididae in which the typical Aphidian characters are specialized in the line of reduction or loss, as seen in the number of segments to the antennae, in the spur, sensilla, and sensoria; reduction in venation is also carried further in this subfamily than in the preceding. The subfamily is typically subterraneous or protected in habitat, and found in folds of leaves, in crevices of bark, or in galls. Positive pemphigian characters are seen in the position of the antennae and in the great development of the dermal glands. The antennae are usually shorter than half the length of the body, and inserted on the under side of the head in depressions not seen from above; sensoria are often crowded and therefore usually transverse or annulate; media of the fore wings usually simple, or with one branch, rarely with two branches; cornicles very short and appear as pores, or are wanting. It may be noticed that in Lachnea the antennae are inserted on the sides of the head in front of the eyes, in the Aphidea and the Macrosiphea lines they tend to become dorsal, while in the Pemphiginae they have moved to a ventral position. Only one series is recognized:

a. The Mindarea-Pemphigea series.................................... 107

107. Series MINDAREA-PEMPHIGEA. The characters of the series are the same as those for the subfamily. The following supertribes are at present recognized:

a. Radial sector arising from behind the stigma; found on Conifera........ Supertribe MINDAREA 108

b. Sector arising from the middle of the stigma; fundatrix with six segments to the antennae; sexes with rostrum; found on woody plants.......... Supertribe PHYLLAPHIDEA 111

c. Fundatrix usually with five segments to the antennae, sometimes with six; sexes without rostrum; found in folded or twisted leaves, sometimes in galls ....Supertribe SCHIZONEUREA 121

d. Fundatrix usually with only four segments to the antennae; sexes without rostrum; found in galls and on roots........Supertribe PEMPHIGEA 129

108. Supertribe MINDAREA. In the Mindarea the stigmal vein arises from the base or back of the stigma and runs as a straight vein to the margin of the wing. This is considered as a very primitive condition that is known also from fossil forms. Only one tribe is known:

a. The tribe MINDARINI... 109

109. Tribe MINDARINI. With the same characters as the supertribe. Only one genus is known at present:

a. Genus MINDARUS 110

110. Genus MINDARUS Koch, 1857. Type: *Mindarus abietinus* Koch, 1857. Antennae 6-jointed; sensoria round or oval; cauda obvious; the sexes are both apterous and provided with rostrum. Found exclusively on Conifera.

(122) MINDARUS ABIETINUS Koch, 1857

Found on pine and spruce, twisting the needles.

111. Supertribe PHYLLAPHIDEA. The position of the antennae indicate the Pemphiginae relations of all the tribes included. Some Phyllaphidini and Vacunini show Callipterini characters, while the Anoeciini and Vacunini also show Chaitophorini relations. The following tribes may be recognized:

a. Media twice branched; sexes with male alate and female apterous........ Tribe PHYLLAPHIDINI 112

b. Media with only one branch; sexes sometimes both alate or both apterous.. Tribe TAMALIINI 114

c. Antennae with long hairs; sexes both small and apterous................. Tribe ANOECIINI 117

d. Hind wing with only one oblique vein; sexes alate or apterous.......... Tribe VACUNINI 119

112. Tribe PHYLLAPHIDINI. Forms living free on plants, protected by abundant secretion; media of fore wings with two branches:

a. Genus PHYLLAPHIS 113

113. Genus PHYLLAPHIS Koch 1857. Type: *Aphis fagi* Linnaeus, 1758. Cauda globate; anal plate slightly emarginated; sensoria oval.

(123) PHYLLAPHIS FAGI (Linnaeus) Koch, 1857
Not known from Minnesota.

114. Tribe TAMALIINI. Type: *Pemphigus coweni* Cockerell, 1905. Antennae 6-jointed; cauda short and broad, not extending beyond the anal plate; cornicular pores slightly raised above the surface; media with one branch. Found in gall-shaped folds or between united leaves. Two genera may be recognized:

a. Found in pod-like folded leaves of *Arctostaphylus*.....Genus TAMALIA 115
b. Found in folded margins on the leaves of oak, or between united leaves.. Genus STEGOPHYLLA 116

115. Genus TAMALIA (Pergande) Baker, 1920. Type: *Pemphigus coweni* Cockerell, 1905. Oviparous female sometimes alate; media with one branch in the fore wings; cauda entire, short, and rounded; anal plate not divided.

(124) TAMALIA COWENI (Cockerell) Baker, 1920
Found in folded leaves of *Arctostaphylus*.

116. Genus STEGOPHYLLA gen. nov. Type: *Phyllaphis quercicola* Baker, 1916. The first generation is found in folded margins on oak leaves. Later generations spread on under side of leaves, or between those folded by other insects. Antennae 6-jointed; media of fore wings with only one branch; in the sexuales both the male and the female are apterous; summer generations with conspicuous flocculent matter.

(125) STEGOPHYLLA QUERCICOLA (Baker)
Found on white oak.

117. Tribe ANOECIINI. Antennae 6-jointed, with rather large, round or oval sensoria, and covered with long hairs as in the Chaitophorini; media with only one branch; cauda short, broad and rounded like the anal plate; sexes small and both apterous and provided with rostrum. One genus is known:

a. Characters as for the tribe..........................Genus ANOECIA 118

118. Genus ANOECIA Koch, 1857. Type: *Aphis corni* Fabricius, 1775. One species is sometimes found in Minnesota:

(126) ANOECIA CORNI (Fabricius) Koch, 1857
Found on dogwood.

119. Tribe VACUNINI. Antennae 5-jointed; body and appendages more or less hairy as in Chaitophorini.

a. Genus VACUNA 120

120. Genus VACUNA (Heyden) Kaltenbach, 1843. Type: *Aphis dryophila* Schrank, 1801. Heyden included *coccinea* and *dryophila* without indicating either as type. His description of the genus would imply *dryophila* as the type rather than *coccinea,* which he interpreted as also having five segments to the antennae like *dryophila.* Kaltenbach restricted the genus to *dryophila* and placed *coccinea* in Boyer's genus *Phylloxera.* Hence *Vacuna* (Heyden) Kaltenbach, 1843 in sen. str. is monotypic with *dryophila* as the type, as implied and accepted by most authors since the time of Kaltenbach. There is no good reason for discarding this well known term. Formerly authors endeavored to conserve the older terms; modern writers too often discard them on mere technicalities. Neither Heyden nor Kaltenbach recognized types in the modern chronological sense but their genera were erected on all the species included. Heyden had no true conception of the genus *Phylloxera,* and the species in hand he attempted to interpret as a *Vacuna.* Kaltenbach corrected this and restricted *Vacuna* as now understood.

(127) VACUNA DRYOPHILA (Schrank) Heyden, 1837
Not known from Minnesota.

121. Supertribe SCHIZONEUREA. Sexes small and without rostrum; fundatrix with 6, 5, or 4 segments to the antennae; media with one branch or simple; found in folded leaves, in nests of ants, or in true galls. The following tribes may be separated:

a. Fundatrix with 6 or 5 segments; media with one branch; cornicles usually present as pores; antennae of migrant 6-jointed; found in folded leaves.. Tribe SCHIZONEURINI 122
b. Cornicles wanting; media of fore wings simple; antennae of migrant with 5 or 6 segments; found in nests of ants.............. Tribe FORDINI 124
c. Cornicles wanting; media of fore wings with one branch or simple; fundatrix with only four segments to the antennae; migrant with 5 or 6; found in true galls...................... Tribe TETRANEURINI 125

122. Tribe SCHIZONEURINI. Media of fore wings with one branch; transverse veins in hind wings far apart at place of origin; migrant with six segments to the antennae; fundatrix with five, or sometimes with six segments; wax glands composed of large facets arranged concentrically. One genus is represented in Minnesota:

a. Media with one branch........................ Genus SCHIZONEURA 123

123. Genus SCHIZONEURA Hartig, 1837. Type: *Aphis lanigera* Hausmann, 1801. Eriosoma was used by Leach in a broad and loose sense, contrasted with Aphis and is equivalent to Pemphiginae as a subfamily name. "Eriosoma has its body covered by wooly matter; its abdomen has neither horns nor tubercles, and its antennae are short. The body of Aphis is naked, and the abdomen is furnished with a tubercle, or hornlike process on each side." (Trans. Hort. Soc. London. Vol. 3, 1820). Schizoneura and Pemphigus have been accepted by most writers since the time of Hartig, and have gone so extensively into the literature, that it would be to a considerable disadvantage to change it now on the slight claim that Leach may have for his Eriosoma. The following species are found in Minnesota:

(128) SCHIZONEURA LANIGERA (Hausmann) Hartig, 1841

Rather common on apple; the winter form is the rosette on American elm.

(129) SCHIZONEURA AMERICANA Riley, 1879

Folding the leaves of elm from the sides.

(130) SCHIZONEURA RILEYI Thomas, 1879

Found on the trunk in crevices or injuries on elm.

124. Tribe FORDINI. Cornicles wanting; media of fore wings simple; hind wings with two transverse veins. Found in nests of ants and underground on roots. None are known from Minnesota, but Forda with five segments to the antennae, and Geoica with six, may be looked for.

125. Tribe TETRANEURINI. Media simple or with one branch; fundatrix with four segments to the antennae; migrant with five or six; no cornicles present. Found in galls and on roots of plants. The following genera are found in Minnesota:

a. Media simple; hind wings with one transverse vein.......................
Genus TETRANEURA 126

b. Media with one branch; hind wings with one transverse vein...........
Genus COLOPHA 127

c. Media with one branch; hind wings with two transverse veins............
Genus MELAPHIS 128

126. Genus TETRANEURA Hartig, 1841. Type: *Aphis ulmi* Linnaeus, in part, 1758. Media of fore wings simple; hind wings with only one transverse vein; found in galls on Ulmus.

(131) TETRANEURA ULMI (Linnaeus in part) Hartig, 1841

Found in small galls on European elm; not known from Minnesota.

127. Genus COLOPHA Monell, 1877. Type: *Byrsocrypta ulmicola* Fitch, 1859. Media typically with one branch, but often simple; hind wings with one transverse vein; galls are formed on leaves of Ulmus, summer generations underground on roots:

(132) COLOPHA ULMICOLA (Fitch) Monell, 1877

The well known Cockscomb gall on American elm; summer generations are found on roots of grasses.

128. Genus MELAPHIS Walsh, 1867. Type: *Byrsocrypta rhois* Fitch, 1866. Media usually simple, but often with one branch; hind wings with two transverse veins.

(133) MELAPHIS RHOIS (Fitch) Walsh, 1867

Found in rather large thin walled galls on Rhus.

(134) MELAPHIS ULMIFUSUS (Walsh)

Found in large sacklike galls on Red elm or *Ulmus fulva*.

129. Supertribe PEMPHIGEA. Sensoria transverse or oval, not annulate, and usually not extending around the segment; the transverse veins of the hind wings usually arising close together and with the bent radius have a tridentate appearance; cornicles wanting; wax glands composed of small and irregularly placed facets:

a. Migrant with 6-jointed antennae; fundatrix with five segments; wax glands present on the head as well as on the rest of the body; found in twisted leaves or free......................Tribe PROCIPHILINI 130
b. Migrant with 6-jointed antennae; fundatrix with only four segments; wax glands not present on the head; spring generations found in true galls ....Tribe PEMPHIGINI 133
c. Migrant with three to five segments to the antennae; fundatrix with four segments; hind wings with one or two transverse veins; the cubital vein appearing as a branch of the anal...........Tribe HORMAPHIDINI 136

130. Tribe PROCIPHILINI. Large forms with large wax glands on the head as well as on the abdomen; usually found exposed or in crumpled leaves; the following genera are known from Minnesota:

a. Found in twisted leaves or free; sensoria transverse.................... Genus PROCIPHILUS 131
b. Living free on their host plant; sensoria oval......................... Genus NEOPROCIPHILUS 132

131. Genus PROCIPHILUS Koch, 1857. Type: *Aphis bumeliae* Schrank, 1801. Antennae rather long for a Pemphiginae, basal part of the terminal segment elongated. Found in twisted leaves on ash and alder.

(135) PROCIPHILUS FRAXINIFOLII (Riley) Pergandi, 1912

Found in twisted leaves on ash.

(136) PROCIPHILUS APPROXIMATUS Patch, 1917
A very large form also found on ash.

(137) PROCIPHILUS TESSELLATA (Fitch) Pergandi, 1912
Winter host soft maple, summer host alder.

132. Genus NEOPROCIPHILUS Patch, 1912. Type: *Pemphigus attenuatus* Osborn and Sirrine, 1893. Strongly covered with white matter; living free on the host plant.

(138) NEOPROCIPHILUS ATTENUATUS (Osborn and Sirrine) Patch, 1912
Found on the stems of Smilax.

133. Tribe PEMPHIGINI. Antennae of migrant 6-jointed; in fundatrix 4-jointed; no wax glands on the head, or rarely so; media simple and hind wings with two oblique veins arising close together; wax glands made up of a number of small, irregularly arranged, facets; spring generations usually found in galls. The following genera are represented in Minnesota:

a. Spur of the terminal segment short................Genus PEMPHIGUS 134
b. Spur of the terminal segment much longer than the basal part............
Genus MORDWILKOJA 135

134. Genus PEMPHIGUS Hartig, 1837. Type: *Aphis bursaria* Linnaeus, 1758. Media of the fore wings simple; sensoria on the antennae transverse or oval, usually not extending around the segment; spur very short. Spring generations are usually found in galls or folds on leaves, and summer generations on roots of plants and on Compositae. The following species are known from Minnesota:

(139) PEMPHIGUS BURSARIUS (Linnaeus) Hartig, 1841
Found on Lombardy poplar, *Populus nigra*, in galls on the petiole. Rather plentiful around Minneapolis.

(140) PEMPHIGUS POPULICAULIS Fitch, 1859
Found in galls on the petiole of cottonwood; close to the base of the leaf and with an oblique opening.

(141) PEMPHIGUS POPULITRANSVERSUS Riley, 1879
Found in galls on the middle of the petiole of cottonwood leaves, with a small transverse opening.

(142) PEMPHIGUS POPULIGLOBULI Fitch, 1859
Found in a globular gall near the base of the leaf on balsam poplar.

(143) PEMPHIGUS POPULIMONILIS Riley, 1879
Found in small galls arranged in row along the midvein on the leaves of balsam poplar. (*Thecabius* Koch.)

(144) PEMPHIGUS POPULIVENAE Fitch, 1859

Found in a compressed gall on the midvein of balsam poplar. (*Pachypappa* Koch.)

(145) PEMPHIGUS PSEUDOBYRSA (Walsh) Thomas, 1879

Found in a widely open, somewhat compressed gall on the midvein of Cottonwood leaves; eventually the whole leaf folds ventrally from the sides. (*Pachypappa* Koch.)

135. Genus MORDWILKOJA Del Guercio, 1909. Type: *Byrsocrypta vagabunda* Walsh, 1862. Spur of the terminal antennal segment very long for a Pemphiginae; much longer than the basal part; the marginal sensoria are distributed on the spur.

(146) MORDWILKOJA VAGABUNDUS (Walsh) Del Guercio, 1909

The spring generation forms a very large and irregular gall at the tip of the branches of cottonwood.

136. Tribe HORMAPHIDINI. Antennae of the migrant 3- to 5-jointed; sensoria annulate; cornicles usually wanting; cauda distinct and globate, and anal plate emarginated; media of the fore wings simple, and the cubitus appearing as a branch of the anal; hind wings with one or two oblique veins. The Hormaphidini represent an extreme development of the Pemphiginae line, and should, probably, be included with the Vacunini in the Phyllaphidea group. Two genera are recognized in the tribe:

a. Antennae have three segments in the migrant......Genus HORMAPHIS 137
b. Antennae have five segments in the migrant..Genus HAMAMELISTES 138

137. Genus HORMAPHIS Osten-Sacken, 1861. Type: *Byrsocrypta hamamelidis* Fitch, 1851. Fundatrix and migrant with only three segments to the antennae. Galls are found on witch-hazel. The genus is not known from Minnesota.

138. Genus HAMAMELISTES Shimer, 1867. Type: *Hamamelistes spinosus* Shimer, 1867. The fundatrix with four segments to the antennae and the migrant with five. Forms a spinous gall on witch-hazel.

(148) HAMAMELISTES PAPYRACEAE (Oestlund)

Pergande considered this the same as spinosus, but this may be considered an open question. The above form is rather common here as well as in the northern parts of the state, one or two hundred miles from the nearest witch-hazel brush, which enters the state only in the extreme southeastern corner.