REPORT

OF THE

STATE BOARD OF AGRICULTURE

ON THE WORK OF

EXTERMINATION OF THE GYPSY MOTH.

JANUARY, 1898.

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WRIGHT & POTTER PRINTING CO., STATE PRINTERS,
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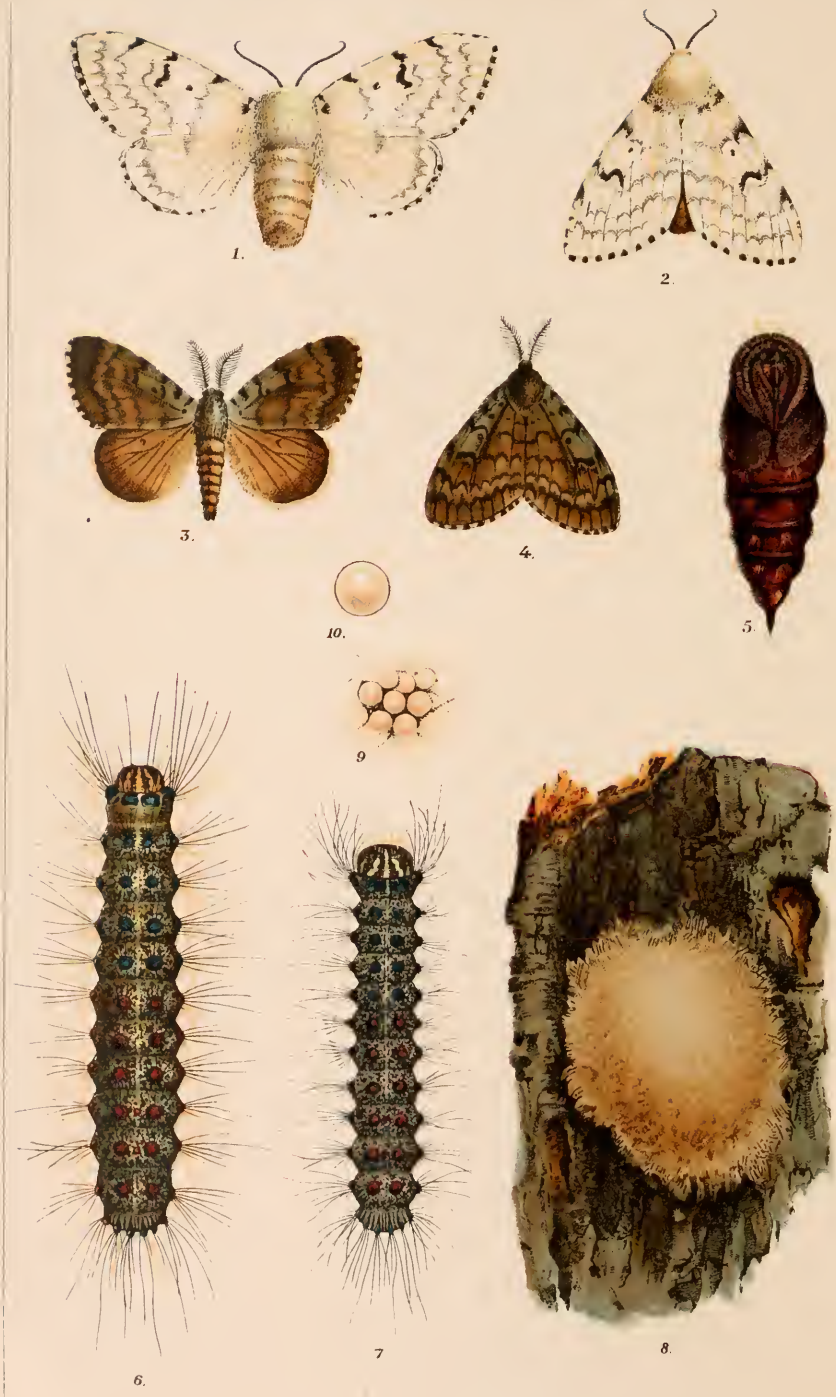

Drawn by Joseph Bridgham

Geo. H. Walker & Co., Boston.

GYPSY MOTH.

An Explanation of Plate I, with a Short Description of the Different Forms of the Gypsy Moth and its Feeding Habits.

The Eggs.

[Fig. 8, cluster of eggs on bark; Figs. 9 and 10, eggs magnified.]

The eggs are deposited in clusters, averaging about six hundred eggs each, and covered with yellow hairs from the body of the female moth. These egg-clusters are usually found in sheltered places on the bark or in the crevices and cavities of trees, stumps and undergrowth; also on fences and buildings and in the crevices of stone walls and other objects, near the plants or trees on which the insect feeds. The eggs are laid in July, August and September, and hatch after the foliage starts in the late spring or early summer of the ensuing year; therefore the insect passes the fall, winter and early spring in the egg.

The Larva or Caterpillar.

[Figs. 6 and 7.]

When first hatched the caterpillars are less than one-fifth of an inch in length. As they grow larger they may be seen in clusters upon the trunks and branches of trees or in the cavities and other hiding-places where they gather in June, July and the first part of August.

The Pupa.

[Fig. 5.]

The caterpillar when fully grown sheds its outer covering and becomes a pupa or chrysalis. This usually occurs in July or August. The pupa may be found in the same situations as the eggs. In Massachusetts the insect usually remains in the pupal state from ten to thirteen days, emerging as a moth at the end of that period.

The Moth.

[Figs. 1 and 2, female; Figs. 3 and 4, male.]

The female moth usually deposits her eggs very near the abandoned pupa case, and within a few hours after emerging from it. She dies soon after. The male is a rapid flyer. The female does not fly.

Habits of the Caterpillars.

The gypsy moth feeds only when in the larval or caterpillar state. In Massachusetts the eggs of the gypsy moth begin hatching about April 20, and the young continue to emerge until the middle of June. The length of larval life varies somewhat according to circumstances, but probably averages at least ten weeks; therefore the feeding season in this country lasts about four months. When the caterpillars are first

hatched from the eggs they are light in color and covered with whitish hairs. In a few hours they assume a dark hue. They usually remain on or near the egg-cluster until they change in color, and should the weather be cold they sometimes remain for several days in a semi-torpid condition upon the egg-cluster. If the temperature is favorable they usually search for food before they are twenty-four hours old. During the first few weeks of their existence they remain most of the time on the leaves, feeding mainly on the under side. Their feeding habits are so uncertain that no rule can be given which will apply to all individuals, but before they are half-grown they generally begin to manifest their gregarious instincts. At that time and for the rest of their existence as caterpillars they spend a large part of the day clustered in sheltered situations, and feed principally at night, going up the trees and out on the branches after dark and returning before daybreak. When they are so abundant that the food supply is insufficient they evince much restlessness, and feed in numbers during all hours of the day and night. They may then be seen hastening to and fro, both up and down the trees. Those which have fed sufficiently are at once replaced by hungry new-comers, and the destruction of the foliage goes on incessantly.

At such times the trunks and lower branches of trees are covered with a moving mass of caterpillars, hurrying throngs are passing and repassing, and nearly every leaf or denuded stem bears up one or more of the feeding insects. The rustling caused by their movements and the continual dropping of excrement is plainly audible. On tall trees the larger caterpillars appear to crawl to the higher limbs, and they seem to prefer to feed well out toward the end of the branches. They do not feed gregariously except when in great numbers; therefore they seldom strip one branch only, as do the larvæ of the *Euvanessa antiopa*, but scatter throughout the trees, eating a little from each leaf. Early in the season when they are small and few in numbers, their ravages are scarcely noticed; but as they grow larger and more numerous, their inroads on the tree decrease the foliage area night by night, until suddenly all the remaining leaves are eaten, and the tree is stripped in a single night.

Food Plants.

The gypsy moth is known to destroy the foliage of nearly all native and introduced trees and plants of economic importance. The list of its food plants includes nearly all evergreen and deciduous trees, most bushes, shrubs, vines and vegetables, and it has been seen to eat grass and grain. Wherever the caterpillars become numerous they move slowly, devouring nearly every green leaf and bud as they go. They feed during a much longer season than the canker worm or the tent caterpillar. In the months of June, July and August, 1891, trees which had been stripped early in the season and whose leaves had again put out were again defoliated by these caterpillars and kept bare all summer; therefore, not only was all prospect of a fruit harvest destroyed, but many trees were killed by this continual defoliation.

Commonwealth of Massachusetts.

To the Senate and House of Representatives of the Commonwealth of Massachusetts.

I have the honor to present herewith to the General Court the report to the State Board of Agriculture of the committee of said Board having in charge the gypsy moth work. I present also the reports of the director of field work and the entomologist to said committee; the three reports together constituting the report of the State Board of Agriculture on the extermination of the gypsy moth. The statement of receipts and expenditures and the recommendations and suggestions contained in said report, having been adopted by said Board, are presented in accordance with the provisions of chapter 210, Acts of 1891, as their recommendations and suggestions.

WM. R. SESSIONS,
Secretary of the State Board of Agriculture.

BOSTON, Jan. 1, 1898.

Commonwealth of Massachusetts.

To the Massachusetts State Board of Agriculture.

Your committee, to which was committed the work of exterminating the gypsy moth, under the orders of the Legislature, herewith presents the report of expenditures and of work performed during the year 1897.

The balance on hand Jan. 1, 1897, as reported last year, was $8,849.85. This balance was retained to enable the committee to close up the work and turn over the material on hand belonging to the State, without the necessity of a deficiency appropriation, should the Legislature decide to make no further appropriation. But, under the advice of authorized State officers, the committee was led to conclude that the work could be continued "during the month of January, until the pleasure of the General Court should be made known, at the rate of expenditure authorized by the appropriation of the preceding year." In this way the committee was enabled to avoid the discharge of the efficient men then in its employ.

The Legislature acted promptly, and on February 26 appropriated $150,000 for the work of 1897. This prompt action, so different from past experience, was in a high degree advantageous, as it enabled the committee to do an immense amount of necessary work that could be done only before the appearance of the young caterpillars in the spring. The sum appropriated by the Legislature, however, was only three-fourths of the amount estimated by the committee as necessary for the effectual carrying on of the work required by law. With only three-fourths of the required amount available, the plans for the year were necessarily revised, and much work that had been planned had to be abandoned and must now be reported as still undone.

During the years 1895–96 most of the territory comprised in the infested towns had been quite carefully in-

spected, and, as it was believed that no large unknown colonies existed in the infested region, it was planned in 1897, first, to work thoroughly all known colonies, especially those in the Saugus woodlands. During January, February, March and the first part of April the men were employed in cutting underbrush and dead wood, and in trimming and otherwise preparing the infested localities for the work of the burlapping season. As soon as the appropriation became available the force was increased, so that on April 1 three hundred and fifty-four men were in the field. This force was largely employed during the first part of April in continuing the cleaning up of infested localities and destroying the eggs of the moth in woodland colonies, principally in Saugus and Medford. A supply of burlap was purchased, and during the latter part of April and the month of May was put on the trees in most of the known infested localities. While this was being done, the scattered eggs of the moth upon the ground in the woodland commenced hatching and the caterpillars began ascending the trees. In some of the worst colonies, where the undergrowth had been removed, the trees had been previously banded with insect lime. In these places the caterpillars were either destroyed by starvation or killed by fire before they could ascend the trees. In other cases spraying was resorted to. Arsenate of lead was the insecticide principally used, and, though its effect was somewhat neutralized by continuous wet weather, it greatly reduced the number of caterpillars. During the summer the force of men, which at one time numbered three hundred and eighty-seven, was used almost entirely in attending the burlaps. While the increase of the appropriation over that of 1896 has enabled the committee in 1897 to clear away the underbrush from the worst infested woodland colonies and to destroy a large proportion of the caterpillars in the Saugus woods, the legislative reduction of twenty-five per cent. from the committee's estimate of $200,000 for 1897 has made it impossible to extend to all quarters the scheme of work planned for the year; hence the work in the Medford woods (Middlesex Fells region) was not so complete as that done in Saugus.

The force of men was necessarily reduced in August by the discharge of one hundred and twenty-five men, and all work was suspended for two weeks in September, therefore it was impossible to inspect thoroughly all of the colonies when the burlap was taken off. The known colonies in the Saugus woods were inspected in the latter part of September and in October, and the eggs on the trees destroyed. This having been done, the men in that section were put at work inspecting the known colonies in Lynnfield, Salem, Marblehead, Swampscott and Peabody, and destroying the few eggs which could be found in these towns. The rest of the force was concentrated in the Middlesex Fells region, in Medford, where the moths had been hardly held in check by the work of the previous winter, spring and summer. Here a force of ninety men was kept at work destroying the eggs of the moth until December, when, the appropriation having been nearly exhausted, a large proportion of the men were discharged.

The result of the year's work is, that where there were three badly infested colonies of a thousand acres each in the woods of the infested region there now remains only one such colony. In that one the increase of the moths has now been checked, but they are more widely scattered there than they were in 1896; therefore the cost of treating this Middlesex Fells region will be greater another year than it would have been had sufficient means been provided in 1897 to check the increase and spread of the moth there. The known colonies in the outer towns have been attended to, and their favorable condition, as reported last year, has been maintained and in many instances improved. Only one new point of infestation outside of last year's lines has been discovered, and this place, situated in the town of Lincoln, has been promptly and carefully attended to. It was discovered in woodland at some distance from the highway. From all indications, it has been infested for several years. It would have been found long before had sufficient means been provided for a thorough inspection of all the towns near the infested region.

The reports of past years have stated that there were large woodland colonies of the moth in the central part of the in-

fested region, which, from lack of money, have necessarily been neglected, in order to attend to the outer circle of infested towns. In this outer circle the object has been to reduce the area infested and to prevent the moths spreading into new territory, beyond the known line of infestation. The committee has also reported that from the woodland colonies, in the central towns, the moths would be liable to spread into territory not previously infested and also into the area that had been cleared of the moth. The woodland in Medford, Malden, Melrose, Winchester and Stoneham has largely been taken for park purposes, and developed by the construction of boulevards and roads for driving and bicycling and paths for foot passengers; in short, it has become a place of resort for the people. Street-car lines have also been constructed on roads passing through infested woods in other towns. The result has been, as was predicted in former reports, that the caterpillars have been brought out of these woodland colonies on carriages and teams and on the clothing of persons, and thus land already cleared at much labor and expense has become reinfested. To prevent the neutralization of exterminative work in this way, great efforts have been made at large expense during the past year to suppress these larger colonies. Vast quantities of eggs were destroyed during the winter and early spring, large areas of woods and brush were thinned out or cut down, and much land was burned over. The plan proposed by the committee in the last report was to do this work and also continue the careful inspection of the outside territory, *i. e.*, that beyond the outer circle of infested towns, as well as that formerly infested but now thoroughly cleared. This plan has been followed as closely as was possible with the amount of money appropriated. But only three-quarters of the work planned could be accomplished with three-fourths of the appropriation asked for. The trees in the vicinity of all points where the moths have been found in the outer towns within the past three years have been burlapped and carefully attended. This has served to verify the work of former years and to show where that work was not absolutely completed, and has also proved that caterpillars have, as was feared, been scattered from the badly infested woodland colonies in the cen-

tral towns into territory formerly cleared. The outer towns are in good condition, and the burlap has proved our last year's statement of the situation to have been correct in nearly all cases. Had $200,000 been provided for the work of the season of 1897, all the known colonies in the infested region could have been cleaned up during the spring and thoroughly worked during the summer. This would have prevented the scattering of the moths from these badly infested colonies into territory previously cleared; the committee could have avoided the discharge of many experienced and trustworthy men, and by retaining their services the known infested localities could have been put in such excellent condition that in the work of 1898 the badly infested colonies could have been attended to at less cost.

The work of the past few years has convinced the committee that extermination of the moth is not only possible, but certain, if sufficient sums be promptly appropriated for the purpose. The committee recommends that $200,000 be appropriated for the work of 1898. While a larger sum than that could now be used to advantage, the committee believes that under the present conditions, with our experienced and trained men, a long stride could be made with that sum toward extermination. Most of the worst colonies of the moth are now so reduced that with $200,000 they all can be attended to and a reasonably thorough inspection made of all the towns in the infested territory.

Unless the work above outlined can be done during 1898, extermination will be gravely imperiled by reinfestation from the central woodland colonies. Inadequate appropriations necessitate doing the same work over and over, year after year, with comparatively little progress toward extermination; and the committee believes that, unless the necessary means can be provided, the Legislature had better make no appropriation, and so abandon the work.

The appropriation for 1897 is exhausted, and the committee hopes that the Legislature will act promptly, to save the dispersion of the force, so that the work may go on consecutively, and the loss be avoided which always comes from cessation of work.

Interest in the extermination of the gypsy moth is wide-

spread, particularly among economic entomologists and agriculturists. Scientific men in most of the countries of Europe have obtained the committee's reports and express their approval of the work. Prominent journals in Europe have published comprehensive reviews and discussions of the work, in every case speaking of it favorably. The economic entomologists of this country with one accord express themselves as anxious that the work should be continued, not only for the protection of the country from a new imported pest, but as a demonstration of what government can do for the advantage of the people; many of them having stated that they believe it would be a public calamity to have the work stopped.

At the National Farmers' Congress, held at St. Paul, Aug. 31 to Sept. 1, 1897, the matter, as in former years, was considered, and the following resolve adopted: —

Resolved, That the efforts of the Commonwealth of Massachusetts in endeavoring to exterminate the imported pest known as the gypsy moth meet with our hearty approval, and we, members of the Farmers' National Congress, assembled at St. Paul, earnestly appeal to the Congress of the United States to aid our sister State in exterminating what is liable to prove a national pest if neglected.

At the last meeting of the Association of Economic Entomologists, held in Detroit, Aug. 12 and 13, 1897, the following preamble and resolve were unanimously adopted: —

Whereas, The Association of Economic Entomologists is familiar with the efforts being made by the State of Massachusetts to exterminate the gypsy moth; and

Whereas, On two former occasions it has endorsed this undertaking by public resolutions; and

Whereas, The existence of the gypsy moth in Massachusetts is a standing menace, not only to the agricultural and forestry interests of that State but to those of the country at large; therefore, be it

Resolved, That this association would urge upon the people of Massachusetts the danger of dilatory measures, and the wisdom and great importance of providing liberally for the work of exterminating the gypsy moth.

Workers killing the eggs of the gypsy moth in the Middlesex Fells Reservation. This illustrates the expensive work that must be done in badly infested localities in forest parks.

In January, 1897, a careful inspection and investigation of the exterminative work was made, under the auspices of the Massachusetts Society for Promoting Agriculture, by Prof. John B. Smith, entomologist of the New Jersey Experiment Station. His report has been largely given to the public through the press. In it he speaks in the highest terms of the work of the committee, and expresses the opinion that extermination is possible if sufficient means are seasonably provided. He recommended that it would be well to investigate the natural enemies of the gypsy moth in Europe, with a view to introducing any insect enemy of the moth that might be of advantage. While the members of your committee consider the results of such an investigation to be problematical, they will be ready at any time to carry it out should the Legislature provide the means.

The entomologist of the United States Department of Agriculture, under the instruction of Congress, has been making an extended inspection of the work and an investigation of the methods in use. The report of his investigation will very soon appear as a bulletin of the United States Department of Agriculture.

Experiments have been continued in perfecting spraying machinery and insecticides at the insectary in Malden and the experiment station at Amherst. In addition to the regular experimental work, a large number of injurious insects, erroneously supposed to be the gypsy moth, which were sent to the office of the committee by residents of the infested region, have been identified and advice given concerning remedies.

The committee desires in this connection to emphasize its grateful appreciation of the value of the scientific work as conducted by Prof. C. H. Fernald, entomologist of the Board.

Reference is also made to the reports of Prof. C. H. Fernald, entomologist, and E. H. Forbush, director, presented herewith as a part of the report of the committee.

Financial Report for 1897.

The gypsy moth committee of the State Board of Agriculture presents below its financial report for the year 1897: —

Balance on hand Jan. 1, 1897,		$8,849 85
Appropriation Feb. 26, 1897,		150,000 00
		$158,849 85
Wm. R. Sessions, expenses,	$20 25	
E. W. Wood, expenses,	20 96	
Augustus Pratt, expenses,	61 00	
F. W. Sargent, expenses,	50 40	
J. G. Avery, expenses,	140 55	
S. S. Stetson, expenses,	46 75	
C. H. Fernald, expenses and remuneration,	561 29	
E. H. Forbush, director, salary,	2,300 00	
Travelling expenses of director and men,	1,350 47	
Teaming, livery and board of horses,	3,653 30	
Wages of employees,	134,711 54	
Rent of offices,	427 64	
Supplies, tools, insecticides, etc.,	13,206 76	
		$156,550 91
Balance on hand Jan. 1, 1898,		2,298 94
		$158,849 85

The balance indicated as on hand Jan. 1, 1898, will all or nearly all be required to pay bills for labor, material and running expenses already contracted; hence the appropriation must be regarded as practically exhausted.

E. W. WOOD,
S. S. STETSON,
JOHN G. AVERY,
AUGUSTUS PRATT,
F. W. SARGENT,
WM. R. SESSIONS,

Committee of the Board of Agriculture in Charge of the Gypsy Moth Work.

Report of the Entomologist.

To the Committee on the Gypsy Moth.

Gentlemen: — The most important question arising in connection with the work on the gypsy moth is whether it is possible to exterminate the pest. If this can be done, there is no question but that it is the wisest policy to continue the work till the extermination of this insect is accomplished. I have made frequent and careful examinations of the work from the beginning, and have seen colony after colony absolutely exterminated, some of them in localities where the difficulties in the way appeared to be insurmountable and as great as could be found anywhere, and yet the insect was completely exterminated by the force under the oversight of the field director. Not only have single colonies been exterminated, but entire towns have been cleared and for several years no gypsy moths have been found in them.

Several years ago all the leading economic entomologists of the country were invited to inspect the work of extermination and report on the same. Some of these gentlemen before visiting the territory expressed the opinion that this insect could not be exterminated; but, having made a careful study of the territory, the apparatus and the methods of work, they all became thoroughly convinced that extermination is possible, provided sufficient money be appropriated for the purpose. The reports of these gentlemen have been published in previous gypsy moth reports. Last winter the members of the Society for the Promotion of Agriculture employed Prof. J. B. Smith of Rutgers College as an expert to investigate the work and make a written report to them. Professor Smith, who is undoubtedly one of the very highest authorities on economic entomology, made a very careful study of the infested territory, the methods of work, etc., spending nearly a week in his investigations, and came to

the conclusion emphatically that extermination is not only possible but entirely practicable. The report of Professor Smith was a masterly production, and I deeply regret that the Society for the Promotion of Agriculture has not seen fit to publish it.

Since all the experts who have carefully and fully investigated the matter believe extermination to be possible, and, as previously stated, we have already exterminated numerous colonies, many of them in the most unfavorable places and of considerable extent, there can be no question but that what has been done in one place can be done in another, and that the complete extermination of this insect is possible, so that the result is dependent entirely upon the action of the Legislature.

I have no doubt that the gypsy moth would have been practically exterminated by this time if the Legislature had each year made the full appropriation asked for, and made it available early in the season.

The next important question is, how long it will take to complete the work of exterminating this pest and how much it will cost. The estimate of time and money given in my report of last year is as close an estimate as I can make at this time, since we were not able during the past year to make that progress in the work which we should have made if the last Legislature had appropriated the full amount for which the committee asked, instead of a much smaller sum. That estimate was "an appropriation of not less than $200,000 a year for a term of not less than five years, and then an appropriation of not less than $100,000 a year for a term of not less than five years. After this an appropriation of perhaps $15,000 a year for a period of five years will be required." The first five years, with the full appropriation of $200,000 a year, will reduce the territory to such an extent that with $100,000 a year for the next five years the insect will be practically exterminated, and the remaining five years will be spent in a careful watch of the entire territory, lest a few insects might have been overlooked in isolated localities. Unless a sufficient amount is appropriated to make a very substantial gain each year, it would be better to abandon the work entirely.

Workers destroying masses of gypsy moth eggs on rocks and ledges, showing costly work that must be done in badly infested forest parks.

The metropolitan park system in Boston and some of the adjacent cities and towns is threatened by this insect, and, in fact, the Middlesex Fells reservation belonging to this system is already infested by the gypsy moth. The expense of exterminating this insect in a public park is far greater than from the same area of ordinary forest land, for the reason that in the latter case all the shrubs, underbrush and small trees can be cut down and burned, or, if need be, the land can be entirely cleared and burned over; while this course could not be adopted in a public park like the Boston Common or Public Garden, or even in Franklin Park or any portion of the metropolitan park system. If, therefore, the State should abandon the work of exterminating the gypsy moth, this insect would soon spread all over these parks, and the tax payers of Boston would be perpetually taxed for one-half of the expense of clearing the moth from the metropolitan parks, while the other cities and towns in the metropolitan district would pay the other half, and Boston would be taxed for the entire expense of the work in the Boston parks. I feel very sure that any one who has had any considerable experience in the field work on the gypsy moth would agree with me in the opinion that the annual tax on the city of Boston and the other towns of the district would then be far more than it will be if the Legislature makes the necessary appropriations for the extermination of this insect within the limits of Massachusetts. And it must especially be remembered that this question of gypsy moth extermination is by no means mainly a local one.

Should the gypsy moth escape from control, — as it assuredly would do if the work of extermination were to cease, — it would spread in all directions, doing incalculable damage over the whole State. Extermination would then be impracticable, and a perpetual warfare against the moth — most unsatisfactory in results, yet necessitating oppressive expense to all time — would then be entailed upon the people of Massachusetts. The most economic policy for the tax payers of Boston, as well as for the entire Commonwealth, is to have the insect exterminated as soon as possible.

It is an unwise and dangerous policy to make smaller

appropriations than are necessary for a vigorous prosecution of this work. The supposition that, as in many other public works, a small appropriation will carry it on to a certain point, and then, if left, it can be taken up again and carried on from where the work left off, is an incorrect one, for the reason that this insect is continually multiplying and spreading when left to itself, and there is always the danger in such times that it may be carried off accidentally along the lines of travel to remote parts of this State or even into other States. This insect will therefore be a constant menace to us until it is absolutely exterminated from the land.

Respectfully submitted,

C. H. FERNALD.

Field Director's Report.

To the Committee on the Gypsy Moth.

Gentlemen: — In submitting this report the director has endeavored to comply with your recent request to present (1) a brief report of the year's work and its results; (2) a condensed report on the present condition of each infested town or city; (3) the causes which have led to the increase of the gypsy moth in the central woodlands; (4) a statement showing how extermination can be accomplished in these woodlands; (5) a record of the progress of extermination; (6) the reasons why, if the gypsy moth is to be exterminated from Massachusetts, larger appropriations must be granted.

The Work of the Winter and Spring.

In January and February, 1897, the force, numbering one hundred and thirty-four men, was employed mainly in killing the eggs of the gypsy moth in the woodlands most infested, in cutting worthless trees and in otherwise preparing these woods for the summer work.

In addition to pushing exterminative work in all the known colonies, it had been planned to make in 1897 an inspection, wherever needed, of the entire infested territory; but when the desired appropriation for 1897 ($200,000) was cut down by the Legislature to $150,000, this inspection was of necessity given up.

The appropriation became available Feb. 26, 1897. The force was then increased as rapidly as the preservation of its effectiveness permitted, and was mainly concentrated in the localities most infested. The largest force was massed in Saugus. Here and also in the Fells and Mystic woodland

colonies* work similar to that of January and February was continued, weather permitting, well into the spring.† More than one thousand acres were thus worked. The undergrowth of many colonies in the great pastures of Salem and Swampscott was cut and burned. In former years this winter and spring work of egg-killing and cleaning up has been greatly hampered by delay in the legislative grants; this year the granting of the appropriation at a comparatively early date enabled this work to be much more thoroughly done than it has ever been done before, and with correspondingly satisfactory results.

Experiments in killing Eggs in Stone Walls.

The moths frequently assemble along stone walls. In past years, when the eggs of the moth abounded in these walls, the walls were torn down, and often had to be rebuilt at a heavy cost. Most of this work has now been done away with. When, in 1897, the young caterpillars hatching in a wall congregated upon the shrubbery, close to either side of it, they were destroyed in quantities, together with the shrubbery, by the use of the cyclone burner. Trees close to the wall were cut away. If then any living caterpillars were left they were forced to give up the wall as a gathering place (as they then had to go some distance for food), and were taken later under burlaps on adjacent trees. In cases where full-grown caterpillars resorted to a wall to pupate, they were destroyed by driving the cyclone flame through it.

Experiments made by Assistant Entomologist Kirkland prove that paraffin gas oil, a nearly crude petroleum oil, is destructive, in temperate or warm weather, to gypsy moth eggs. At the suggestion of Supt. C. S. Williams, experiments were made in spraying certain stone walls with this

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* Webster defines a colony (under the head of natural history) as a number of animals or plants living together beyond their usual range. In the gypsy moth work the word "colony" has been applied to the moth when it has been found isolated from others of its kind by a belt of uninfested territory.

† The localities referred to here are three great groups of colonies, which have been alluded to in former reports. These groups contain about one thousand acres each. The Saugus colonies centre in the Saugus woods; the Fells colonies, in the Middlesex Fells; the Mystic colonies, to the west of the Mystic lakes in the woods of Arlington, Winchester, Lexington and Woburn.

cheap crude oil, delivered from a cyclone burner, but not ignited. The oil penetrated the crevices in the walls and destroyed the eggs hidden there. These experiments were so satisfactory that it will be desirable to continue them on a larger scale.

Burlapping.

The early date when the appropriation became available permitted the purchase of burlap in advance of the rise in prices, caused by the new tariff. About one thousand dollars was thus saved.

In April and May burlap was cut up, sent into the field and applied to the trees in infested forest lands where the underbrush had been cleared away. Throughout the whole infested region the most work was done, in the burlap season, where the greatest number of caterpillars were known to be. Every practicable effort was made, however, to destroy, by burlapping, the few caterpillars still remaining in colonies almost exterminated. This was especially the case in the outer towns.

The unusual amount of rain in June seemed to interfere with the movements of the caterpillars. In many of the large colonies they remained mostly among the leaves and branches, instead of coming down the trunks to the burlaps; therefore, during this month the burlaps were not so effective as usual. In the Saugus woods the caterpillars were shaken to the ground by jarring the trees. They would then crawl up the tree trunks and crowd under the burlaps, where they were crushed by the workers. Had not this method been followed, the trees in many localities would have been completely stripped. Later, when the caterpillars were about to pupate, they resumed their normal habits and crowded under the burlaps. When the moths had all deposited their eggs the burlaps were generally removed, and many eggs clustered under or near them on the trees were destroyed.

Spraying.

During May and June rains unfortunately prevailed, interfering seriously with the spraying, which, however, so decimated the caterpillars that, as a rule, the sprayed trees were not stripped.

Arsenate of barium, used in spraying somewhat more extensively than heretofore, proved less satisfactory than arsenate of lead. This latter insecticide, when mixed with sufficient glucose, maintained its superiority over all others. The best results from spraying were obtained on undergrowth, shrubbery, hedges and low trees.

With the object of devising some mechanical means for reaching the upper limbs of tall trees, models have been made, and one machine has been constructed and actually tested in the field. While it is not difficult to invent such a machine to do effective work on level streets and lawns, no device yet perfected can be used to advantage for spraying tall trees, growing close together on our rugged hillsides. Experiments looking to this end are still going on. Improvements have also been made in hose, couplings, extension poles, pumps and nozzles. A new set of spraying outfits is now being constructed at the headquarters in Malden.

Work of the Fall and Winter.

On account of the rapid decrease of the appropriation, the force was greatly reduced in August, and all work was suspended for two weeks in September. On September 20 the fall work was begun. Inspection and egg-killing were carried on in all the known colonies in Saugus woods, and all of those in the towns to the north and east of Saugus. When this was finished the men employed in the eastern division were concentrated in Saugus, where an inspection of the residential portion of the town was begun, and this was nearly finished when, the appropriation being nearly exhausted, the men were discharged. In October a rapid inspection of Malden, most of which could not be burlapped during the summer, was begun, and the greater part of the eggs there were destroyed. Some of the nearly exterminated woodland colonies in the outskirts of the western part of the infested region were thoroughly examined, and some inspection was made of territory outside the limits of known infestation. Nearly three-fourths of the men were then concentrated and employed in egg-killing in the Middlesex Fells region. Early in December, the appropriation being nearly expended, the work was stopped; therefore, although

enormous quantities of the eggs of the moth were destroyed in these woods in November, nearly all the good weather of December was lost. This was a great misfortune, for it has left this excellent work but little more than half done, and it will now be a difficult task to complete it before the eggs hatch in the spring.

Summary of the Year's Work.

The figures given below represent such proportion of a year's work as can be accurately tabulated. The trees were mainly cut on the 1,010 acres of land, where the underbrush was cut and burned. The buildings, fences and other structures which are reported as infested were merely harboring or hiding places of the moth. Usually the eggs were found upon, about or underneath these structures.

It will be noticed that no figures giving the number of the trees found infested or the numbers of the different forms of the moth destroyed appear in these tables. This may be explained as follows: —

Every effort has been made in the field work to economize time and material, wherever it could be done without interfering with the efficiency of the work. In woodlands most infested, especially in the Middlesex Fells region, only enough trees were marked to indicate the presence of the moth. This was a great saving of time and white paint, but it made a correct record of the number of trees found infested in these colonies a practical impossibility. Where only one tree in twenty was marked as infested during 1897, no accurate account of infested trees could be made. This invalidated the entire record of infested trees, and the time ordinarily taken to count and record them has been saved.

The record of the number of caterpillars and other forms of the moth taken is not given, for in one or two of the most densely infested localities the caterpillars were found in such masses that any attempt to count them would have been a great waste of time. Furthermore, it was necessary to destroy them immediately, to prevent their spreading. In many other colonies spraying was almost entirely depended upon to destroy the caterpillars. In other cases spraying and fire were used to destroy the caterpillars and

the eggs. Many trees were cut down and burned with the eggs upon them. Therefore the number of different forms of the moth destroyed during the year cannot be correctly stated; but the records of moths killed in the outer towns are very accurate, and enough has been learned from the figures taken to show that approximately ninety-five per cent of the different forms of the moth were killed in Medford and Saugus woods and in adjacent territory.

Work Done.

Trees (fruit, shade and forest): —	
Inspected (number of times),	12,202,692
Burlapped,	1,117,628
Banded with insect lime,	4,715
In which cavities have been cemented or covered,	1,949
Sprayed,	21,479
Scraped,	1,401
Trimmed,	81,545
Trimmed for burlap,	39,615
Cut,	279,101
Cutting and burning: —	
Acres of brush and shrubbery cut and burned,	1,010
Acres of ground burned over with oil,	62
Acres of ground burned over without oil,	122
Buildings: —	
Inspected,	12,998
Found to be infested,	1,138
Wooden fences: —	
Inspected (rods),	72,652
Found to be infested,	1,150
Stone walls: —	
Inspected (rods),	18,534
Found to be infested,	596
Burned out (rods),	1,683

False Alarms.

During 1897, as in former years, reports of the presence of supposed gypsy moths or of injury caused by them have been received from towns within the infested region and from other towns in the State; but in no such case has any evidence of the moth been found by our investigation outside of the region previously known to be infested, except in Lincoln.

Towns and Cities that have been falsely reported as infested by the Gypsy Moth in 1897.

Barnstable,	Methuen,	Wellesley,
Danvers,	Natick,	Wenham.
Dennis,	Newton,	Hebron, N. H.
Fitchburg,	Plympton,	Haverhill, N. H.
Haverhill,	Quincy,	

Number of Employees in 1897.

The figures given below do not fully represent the number of employees on the pay roll, which at the height of the season reached nearly four hundred, but give the number of those actually at work each week: —

Jan 1–Jan. 2,	134	June 28-July 3,	352
Jan 4–Jan 9,	133	July 5-July 10,	343
Jan. 11-Jan. 16,	135	July 12–July 17,	339
Jan. 18–Jan. 23,	144	July 19–July 24,	333
Jan. 25-Jan. 30,	144	July 26-July 31,	328
Feb 1–Feb 6,	150	Aug. 2–Aug. 7,	324
Feb. 8-Feb. 13,	151	Aug. 9–Aug. 14,	324
Feb. 15–Feb. 20,	151	Aug. 16–Aug. 21,	207
Feb 22–Feb. 27,	152	Aug. 23–Aug. 28,	204
March 1-March 6,	164	Aug. 30–Sept. 4,	202
March 8-March 13,	164	Sept 20-Sept. 25,	201
March 15–March 20,	249	Sept. 27–Oct. 2,	188
March 22–March 27,	249	Oct 4-Oct. 9,	188
March 29–April 3,	354	Oct. 11–Oct. 16,	189
April 5–April 10,	354	Oct. 18–Oct. 23,	184
April 12-April 17,	368	Oct. 25-Oct. 30,	184
April 19-April 24,	383	Nov. 1-Nov. 6,	182
April 26-May 1,	370	Nov. 8–Nov. 13,	183
May 3-May 8,	371	Nov. 15-Nov. 20,	183
May 10-May 15,	371	Nov 22–Nov. 27,	179
May 17–May 22,	360	Nov. 29-Dec. 4,	175
May 23–May 29,	360	Dec. 6-Dec. 11,	173
May 31–June 5,	361	Dec 13-Dec. 18,	29
June 7-June 12,	353	Dec. 20–Dec 25,	29
June 14-June 19,	353	Dec. 27–Dec. 31,	48
June 21-June 26,	352		

The Present Condition of the Infested Region.

To give an absolutely accurate report of the condition of the infested territory is impossible, unless the whole region has been gone over within the year. The report given below indicates mainly the condition of the known colonies. For the following reasons the clearing of the moth from any new towns cannot this year be reported: —

1. Because of insufficient means, the greater part of the work had to be confined to the central towns (more especially within the Middlesex Fells and the Saugus woods), where it was of the first importance to prevent, by a general destruction of the moths, their conveyance from these central colonies back into territory wholly or nearly cleared.

2. There has been during the year no thorough inspection of all the territory of the outer infested towns.

Arlington.

The condition of Arlington appears better than at any time since the work was begun in 1891. Only a few caterpillars were found in 1897, in the most easterly part of the town. The wooded section in the northern portion, in which some of the worst infested colonies have been found since 1891, was burlapped during the summer and inspected. Although the number of men which could be spared for the work was inadequate, the condition of this woodland is now greatly improved. Comparatively few egg-clusters have been found there. Only one of the woodland colonies appeared to be much infested in 1897, and but few caterpillars have been found elsewhere in the Arlington woods this year.* Many of the estates formerly infested have produced no moths this year, and only here and there along the roads have occasional moths been found. A few orchards are still considerably infested. Little except burlapping and other necessary summer work in known infested localities has been done in Arlington for the past three years. It is some time since the entire town was thoroughly inspected. In 1897, however, most of the town was covered either during the burlapping season or afterward.

* The phrase "this year," as used in this report, refers exclusively to 1897.

Belmont.

In many of the old colonies in Belmont no form of the gypsy moth has been found for two or three years, In these colonies the moth has been, no doubt, exterminated. Although in the infested places and their vicinity the trees have been well burlapped and carefully watched during the summer, very few caterpillars have been found except in the hill section to the west of the centre of the town. Here, among the shrubbery and trees on several highly cultivated and valuable estates, a good many caterpillars were taken. On the north side of the town, along both sides of Pleasant Street, several farms are still somewhat infested, and there are also a few small colonies near the Cambridge line; elsewhere the town contains few moths, so far as known. A few egg-clusters were found in the fall in the Beaver Brook reservation of the metropolitan park system, near the Waltham line.

Beverly.

No gypsy moths have been found in Beverly for the past two years. All the known colonies appear to have been exterminated.

Boston.

At Orient Heights, East Boston, 577 caterpillars were found early in the season. In all the colonies in the remainder of Boston, including Charlestown, South Boston, Dorchester, Roxbury, West Roxbury and Brighton, only 195 caterpillars were taken, The trees in the East Boston colony were climbed and carefully looked over in the latter part of the summer, and no form of the moth was found at this inspection.

South Boston as a whole has had no tree-to-tree inspection for the past few years. The only colony there known to be infested was burlapped this year, and 42 caterpillars were found. Nothing has been done there since the burlapping season. The place should, if possible, have an inspection in 1898. Only 1 caterpillar was found in the Roxbury district in 1897. No moths were found in Franklin Park this year, although a thorough inspection was made of a greater part of the park. This still further confirms the belief that Frank-

lin Park is now free from the moth. In 1897 no moths were found in Charlestown; 1 caterpillar was found in Brighton, at a place where a large number of teams are stabled. In Dorchester, where 18 bushels of caterpillars were gathered in 1895, only 151 caterpillars were found in 1897.

Brookline.

The two colonies which were found in Brookline in 1896 were quite thoroughly burlapped that season. A few hidden eggs had hatched in 1897 in each of these colonies before the spring inspection was finished. In one, however, the caterpillars were all destroyed early in the season. In the other all were, apparently, destroyed, except in that part of the colony where the inspection and cleaning up was not finished in the spring. There the most of the caterpillars were killed and a few egg-clusters were destroyed in the fall, The cleaning up of this colony was not finished when the men were laid off in December.

A careful survey of the boundary between Newton and Brookline shows that two trees (formerly, but not now, infested) included in one of the Brookline colonies stand just over the line in Newton. A search made in the fall in the northern part of Newton, adjoining Brookline, resulted in the discovery of a male pupa case of the gypsy moth. This discovery is not regarded as significant, but, since Newton borders on the infested region, the city should be carefully watched.

Burlington.

In the colony reported last year as infested a few caterpillars were found in 1897. Altogether 9 caterpillars, 1 pupa and 3 egg-clusters were found in the town. From a small colony in Woburn, near the Burlington line, a few stragglers crossed into Burlington, which accounts for two of these egg-clusters. The continued infestation of Burlington is readily traceable to large teaming operations conducted by one man.

Cambridge.

The tree-to-tree inspection of Cambridge, which was begun in 1896, had to be given up in 1897, in common with other work, on account of the reduction of the appropriation;

therefore only about one-fourth of the city was inspected in this manner. All the known colonies were burlapped and carefully looked after during the summer. Most of the old colonies appear to have been exterminated before 1897. There are still some in which a few caterpillars were found. Only 3 caterpillars were killed in North Cambridge, in a locality where some years since 35,000 egg-clusters were destroyed within a week. There are a few places in Cambridge where numbers of caterpillars were taken. On some of these estates the trees and shrubbery are of such historic value that it is not advisable to destroy them; thus extermination is rendered extremely difficult. The discovery of single caterpillars here and there under the burlap indicates that they are scattering into Cambridge from the central towns.

Chelsea.

In the southern half of the city only a single pupa was found in 1897. Here all the trees in the immediate vicinity of the colonies infested in 1895 were burlapped and carefully looked over. In the northern half of the city caterpillars were found in ten localities. Later in the season a new colony was found on a dumping ground, among some low bushes. Here 2,016 pupæ were found; 94 egg-clusters were also destroyed at the last of the burlapping season.

As Chelsea has in the past been generally infested, and in some sections the moth has been very numerous indeed, the good condition indicated by this report is remarkable.

The entire city had a tree-to-tree examination in 1895, and was quite thoroughly burlapped in 1894 and 1895; but, as Chelsea is immediately adjacent to Everett and quite near Malden, it is to be expected that caterpillars will be carried there through the ordinary channels of traffic and travel so long as these cities remain uncleared.

Danvers.

Gypsy moths have not been found in Danvers within the past three years. The places formerly infested have been examined; but, on account of the traffic between it and the infested towns and also between it and Boston, another inspection soon is desirable.

Everett.

Most of the trees in Everett were burlapped in 1897 and the burlaps attended; although the moths are still widely distributed through the city, considerable progress has been made since 1896. In that year 462,477 caterpillars were taken under the burlap. In 1897 only 152,202 were taken in the same manner. A thorough inspection of the city should now be made, and all the eggs killed before hatching time.

Lexington.

The colonies formerly known in East Lexington and Lexington Centre, on both sides of Massachusetts Avenue, are now apparently exterminated. This appears to be true also of the scattered colonies on the farms, for in most of these no caterpillars have been found during the summer. Only 3 caterpillars have been found on Massachusetts avenue during the summer, where formerly many thousands were found. The large woodland colonies in the eastern part of the town, formerly so badly infested, are now in far better condition. One tract of about twenty acres has been cut off by the owners and burned over by your agents. No caterpillars have been found since on this tract. Much of the adjacent woodland, which in the past has been considerably infested, has been burned over by forest fires. Infested portions of this woodland have been burlapped and inspected during the summer, and in nearly all of them but few caterpillars have been found. The fall inspection has revealed but few egg-clusters. Only one of the large wood colonies in the north of Lexington has been found infested this year, and in that only 101 caterpillars were killed on a few trees.

The town had a tree-to-tree inspection in 1895; since that time all the colonies which had not then been exterminated have been very carefully worked.

Lincoln.

July 13, 1897, a colony was reported from Lincoln. It was situated less than a mile from the boundary of Waltham, the nearest town in the infested region as heretofore known.

Here the caterpillars had already stripped the trees on about a half acre of ground in the edge of a strip of woodland, and many were travelling north and east across a grass-grown field, eating the grass as they went. The owner, seeing there were two or three caterpillars on each stalk of grass, immediately cut it and saved part of the crop. The owner of the woodland set men at work gathering the caterpillars and pupæ in baskets, and burning them in fires built for that purpose. Your agents were soon on the ground, and began destroying the caterpillars with the cyclone burner. They were swept and shaken from the trees and burned, until few could be found in the centre of the colony. In the meantime, those in the field had left the grass as soon as it began to dry in the sun, and, crossing the field, swarmed into the trees and undergrowth on a wooded hillside. Here their progress was arrested by the cyclone burner.

An inspection of the country in the vicinity was begun in August. As the colony was near the southern boundary of Lincoln, the northern part of Weston, which adjoins Lincoln, was inspected, but no indications of the moth were found there. In a later inspection of the territory immediately about the colony a few egg-clusters were found just over the Lincoln line in Weston. Continued inspection has enlarged the known area of the colony, and it is now known that the moths are scattered half a mile to the north and east from the centre. This inspection was brought to a close by the cessation of field work in December, and should be finished as soon in 1898 as the weather conditions will permit. The vast number of caterpillars found here, their distribution over so large a territory, and other signs of long occupation, all indicate that the colony has been established for several years. The owner of the infested property has lived in Cambridge during the winters, and has driven back and forth in the summers when the gypsy moth was most numerous in that city. In all probability this colony was established at that time, or before the work of exterminating the gypsy moth was begun. The situation of the colony at some distance from the main road explains why it was not found in the roadside inspection of Lincoln made some years ago. Had it been possible earlier

to make a tree-to-tree inspection of Lincoln and the other towns around the boundary of the infested region, this colony would long since have been discovered.

Lynn.

Previous to 1897 more than 1,200 estates in the city proper had been found infested; but this year 7 caterpillars, found on seven widely scattered trees, a few caterpillars killed in another locality and a few egg-clusters found in the fall inspection, constitute all the finds recorded. The known colonies in the Lynn woods have been very much improved in condition, and some of them have been nearly if not quite exterminated this year. The chief difficulty in exterminating the moth from this great forest park is that it is not advisable to use there those drastic and sweeping measures which are so effectual in woodland colonies. Nevertheless, as the moths are decreasing year by year, it seems probable that they can be exterminated from the Lynn woods by the methods now in use. Owing to a lack of means, a large portion of this woodland has not been examined for several years. Although no colonies are known in that portion, its nearness to the badly infested Saugus woods makes it probable that small colonies will be found there on inspection.

Lynnfield.

All the colonies discovered in 1891–92 in the orchards and along the roads of Lynnfield were exterminated three years ago. A later inspection of the woods resulted in the discovery of a considerable number of large and dangerous colonies. The work of the last three years has much reduced these colonies, and some of them now appear to be exterminated. This is true also of one discovered in the woods of northern Lynnfield, near the Reading line, in 1896. Two colonies recently found on the roads have been carefully worked this year, but will need to be watched for at least two seasons. There were found under the burlap in Lynnfield, in 1896, 15,084 caterpillars and 22,022 pupæ; in 1897 the burlapping was more extended, but only 194 caterpillars and 81 pupæ were found.

Malden.

It was reported in 1896 that for several years very little injury had been done by the gypsy moths to the foliage in Malden. Still less injury was done in 1897, but, as only a small portion of the city was burlapped, the moths increased in number considerably during the summer. Most of the city was rapidly gone over in the fall, and all the eggs seen in this rapid inspection were destroyed. Although the eggs are not now very numerous anywhere, the city is, as last year, generally infested, and it is probable that no advance toward extermination has been made in Malden by the work of this season. Situated in the centre of the infested region, Malden has been perforce neglected. Most of the trees should be burlapped in 1898, and everything possible should now be done to exterminate the moth there, as otherwise it cannot be prevented from spreading into the neighboring towns.

Marblehead.

The gypsy moth has been found in 1897 in only one locality in Marblehead. This colony was mentioned in the last annual report. All eggs which could be found were destroyed in the spring. The eggs were distributed along a stone wall overgrown with underbrush, and a few caterpillars hatched from scattered eggs in the wall and from eggs hidden in hollow trees. The undergrowth along the wall was then burned and the trees burlapped. Only two egg-clusters were found in the fall. The entire town had a tree-to-tree inspection in 1896-97. It now needs an occasional inspection to prevent its becoming reinfested.

Medford.

Medford, where the moth was first introduced into this country, is situated near the centre of the infested district, and is now, as in 1891, the place most infested of all the region. The centre of infestation, however, has changed from the residential and business portion, in which much restrictive work has been done, to the woodlands of the Middlesex Fells. There the moth has hardly been held in check by all

the work which could, under the circumstances, be done. More egg-clusters still remain there than are to be found anywhere else in the infested region. Those sections of the city where the moths were known to be most numerous, including the Middlesex Fells colonies, were burlapped in the spring. These burlaps were as well attended as could be expected by the twenty-five men allotted to Medford. Although the work done during the summer failed to hold the moth in check in the woods, it kept the borders of the woodland roads quite clear from the pest, and there were only two or three localities where the trees were stripped. The concentration of nearly three-fourths of the entire force in these woods during October and November has made it possible to put them in better condition than they otherwise would have been, but there are several colonies in which the eggs on the trees have not yet been destroyed. This work and that of preparing the woodland colonies for the work of next summer would employ 100 men from Jan. 1, 1898, to the hatching season, while burlapping, spraying, egg-killing and other absolutely necessary work would keep them very busy for the remainder of the year.

Melrose.

The northern half of Melrose was burlapped in 1896 and 1897. Few caterpillars were found in 1897. South of the centre of the town no work was done in 1896, except an inspection of the residential part in the fall. This part of the town was, however, burlapped in 1897. It was found that the number of the moths had increased considerably, especially in the woodlands near the Malden line; but their number was greatly reduced by the work of the burlap season. Effective work was done in several colonies in that part of Melrose which is located in the Middlesex Fells reservation, and on the later inspections of the burlaps few caterpillars were found. The general condition of the town is now better than in any previous year. In many of the places now marked as infested only single caterpillars were taken. The position of the town, lying, as it does, with the badly infested woods of Saugus on the east, Malden on the south and

the Middlesex Fells on the west, will render it impossible to keep the moths out so long as they are numerous in the adjacent woodlands.

Nahant.

No gypsy moths have been found in Nahant for more than two years.

Peabody.

The gypsy moth is believed to be exterminated from all the old infested localities in the centre of Peabody, and in only three of the woodland colonies have moths been found this year. In one of these, 1 caterpillar was found; in another, only 2. The third—the large woodland colony in the vicinity of Spring Pond which has been so badly infested in years past — appears now to be cleared of the moth; but, on account of its extent, and the fact that caterpillars were found there this year, it must be carefully watched for at least two years. In 1896, 129,408 caterpillars and 379 pupæ were taken there; in 1897, only 458 caterpillars and 14 pupæ were taken. In the summer a colony was found in the central part of the town, which had become infested since any work had been done there. This colony has since been cleaned, but will require careful watching another year.

The reduction in the number of the different forms of the moth found in Peabody indicates that a great improvement has been made in the town.

Reading.

In 1896 no living form of the moth was found in Reading, but in the winter of 1896-97 one hatched egg-cluster and one dead pupa were found on a farm north of the centre of the town. This place was burlapped in the summer of 1897, and 10 caterpillars and 13 pupæ were found there. No form of the moth was found elsewhere in Reading.

Revere.

The only considerable tract of woodland in Revere adjoins Malden and Saugus, and is situated near Franklin Park. This tract had never been thoroughly worked over until

1897, and it was here that most of the moths found were killed. These woods became infested because of their nearness to infested woods just over the line in Saugus and Malden. Early in the season this tract was looked over and a considerable portion of the underbrush cut out and burned. The trees were burlapped and attended through the summer.

Although the town has had no inspection during the fall, winter or spring for several years, most of the residential portions, including all the known colonies outside of the woodland before mentioned, were gone over either in 1895 or 1896, and for three years nearly all the trees in town have been burlapped each summer and well attended, so that it has been kept in excellent condition; but its situation is close to the central infested towns, and thousands of people travel from them to the Revere beaches during the summer. On this account the moth will probably be found in Revere so long as the central towns continue to be infested.

Salem.

All but two of the old colonies in the business and residential part of Salem appear to have been exterminated. In one of these colonies all the eggs which were found in the winter of 1896-97 were destroyed. In the summer of 1897 caterpillars were taken here. In the fall inspection two egg-clusters were found in the other colony.

In the Salem pastures many colonies of gypsy moths have formerly been found. The vegetation on this tract consists largely of red cedar interspersed with hard-wood trees, and the ground is overgrown with barberry bushes and ground juniper. The density of this growth renders a thorough search for eggs impossible, but the young caterpillars can readily be found on the low foliage. A search of a large portion of the pastures was made during the spring, and wherever caterpillars were found most of the trees were cut and the ground and undergrowth burned over with oil. Apparently this has exterminated the caterpillars from most of these pasture colonies; but this region will need a careful watching for some years.

Most of the different forms of the moth found in Salem in 1897 were taken in the pastures.

Saugus.

In years past a number of moth colonies have been found in the villages of Saugus and along the roads. These were worked and closely watched for two or three years. A later discovery of the woodland colonies made it necessary to devote to the woodland much of the time formerly given to the villages. Nothwithstanding the best use that could be made of that part of the appropriation which could be apportioned to Saugus, the woodland colonies have been extending until 1897, when the exigencies of the work necessitated the massing of about one hundred men in Saugus for several months. Nearly all of the infested woods were cleared of underbrush and the dead trees cut out. In some of the worst colonies the live trees were thinned out; in others, the owners cut the wood and the ground was then cleared and burned over. Most of the colonies were thoroughly burlapped. This burlapping was followed up during the summer, with the result that the moths are now nearly exterminated from several of these colonies, and the improvement in the condition of nearly all of them is remarkable. For example, in the five worst colonies 437,150 egg-clusters laid in 1896 and only 40,457 egg-clusters laid in 1897 were taken. There is a portion of the Saugus woodland which has not been inspected for years. This should be inspected during the winter of 1897–98, and any colonies found should be cleared up and thoroughly worked. Another year of such work as has been done in Saugus in 1897 should bring all the large colonies which have been worked this year very near to extermination.

Somerville.

The good condition of Somerville, as reported last year, has been maintained and somewhat improved so far as the known colonies are concerned. There are a few localities in which the moth still hangs on. Only 1,047 caterpillars were taken in the city in the summer of 1897. On account of the proximity of Medford, Somerville must be carefully watched and inspected to prevent reinfestation.

Hemlock killed by the gypsy moth in the Saugus woods.

Wakefield.

In 1896 the number of known colonies in Wakefield had been reduced to five. In 1897 no moths were found in two of these, but one of the colonies in Saugus woods has extended over the line into Wakefield, and some thousands of caterpillars were taken there.

As all the old colonies in the central and northern part of the town had been exterminated some years since, there has been very little work done there since 1894, when a tree-to-tree inspection of the whole town was made. An examination of the centre of the town was made by one man in November, 1897, and two egg-clusters were found.

Watertown.

The last inspection was begun here in 1896 and finished in 1897, when one small colony was found. This will require to be watched another year. Outside of this colony the moths were found in Mt. Auburn cemetery only, which is partially in Cambridge.

Winchester.

In the residential and business portions of Winchester few gypsy moths were found in 1897. In many of the village estates that have been found infested this year, only one, two or three caterpillars have been found. The caterpillars have been most numerous on the farms in the outskirts of the town, especially in the orchards and woods in the western and southern sections, adjoining Lexington, Arlington and Medford. The worst infested of these woodland districts were cleared of underbrush in the winter of 1896–97 and the following spring, and burlapped. In two or three of the colonies large numbers of the caterpillars were killed, and the numbers of the moths greatly reduced, so that now very few eggs can be found there. In other colonies where many caterpillars were killed in 1895–96 very few were found in 1897. In one of the worst colonies 33 acres of woodland were cut by the owners and the underbrush was burned. Wherever, in this tract, caterpillars were found in the spring, the ground and sprouts

were burned over, and no evidence of the moth has been discovered on this ground since. In another colony, in which caterpillars have been abundant during the past two summers, your agents cut off the wood from about ten acres. The ground here was burned over wherever caterpillars appeared in the spring, and only two egg-clusters have been found in this lot since the burning. In the south-eastern portion of the town, bordering on the Middlesex Fells reservation, is a tract of farm land where there have been strips of badly infested woodland. Most of this was cut or cleared up in the spring of 1897, and vast numbers of the eggs were destroyed by fire. This work and the burlapping of the summer has greatly reduced the moths in this section and prevented their distribution to other parts of the town.

Although Winchester has been more carefully examined during the burlap season than last year, the number of caterpillars killed was much smaller. The numbers killed were as follows: in 1896, 243,639; in 1897, 130,221.

Most of Winchester has been inspected quite thoroughly within three years, either in the burlapping season or during the fall, winter and spring.

As a whole, Winchester is now in better condition with regard to the gypsy moth than it has been at any time during the past few years.

Winthrop.

All the colonies in Winthrop in which any form of the moth was found in 1896 were burlapped in 1897. The trees were climbed and carefully inspected. Only 23 caterpillars and 3 pupæ were found. An inspection of the infested localities was made when the burlap was taken off, but no eggs were found. The entire town was very thoroughly inspected in 1896, and nearly all the trees in the town were burlapped for three years in succession. The results reached are largely due to a liberal use of burlap. The moth appears to be nearly exterminated from Winthrop, but, as there is much driving there during the summer from Malden, Medford and other infested towns, it is probable a few caterpillars will be distributed there annually so long as they are to be found in numbers in these central towns.

Woburn.

In the residential and business parts of Woburn only a few scattering caterpillars were found here and there during the summer of 1897, with the exception of two localities, where new colonies were discovered in the spring about the time the eggs were hatching. These colonies were thoroughly treated by fire and followed up by burlapping. Another season they will require only careful watching and burlapping. On account of the discovery of these colonies, the number of caterpillars taken in Woburn this year was practically the same as the number taken last year. In the woodland, in the south-west corner of the city, where the largest colonies of the moth had been found in past years, the cutting and burning of infested wood and brush have been extended to the Winchester line. No moths have been found on this tract since. Two wood lots near the Lexington line have also been cut, and no doubt this and other measures will eventually result in the extermination of the moth in that section. The single isolated caterpillars found indicate that they have been redistributed in Woburn during the past summer by such means as originally infested the town. If the moths can now be exterminated from the badly infested centres in the inner towns, which are now reinfesting Woburn and the other outer towns, there will be no difficulty in clearing Woburn of the gypsy moth within a short time.

The Increase of the Moth in the Central Woodlands.

It becomes necessary now to revert to the history of the efforts to exterminate the gypsy moth in former years.

In 1892 your committee ascertained, and then duly reported, that at least 400 acres of central woodland were known to be more or less infested by the gypsy moth, and asked for means sufficient to stamp out the moth from these forested tracts. Furthermore, your committee predicted that, in case sufficient appropriations were not granted, there would be great danger that the insect might extend its hold in these woodlands, with the result that it might be much more difficult to secure its extirpation. Means adequate for the purpose were not then nor afterwards granted.

Your committee has from year to year, as in duty bound, reported that an alarming increase and spread of the moth was progressing in these woodlands, in spite of all the work that could be done to check it with manifestly insufficient appropriations.

In 1895 your committee ascertained and duly reported that the forest infestation of 1892 (400 acres) had increased to 3,000 acres. The increased appropriation granted in 1895 made possible the cleaning up of a small part of these woodlands; but, as the appropriation was greatly reduced and delayed again in 1896, much of the advantage gained by the work done in 1895 was lost. At least 2,000 acres of these woods were found in the winter of 1896–97 to be in a worse condition than ever before. Had this increase and spread been allowed to go on in 1897, no doubt the cost of the necessary exterminative work in these woodlands in 1898 would have been greater than that of handling the colonies in all the rest of the infested region, and in fact greater than any annual appropriation which has thus far been granted.

Methods of Extermination in Woodlands.

It was long since proved that the gypsy moth could readily be exterminated from open and cultivated lands, orchards and shade trees; it has now been abundantly shown that it can be exterminated from the woods. In forest park lands, where it is not advisable to cut away or burn trees, shrubbery and vines, progress has been necessarily slow; but in ordinary woodland extermination has progressed more rapidly. In some cases the wood was cut off by the owner, and, after undergoing a sufficient quarantine, was marketed by him. The brush was then burned, the land cleaned up and the ground burned over. In other cases, where the land was sparsely wooded and more or less grown up to underbrush, it was cleared and burned over. Where the land was valuable for prospective building purposes, it was burned over and nearly cleared, leaving a few of the finer shade trees only, thus greatly reducing the number of trees to be afterwards burlapped and inspected. In other cases the number of trees was

reduced by cutting out only the worthless trees, and the ground cleaned up by removing and burning the underbrush. In certain colonies where the moth had appeared in many thousands, the eggs on the trees were destroyed and the ground burned over with oil. Later the trees were banded with Raupenleim, to prevent the caterpillars ascending, and the few caterpillars which hatched from the eggs remaining on the ground were thus starved. Any one of these methods will bring about extermination, if supplemented by such others as can be used to the best advantage. Extermination here, as elsewhere, must be verified through several years by a thorough search in the summer for the caterpillars and in the winter for the eggs of the moth.

The Progress of Extermination.

All practical entomologists who have followed the work of extermination for the past six or seven years are now convinced that the gypsy moth can be exterminated, and that its extermination, under the present methods, is only a question of time and adequate appropriations. People who hold opposite opinions seem to be impressed by the belief that the gypsy moth is generally distributed over the whole so-called infested territory of more than 200 square miles. This, emphatically, is not the case, nor has it ever been the case. Outside the central towns the moth is found only in isolated swarms or colonies, separated by wide intervals of uninfested ground. In fact, the greater part of the region called infested has never been invaded by the moth. For this reason it is never necessary to make a careful, thorough search over all the territory of the towns in the infested region, for the purpose of discovering single caterpillars or moths. Such scrupulous searching is essential only in and around the known colonies. In seeking for and destroying the moth in these colonies, the greater part of the appropriation has always been expended, and must always be, so long as the moths are numerous. But there should also be, from time to time, a rather rapid search of all the region between the colonies. This should be conducted in the fall, winter and early spring, — when deciduous trees bear little or no foliage, — to provide against the establishment of new colonies.

This search over the entire country is what is called a tree-to-tree examination, and is made, not to find the last caterpillar or the last moth, but to find the last colony. When that is found, careful inspection, burning, spraying, burlapping and other means must be utilized to destroy the last moth in that locality.

When any given locality has been apparently freed from the moth, extermination there must be verified by careful examinations for a term of years before it can be authoritatively announced.

The methods now in use have always exterminated the moth wherever they have been followed without interruption for a reasonable period. A personal examination of the colonies known to have been infested in 1897 leads to the conclusion that much more progress toward extermination has been made this year than in any previous season. Outside the Fells region, except in Malden and Medford, the condition of nearly all the known colonies has been greatly improved by the work of 1897. Against this favorable statement must be set the fact that less inspection than usual has been made in 1897, except in or near the vicinity of the known colonies. The residential and business sections of several of the outer towns were, however, burlapped almost entirely this year, and the burlap carefully inspected. This resulted in the picking up of a stray caterpillar here and there on territory not lately infested. The discovery of such strays does not indicate the local hatching of even a single egg-cluster, but rather demonstrates that the caterpillars have been disseminated by vehicles and pedestrians within the past two years from the large colonies (especially the woodland colonies) in the central towns into territory previously cleared. But, it may be asked, why was not the moth eradicated from these central woodlands while the colonies there were still small, and, therefore, comparatively easy to exterminate? This was not done for the reason that before it could be attempted there were discovered in the woodlands of the outer towns larger colonies which were then in worse condition than were those in the inner towns. As money enough had not been provided to attend to all, it became necessary to attend to the outer towns first, on account of

their position near the border of the infested region. The first duty of the committee, under the law, was to "prevent the spreading" of the gypsy moth; and there was evidently more danger then of the moths spreading from these outer colonies into territory outside the infested region than there was of their spreading into this outside territory from the forest colonies in the central towns.

In summing up the progress of extermination, it may be fairly stated that in the outer two-thirds of the district known as the infested region there remain now only a few known colonies, most of which are on the verge of extermination. From this portion of the infested region the moth now appears to be almost, if not quite, exterminated.

The problem of extermination is now considerably simplified. The large colonies in the woodlands of the outer towns have been either exterminated or so reduced that their extermination is a matter of a short time. Serious danger from this source of the conveyance of the moth into towns beyond the border of the infested region has been eliminated. It is true that the large woodland colonies in the Fells are not improved. But a large force of men, which has heretofore been of necessity scattered in isolated colonies in the outer towns, can now be concentrated nearer the centre of the infested region, in the Fells and Saugus colonies, and in Malden, Medford and Everett, where the work can be more economically supervised and directed.

Why Larger Appropriations are needed.

As it has been already stated that progress has been made with past appropriations, the question may well be asked, Why, then, are larger appropriations now required? It may be answered in brief that we have now reached a time when much more rapid progress must be made, or the success of the whole work will be put in imminent peril. This is clear for the following, among other reasons: —

1. A vast amount of work is immediately required in the central woodlands, where, otherwise, the area now occupied by the moth will greatly increase each year, thereby either greatly increasing the final cost of extermination, or, by the

enormous expense involved, compelling the abandonment of the whole exterminative work.

2. The increased danger of disseminating the moth, due to the constant opening to travel of new paths, parkways, boulevards and trolley lines, leading into and through these woodlands, also makes immediate extermination necessary there.

3. If extermination in these woodlands is to succeed, it must be begun at once, and on a large scale. The work must be of the most thorough nature, and it must be followed up throughout every month of the year.

4. Much of this woodland has been taken for metropolitan or municipal parks; other large portions are highly valued for prospective building purposes. While cutting and burning all the trees on these forested lands might be in the end the most economical course, such measures need hardly be considered in the case of public parks; there less drastic methods are recommended. If the trees are to be generally preserved there, and it seems that they must be, the extermination of the moth from these lands will be extremely expensive. With larger appropriations in the past, advantage could have been taken of the favorable conditions then existing. The moth could have been readily and rapidly exterminated from the colonies, then comparatively very small, in the central woodlands, and thus, of course, prevented from spreading over the large tracts it now occupies. A great deal of money would thus have been saved in the end.

5. The reduction of past appropriations and the delay in making them has necessitated a repetition of merely partial work year after year in many colonies, deferring their extermination and increasing its ultimate cost three to ten times. The force in not a few instances has been compelled to skip from one part of the territory to another, much as if a fire department, in attempting to control a fierce conflagration with an insufficient number of men, should run about from one outbreak to another, completely subduing none. Under this policy the moth has increased and spread in every place which has been for the time necessarily neglected.

6. Experience demonstrates that the moth colonies cannot be exterminated in detail. On the contrary, if extermination is to succeed, every effort must be made each year to

exterminate all these colonies simultaneously. In the fall of 1897, as in previous years, much work had to be left undone, in order that the most dangerous colonies might be looked to. To do the required work in the Middlesex Fells, it was necessary to neglect for two months all the outer and intermediate colonies in two-thirds of the infested region. It will require a large sum of money to thoroughly inspect these colonies, and destroy, before hatching time, the few egg-clusters still remaining there. To do the required work in the generally infested central woodland and residential territory in Medford, Melrose, Malden, Everett and Saugus, with portions of contiguous towns, will cost a larger sum than has hitherto been used in any year in the entire infested territory.

7. The moth, within the last three years, has shown alarming evidence of increased vigor and fertility, and has suffered little perceptible check from its parasitic or other natural enemies. Unless the moth is stamped out promptly, circumstances favorable to its still further increase may arise.

8. The discovery within the last two years of three colonies of the moth outside of what has been known as the infested region, emphasizes the necessity of another and more thorough examination of all the towns bordering upon it. If an undiscovered extra limital colony has already become established near the infested region, a thorough examination of a belt, two towns wide, outside the boundary of known infestation, would bring it to light. Such an inspection, covering the greater part of 1898 and the two following years, ought to be made. Its cost would be heavy.

Conclusion.

If, through further reduced and delayed appropriations, the moths in the central woodlands should be allowed to increase in numbers and spread over more territory, even though they might be so well held in check there as for a time to do no appreciable injury, it would be but a few years before the annual cost of exterminative work in the woods alone would be greater than all the money heretofore expended in the entire region. It must be borne in mind, too, that, if the central woods are now to be cleared, the residential parts of the towns and cities immediately adjoining these

woods must also be promptly cleared of the moth, in order that infestation may not be carried thence again into the cleared areas both of forest and open country. The money which has been thus far expended in the extermination of the gypsy moth has accomplished much by protecting the orchards, gardens and forests of the infested region, and preventing the spread of the moth throughout the State. It has furnished an object lesson to the citizens who would have to deal with the pest should the Commonwealth fail to support the work. But, if extermination should be further delayed by insufficient support, the money already expended will have been thrown away, so far as accomplishing the end in view is concerned, and in all probability the moth will again occupy, not only the region from which it has been cleared, but in due time the entire State also, from which it will doubtless spread over the United States.

In short, the situation is this: in the outer towns, where extermination has been pushed, it has succeeded; in the central towns, where, because of insufficient means, suppression only could be tried, it has failed. Not only has this enforced policy of mere suppression in the centre resulted in failure, but it has also allowed the moth to spread, thus jeopardizing again the outer towns. It is plain that the only way to prevent the spread of the moth is to exterminate it from the land. Further appropriations can be justified only by a supreme effort to exterminate. No further progress in extermination *in toto* is now possible with an appropriation of less than $200,000. With the large number of experienced men now available, even a larger sum could be used to advantage in 1898. It would be better to give up the work now than to continue it with insufficient appropriations, for in either case the moth will eventually escape and spread over the country. If Massachusetts has not the energy to crush this potent foe to agriculture and forestry while she now has it in the hollow of her hand, — if she cannot now provide ample appropriations for this purpose, — then let not another dollar be expended.

Respectfully submitted,

E. H. FORBUSH.

APPENDIX.

The following papers represent as much of the scientific part of the work for the extermination of the gypsy moth during the past year as has been completed and prepared for publication. The gypsy moth committee have held very broad and comprehensive views concerning both the scientific investigations and the field work, for they recognize the fact that all possible discoveries bearing on the destruction of this insect pest should be made and given to the public. This very wise policy has received the highest commendation from leading scientific men both in this country and in Europe.

C. H. FERNALD.

ARSENATE OF LEAD AS AN INSECTICIDE.

C. H. FERNALD, ENTOMOLOGIST.

In the work of destroying the gypsy moth it was soon discovered that Paris green would not kill many of the caterpillars, even when used in as large a proportion in water as was possible without injury to the foliage of the trees. It therefore seemed necessary to discover, if possible, some insecticide that would destroy the caterpillars and at the same time not injure the most delicate foliage. Mr. F. C. Moulton, who was employed by the gypsy moth committee as chemist, was directed to investigate the various compounds of arsenic, and endeavor to find some substitute for the insecticides then in use which possessed the necessary properties. After a long series of experiments, in 1892 he was so fortunate as to discover arsenate of lead, which certainly possesses the desirable characteristics more fully than any insecticide previously known.

The first public mention of arsenate of lead was made in the report of the Massachusetts Agricultural College, October, 1893, p. 23. In Bulletin No. 24 of the Hatch Experiment Station, Amherst, Mass., published in April, 1894, a more complete account was given of this insecticide and of experiments with it on the tent caterpillar and Colorado potato beetle. Mention was also made of this insecticide under the name of "gypsine" in the report of the gypsy moth committee for 1894, pp. 20 and 35. The name "gypsine" was given to this insecticide by Mr. Moulton, but, as there was an entirely different product on the market by the same name, this insecticide was called arsenate of lead, to avoid confusion. In the report of the gypsy moth committee, February, 1894, p. 20, the announcement of the discovery of arsenate of lead by F. C. Moulton was made by Mr. E. H. Forbush, the field director, and the formula was given. In the same year Prof. James Fletcher, in "Evi-

dence before the Standing Committee on Agriculture," in the Canadian Parliament, pp. 19 and 20, referred to this new insecticide; and again in the report of the Entomological Society of Ontario, p. 71 (1894), he referred to its value. In the seventh annual report of the Vermont Agricultural Experiment Station, p. 123 (1894), Dr. G. H. Perkins, the entomologist, recommended the use of arsenate of lead for the destruction of several different kinds of insects, and gave the formula for making it.

Arsenate of lead was described by Mr. E. H. Forbush, with its effects, value and limitations, in the report of the gypsy moth committee for 1895, p. 16. Mr. C. P. Lounsbury, in Bulletin No. 28 of the Hatch Experiment Station, p. 9 (1895), recommended this insecticide for the destruction of canker worms. In the Massachusetts Crop Report of June, 1895, Mr. A. H. Kirkland gave a general description of arsenate of lead, its cost, etc. In the fifteenth annual report of the New Jersey State Agricultural Experiment Station, p. 400 (1895), Prof. J. B. Smith described arsenate of lead, and recommended it highly for use against the elm-leaf beetle. In the "Proceedings of the Association of Economic Entomologists," p. 24 (1895), Mr. C. L. Marlatt gave an account of this insecticide, with a formula for its preparation furnished by Mr. K. P. McElroy of the Division of Chemistry of the Department of Agriculture, Washington, D. C.

A more complete account of arsenate of lead, with the history of its discovery, uses and numerous experiments performed with it, was given in "The Gypsy Moth," by Forbush and Fernald, pp. 69, 80, 87, 142, 143, 145, 449–473 (1896), and Mr. Forbush gave an account of its use on hedges in the report of the gypsy moth committee, p. 18 (1896). In Bulletin No. 36 of the Hatch Experiment Station, p. 6 (1896), Mr. R. A. Cooley recommended the use of this insecticide against the elm-leaf beetle. In the same year Prof. J. B. Smith, in his "Economic Entomology," p. 436, described and recommended arsenate of lead as an insecticide for leaf-eating insects. In the "Proceedings of the Association of Economic Entomologists" for 1896, p. 27, Mr. A. H. Kirkland gave an account of arsenate of lead; and in the same volume, p. 44, Prof. J. B. Smith referred to the ease with which this

insecticide is prepared. In the proceedings of the same society for 1897, p. 46, Mr. Kirkland gave a full account of the use of arsenate of lead against the gypsy moth.

This insecticide is easily prepared by putting 11 ounces of acetate of lead in 4 quarts of water in a wooden pail, and 4 ounces of arsenate of soda (50 per cent.) in 2 quarts of water in another wooden pail, and when entirely dissolved mixing them in a hogshead containing 150 gallons of water, when a chemical reaction will take place, forming arsenate of lead as a fine white powder in suspension in the water. If cold water be used, the solution of the acetate of lead will require a little time; but, however, if the water be hot, it will dissolve very quickly. It is customary to add from 2 to 4 quarts of glucose to the above amount of water. If it is desired to use larger proportions of the arsenate of lead, it is only necessary to use more acetate of lead and arsenate of soda, but in the proportions given above. A more detailed and exact explanation is given in a following paper by Mr. F. J. Smith.

Arsenate of lead has already proved to be the most valuable insecticide known for the destruction of the gypsy moth. It does not injure the foliage of the most delicate plants, even when used in as large a proportion as 25 pounds, or even more, to 150 gallons of water; in fact, there is no known arsenical insecticide so harmless to vegetation as arsenate of lead. This substance remains in suspension in water much longer than Paris green, because of its very low specific gravity, which is 1.00668, while that of Paris green is 3.42225. In spraying, the low specific gravity of arsenate of lead and its consequent suspension in water for a considerable length of time make it possible to distribute it more evenly over vegetation. The white color is also a decided advantage, for one is able to see at a glance whether a tree or shrub has been sprayed; and it is a noteworthy fact that this insecticide adheres to the foliage far longer than any similar substance now in use.

What has been said with regard to the value of this insecticide for the destruction of the gypsy moth is also true in the case of other leaf-eating insects. In every case where we ourselves have performed experiments on these insects, and in all cases reported by others who appear to understand

the use of it, the most satisfactory results have been obtained. It is undoubtedly true that larger proportions of this substance must be used than of Paris green, but this can be done with entire safety to the vegetation. The cost of the insecticide forms a very small part of the cost of spraying; and since arsenate of lead remains on the foliage so much longer than other insecticides, a much larger proportion can be used and even then be much cheaper than substances which wash off readily in showers, making it necessary to spray the trees a second time.

A large percentage of the spraying done in orchards at the present time is with a mixture of an insecticide and a fungicide; because, as has already been said, the great expense is in the labor, and not in the materials used; and when the insecticide and fungicide can be applied together, the cost of one spraying is saved. We have not experimented as yet with a fungicide mixed with arsenate of lead, but our chemist, Mr. F. J. Smith, informs me that he does not think there will be any reaction between arsenate of lead and the Bordeaux mixture to prevent using them together, but that they may be mixed and used as readily as Paris green and the Bordeaux mixture. Professor Craig, in his report as horticulturist of the Experimental Farms, 1895, p. 119, records excellent results with arsenate of lead against the codling moth, and also good success in using the insecticide and Bordeaux mixture together.

Spraying may almost be regarded as a fine art. Not every one of those even who have had a long experience at the work can spray a tree properly. I have repeatedly examined trees which had been sprayed by those who considered themselves experienced hands at the work, and found the leaves so wet that the water was dripping from them or standing on the surface in such quantity that the poison was settling on the lower part, where it either ran off, or, when the water evaporated, the poison was confined to a fractional portion of the leaf. Spraying should be done with a nozzle that gives only a fine, mist-like spray, and should be stopped before it runs on the leaves. This is more easily said than done, but we often find men who seem to catch the idea, and stop at the exact time.

ARSENATE OF LEAD: ITS MANUFACTURE AND CHEMICAL COMPOSITION.

FREDERIC J. SMITH, M.S., CHEMIST TO THE COMMITTEE.

The value of arsenate of lead as an insecticide has been fully set forth in the preceding paper by the entomologist. Since this insecticide has come into such general use, the present seems a proper time to place on record the essential facts concerning the ingredients used in making arsenate of lead, the chemical reactions that are involved and the exact composition of the final product. The results of our work will, it is hoped, be all the more serviceable to economic entomologists because it is apparent that the preparation of this substance has not been generally understood, as is shown by several erroneous and conflicting statements which have been published concerning this subject.

To be exact, the arsenate of lead used in spraying operations is not a salt whose composition may be definitely expressed by a single formula, but instead is a mixture of both di-plumbic and tri-plumbic arsenates, the relative quantities of each depending principally upon the source of the soluble lead salt used. Since the term "arsenate of lead" has now become so well established, it will be used in its general sense in the present paper.

Ingredients.

Theoretically, in the preparation of arsenate of lead it is only necessary to form a chemical union between the common lead oxide (litharge), PbO, and arsenic pentoxide, As_2O_5; but, in order to obtain a product suitable for use as an insecticide, the chemical union must take place between soluble salts containing these oxides. In general practice, arsenate of lead suitable for spraying purposes is prepared by bringing together commercial grades of acetate or nitrate

of lead and arsenate of soda. Owing to the variable composition of these commercial salts, a chemical analysis of each is indispensable, as indicating the relative amounts to be used. All such calculations must be based upon the quantity of lead oxide (PbO) found in the lead salt and that of arsenic pentoxide (As_2O_5) contained in the arsenate of soda, making due allowance for other acidulous radicals which may precipitate the lead.

Both the acetate and the nitrate of lead are extensively used in paint and dyeing industries, and especially as mordants in calico printing. Arsenate of soda is chiefly used to remove mordants.

Acetate of Lead, Lead Acetate, Sugar of Lead.

$$Pb(C_2H_3O_2)_2 3H_2O.$$

So far as is known to the writer, this salt is the one generally used as a source of soluble lead oxide for the preparation of arsenate of lead. Acetate of lead may be obtained in the market in all grades, from clear, transparent crystals to dark gray or brown lumps, and is usually quite free from adulteration. It is prepared either by exposing litharge (PbO) to the action of the vapors of pyroligneous acid, or by dissolving metallic lead in pyroligneous acid and recrystallizing the products from water solutions. Pure lead acetate crystallizes in four-sided prisms, containing three molecules of water of crystallization. Crystals formed by the sudden cooling of a hot saturated water solution separate in a more finely divided condition than those formed by a slow evaporation. The finer crystals are especially desirable when the salt is to be used for technical purposes, or when it is necessary to dissolve a large quantity in a short space of time.

When the crystallized salt is exposed to the action of the air there is a rapid loss of water of crystallization (efflorescence) and also a slow formation of lead carbonate, due to the action of carbon di-oxide contained in the air. Thus the percentage composition of crystallized lead acetate may be materially changed. Loss of weight by efflorescence yields a product containing a higher percentage of actual lead acetate than the original crystallized salt, accompanied by

an increase of insoluble lead carbonate. The increase in the percentage of lead acetate that accompanies efflorescence is well illustrated by sample No. 4 of Table No. 1. Pure crystallized lead acetate contains 58.81 per cent. of lead oxide; but this sample, which had been exposed to the air in a loosely covered vessel for over six months previous to analysis, yielded 66.795 per cent. of lead oxide. The following table indicates the amounts of available lead oxide contained in different market grades of acetate of lead: —

Table No. 1.

SAMPLE.	Percentage of Lead Oxide (PbO).
No. 1, crystallized acetate lead, from drug store, . .	59.525
No. 2, crystallized acetate lead, from drug store, . .	61.548
No. 3, crystallized acetate lead, from drug store, . .	60.650
No. 4, crystallized acetate lead (effloresced), . . .	66.795
No. 5, "chemically pure white acetate lead powder," from wholesale chemist.	62.500
No. 6, "white acetate lead granulated," from wholesale chemist.	60.800
No. 7, "white acetate lead lumps," from wholesale chemist,	60.550
No. 8, "brown acetate lead," from wholesale chemist, .	62.290

Samples Nos. 1, 2 and 3 were supposed to be chemically pure. No. 4 has been previously described. No. 5 is somewhat more expensive than the other market grades, is in a very finely divided condition and dissolves very readily in water. No. 6 is the grade used last year by the gypsy moth committee for the preparation of arsenate of lead. This salt contains many lumps, which consist of finely divided crystals. These lumps dissolve readily in cold water. No. 7 dissolves slowly in cold water, but easily in hot water. No. 8 contains a considerable amount of tarry matters and a small quantity of basic acetate of lead. In handling any of these salts, proper care should be taken to avoid inhaling their dust. Lead is a "cumulative" poison, and when once absorbed is with difficulty eliminated from the system.

Nitrate of Lead, Lead Nitrate, Lead Saltpetre.

$Pb(NO_3)_2$.

The comparative cheapness of this salt first suggested its possible value for the preparation of arsenate of lead. Experiments made during the summer of 1897 indicate that arsenate of lead prepared from the nitrate also possesses properties quite as important as the lower market price of the latter salt. The grade of this salt most common in the market varies somewhat in its chemical composition. It is prepared by dissolving "lead scale" or litharge (PbO) in hot dilute nitric acid; upon evaporation, the nitrate of lead crystallizes out in transparent octohedral crystals. Lead nitrate has the advantage of containing a high percentage of lead oxide. In the reaction between lead and nitric acid there is a tendency toward the formation of basic salts, and the commercial lead nitrate usually contains a higher percentage of lead oxide than the chemically pure crystals. Lead nitrate is not affected by exposure to the air, and does not dissolve in water as readily as the acetate. The results obtained from the analyses of three samples of lead nitrate are given in the following table: —

Table No. 2.

SAMPLE.	Percentage of Lead Oxide (PbO).
No. 1, nitrate of lead, from drug store, ...	68.37
No. 2, nitrate of lead, from drug store, ...	67.76
No. 3, nitrate of lead, from wholesale chemist, . . .	66.37

Arsenate of Soda, Arseniate of Soda, Di-sodic Arsenate, Hydrodi-sodium Arsenate.

$Na_2HAsO_4(H_2O)^n$.

Aside from the mono-metallic arsenates, the soluble salts of arsenic acid are limited to those of the alkaline metals. Of the latter, the arsenates of potash and ammonium are

rarely met with, and have but a limited use in medicine; while sodium arsenate, from its abundance in the market and low cost, is the only one that may be profitably considered as a source of soluble arsenic acid. Several grades of this salt, containing from 50 to 75 per cent. of arsenate of soda, are found in the market.

The sodium arsenate of commerce was formerly prepared by dissolving common white arsenic in a hot solution of caustic soda, with the addition of a sufficient quantity of sodium nitrate, the whole being evaporated to dryness and fused, when the sodium arsenite became oxidized to sodium arsenate. At the present time, commercial arsenate of soda is chiefly produced as a secondary product of the German aniline industries. I am informed by Mr. John S. Rigby, F.R.S., of Liverpool, that English manufacturers of sulphuric acid are now using white arsenic in the place of sulphuric acid for decomposing nitrate of soda in the nitre pots, and are thus producing arsenate of soda as a by-product.

The pure crystallized salt sold by druggists is prepared by dissolving the crude arsenate of soda in water and concentrating the solution, when di-sodium arsenate having the formula $Na_2HAsO_47H_2O$ crystallizes out.

Pure di-sodium arsenate is isomorphous with di-sodium phosphate, and possesses almost identical physical and chemical properties. Under ordinary conditions di-sodium phosphate crystallizes with 12 molecules of water, but di-sodium arsenate crystallizes with 12 molecules of water only when the solution is evaporated and crystallized below the temperature of 18° C. (Fresenius, J. pr. Chemie 56, 30.) In discussing the preparation of arsenate of lead Mr. K. P. McElroy unfortunately overlooked the fact that the arsenate of soda containing 12 molecules of water is quite unsuitable for the purpose, and hence the directions given by him ("Proceedings of the Association of Economic Entomologists," 1895, p. 24) are misleading. The amount of water in the commercial salt is dependent upon its manner of preparation and care in storage. All the commercial grades contain less water of crystallization than the crystallized salt, $Na_2HAsO_47H_2O$, commonly sold by druggists, and when

the composition of the commercial salt is expressed as a formula, the water present may be written as $(H_2O)^n$, where n = the number of molecules of water.

The most economical grades of arsenate of soda for the preparation of arsenate of lead are those containing the highest percentage of arsenic pentoxide, As_2O_5, and the least amounts of chlorine and other foreign substances. A high percentage of arsenic acid alone is not necessarily indicative of the purity or value of the salt. The great variation in the composition of the different grades of arsenate of soda is exhibited in Table No. 3, and is probably due to different processes of manufacture, and possibly, in the case of the first sample, to adulteration with salt (NaCl).

Table No. 3.

CONSTITUENTS.	Sample No. 1.	Sample No. 2.
	Per Cent.	Per Cent.
Water at 200° C.,	7.73	26.72
Chlorine,	17.81	2.60
Arsenic pentoxide (As_2O_5),	39.69	45.39
Sodium oxide,	14.03	15.07
Sodium as chloride,	11.54	1.70
Potassium oxide,	6.02	7.63
Insoluble matter,	1.87	.19
Sulphates and nitrates (estimated),	1.31	.70
	100.00	100.00

Sample No. 1 is known to the trade as "50 per cent. arsenate soda," and is sold at a lower price than the "65 per cent. arsenate soda" represented by sample No. 2. For the preparation of arsenate of lead it will suffice to determine the amounts of arsenic pentoxide and chlorine present in the arsenate of soda. Determinations made from four representative samples of arsenate of soda follow: —

Table No. 4.

SAMPLE.	Arsenic Pentoxide.	Chlorine.
	Per Cent.	Per Cent.
No. 3, chemically pure crystals, from drug store, .	36.86	–
No. 4, chemically pure crystals, from drug store, .	36.77	–
No. 5, commercial, 58 to 60 per cent., . . .	37.70	.75
No. 7, commercial, 68 to 70 per cent., . . .	47.80	.57

*The Presence of Chlorine in Arsenate of Soda.**

There are probably no commercial grades of arsenate of soda wholly free from chlorine but its presence to the amount of 2 or 3 per cent. does no serious harm. If chlorine be present to a greater extent than 4 or 5 per cent., upon the addition of the soluble lead salt to the impure arsenate of soda a considerable quantity of chloride of lead will be precipitated. This but wastes the soluble lead salt, since chloride of lead has practically no value as an insecticide. The reaction in this case may be expressed by the following equation: —

$$Pb(C_2H_3O_2)_2 3H_2O + 2NaCl = PbCl_2 + 2NaC_2H_3O_2 + 3H_2O.$$

The solubility of lead chloride in water at 20° C. is .9712 part to 100 (Formanck), and in hot water 1 part to 22 (Wittstein).† The arsenate of lead should be precipitated in a dilute solution, and where possible, brook or hydrant water should be used in preference to colder spring or well water.

Arsenate of Lead, Lead Arsenate.

Arsenate of lead may be prepared by mixing a solution of arsenate of soda with a solution containing either acetate or nitrate of lead. As previously stated, it consists of a

* Several other impurities, such as arsenious acid, sulphates, nitrates, etc., also occur in commercial arsenate of soda. The arsenious acid, upon the addition of a soluble lead salt, is precipitated as arsenite of lead, which possesses considerable value as an insecticide.

† A. M. Corney, "Dictionary of Chemical Solubilities," 1896, p. 206.

mixture of the di-plumbic and tri-plumbic arsenates, their relative proportions varying according to the conditions of temperature and concentration at the moment of precipitation.

Where the acetate of lead is used approximately, the whole of the arsenate of lead product consists of tri-plumbic arsenate, as indicated by the following reaction: —

$$3Pb(C_2H_3O_2)_2 3H_2O + 2Na_2HAsO_4(H_2O)^n =$$
$$Pb_3(AsO_4)_2 + 4NaC_2H_3O_2 + 2C_2H_4O_2 +_n(H_2O).$$

In order to prepare arsenate of lead successfully, great care must be taken to establish an exact ratio between the quantities of the soluble lead and arsenic salts, otherwise injury to the foliage may result. The reaction between acetate of lead and arsenate of soda may be summarized as follows: —

$$3PbO + As_2O_5 = Pb_3(AsO_4)_2.$$

One part $Pb_3(AsO_4)_2$ requires .74416 part PbO and .25584 part As_2O_5. Experience has shown that it is advisable to increase the amount of lead oxide to .77812, in order to insure an excess of lead. A single example will suffice to show how the relative amounts of soluble lead and arsenic salts may be fixed.

Let it be required to prepare 1 pound of arsenate of lead from samples of lead acetate (X) and sodium arsenate (Y), containing respectively 60 per cent. lead oxide (PbO) and 40 per cent. arsenic pentoxide (As_2O_5): —

$$X = \frac{.77812}{.60} = 1.2969 \text{ pounds lead acetate.}$$

$$Y = \frac{.25584}{.40} = .6396 \text{ pound arsenate of soda.}$$

Should the arsenate of soda contain 7 per cent. chlorine, in addition to the arsenic pentoxide, there would be required an additional amount of lead acetate (Z) to complete the reaction between the two salts. One part chlorine is equivalent to 3.1408 parts PbO, and the amount of lead acetate required is determined as follows: —

$$Z = \frac{.6396 \times .07 \times 3.1408}{.60} = .2343 \text{ pound lead acetate.}$$

Adding the values of X and Z, we find that 1.5312 pounds lead acetate are required for the reaction with .6396 pound arsenate of soda of the grade specified. Expressing these quantities in avoirdupois weights, 1 pound arsenate lead requires 1 pound $8\frac{1}{2}$ ounces acetate of lead and $10\frac{1}{4}$ ounces arsenate soda.

The following equation represents the reaction between arsenate of soda and nitrate of lead: —

$$5Pb(NO_3)_2 + 4Na_2HAsO_4(H_2O)^n =$$
$$Pb_3(AsO_4)_2 + 2PbHAsO_4 + 8NaNO_3 + 2HNO_3 + {}_n(H_2O).$$

The essential features of this reaction may be summarized as follows: —

$$5PbO + 2As_2O_5 + H_2O = Pb_5H_2(AsO_4)_4.$$

One part $Pb_5H_2(AsO_4)_4$ requires .70 part PbO and .30 part As_2O_5. A proper excess of lead oxide may be obtained by increasing the quantity mentioned to .7914, which will insure the complete precipitation of the arsenic.

Let it be required to prepare 1 pound of arsenate of lead from samples of lead nitrate (X) and sodium arsenate (Y), containing respectively 66 per cent. PbO and 40 per cent. As_2O_5: —

$$X = \frac{.7914}{.66} = 1.1990 \text{ pounds lead nitrate.}$$

$$Y = \frac{.3000}{.40} = .7500 \text{ pound arsenate of soda.}$$

Should the arsenate of soda contain 7 per cent. chlorine, as in the preceding case, the additional amount of lead nitrate (Z) required may be determined as follows: —

$$Z = \frac{.7500 \times .07 \times 3.1408}{.66} = .2498 \text{ pound lead nitrate.}$$

Adding the values of X and Z, we find that 1.4488 pounds lead nitrate and .75 pound arsenate of soda are required for the preparation of 1 pound arsenate of lead. In avoirdupois terms the relative weights stand as follows: 1 pound $2\frac{3}{4}$ ounces nitrate of lead and 12 ounces arsenate of soda.

Freshly prepared arsenate of lead consists of very finely divided particles, slightly aggregated into a flocculent, curdy white precipitate, having a specific gravity of about 1.00668, and remaining in suspension for a remarkably long time. The flocculent character of the precipitate facilitates its uniform application to the foliage, and when applied as a fine spray it soon dries to a tenacious and permanent film. In drying in mass this salt becomes compact and increases in specific gravity. Analyses of two air-dried samples of arsenate of lead, prepared respectively from the acetate and nitrate of lead, gave the following results: —

Table No. 5.

CONSTITUENTS.	Sample No. 1.	Sample No. 2.
	Per Cent.	Per Cent.
Water,	2.37	5.11
Lead oxide, PbO,	73.10	69.85
Arsenic pentoxide, As_2O_5,	21.80	24.92
Chlorine,	2.40	Trace.
Other acidulous radicals,	Trace.	Trace.
	99.67	99.88

In the preceding table sample No. 1 was prepared from "white granulated acetate of lead" and "50 per cent. arsenate of soda;" No. 2 was prepared from commercial lead nitrate and "65 per cent. arsenate of soda."

Where arsenate of lead is to be made on a large scale, after determining the relative amounts of the salts to be used it is advisable to test the formula by preparing a trial quantity, and examining the supernatant liquid for soluble lead and arsenic. For this purpose it is necessary to filter a portion of the supernatant liquid. If an excess of lead is present, by adding a few drops of potassium neutral or bi-chromate solution a beautiful chrome yellow precipitate is formed. A simple test for soluble arsenic acid may be made by adding to a portion of the filtered solution a few drops

of lead acetate solution. A white precipitate indicates the presence of soluble arsenic. From the injury to foliage produced by soluble arsenic in spraying mixtures, it is of prime importance that the liquid should show the presence of an excess of lead. When the nitrate of lead is used, the reaction may sometimes show an excess of lead before the arsenic is fully precipitated. In such cases, if the test for arsenic be made, a decided reaction will reveal its presence, and it becomes necessary to add a sufficient quantity of lead nitrate to complete the reaction.

The gypsy moth committee use annually several tons of arsenate of lead, preparing it, previous to 1897, according to the formula originally given by Mr. Moulton, "sodic arseniate, 29.93 per cent.; plumbic acetate, 70.07 per cent." (Report of the Massachusetts State Board of Agriculture, 1893, p. 282.) Careful investigations have shown that there is a difference in the chemical composition of these commercial salts that cannot be ignored, and that single arsenic and lead salts cannot be taken as types to fix the relative proportions. These salts were mixed together, weighed out in suitable quantities and placed in bags. Previous to being added to the contents of the spraying tank, this mixture was boiled in a kettle until the reaction between the salts was complete. While results obtained from arsenate of lead prepared in this manner are far superior to those obtained by the use of Paris green, several objectionable features developed, the principal one being an incomplete reaction between the mixed salts stored in bags. By this process the particles of arsenate of soda became coated with a thin crust of arsenate of lead, and when sprayed upon the foliage broke down, liberating soluble arsenic and injuring the leaves. Arsenate of lead mixture prepared by grinding together the commercial salts is also of variable composition, and gives very uneven results. Some samples contain a great excess of lead, while in others the arsenate of soda predominates. Because of the incomplete reaction previously mentioned and the uneven composition of the mixture, the arsenate of lead thus obtained often possesses mechanical properties that hinder its application to the foliage.

The best results in the preparation of arsenate of lead have

been obtained by the method adopted during the season of 1897. The amounts of lead oxide and arsenic pentoxide in the commercial salts having been determined the necessary quantities of acetate of lead and arsenate of soda were fixed. The work of weighing the salts was carried on rapidly by the aid of ballasts, on balance scales. The acetate of lead was placed in a strong paper bag which was sufficiently large to hold the smaller bag of arsenate of soda, and the whole made into a single package and tied with stout twine. A printed label giving directions for the preparation of arsenate of lead was attached to each package. When needed for spraying the salts were dissolved separately by suspending each in a small basket in a wooden* tub or keg of water. When the solutions thus obtained are poured into the spraying tank partially filled with water, arsenate of lead is thrown down as a fine white precipitate. Acetate of lead dissolves in water at about the rate of 1 pound to 1 gallon; arsenate of soda dissolves readily at the rate of 1 pound to 3 quarts of water. Both these salts dissolve easily in smaller quantities of hot water, and where the latter is available it should be used in preference to cold water. In either case great care must be taken to avoid spilling the solutions before precipitation.

It should be recognized that the arsenate of lead commonly sold in the market is a mixture and not a compound, and in reality contains but about 50 per cent. of actual arsenate of lead. In making recommendations concerning the use of this insecticide, care must be taken to indicate whether the arsenate of lead or arsenate of lead mixture is to be used. Table No. 6 gives the amounts of "white granulated acetate lead" and "65 per cent. arsenate soda" necessary to make known quantities of arsenate of lead. In this case the acetate of lead contains 60 per cent. PbO, and the arsenate of soda 45 per cent. As_2O_5 and 3 per cent. chlorine.

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* Metallic pails should never be used.

Table No. 6.

Arsenate of Lead.		Acetate of Lead Required.		Arsenate of Soda Required.		Arsenate of Lead Mixture.	
lbs.	oz.	lbs.	oz.	lbs.	oz.	lbs.	oz.
–	1	–	$1\frac{3}{4}$	–	$\frac{3}{5}$	–	2
–	3	–	4	–	$1\frac{7}{10}$	–	$5\frac{7}{10}$
–	5	–	$6\frac{3}{4}$	–	$2\frac{7}{8}$	–	$9\frac{1}{2}$
–	8	–	$10\frac{1}{2}$	–	$4\frac{3}{5}$	–	$15\frac{1}{10}$
1	–	1	5	–	$9\frac{1}{2}$	1	$14\frac{1}{2}$
3	–	3	15	1	$11\frac{1}{4}$	5	$10\frac{1}{4}$
5	–	6	9	1	$13\frac{1}{3}$	8	$6\frac{1}{3}$
10	–	13	2	5	$10\frac{5}{6}$	8	$12\frac{5}{6}$

Table No. 7 gives the amounts of an average nitrate of lead and the same grade (65 per cent.) of arsenate of soda necessary to make known amounts of arsenate of lead. In this case the nitrate of lead contains 66.5 per cent. PbO and the arsenate of soda 45 per cent. As_2O_5 and 3 per cent. chlorine.

Table No. 7.

Arsenate of Lead.		Nitrate of Lead Required.		Arsenate of Soda Required.		Arsenate of Lead Mixture.	
lbs.	oz.	lbs.	oz.	lbs.	oz.	lbs.	oz.
–	1	–	$1\frac{1}{3}$	–	$\frac{5}{8}$	–	2—
–	3	–	4	–	2	–	6
–	5	–	$6\frac{2}{3}$	–	$3\frac{3}{8}$	–	10+
–	8	–	$10\frac{1}{4}$	–	$5\frac{1}{3}$	–	$15\frac{1}{2}$+
1	–	1	$4\frac{1}{2}$	–	$10\frac{3}{4}$	1	15+
3	–	3	$13\frac{1}{2}$	2	–	5	$13\frac{1}{2}$
5	–	6	$6\frac{1}{2}$	3	$5\frac{1}{3}$	9	$11\frac{5}{6}$
10	–	12	13	6	$10\frac{2}{3}$	19	$7\frac{2}{3}$

EXPERIMENTS WITH INSECTICIDES.

A. H KIRKLAND, A. F BURGESS.

The dependence that necessarily must be placed upon spraying with insecticides as a means of controlling the gypsy moth in park lands and other places where more heroic measures cannot be employed has led the committee to encourage extensive investigations, under the direction of the entomologist, of insecticides both new and old, these experiments having for their object the discovery of poisons that may be used effectively against the gypsy moth, as well as the cheapening of the ones already in use. The discovery by F. C. Moulton in 1893 of the insecticidal value of arsenate of lead, and the reduction of the cost of this poison in 1897 to the extent of over one hundred dollars per ton through joint investigations by the chemist and entomologists, are among the practical results of this work.

In the course of these experiments a mass of facts has accumulated which it now seems desirable to place on record. While the field of our investigations has been a limited one, the application of the results to other insects gives the matter a wider significance. In considering the value of the insecticides here discussed in relation to insects other than the gypsy moth, the remarkable resistance to arsenical poison shown by this insect should be taken into consideration.

It will be noticed that the experiments in part cover the caterpillar seasons of two years. In such cases the work of 1897 has been a continuation, on a larger scale, of that of 1896. In the indoor experiments the larvæ were confined in suitable cages and supplied daily with freshly poisoned food. In the experiments out of doors the insects were confined in large cloth bags upon branches previously sprayed with the

insecticide. The larvæ used in the earlier experiments were obtained by the artificial incubation of the eggs.

For the sake of brevity the results of the experiments are presented in tabular form. The heading of each table states the age of the larvæ used, the poisons and amounts of each to 150 gallons of water. The figures indicate the total number of larvæ found dead on successive days. In each experiment ten larvæ were used. The check experiments afford data concerning the normal death-rate of larvæ feeding on unpoisoned food.

Paris Green *v.* White Arsenic.

Indoor Experiments, commenced Feb. 8, 1897.—Larvæ in First Stage.

NO. OF DAYS.	Paris Green, 1-150.	Arsenic, 1-150.	Paris Green, 2-150.	Arsenic, 2-150.	Paris Green, 3-150.	Arsenic, 3-150.	Paris Green, 5-150.	Arsenic, 5-150.	Paris Green, 8-150.	Arsenic, 8-150.	Check No. 1
1, ...	-	-	2	-	-	2	1	1	1	5	-
2, ...	1	3	6	1	1	2	2	1	3	8	-
3, ...	2	5	7	2	3	5	4	2	10	10	-
4, ...	3	6	8	7	6	9	5	9	-	-	4
5, ...	7	8	8	7	9	9	5	9	-	-	5
6, ...	10	10	10	10	10	10	10	10	-	-	7

Duplicate Experiment, commenced March 26, 1897.

NO. OF DAYS.	Paris Green, 1-150.	Arsenic, 1-150.	Paris Green, 2-150.	Arsenic, 2-150.	Paris Green, 3-150.	Arsenic, 3-150.	Paris Green, 5-150.	Arsenic, 5-150.
1, ...	-	-	2	-	2	-	-	6
2, ...	6	6	8	7	6	2	4	9
3, ...	10	7	9	8	7	8	6	9
4, ...	-	10	10	10	9	10	6	10
5, ...	-	-	-	-	10	-	8	-
6, ...	-	-	-	-	-	-	9	-
7, ...	-	-	-	-	-	-	10	-
8, ...	-	-	-	-	-	-	-	-
9, ...	-	-	-	-	-	-	-	-
10, ...	-	-	-	-	-	-	-	-

Duplicate Experiment, etc. — Concluded.

NO. OF DAYS.	Paris Green, 8-150.	Arsenic, 8-150.	Paris Green, 10-150.	Arsenic, 10-150.	Checks.			
					No. 1.	No. 2.	No. 3.	No. 4.
1, ...	4	6	4	2	2	-	-	-
2, ...	6	9	4	7	2	-	-	-
3, ...	7	9	7	10	2	-	-	-
4, ...	9	10	7	-	2	-	-	-
5, ...	9	-	8	-	2	-	-	-*
6, ...	9	-	9	-	2	-	-	-
7, ...	9	-	9	-	2	-	-	-
8, ...	9	-	9	-	2	-	-	-
9, ...	9	-	10	-	2	-	1	-
10, ...	10	-	-	-	2	-	1	-

* One larva lost.

Indoor Experiments, commenced April 5, 1897. — Larvæ in Second Stage.

NO. OF DAYS.	Paris Green, 1-150.	Arsenic, 1-150.	Paris Green, 2-150.	Arsenic, 2-150.	Paris Green, 3-150.	Arsenic, 3-150.	Paris Green, 5-150.	Arsenic, 5-150
1, ...	4	5	5	3	-	-	6	5
2, ...	5	5	5	3	1	3	8	9
3, ...	6	7	6	5	1	4	8	10
4, ...	8	8	7	6	4	6	9	-
5, ...	8	9	8	7	5	8	10	-
6, ...	9	9	8	9	7	8	-	-
7, ...	10	9	10	10	9	9	-	-
8, ...	-	9	-	-	10	9	-	-
9, ...	-	10	-	-	-	10	-	-

Indoor Experiments, etc. — Concluded.

NO. OF DAYS.	Paris Green, 8-150.	Arsenic, 8-150.	Paris Green, 10-150.	Arsenic, 10-150.	Checks.			
					No. 1.	No. 2.	No. 3.	No. 4.
1, ...	4	5	5	3	-	-	-	-
2, ...	6	8	5	5	-	-	-	-
3, ...	9	9	7	8	-	-	-	-
4, ...	9	10	8	8	-	-	-	-
5, ...	9	-	9	10	-	-	-	-
6, ...	9	-	10	-	-	-	-	-
7, ...	9	-	-	-	-	-	-	-
8, ...	10	-	-	-	-	-	-	-
9, ...	-	-	-	-	-	-	-	-

Outdoor Experiments, commenced May 20, 1897. — Larvæ in Second Stage.

NO. OF DAYS.	Paris Green, 1-150.	Arsenic, 1-150	Checks.			NO. OF DAYS.	Paris Green, 1-150.	Arsenic, 1-150.	Checks.		
			No. 1.	No. 2.	No. 3.				No. 1.	No. 2.	No. 3.
1, . . .	3	-	-	-	-	6, . . .	9	7	8	6	7
2, . . .	6	4	-	-	-	7, . . .	9	9	8	6	7
3, . . .	7	6	-	-	-	8, . . .	9	9	9	9	9
4, . . .	8	7	5	6	1	9, . . .	10	9	9	9	10
5, . . .	9	7	8	6	7	10, . . .	-	10	9	9	-

Indoor Experiments, commenced April 15, 1897. — Larvæ in Third Stage.

NO. OF DAYS.	Paris Green, 1-150.	Arsenic, 1-150.	Paris Green, 2-150.	Arsenic, 2-150.	Paris Green, 3-150.	Arsenic, 3-150.	Paris Green, 5-150.	Arsenic, 5-150
1, ...	-	1	1	-	6	3	3	6
2, ...	3	3	5	3	7	5	5	7
3, ...	3	4	7	6	8	8	8	10
4, ...	6	6	8	8	10	10	9	-
5, ...	6	8	9	8	-	-	10	-
6, ...	8	8	10	10	-	-	-	-
7, ...	10	8	-	-	-	-	-	-
8, ...	-	8	-	-	-	-	-	-
9, ...	-	9	-	-	-	-	-	-
10, ...	-	10	-	-	-	-	-	-

Indoor Experiments, etc. — Concluded.

NO. OF DAYS.	Paris Green, 8-150.	Arsenic, 8-150.	Paris Green, 10-150.	Arsenic, 10-150.	Checks.*			
					No. 1.	No. 2.	No. 3.	No. 4.
1, ...	7	5	7	5	-	-	-	-
2, ...	8	7	9	10	-	-	-	-
3, ...	10	10	10	-	-	-	-	-
4, ...	-	-	-	-	1	-	3	-
5, ...	-	-	-	-	1	-	3	1
6, ...	-	-	-	-	1	-	3	1
7, ...	-	-	-	-	1	-	4	1
8, ...	-	-	-	-	-	-	-	-
9, ...	-	-	-	-	-	-	-	-
10, ...	-	-	-	-	-	-	-	-

* Discontinued at the end of one week, as all the living larvæ had molted.

Outdoor Experiments, commenced May 28, 1897. — Larvæ in Third Stage.*

NO. OF DAYS.	Paris Green, 1-150.	Arsenic, 1-150	Checks.			NO. OF DAYS.	Paris Green, 1-150.	Arsenic, 1-150	Checks.		
			No. 1.	No. 2.	No. 3.				No. 1.	No. 2.	No. 3.
1, . . .	-	-	-	-	-	12, . . .	4	6	3	-	-
2, . . .	-	1	-	-	-	13, . . .	4	6	3	-	-
3, . . .	-	2	1	-	-	14, . . .	4	6	4	-	-
4, . . .	1	2	1	-	-	15, . . .	4	6	4	-	-
5, . . .	2	4	1	-	-	16, . . .	4	6	6	-	4
6, . . .	4	5	1	-	-	17, . . .	4	6	7	2	4
7, . . .	4	5	1	-	-	18, . . .	4	6	7	2	4
8, . . .	4	5	1	-	-	19, . . .	4	6	7	4	6
9, . . .	4	5	1	-	-	20, . . .	4	6	7	4	7
10, . . .	4	6	3	-	-	21, . . .	4	6	7	4	7
11, . . .	4	6	3	-	-						

* Discontinued at the end of twenty-one days.

Indoor Experiments, commenced April 26, 1897. — Larvæ in Fourth Stage.

NO. OF DAYS.	Paris Green, 1-150.	Arsenic, 1-150.	Paris Green, 2-150.	Arsenic, 2-150.	Paris Green, 3-150.	Arsenic, 3-150.	Paris Green, 5-150.	Arsenic, 5-150.
1, ...	2	-	4	1	4	6	5	9
2, ...	4	2	5	2	4	9	8	9
3, ...	7	4	6	2	6	9	9	9
4, ...	7	6	7	5	7	9	9	10
5, ...	10	8	8	10	10	10	10	-
6, ...	-	10	8	-	-	-	-	-
7, ...	-	-	8	-	-	-	-	-
8, ...	-	-	9	-	-	-	-	-
9, ...	-	-	10	-	-	-	-	-

Indoor Experiments, etc. — Concluded.

NO. OF DAYS.	Paris Green, 8-150.	Arsenic, 8-150.	Paris Green, 10-150.	Arsenic, 10-150.	Checks.			
					No. 1.	No. 2.	No. 3.	No. 4.
1, ...	5	7	3	3	-	-	-	-
2, ...	7	8	3	8	-	-	-	-
3, ...	8	8	4	8	-	-	-	-
4, ...	9	8	8	8	-	1	-	1
5, ...	9	9	9	9	-	1	-	1
6, ...	10	10	9	10	-	5	-	2
7, ...	-	-	9	-	-	5	-	2
8, ...	-	-	10	-	-	5	-	2
9, ...	-	-	-	-	-	5	-	2

Outdoor Experiments, commenced June 1, 1897. — Larvæ in Fourth Stage.

NO. OF DAYS.	Paris Green, 1-150.	Arsenic, 1-150.	Checks.			NO. OF DAYS.	Paris Green, 1-150.	Arsenic, 1-150.	Checks.		
			No. 1.	No. 2.	No. 3.				No. 1.	No. 2.	No. 3.
1, . .	1	-	-	-	-	12, . .	1	4	-	-	1
2, . .	1	-	-	-	-	13, . .	1	4	-	-	1
3, . .	1	1	-	-	-	14, . .	2	4	-	-	1
4, . .	1	1	-	-	-	15, . .	2	4	-	-	2
5, . .	1	3	-	-	-	16, . .	2	7	-	-	2
6, . .	1	3	-	-	-	17, . .	2	9	-	-	2
7, . .	1	3	-	-	-	18, . .	2	9	-	-	2
8, . .	1	3	-	-	-	19, . .	3	10	-	-	2
9, . .	1	3	-	-	-	20, . .	3	-	2	-	2
10, . .	1	4	-	-	1	21, . .	4*	-	2	4	4
11, . .	1	4	-	-	1						

* Discontinued.

Outdoor Experiments, commenced June 11, 1897. — Larvæ in Fifth Stage.

NO. OF DAYS.	Paris Green, 1-150.	Arsenic, 1-150.	Checks.			NO. OF DAYS.	Paris Green, 1-150.	Arsenic, 1-150.	Checks.		
			No. 1.	No. 2.	No. 3.				No. 1.	No. 2.	No. 3.
1, . .	-	-	-	-	-	12, . .	6	5	3	1	-
2, . .	-	-	-	-	-	13, . .	7	6	3	1	-
3, . .	-	1	-	-	-	14, . .	7	7	5	2	-
4, . .	-	1	-	-	-	15, . .	7	7	6	4	-
5, . .	-	1	-	-	-	16, . .	7	7	7	4	-
6, . .	-	1	-	-	-	17, . .	9	7	7	4	-
7, . .	3	1	-	-	-	18, . .	9	7	7	6	-
8, . .	3	1	2	-	9	19, . .	10	8	-*	-*	-
9, . .	3	1	2	-	10	20, . .	-	8	-	-	-
10, . .	3	2	2	-	-	21, . .	-	9*	-	-	-
11, . .	5	5	3	1	-						

* Discontinued.

Outdoor Experiments, commenced June 26, 1897. — Larvæ in Sixth Stage.

[NOTE. — Superior figures, in all cases, indicate the number of larvæ pupating on the corresponding days.]

NO. OF DAYS.	Paris Green, 1-150.	Arsenic, 1-150.	Checks.			NO. OF DAYS.	Paris Green, 1-150.	Arsenic, 1-150	Checks.		
			No. 1.	No. 2.	No. 3				No. 1.	No. 2.	No. 3.
1, . .	-	-	-	-	-	12, . .	4^{1}	-	-	3^{2}	3^{2}
2, . .	-	-	-	-	-	13, . .	5	-	-	4	3^{2}
3, . .	-	-	-	-	-	14, . .	5	-	-	4	3
4, . .	1	2	-	-	-	15, . .	5	-	-	4	3
5, . .	1	3	-	-	-	16, . .	6	-	1^{1}	4	3
6, . .	1	6	-	-	-	17, . .	7	-	-	4^{2}	3
7, . .	1	10	-	-	-	18, . .	7	-	-	4	4
8, . .	1	-	$-^{1}$	3	1^{1}	19, . .	7	-	-	4	-
9, . .	2	-	-	3	1	20, . .	7	-	-	4	-
10, . .	2	-	$-^{2}$	3	1^{1}	21, . .	8	-	-	4^{2}	-
11, . .	3	-	$-^{5}$	3^{1}	1						

By the direction of Professor Fernald, the preceding experiments were performed in order to determine the relative insecticidal effects of Paris green and arsenic on the gypsy moth. While arsenic seems slightly superior to Paris green so far as killing effects are concerned, its high specific gravity renders it difficult of suspension in water, and hence it cannot be applied evenly to the foliage. We have long since abandoned the use of Paris green in our spraying operations, and neither this poison nor arsenic can compete with arsenate of lead as a means for destroying the gypsy moth. The high death rate of the larvæ in the check experiments is a probable consequence of the remarkably wet season of 1897.

Scheele's Green.

Field Experiment, June 22, 1897.

Twenty square rods of badly infested oak timber and brush land were thoroughly sprayed with Scheele's green, at the rate of 5 pounds to 150 gallons of water.

July 1. About 10 per cent. of the larvæ are dead. Foliage slightly burned.
July 5 No more larvæ dead. Foliage badly burned
July 11. Trees stripped by the larvæ, except where the foliage has been killed by the poison.

In the above experiment the object was to destroy the caterpillars, regardless of the effect upon the foliage.

LEAD ARSENITE *v.* LEAD ARSENATE.

Indoor Experiments, commenced June 13, 1896. — Larvæ in Fifth Stage.

NO. OF DAYS.	Lead Arsenite, 2-150.	Lead Arsenate, 2-150.	Lead Arsenite, 5-150.	Lead Arsenate, 5-150.	Lead Arsenite, 10-150.	Lead Arsenate, 10-150.
1,	-	-	-	-	-	-
2,	-	-	-	-	-	-
3,	-	-	-	-	-	-
4,	-	-	-	-	2	1
5,	-	-	-	-	2	3
6,	-	-	1	-	2	4
7,	-	-	2	1	2	5
8,	-	-	2	1	2	5
9,	-	2	2	3	3	9
10,	-	2	2	4	3	9
11,	-	2	2	5	3	9
12,	-	3	2	6	3	9
13,	-	4	2	8	4	9
14,	2	7	2	8	4	9
15,	2	7	2	8	4	9
16,	2	8	2	9	4	10
17,	2	8	2	10	4	-
18,	2	8	2	-	4	-
19,	2	8	2	-	4 [1]	-
20,	2	9	2	-	4	-
21,	2	10	2	-	4	-
22,	2	-	2	-	4	-
23,	2*	-	2	-	4	-
24,	-	-	2*	-	5	-
25,	-	-	-	-	5	-
26,	-	-	-	-	7*	-

* Discontinued.

Outdoor Experiments, commenced June 19, 1896. — Larvæ in Sixth Stage.*

NO. OF DAYS.	Lead Arsenite, 2-150.	Lead Arsenate, 2-150.	Lead Arsenite, 5-150.	Lead Arsenate, 5-150.	Lead Arsenite, 10-150.	Lead Arsenate, 10-150.
1,	-	-	-	-	-	-
2,	-	-	-	-	-	-
3,	-	-	-	1	-	1
4,	-	-	-	1	-	1
5,	-	-	-	1	2	2
6,	-	-	-	1	2	2
7,	-	-	-	1	2	2
8,	-	-	-	1	2	4
9,	-	-	-	1	2	4
10,	2	-	-	1	2	6
11,	2	-	-	1	2	6
12,	3	-	-	1	2	6
13,	3	-	-[1]	2	2	6
14,	3†	-†	2	2[1]	2	7
15,	-	-	2†	2†	2	7
16,	-	-	-	-	2	7
17,	-	-	-	-	2	7
18,	-	-	-	-	2	7
19,	-	-	-	-	3	7
20,	-	-	-	-	3	8
21,	-	-	-	-	4	8
22,	-	-	-	-	4	8
23,	-	-	-	-	4	8
24,	-	-	-	-	4	8[1]
25,	-	-	-	-	4	9
26,	-	-	-	-	4	-
27,	-	-	-	-	7	-
28,	-	-	-	-	8[2]	-

* No burning of foliage appeared in these experiments. † Discontinued.

These experiments with chemically pure arsenite of lead *v.* arsenate of lead mixture (containing in reality only about 50 per cent. chemically pure arsenate of lead) show the relative superiority of the latter. The specific gravity of the arsenite of lead is much greater than that of the arsenate, and for this reason it cannot be so evenly applied to the foliage.

BARIUM ARSENATE.*

Outdoor Experiments, commenced June 1, 1896. — Larvæ in Fourth Stage.

NO. OF DAYS.	Barium Arsenate, 1-150.	Check.	Barium Arsenate, 2-150.	Check.	Barium Arsenate, 3-150.	Check.	Barium Arsenate, 4-150.	Check.	Barium Arsenate, 5-150.	Check.	Barium Arsenate, 10-150.	Check.
1, . .	-	-	-	-	-	-	-	-	-	-	-	-
2, . .	-	-	-	-	-	-	-	-	-	-	-	-
3, . .	1	-	-	-	1	-	1	-	1	-	-	-
4, . .	1	-	-	-	1	-	1	-	1	-	-	-
5, . .	2	-	-	-	6	-	3	-	2	-	5	-
6, . .	2	-	-	-	6	-	3	-	2	-	5	-
7, . .	2	-	-	-	6	-	3	-	2	-	5	-
8, . .	2	-	-	-	6	-	3	-	2	-	5	-
9, . .	2	-	-	-	6	-	3	-	2	-	5	-
10, . .	2	-	-	-	6	-	3	-	2	-	5	-
11, . .	3	1	2	-	8	-	5	-	5	-	7	-
12, . .	3	1	2	1	8	-	5	-	5	-	7	-
13, . .	3	1	2	1	8	-	5	-	5	-	10	-
14, . .	3	1	2	1	8	-	5	-	5	-	-	-
15, . .	3	1	2	1	8	-	5	-	5	-	-	-
16, . .	3	1	5	1	8	-	5	-	5	-	-	-
17, . .	3†	1†	5†	1†	10	-†	10	-†	10	-†	-	-†
18, . .	-	-	-	-	-	-	-	-	-	-	-	-

* Foliage uninjured. † Discontinued.

Outdoor Experiments. — Larvæ in Sixth Stage.

NO. OF DAYS.	June 22, 1896.			June 25, 1896.
	Barium Arsenate, 12-150.*	Barium Arsenate, 15-150.*	Barium Arsenate, 20-150 †	Barium Arsenate, 40-150.*
1,	-	-	-	-
2,	-	-	1	6
3,	-	-	1	6
4,	-	1	4	10
5,	1	6	7	-
6,	1	6	7	-
7,	2	10	10	-
8,	2	-	-	-
9,	2	-	-	-
10,	2	-	-	-
11,	6	-	-	-
12,	6	-	-	-
13,	6	-	-	-
14,	6	-	-	-
15,	8	-	-	-
16,	10	-	-	-

* Foliage slightly burned. † Foliage badly burned.

Barium Arsenate.

Field Experiments.

Ten pounds to 150 gallons; glucose, 1 gallon to 150; 50 square rods red oak and white oak brush; larvæ in second and third stages. Echo Street, Malden.

Sprayed May 24, 1897: —
May 26. No results.
May 28. No results.
May 29. No results.
June 3. Few larvæ dead; foliage burned Discontinued.

Ten pounds to 150 gallons; glucose, 1 gallon to 150; 30 square rods white oak and red oak brush; larvæ in second and third stages. Valley Street, Medford.

Sprayed May 24, 1897: —

May 26. No results.

May 28. No results.

May 29. No results.

June 3. Few larvæ dead; foliage burned; tender foliage badly burned. Discontinued

The barium arsenate used in the two preceding experiments had stood in the "mother liquor" all winter, and had developed a considerable amount of soluble arsenic. In the following experiment the barium arsenate was freshly prepared: —

Ten pounds to 150 gallons; glucose, 1 gallon to 150; 100 square rods oak, pine and white birch brush; larvæ in fourth and fifth stages. Hawkes' Farm, Saugus.

Sprayed June 18–19, 1897: —

June 24. Many larvæ dead. Special Inspector Little agrees with me in estimating that 60 per cent. of the larvæ have been killed Not as many dead as where arsenate of lead, 20-150, is used. No burning apparent; poison does not show well on foliage

June 29. Sprayed area in about the same condition as on June 24; more larvæ have died, but there are many large ones still feeding; bushes are being stripped; poison disappeared; no burning of note.

July 3. Poison has stopped killing; slight burning on tender foliage; effect not as good as where arsenate of lead, 20-150, is used. The greatest fault seems to be in the ease with which the poison is washed from the foliage Larvæ pupating. Discontinued.

The experiments with barium arsenate in 1896 gave so good results that we were hopeful that this insecticide would prove superior to lead arsenate. Its killing effects on larvæ in confinement are certainly superior to those of arsenate of lead. In the field spraying operations it was found that the poison did not adhere to the foliage for a sufficiently long time to kill the larvæ. With the lessening of the cost of arsenate of lead we have now effected, barium arsenate cannot compete with it.

Lead Phenolate.*

Outdoor Experiments, commenced July 1, 1897. — Larvæ in Fifth Stage.

NO. OF DAYS.	Lead Phenolate, 1-150.	Lead Phenolate, 2-150.	Lead Phenolate, 3-150.	Lead Phenolate, 5-150.	Lead Phenolate, 8-150.	Lead Phenolate, 10-150.
1, ...	-	-	-	-	-	-
2, ...	-	-	-	-	-	-
3, ...	-	-	-	-	-	-
4, ...	-[1]	-	-	-	-	-[1]
5, ...	1[1]	1	-	-	-	-
6, ...	1	5	-	-	-[1]	-[2]
7, ...	1[1]	5	-	-	-	-
8, ...	2	5[1]	1[1]	-[3]	1[1]	-
9, ...	2	6	1	-	1	-
10, ...	2	6	2[1]	-	3	-
11, ...	2	6	2	-	3	-
12, ...	2	7	3[2]	1[1]	4	-
13, ...	2	9	3[3*]	3	5	-
14, ...	2	-	-	3	5[1]	1[2]
15, ...	3	-	-	4	5	1
16, ...	5	-	-	5	5	1
17, ...	5[1]	-	-	5	5	2
18, ...	6	-	-	5	5	2
19, ...	-	-	-	5	5	2[2]
20, ...	-	-	-	5	5	2
21, ...	-	-	-	5	5	2[1]

* Foliage uninjured.

Outdoor Experiments, commenced July 1, 1897. — Larvæ in Sixth Stage.

NO. OF DAYS.	Lead Phenolate, 1-150.	Lead Phenolate, 2-150.	Lead Phenolate, 3-150.	Lead Phenolate, 5-150.	Lead Phenolate, 8-150.	Lead Phenolate, 10-150.
1, ...	-	-	-	-	-	-
2, ...	-	-	-	-	-	-
3, ...	1	-[1]	-	-	-	-
4, ...	1	-	-	-	-[1]	-
5, ...	1[2]	-[2]	-[1]	-[2]	-[1]	-
6, ...	1	-	-[1]	2[2]	-	-
7, ...	2	-[2]	-	2	-[1]	-[1]
8, ...	2[1]	-	-[2]	3[2]	-	1
9, ...	3	-[1]	1	4	-[1]	1
10, ...	3	-[2]	1[3]	-	-	1
11, ...	3	-	1	-	1	1[2]
12, ...	4[3]	-	1[2]	-	1[1]	1[4]
13, ...	-	-	-	-	1[1]	1
14, ...	-	-	-	-	1[1]	1
15, ...	-	-[1]	-	-	1[2]	1
16, ...	-	-	-	-	-	1[1]
17, ...	-	-	-	-	-	1
18, ...	-	-	-	-	-	1
19, ...	-	-	-	-	-	2
20, ...	-	1	-	-	-	-
21, ...	-	-	-	-	-	-

Phenolate of Lead.

Field Experiment.

Grayish white salt of low specific gravity; mixes with difficulty in water; particles coarse; 10 pounds to 150 gallons; glucose, 6 quarts to 150 gallons; large apple tree badly infested; larvæ in fifth and sixth stages. Fenwick Street, Malden.

Sprayed July 1, 1897: —
July 3. No larvæ dead.
July 10. No larvæ dead. No burning.
July 19. No larvæ dead. Greater part of larvæ pupating.
July 21. No larvæ dead. No burning Discontinued.

It would seem as though so powerful an organic poison as phenol would have had more effect upon the larvæ.

Di-Plumbic Arsenate *v.* Tri-Plumbic Arsenate.

Outdoor Experiments, commenced July 9, 1897. — Larvæ in Fifth Stage.

NO. OF DAYS.	Di-Plumbic Arsenate, 5-150.	Tri-Plumbic Arsenate, 5-150.	Di-Plumbic Arsenate, 10-150.	Tri Plumbic Arsenate, 10-150.	Di-Plumbic Arsenate, 15-150.	Tri-Plumbic Arsenate, 15 150.	Di-Plumbic Arsenate, 20-150.	Tri-Plumbic Arsenate, 20-150.
1, ...	–	–	–	–	–	–	–	–
2, ...	–	–	–	–	–	–	–	–
3, ...	1	–	–	–	–	–	–	–
4, ...	2	–[2]	–	1[1]	–[1]	1	–	3[1]
5, ...	4[2]	–	2[1]	1	–	1	1[1]	4[1]
6, ...	4	2[1]	2	1[1]	1	3[2]	5	4[1]
7, ...	4[1]	2	2	1	1	3[1]	6	4
8, ...	4	2	3[1]	1	2	4	7	5
9, ...	4[1]	3	4	2	2	4	7	5
10, ...	4	4[1]	4	4	8[1]	4[1]	7	5
11, ...	4	4	5	4	–	5	8	5
12, ...	4	4	6	4	–	5	8	5
13, ...	4	4	6	4	–	5	8	5
14, ...	5	4	6	4	–	5	8	6
15, ...	5	5	6[1]	5	–	5	8	6
16, ...	6	5	6	5	–	6	8	6
17, ...	–	5	6[1]	6	–	–	9	6
18, ...	–	5	–	6	–	–	–	6
19, ...	–	5	–	6	–	–	–	6
20, ...	–	5	–	6	–	–	–	6
21, ...	–	5*	–	6*	–	–	–	6*

* Discontinued.

Outdoor Experiments, commenced July 9, 1897.—Larvæ in Sixth Stage.*

NO. OF DAYS.	Di-Plumbic Arsenate, 5-150.	Tri-Plumbic Arsenate, 5-150.	Di-Plumbic Arsenate, 10-150.	Tri-Plumbic Arsenate, 10-150.	Di-Plumbic Arsenate, 15-150.	Tri-Plumbic Arsenate, 15-150.
1, ...	-	-	-	-	-	-
2, ...	-	-	-	-	-	-
3, ...	-	-	-	-	-	-
4, ...	-	1 [5]	-	- [2]	1	2
5, ...	- [2]	1 [1]	- [1]	1 [1]	1	2
6, ...	-	1	-	1	4 [1]	3 [1]
7, ...	3	1	-	1 [2]	4	3
8, ...	5 [1]	1	1	1	4 [2]†	3
9, ...	5	1 [1]	2	2	4	3 [1]
10, ...	5	1 [1]	2	2	4 [1]	3 [1]
11, ...	7	1	4 [1]	2	5	3
12, ...	-	1	5	2 [1]	-	4
13, ...	-	1	5	2	-	4
14, ...	-	2	6	2	-	5 [2]
15, ...	-	-	6	2 [1]	-	-
16, ...	-	-	7 [1]	2	-	-
17, ...	-	-	-	2 [1]	-	-
18, ...	-	-	-	-	-	-
19, ...	-	-	-	-	-	-
20, ...	-	-	-	-	-	-
21, ...	-	-	-	-	-	-

* Foliage uninjured. † One larva lost.

Outdoor Experiments, etc.* — Concluded.

NO. OF DAYS.	Di-Plumbic Arsenate, 20-150.	Tri-Plumbic Arsenate, 20-150.	CHECKS.		
			No. 1.	No. 2.	No. 3.
1,	-	-	-	-	-
2,	-	-	-	-	-
3,	-[1]	-	-	-	-
4,	-	-[3]	-	-	-
5,	1[1]	3[4]	-	-	-
6,	1	-	-	-	-
7,	1	-	-	-	-
8,	1	-	-[1]	3	1[1]
9,	1	-	-	3	1
10,	2[1]	-	-[2]	3	1[1]
11,	5	-	-[5]	3[1]	1
12,	5	-	-	3[2]	3[2]
13,	5	-	-	4	3[2]
14,	5	-	-	4	3
15,	5	-	-	4	3
16,	5	-	1[1]	4	3
17,	6[1]	-	-	4[2]	3
18,	-	-	-	4	4
19,	-	-	-	4	-
20,	-	-	-	4	-
21,	-	-	-	4[1]	-

* Foliage uninjured.

DI-PLUMBIC ARSENATE.

Field Experiments.

Twenty pounds to 150 gallons; glucose, 1 gallon to 150; red oak and white oak brush; badly infested; larvæ in fifth and sixth stages. Pierce Street, Malden.

Sprayed June 25, 1897
June 29. Killing well.
July 1. Killing well. Stripping of foliage has stopped.
July 3. Killing well. Eighty per cent. of the larvæ are dead
July 10. Killing well. Many larvæ pupating
July 15. Poison nearly through killing, because of pupation of larvæ. Has given excellent results; no burning of foliage.
July 21. Few dead larvæ; no burning. Poison has killed as well or a little better than the tri-plumbic arsenate.

Twenty pounds to 150 gallons; glucose, 1 gallon to 150; red oak and white oak trees of medium size, badly infested by larvæ in fifth and sixth stages. Pine Hill Path, Metropolitan Park Reservation, Medford.

Sprayed June 26, 1897: —

June 29. Killing well. Dead larvæ plenty in path.
July 1. Killing well. Dead larvæ plenty in path.
July 5. Killing well.
July 10. Killing well. Sixty per cent. of the larvæ dead.
July 21. Poison still killing, although the greater part of the larvæ have transformed. No burning of foliage. The results from the experiment are equally as good as those where the tri-plumbic arsenate is used.

Tri-Plumbic Arsenate.

Field Experiment.

Check experiment on the preceding; 20 pounds to 150 gallons; opposite side of path.

Sprayed June 26, 1897: —

June 29. Killing well.
July 1. Killing well. Plenty of dead larvæ.
July 5. Killing well. Plenty of dead larvæ.
July 10. Still killing; no burning; about sixty per cent. of the larvæ dead.
July 21. Few dead larvæ; greater part pupated.

The di-plumbic arsenate was prepared from nitrate of lead. So far, this insecticide seems equal if not superior to the tri-plumbic arsenate. Extensive field experiments will be made with the di-plumbic arsenate during the season of 1898, should the Legislature provide means for the continuation of this work.

The "di-plumbic arsenate" is composed of about two-thirds di-plumbic arsenate and one-third tri-plumbic arsenate. The tri-plumbic arsenate is approximately pure.

DANGER FROM THE USE OF ARSENATE OF LEAD.

A. H. KIRKLAND, M.S.

A matter of considerable importance in extensive spraying operations with arsenic compounds is the frequent complaint of arsenical poisoning on the part of those who apply the poison to the foliage. In our work against the gypsy moth such complaints are not uncommon, and, since our employees apply from two to three tons of this insecticide to infested trees and shrubbery in a spraying season of from four to six weeks, it has sometimes appeared that these complaints might rest on a basis of fact. Cases of supposed arsenical poisoning are of more frequent occurrence toward the close of the spraying season; and to get at the actual physical condition of our men at such a time, a series of investigations was attempted late in June, 1897.

It is conceded by physicians and toxicologists that when arsenic is taken into the system, either *via* the mouth, lungs or skin, it is chiefly eliminated by means of the kidneys, and that the presence of arsenic in the urine of a sick man is fairly conclusive evidence of arsenical poisoning. An effort was made, but with only partial success, to collect twenty-five samples of urine from men who for some time had been engaged in spraying. Two rather interesting discoveries were made at this time: first, the almost complete indifference on the part of the men in normal health in regard to the whole matter; and second, the enumeration by those who were temporarily out of health of many alarming symptoms which were ascribed to the effects of the poison. Only eight samples were obtained, and these were sent to Mr. F. J. Smith for analysis, with the following results: —

No. 1. — Taken 8 A.M., June 27. Man in good health; had been engaged in spraying about two weeks; trace of arsenic found.

No. 2. — Taken 8.15 A.M., June 24. Man enjoyed good health up to the spraying season; had been engaged in spraying three weeks and during the last week had suffered from loss of appetite, with considerable disturbance of the digestive system; 17.6 mg. arsenic per litre were found.

No. 3. — Taken 12 noon, June 24. Man in fair health, aside from an occasional "bilious attack;" had sprayed for three weeks; no arsenic found.

No. 4. — Taken 12.30 P.M., June 24 Man in good health, but appetite poor at times; had worked at spraying for three weeks; no arsenic found.

No 5. — Taken 1.30 P.M., June 24. Man in excellent health; had sprayed for six days; trace of arsenic found.

No. 6. — Taken June 26. Man in poor health; was well until after he had worked at spraying about two weeks; had sprayed nearly four weeks; trace of arsenic found.

No. 7. — Taken June 26. Man had complained of various derangements of his digestive system; had sprayed for "over three weeks;" .2 mg of arsenic per litre found.

No. 8. — Taken June 1. Man in poor health; had been engaged in experimenting with Paris green and other arsenical compounds for about three months; 4 mg. arsenic per litre found.

The results of these analyses show conclusively that in some cases men engaged in spraying acquire dangerous amounts of arsenic. That actual sickness resulting from this work is rare, is shown by the fact that but few of our many employees lose time from this cause. A case of this kind investigated by the writer in 1896 proved to be one of unmistakable arsenical poisoning, which in this instance was not strange, since less than one week previous to the time the man was taken sick he was observed to be especially careless in the use of the poison, allowing the drippings of the spraying pole to run freely up his arms and probably over the greater part of his body. Nowhere, perhaps, do we find a better illustration of the contempt bred by familiarity than in the manner in which men engaged in spraying make use of insecticides. In the case of our employees an excuse is found in the high state of physical vigor that characterizes the whole force, — the natural result of an active, outdoor life.

Strangely enough, the most frequent cause for complaint

in the use of arsenate of lead is an entirely harmless one. The *odor* of the spray when very pronounced often causes considerable anxiety among those engaged in spraying, and in one or two cases has been known to produce nausea. This odor is not produced by the arsenic or the lead, but is the rich creosote smell remaining in the crude acetic acid used in the manufacture of acetate of lead. This acid is one of the resultants of the destructive distillation of wood, and retains the smoky odor even after passing through several chemical reactions.

It may be stated, in general terms, that while an occasional person may become poisoned during extensive spraying operations with arsenate of lead, premonitory symptoms appear in ample time for a change of work to be arranged; and since the conditions existing in the work against the gypsy moth are exceptional, the farmer or fruit grower may use this insecticide with less fear of danger from poisoning than is the case where Paris green or London purple is used. In all cases proper care must be taken in handling the poison and in preventing the exposure of the skin to the spray.

The danger to animals from feeding on grass under trees that have been sprayed is a matter that has at times received a large measure of popular attention in the region infested by the gypsy moth, and at the time of spraying we have always taken the precaution to advise all property owners of the possible danger to their fowls and live stock. The experiment detailed below is of interest in this connection.

On June 26, 1896, sufficient grass to make two large feedings for a horse was cut and spread beneath a pear tree of medium size, and the tree heavily sprayed with arsenate of lead, at the rate of 20 pounds to 150 gallons of water. The drippings from the tree were not sufficient to discolor the grass to any marked degree, so the nozzle was turned on to the grass, and the latter thoroughly drenched. By a previous arrangement with Müller Brothers, tannery proprietors, North Cambridge, a horse had been secured for experimental purposes. This horse weighed about 1,200 or 1,300 pounds, was perfectly sound except for a badly sprained leg, and because of this latter defect was soon to be slaughtered. The grass treated as described was taken to

the tannery and fed to the horse during the afternoon and evening of June 26. On June 28 the writer found the horse well and hearty, and in "*better condition*," so the teamsters at the tannery stated, than before the grass had been fed to him. The poison used in spraying was mixed with cold water, and in a few days it was found that the foliage of the pear tree was badly burned, thus proving the presence of soluble arsenic in the mixture, and showing that it was even more dangerous to animal life than properly prepared arsenate of lead would have been.

DIGESTION IN THE LARVÆ OF THE GYPSY MOTH.

A. H. KIRKLAND, F. J. SMITH.

The remarkable resistance exhibited by the larvæ of the gypsy moth toward internal poisoning has afforded a basis for the suggestion, so frequently made, that the digestive functions in this insect may differ either in character or in degree from that of insects more readily killed by arsenical poisons. To gain a better idea of the nature of the digestive process in the gypsy moth larva, a limited series of investigations was made in the summer of 1896 by the writers, Mr. Kirkland attending to the anatomical and physiological phases of the question, and Mr. Smith conducting the chemical analyses. It was hoped at the time these investigations were discontinued that further study of the subject could be made during the summer of 1897, but this has been prevented by the demands of other work. Although but a few points are established by our studies, it now seems advisable to publish them as a contribution to the knowledge of digestion in insects. We may properly state here our belief in the importance of a thorough understanding of this subject, and that whenever it is reached many obscure points in the behavior of different insects toward internal poisons will be cleared up.

That the processes taking place in the alimentary canal of the gypsy moth larva may be better understood, it may be well to briefly consider the composition of the food consumed and the anatomy of the digestive tract.

The Food of the Gypsy Moth.

In common with other Bombycid caterpillars, the larvæ of the gypsy moth are practically confined for food to leaves of trees, shrubs or plants; in certain rare cases this insect

has been known to devour bark, buds, blossoms and fruit, but, as these are exceptions, they may be properly excluded from consideration.

Leaves may be said to consist of a large amount of organic matter associated with water, and a small quantity of mineral matter. In the ash are found certain elements, such as potash, lime, phosphorus, etc., which play an important rôle in plant economy; but the substances serving as food in leaves are organic, and consist mainly of proteids, carbohydrates and fat. These compounds are present in the protoplasm with which the cells are filled, and, when consumed and assimilated by the insect, serve as muscle builders, sources of fat, energy and heat, repair wasted tissues and bring about the normal growth of the insect. Undoubtedly the proteids are the most important food elements, and probably serve as the source of the chitin of which the body integument is formed. The lignin, cellulose and similar substances found in leaves are of but little value as food.

The Digestive System.

The internal anatomy of the larva, pupa and imago has been fully detailed in another place,* hence it will suffice to state that the digestive system of the larva consists of a pair of stout jaws, a buccal cavity, a pharynx dilating into an anterior stomach in the forward body segments, a stomach proper, extending through a greater part of the body cavity, an intestine and a short dilated rectum. Discharging into the mouth are a pair of salivary glands, while six malpighian vessels are attached to the rectum.

The Digestive Processes.

The jaws of the larva serve to incise and comminute the food which passes directly from the mouth into the anterior stomach, where it is subjected to the action of an alkaline fluid. It is of interest to note that in this stomach, sometimes greatly distended with food, there is always a large

* Kirkland, article on "Internal Anatomy;" "The Gypsy Moth," Forbush-Fernald, 1896.

amount of fluid present. From the anterior stomach the food passes backward into the posterior stomach (the stomach proper), an organ well supplied with strong annular muscle fibres. In this organ the disintegration and digestion of the food become more marked. By the action of the stomach muscles the food is gradually forced along until it reaches the narrow intestine, through which it passes to the rectum, from which the refuse material is voided from time to time.

Microscopic examinations of the contents of different parts of the alimentary canal show that the greater part of the food retains much of its original physical character. The fibrous elements pass through the system practically unchanged. The softer tissues undergo a partial disintegration, but in general the cellular structure can be recognized. In the contents of the cells, however, there is a great change; in food removed from the anterior stomach the cell contents showed only a partial destruction, while in samples from near the intestine the protoplasm had nearly disappeared, only the chlorophyll granules remaining. From these examinations it appears that the process of digestion in this larva is practically one of solution or extraction: the digestive fluids dissolve the soluble proteids, carbohydrates, fats, salts, etc., while the insoluble parts are eventually ejected. The stomach muscles do not perform the function of grinding, otherwise the physical characters of the food would be destroyed before it reached the intestine. Doubtless the function of these muscles is to force the stomach contents posteriorly, and by this movement bring the food more thoroughly in contact with the digestive fluids; the same is probably true of the weaker muscles of the anterior stomach, although these muscles are equally capable of reverse peristalsis, as shown by the ejection of a part of the contents of this organ from the mouth of the larva whenever the insect is roughly handled.

According to Plateau, the products of digestion in herbivorous insects consist of salts in solution, peptones, sugar and emulsified fats. These substances pass by osmosis through the walls of the alimentary canal and mingle with the blood.

The Alkalinity of the Alimentary Canal.

At the time the article on the anatomy of the gypsy moth was prepared it was noticed that the digestive fluids of the larva were strongly alkaline; but, while the fact seemed quite suggestive, investigations of the cause of this alkalinity were deferred until such a time as the assistance of a chemist could be obtained.

For a preliminary examination several full-grown caterpillars were killed by exposure to fumes of chloroform, and the alimentary canal of each carefully removed and washed. After maceration in water the material was subjected to a careful analysis for both organic and inorganic bases and acids, but nothing of an organic nature that could give an alkaline reaction to the digestive fluids could be detected. Repeated examinations of the water extract, however, showed the presence of appreciable amounts of phosphoric acid and potassium, with traces of calcium and magnesium. It is well known that the phosphates of potassium and sodium give an alkaline reaction with litmus, and, since the presence in the digestive fluid of comparatively large quantities of potassium and phosphoric acid was proven, it was apparent that the alkalinity of this fluid is due to the presence of a phosphate of potash.

Having thus determined qualitatively the source of the alkalinity, it seemed desirable to make a quantitative analysis of the digestive systems of a number of larvæ, in order to obtain an accurate idea of the amount of phosphates of potash occurring in each insect. For this purpose the following method was adopted: the alimentary canals of sixty-six larvæ were carefully removed, washed and macerated in water, as in the previous analysis, and, it having been found that the albuminous substances contained in the material seriously interfered with filtration, resort was made to dialysis, with good results. The macerated material was placed in a dialyzing apparatus and suspended in a dish containing a large quantity of freshly distilled water, the whole being kept at a cool temperature, and the water in the dish replaced with a fresh supply at intervals of twelve hours each for seventy-two hours. At the end of this time the water taken

from the dish was evaporated to a convenient volume upon a water bath, when aliquot parts of the liquid were taken for the determination of phosphoric acid and potash. The phosphoric acid was determined by the ammonium molybdate method and the amount of potash estimated as the double chloride of platinum, following as closely as possible the methods of fertilizer analyses adopted in 1895 by the Association of Official Agricultural Chemists. Briefly stated, the results of these analyses were as follows: —

	Grams.		Milligrams.
Phosphoric acid found in 66 larvæ, .	.036998,	per larva,	.560
Potash (K_2O) found in 66 larvæ, .	.073750,	per larva,	1.117
The phosphoric acid as above stated, in the form of tri-potassic phosphate, requires of potash, . .	.073450		
Error, ...	.000300		

This shows conclusively that the phosphoric acid and potash in the alimentary canal of this insect exist in the form of tri-potassic phosphate, K_3PO_4.

Studies on Other Lepidoptera.

To learn how commonly phosphate of potash occurs in the alimentary canal of Lepidoptera, a number of larvæ were dissected and the parts removed for analysis. The following table presents the results of the analyses. Unless otherwise stated, the data pertain to the alimentary canal of the larva of the species mentioned.

		Amount of Potash.	Amount of Phosphoric Acid.
	Sphingidæ.		
1.	*Thyreus abbotii*, ...	Fair,	Fair.
2.	*Thyreus abbotii* (excrement), . . .	Small,	Trace.
3.	*Deilephila chamænerii* Harr., . . .	Fair,	Fair.
4.	*Philampelus achemon* Dru., ...	Fair,	Large.
5.	*Protoparce celeus* Hbn., ...	Fair,	Large.
6.	*Protoparce celeus* (second specimen), . .	Large,	Fair.
7.	*Sphinx drupiferarum* S. and A., . . .	Fair,	Fair.
8.	*Sphinx gordius* Cram., ...	Fair,	Fair.
9.	*Sphinx gordius* (excrement), . . .	Small,	Trace.
10.	*Dolba hylæus* Dru., ...	Small,	Fair.
11.	*Cressonia juglandis* S. and A., . . .	Fair,	Fair.
	Arctiidæ.		
12.	*Pyrrharctia isabella* S. and A., . . .	Fair,	Large.
13.	*Spilosoma virginica* Fabr., ...	Fair,	Fair.
14.	*Hyphantria cunea* Dru., ...	Fair,	Large.
15.	*Halesidota caryæ* Harr., . . .	No test made,	Small.
	Liparidæ.		
16.	*Orgyia leucostigma* S and A., . . .	Fair,	Fair.
17.	*Porthetria dispar* L. (rectum), . . .	Fair,	Small.
18.	*Porthetria dispar* (excrement of female), .	Fair,	Large.
19.	*Porthetria dispar* (fertile nest), . . .	Fair,	Large.
20.	*Porthetria dispar* (fertile nest), . . .	Large,	Large.
21.	*Porthetria dispar* (infertile nest), . .	Large,	Large.
	Notodontidæ.		
22.	*Datana ministra* Dru., ...	Small,	Small.
23.	*Datana ministra* (newly hatched larvæ, whole insect), ...	Trace,	Trace.
24.	*Datana integerrima* G. and R., . . .	Large,	Large.
	Saturniidæ.		
25.	*Attacus cecropia* L. (eggs), ...	Large,	Large.
26.	*Hyperchiria io* Fabr., ...	Fair,	Fair.
	Ceratocampidæ.		
27.	*Anisota senatoria* S. and A., ...	Fair,	Fair.

The results of these analyses show that phosphate of potash, although varying in amount, is a constant ingredient of the digestive fluids of leaf-eating Lepidoptera, and this fact gives additional evidence of the importance of the substance. We would call particular attention to the fact that but little of this compound was found in the excrement examined (Nos. 2, 9). This shows that the phosphate of potash is retained in the system, since the analyses of the alimentary canals of the corresponding insects (Nos. 1, 8) revealed a fair amount of the substance.

The Function of Phosphate of Potash in Lepidoptera.

In the larvæ examined, phosphate of potash was always found associated with albuminoids. This coincidence, which is also common in plants, seems to show that in living organisms there is an intimate relationship between these substances. Schumacher states that if alkaline phosphates "are mixed with a solution of albumen, or if a solution of them is permitted to diffuse against one of albumen, a much greater amount of the latter will pass through the membrane than would otherwise be the case." *

In the fluid obtained as a result of the dialysis of the digestive systems of *dispar* larvæ a small amount of albumen was found associated with the phosphate of potash. This albumen would not coagulate upon the application of heat, but was precipitated by the addition of alcohol.

From the physiological stand-point the natural inference is that the phosphate of potash aids in the assimilation of albuminoids. The facts in the case may be briefly stated as follows: —

Albuminous substances form an important part of the insect's food. The process of assimilation in *dispar* is one of osmosis. Albuminous substances do not readily pass through the stomach walls, but phosphate of potash aids them in their diffusion. Since this compound is present in such large quantities, it seems evident that its function is, as stated, to aid in the osmosis of albuminoids through the walls of the alimentary canal into the blood.

* "Physik der Pflanze," 1867, p. 129.

We incline to the belief that this compound plays a most important rôle in the economy of the insect, in connection with the digestive process and also in the changes taking place in the pupal state. It seems probable that the phosphate of potash bears a somewhat intimate relation to the development of the reproductive system, since eggs of both fertilized and unfertilized female moths contain large quantities of this compound (Nos. 19, 20, 21). It also occurs in the thick fluid ejected by newly emerged imagoes (No. 18).

Relation to Insecticides.

In connection with the discovery of the source of the alkalinity of the digestive fluids of gypsy moth larvæ, two lines of insecticide experiments suggest themselves: —

1. To introduce into the digestive system of the larva some substance that shall be inert in neutral or weak acid media, and which shall react with phosphate of potash, liberating an effective poison.

2. To obtain a substance that, when taken into the digestive system of the insect, shall precipitate the phosphoric acid, thus destroying its function and preventing the assimilation of albuminous food materials.

NOTES ON PREDACEOUS BEETLES, 1897.

A. F. BURGESS, M.S.

During the season of 1897, predaceous beetles, especially those belonging to the genus *Calosoma*, have been abundant in many localities infested by the gypsy moth, in marked contrast to the condition last year, when considerable difficulty was experienced in obtaining sufficient examples of *Calosoma frigidum* Kirby for making studies on its life history. During the past summer the study of this group of beneficial insects has been continued, several new facts concerning their habits ascertained, and the statements made by the writer in the last annual report of the committee have received additional verification.

The climbing habits of the genus have been noticed this year more than ever before, and the killing of caterpillars by these beetles, even in the tallest trees, has been repeatedly witnessed. In a colony of the gypsy moth in Saugus, June 25, 1897, *C. frigidum* was observed to climb nearly to the top of a small oak tree and feed upon the caterpillars. When in the top of the trees or at the ends of the limbs, if the tree is suddenly shaken by the wind the beetles often drop to the ground, and in a piece of woodland where they are abundant they are often heard striking upon the leaves, having fallen or dropped from the trees.

Mr. W. W. Stevens, an inspector who worked in the Saugus colonies, where beetles of this genus were common, informs me that on two occasions he has seen specimens of *C. frigidum* fly, or rather "scale," to the ground from a tree after the manner of a flying squirrel. I have occasionally noticed that the beetles vibrate their wings in confinement, but have flung them into the air repeatedly without seeing them make the slightest effort to fly. Mr. Stevens is of

the opinion, however, that they would not fly upward, but simply extend their wings to lessen the velocity of the fall.

Calosoma scrutator (Fab.) has been found to be fully as active, particularly as regards climbing, as *frigidum*, and, on account of its greater size and strength, is a more formidable enemy to caterpillar life. The amount of good done does not depend entirely on the number of larvæ which the beetles actually eat, as when food is plenty they kill or mutilate a great many which they make no pretence of eating, as is shown by the following statement. Mr. Harry Vinton, while working in a colony of the gypsy moth in Saugus, during June, 1897, saw a *C. frigidum* kill or wound seven of the caterpillars on a tree trunk and then disappear among the brush. All the larvæ were so badly disabled that they could not recover.

The representatives of this genus are found principally in the spring and early summer, and after laying their eggs probably remain in the ground. This has been found to be the case with the beetles kept in confinement in cages. After midsummer the food supply is usually less plentiful, and these beetles probably do not feed on vegetable matter during the latter part of the season, as do some other Carabids. *Harpalus caliginosus* (Fab.), for example, was taken September 23, feeding on the flower-heads of the ragweed (*Ambrosia artemisiæfolia*), one of our most common garden weeds.* Professor Forbes, in his study of the food of Carabidæ, found, from dissecting three *C. scrutator* and nine *C. calidum*, that only food of animal origin was present in the stomachs. He also emphasizes the fact that the mouth parts of this genus are adapted for animal rather than vegetable feeding.†

The Calosomas, aside from being able to hibernate as imagoes, can also live an almost incredible length of time without taking food. The following notes may be of interest in this connection. A single female of *Calosoma willcoxi* Lec., kept in confinement, ate nothing from June 30 to August 18; several specimens of *C. frigidum*, confined in a breeding

* This observation corroborates those of Wm. Trelease ("American Entomologist," 1880, p. 251) and Wm. A. Buckhout (*ibid.*, p. 277).

† Bulletin Illinois State Laboratory of Natural History, Nos. 3 and 6, 1883.

cage, received no food from July 21 to September 1; and specimens of *C. scrutator* have been kept two weeks without food. In all these cases the beetles survived, and seemed to suffer no serious inconvenience. They were, however, a little more sluggish in movement, and remained in the ground more than was the case earlier in the season, when food was plentiful. One of the principal reasons for allowing the beetles to be without food was the scarcity of caterpillars after midsummer. Substitutes for larvæ, such as snails, beef, veal, kidney and grasshoppers, were tried, with very poor results. When snails were used as food for the beetle larvæ, their legs soon became covered with slime, and death followed.

Calosoma frigidum Kirby.

Sept. 24, 1896, two males and three females of this species were placed in a wire cage near the insectary. The cage consisted simply of a cylinder of wire mosquito netting sunk nearly to the level of the ground, the top being covered with a cloth which was held in place by an elastic band. The records of these three females are given here in full. They were captured June 4, 19 and 26, 1896, and each of the first two were immediately placed in separate jars with a male beetle. The first laid seventeen eggs June 5, but deposited no more during the season, although the male was kept in the jar and placed in the cage outdoors at the same time with the female. The second female laid two eggs July 16 and one more on the 18th, the male dying July 22. The third female had no male companion until August 7, and laid no eggs whatever.

On examining the outdoor cage, May 10, 1897, a live beetle was found about four inches below the surface. The cage was covered, but before another examination was made the netting became partly detached and three of the beetles undoubtedly escaped, as only two females could be found in the ground May 17. They were quite active, and had partially eaten a full-grown white grub (*Lachnosterna* sp.?) which was in the cage. No remains of the other beetles could be found, although the ground was examined to the depth of nearly a foot. This shows conclusively that the beetles hibernate as adults.

The two female beetles were placed in separate breeding jars in the insectary and supplied with food, but very little was eaten until June 2, when males were placed in the jars. One female began laying June 6, finished July 14, having deposited eighty-one eggs, and died on the 24th. The other female began laying on the same date as the former, but finished June 25, dying July 3, having deposited one hundred and fifteen eggs. The largest number laid in a single day was nineteen, which is the maximum noted for this species. From the above it will be seen that these two females were kept in confinement for over a year, and that one, if not both, deposited eggs two years in succession. This naturally brings up the question of the number of annual broods of this insect. From the fact that the egg-laying season ranges from the first of June to the middle of August, I am inclined to believe from present knowledge that the greater portion of the species winter as adults which have seldom laid eggs the previous year.

Observations in the field show that after the last part of June the occurrence of this species is very rare. Mr. W. C. Colt, a special inspector of the Board, with the aid of two men captured thirty-one specimens of this species June 24, while at work in a colony of the gypsy moth in Brookline, and informs me that previous to and about this time the beetles were abundant. On the following day he noticed a female laying her eggs, for which purpose she had selected a place about half an inch below the surface of the ground. Mr. Colt further states that from a week after this date to the end of the season not a single beetle was observed. This species has also been found during the past year in Saugus, Winchester, Medford and elsewhere.

Jars partly filled with earth were used for close breeding with about the same amount of success as during the previous season, the results, however, substantiating the facts which were observed last year. Much of the material confined in jars was attacked by mites, while the outdoor experiments were rendered almost useless by the attacks of ants.

In order to test the practicability of rearing the beetles out of doors, a suitable spot was selected beside two small oak

trees, and a cage with a ground area of about a square yard was built. About the middle of June ten males and a like number of females of *frigidum* were placed in the cage, with plenty of caterpillars. Some of the beetles paired the following day, and on examining the ground June 28 a beetle larva was found. Subsequent examinations, however, failed to bring to light any larvæ, and, as ants were numerous in the cage, this doubtless accounts for the non-development of larvæ that may have hatched.

The killing of young beetle larvæ by the common black ant (*Camponotus pennsylvanicus* DeG.) has been previously noted. Several jars containing newly hatched larvæ of *C. frigidum* were accidentally left uncovered over night. In the morning seven of the eleven larvæ present had been killed, and the ants were feeding on the bodies. One hundred and six larvæ which were placed in another outdoor cage during the season suffered in the same manner from ants, and not one completed its transformations.

Some of the larvæ reared in jars until nearly full grown were placed in small cages out of doors, but they were so badly attacked by mites * that none pupated successfully. In one of these cages a larva of this species was attacked by a wire-worm (*Asaphes* sp. ?), the integument being ruptured so badly that the larva died.†

Calosoma scrutator (Fab.).

This beetle, known under the common names of beautiful-bodied searcher, rummaging or green Calosoma, has for years been recognized as one of the most useful predaceous insects. Almost every report on injurious insects credits it with preying upon noxious species. The following list of some of the injurious larvæ which this beetle has been known to attack has been compiled from various sources: —

Tobacco worms, *Protoparce* (sp. ?).
Gypsy moth, *Porthetria dispar* (pupa also).
Tent caterpillar, *Clisiocampa americana*.

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* Through the kindness of Dr. L. O. Howard these mites have been determined by Mr. Nathan Banks as an immature stage of a species of *Histiostoma*.

† A somewhat similar occurrence has been mentioned by Riley in "Insect Life," vol. II., p. 299.

Forest tent caterpillar, *Clisiocampa disstria.*
Army worm, *Leucania unipuncta.*
Cotton worm, *Aletia argillacea.*
Lime tree winter moth, *Hybernia tiliaria.*
Spring canker worm, *Paleacrita vernata.*
Fall canker worm, *Anisopteryx pometaria.*
Oak Tortricid, *Cacœcia fervidana.*
Rocky Mountain locust, *Caloptenus spretus* (nymphs).

This shows *C. scrutator* to be a very general feeder, and that it is particularly fond of our common injurious lepidopterous larvæ. When kept in confinement at the insectary, single beetles killed on an average about four full-grown gypsy moth caterpillars daily. Out of doors the number killed would be increased, as the appetite of the beetles is greater under natural conditions than when kept in confinement.

Calosoma scrutator is found in Canada and the New England States, but is more locally than generally distributed. It is more common in New York and the Middle States, and occurs throughout the United States. Specimens were found this year in infested woodland in Saugus, and through the efforts of Mr. W. W. Stevens a number was received for rearing purposes. The first beetles were received and placed in breeding jars June 24. They fed readily and mated several times, but only seven eggs were laid during the season, six being laid by one female, June 26, and a single egg being deposited by another female, July 1. It is probable that this species, like the other Calosomas thus far observed, lay the bulk of their eggs earlier in the season, and it may be that the females had nearly finished depositing eggs before being placed in confinement.

A part of the eggs was preserved for further study, those remaining in the jar hatching in eight days; all the larvæ died, however, before molting. This species does not thrive in confinement as well as either *frigidum* or *calidum.* August 9 a coarse wire cage was constructed near the insectary, in which were placed nine females, which went into the ground immediately, without taking food. This cage will be examined in the spring, and notes on the hibernation of the species completed.

Calosoma willcoxi Lec.

This species was first described by Dr. Leconte in 1848. It is smaller than any of our *Calosomas* previously studied, and from its green color might be easily mistaken for a diminutive *scrutator*. The middle tibia of the male, however, is straight and not hairy, while that of the male *C. scrutator* is curved, and has a dense brush of hairs on the inner surface near the tip. It occurs in Canada and the United States and has been reported very abundant in Maryland, but is very rare in this vicinity. Its feeding habits are the same as those of the other members of the genus. Riley * reported it feeding on nymphs of the Rocky Mountain locust, and in Canada it has been found climbing the trees and feeding on canker worms.†

Only one specimen has been under observation this season. On June 9, Mr. C. E. Bailey, an agent of the Board, captured this beetle in Newton and brought it to the insectary in perfect condition, where it was confined in a breeding jar. The following day nine eggs were found about an inch below the surface of the earth; only one hatched, the others probably being infertile. The larva was deformed and very sluggish in movement, taking no food whatever, and died two days after hatching. No more eggs were laid, however, and June 30 the beetle went into the ground, where it remained, and ate nothing, until August 18.

The beetle was supplied with full-grown forest tent caterpillars (*Clisiocampa disstria*) and third and fourth molt gypsy moth larvæ, and consumed on the average about one larva per day. Female beetles, however, never eat as large an amount of food when isolated as when confined with males.

Although *willcoxi* has never been observed feeding on the gypsy moth in the field, from the fact that it occurs in the infested districts and feeds on the larvæ in confinement, it may be safely enumerated as an addition to the list of natural enemies of *P. dispar*.

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* First Report United States Entomological Commission, 1878, p. 314.

† Harrington, Report Entomological Society, Ontario, 1893, p. 24.

Calosoma calidum (Fab.).

On the 23d of May a male and female were placed under observation in a breeding jar, and were noted to pair on each of the three succeeding days. The first eggs were laid May 31; the female died July 24, after having deposited eighty-eight eggs. The larvæ hatched in about a week from the date of oviposition, and were isolated in jars and carefully fed daily. A large proportion reached the third larval stage in a healthy condition. At this time the same difficulty was experienced as last year, viz., the dying of the larvæ without any apparent cause.

Quite a number of the larvæ pupated, however, but on examining the jars a few days later the pupæ were found to be dead, having been attacked by mites.* A full-grown larva of *C. calidum*, which was found July 4, fed a few days and pupated in one of the breeding jars, but shared the same fate as the others.

Pterostichus lucublandus (Say).

This is one of our most common ground beetles, and is often found under stones or running about in the grass during the summer. While the members of this genus are considered to be predaceous on other insects, certain species have been charged with doing some damage by feeding on vegetation. This is probably true to some extent, but when these insects are abundant they doubtless do considerable good by feeding on noxious species.

A pair of *lucublandus* were taken *in coitu* under a large rock, June 2, 1897. They were placed in a breeding jar and fed with gypsy moth caterpillars. The smaller ones were devoured greedily, the larger ones, as a rule, being rejected. On July 4, however, I observed the male beetle attack a fourth molt larva of this species. The caterpillar was grasped just behind the head, and, after a fierce struggle, the beetle succeeded in cutting a hole through the integument and began to feed upon the internal portions with great

* Identified by Mr. Banks as "the nymph of some Oribatid, probably of the genus *Oribata*."

avidity. In addition to gypsy moth larvæ, other small caterpillars were provided, which they ate with apparent relish. A pupa of *Orgyia leucostigma* was also eaten by the beetles. The average consumption equalled about one small gypsy moth caterpillar daily. In killing noxious insects these beetles probably will not be found as helpful as some of the larger species of Carabidæ; although they take most of their food on the ground, they are sometimes taken under burlaps, thus indicating that they may also feed in trees.

On June 9 several eggs were found in the earth, from one-fourth to one inch below the surface. Eggs were also laid as follows: June 10, nine; 11, nine; 18, six; and on the 29th, three, — making a total of over thirty eggs deposited. After the last date no eggs were laid. August 19 the female beetle escaped in some unknown way, and the observations with the adults were discontinued. A few of the eggs hatched, but all the larvæ died before pupating.

Harpalus caliginosus (Fab.).

This beetle has been often observed feeding on injurious insects. Among the common ones which have been most frequently noted in the literature are cut worms, army worms and the Colorado potato beetle in its different stages. Professor Riley * found that large numbers of nymphs of the Rocky Mountain locust were consumed by this beetle, while Dr. Howard † has noted that it feeds on the nymphs of another destructive locust, *Schistocera americana*. It is a fact, however, that the food of this beetle consists partly of vegetable matter. I have several times observed it feeding on the flower heads of *Ambrosia artemisiæfolia*, and it has been accused of eating wheat in the stack. Professor Forbes ‡ has discovered some interesting facts in regard to the food of this species by examining the stomach contents. Two specimens, collected in August and September, respectively, were found to have eaten 35 per cent. of animal mat-

* First Report United States Entomological Commission, 1878, p. 314.

† "Insect Life," Vol. VII., p. 228.

‡ Bulletin Illinois State Laboratory of Natural History, No. 6, 1883, p. 45.

ter, while the remainder was of vegetable origin. Of the animal matter, 20 per cent. could not be identified, 10 per cent. consisted of insect food, caterpillars and Diptera being represented, while the remaining 5 per cent. were mites. The vegetable food consisted chiefly of the tissue of grasses and a little pollen from flowers belonging to the family Compositæ. In addition to the above, the spores of a fungus (*Helminthosporium*) amounted to 3 per cent. This shows conclusively that vegetable food is taken freely during this time of year. The fact that the beetles eat such vegetable matter as pollen, seeds of common weeds and spores of fungi, should be counted in their favor rather than against them; and if they are able to subsist on such food during the season when caterpillars and noxious insects are scarce, it is indeed a wise provision. If, however, subsequent observations and investigations show that they actually feed to any great extent on wheat or other vegetable matter of economic importance, we shall be led to believe that their usefulness has in the past been over-estimated.

September 20 a pair of *H. caliginosus* was received from Mr. F. H. Mosher, an inspector of the Board. They were placed in a breeding jar with a larvæ of *Halesidota maculata* and flower head of ragweed. Another female found near the insectary was placed in the jar three days later. The beetles fed on the weed, eating chiefly the seeds, but did not molest the caterpillars. A pair copulated the following day, remaining *in coitu* about three minutes. They were then isolated, and two days later, September 26, seven eggs were found about three inches below the surface of the ground. Two eggs were deposited the following day, and on October 15, no more having been laid, the beetles were placed in a wire cage near the insectary, to obtain notes on their hibernation. The eggs, which were kept in the insectary, hatched in nineteen days from the date of oviposition. Some of these larvæ have also been placed in an outdoor cage for the winter, and an attempt will be made next year to complete the life history of this species.

THE SPECIES OF PODISUS OCCURRING IN THE UNITED STATES.

BY A. H. KIRKLAND, M.S.

As one of the natural checks upon the undesirable increase of many species of insects, the "soldier bugs" of the genus *Podisus* are of considerable economic importance. Arboreal in habits, almost entirely predatory and requiring daily a considerable amount of fresh food, they exert an influence which may entitle them to rank with the beneficial predaceous insects of any order. When disturbed, these bugs emit a decidedly unpleasant odor, and in their passage over berries sometimes impart to the fruit a most nauseating taste, a habit common to many bugs, and one that has given them a most disreputable popular name. Yet when we consider the fact that throughout the season of their activity these soldier bugs are daily destroying the caterpillars that strip our trees, the slugs that devour our potato vines and numerous other species that prey upon our cultivated crops, the occasional annoyance caused by these insects is of but trifling importance. In our work against the gypsy moth no other predaceous insects have been so commonly noticed destroying the caterpillars, and their attacks upon other injurious larvæ have been a matter of frequent observation. During the past four years, in connection with other work, the writer has had many opportunities to observe the feeding habits of our common species, and has published elsewhere, in detail, the life history of two members of this genus. The literature upon these most interesting insects is found in several languages and in the publications of both hemispheres. As a large part of it is somewhat difficult of access to the general student, it has seemed that a compilation of the known facts

concerning our native species might be of value in facilitating their identification.

The Genus Podisus.

This genus was established by Herrich-Schäffer in 1853 ("Wanzenartigen Insecten," Vol. IX., p. 296), to include a number of species having their fore femora unarmed, which, aside from this character, would properly fall into the genus *Canthecona*. At this time he described several species from Brazil, and in the list given in his "Index Hemipterorum Heteropterorum," published during the same year, enumerates some ten species of *Podisus*, among which is *P. luridus* Fab., which had formerly been placed in the genera *Pentatoma* and *Arma*. No type of the genus is designated by Herrich-Schäffer, but as *P. luridus* * is its sole European representative, and was included by him in the genus at the time of its establishment, this species may be properly taken as the generic type. The presence of the ventral spine excludes the species of *Podisus* from the genus *Arma*, under which several were originally described. Stål erected the genus *Telepta* in 1858 ("Bidr. Rio Jan. Hemip.," p. 10) but later transferred the species therein included to *Podisus* ("Enum. Hemip.," 1870, p. 48). In the latter work, *loc. cit.*, he divided the many species of the genus *Podisus* among the sub-genera *Troilus* Stål, *Apateticus* Dall., *Apœcilus* Stål, *Podisus* H. S. and *Tylospilus* Stål, his genus *Telepta* being given as a synonym of the sub-genus *Podisus*.

The genus *Podisus* may be characterized as follows: —

Head nearly quadrangular; basal segment of antenna stout, not reaching to the anterior margin of the head; rostrum stout. Scutellum triangular, extending but little beyond the middle of the abdomen, the apex reaching to or upon the membrane of the wing. Fore femora unarmed; fore tibiæ not dilated. Second abdominal segment with a spine of variable length extending anteriorly.

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* Professor Fernald has kindly given me a pair of *P. luridus*. This species is of about the same size as *P. spinosus*, but differs from any of the representatives of the genus in the United States in that the humeral angles are very prominent and rounded, almost lobate.

A large genus, represented by many species from North, Central and South America, the Antilles and by a single species from Europe and Asia.

Habits.

Before presenting generalities concerning the habits of our native species, it will be proper to say that the statements are based upon a general knowledge of the life histories of *P. serieventris*, *P. placidus*, *P. modestus* and *P. cynicus*. A more intimate knowledge of the early stages of all the species may lead to some changes in the statements here given. It may be remarked that apparently but little attention has been given by entomologists to the rearing of these predaceous insects, probably on account of the difficulty in supplying the young bugs with the fresh food they daily require.

The insects emerge from their hibernating quarters in the spring, at about the time the foliage appears. After feeding for a week or more upon the most abundant caterpillars, the eggs are laid on leaves or branches of trees. The young bugs hatch in the course of a week or two, molt four times, reach the imago state by midsummer, and lay eggs for a second brood, which matures early in the fall. In passing from the last nymph stage to that of the imago the number of joints of the tarsi and the antennæ is increased by one. In the case of the larger species, such as *P. cynicus*, there seems to be but one brood yearly in this latitude. Farther south the number of annual broods may be greater. Both sexes hibernate under leaves on the ground, under the bark of trees or in other sheltered places. The life of the female imagoes in captivity ends soon after the eggs have been deposited.

It has been stated, as a general rule, that the group of insects to which these bugs belong "will bear watching" so far as feeding habits are concerned. Many feed on plants, often to an injurious extent; some are entirely predaceous; while others feed on both plants and insects. The species of *Podisus* whose habits have been recorded feed upon insects almost entirely, and are very beneficial. It should be admitted that Dr. Fitch (Third Report Insects of New York,

1856, pp. 335, 336) includes *P. cynicus* and *P. spinosus* among the insects that attack the limbs of the apple, — a statement that Dr. Lintner (First Report Insects of New York, 1882, p. 331) very properly questions. It is equally doubtful if *P. modestus* attacks the grape vine, as stated by Fitch (*op. cit.*, p. 390); and it would seem possible that the statements of Glover and Saunders in regard to the attacks on plants by some of the above-mentioned species rest on Dr. Fitch's authority, and not on personal observations. Nearly two hundred specimens of our common species of *Podisus* have been collected by the writer and his assistants during the past four years, and in no case have any of these insects been found feeding on plants. When confined *P. serieventris* has been known to puncture the leaves of oak ("The Gypsy Moth," Forbush-Fernald, 1896, p. 402), a performance that has been observed but once. It should, however, be stated that a large part of the normal food of the newly hatched bugs seems to be the sap contained in leaves. So far as our observations extend, the nymphs after molting once are entirely predaceous.

Beneficial insects are so worthy of attention and praise that one may easily dilate upon their good qualities and overlook the harm they do. To state the case fairly with the genus *Podisus*, it will be proper to say that some of the species may occasionally devour a coccinellid beetle or other beneficial insect. Walsh has recorded a single case of the kind ("American Entomologist," 1868, p. 13). If this habit is a common one, we should probably have more records of it. The worst point that the writer has observed in the habits of the species is that when the food supply runs short they will devour each other ("The Gypsy Moth," p. 402). A glance over the list of insects each species is known to destroy will show which way the balance swings. The following table will aid in the separation of the species occurring in the United States: —

SYNOPSIS OF THE SPECIES.*

1.	Membrane with a distinct dark spot at tip,	2.
	Membrane without a dark spot,	5.
2.	Scutellum with a dark V-shaped spot,	*acutissimus.*
	Scutellum without such spot,	3.
3.	Humeral angles produced into slender spines,	*spinosus.*
	Humeral angles acute but not spinose,	4.
4.	Ventral spine very short, not reaching hind coxæ,	*modestus.*
	Ventral spine reaching to or upon hind coxæ,	*serieventris.*
5.	Lateral lobes of head longer than tylus (median lobe),	6.
	Lateral lobes of head not longer than tylus,	8.
6.	Humeral angles produced into stout spines,	*cynicus.*
	Humeral angles not spinose,	7.
7.	Humeral angles rounded, ventral spine very short,	*gillettei.*
	Humeral angles nearly right-angled, ventral spine long,	*crocatus.*
8.	Humeral angles spinose, curved toward head,	*mucronatus.*
	Humeral angles blunt and rounded,	*placidus.*

PODISUS PLACIDUS Uhler. (Plate 1, fig. 1.)

1869, (?) *Stiretrus fimbriatus* Saunders, Can. Ent., vol. II, p. 15.†
1870, *Podisus placidus* Uhler, Amer. Ent., vol. II., p. 203.
1870, *Arma placidum* Saunders, Can. Ent., vol. II., pp. 93, 94.
1872, *Podisus placidus* Lintner, Ent. Contrib., I., p. 150.
1872, *Podisus placidus* Saunders, Rep. Ent. Soc. Ont., p. 31.
1877, *Podisus placidus* Riley, 9th Rep. Ins. Mo., p. 17.
1889, *Podisus placidus* Saunders, Ins. Inj. to Fruits, p. 342.
1895, *Podisus placidus* Gillette-Baker, Bull. 31, Col. Agrl. Expt. Station, Hemipt. Col., p. 13.
1897, *Podisus placidus* Kirkland, Rep. Mass State Bd. Agr., pp. 399-404.
1897, *Podisus placidus* Uhler, *ibid.*, p. 403.
1897, *Podisus placidus* Kirkland, Can. Ent, vol. XXIX., p 115.
1897, *Podisus placidus* Uhler, *ibid.*, p. 116.

Length: male, 9 mm.; female, 10 mm. Body ovate, yellowish brown; ground color creamy yellow, punctate with brick red. Head but little longer than wide, lateral margins dark brown; lateral lobes not longer than tylus, usually a little shorter; tylus punctate laterally, nearly bare in the middle. First segment of antennæ short, yellowish, darker outwardly; second segment

* *Podisus politus* Uhler (Ms.) of Uhler's check list (1886) has been suppressed as a name for a North American species (Uhler in litt.).

† The bibliography given for each species contains only such references as the writer has been able to verify personally.

slender, about three times as long as first; third segment but little more than one-half as long as second; fourth segment two-thirds as long as second; fifth segment a little shorter than fourth, dilated; all segments, except first, pale brownish, lighter at their outer ends. Rostrum pale yellow except at tip, reaching upon hind coxæ; second segment longest, passing front coxæ; third and fourth segments of nearly equal length, the latter brown. Pronotum sparsely punctate before, densely behind, the humeral angles; its anterior margin ivory yellow, bordered posteriorly with a double row of punctures; across the surface there are several transverse irregular wrinkles; sides oblique, straight or but slightly indented, with very minute teeth anteriorly. A pale callous line extends from the middle of the anterior margin to the tip of the scutellum. Post-humeral margins slightly sinuate, posterior margin bordered with an ivory-yellow line. Scutellum reaching to the membrane, sinuate behind the middle, where it is more densely punctate than elsewhere; tip white. Embolium and corium, except at base, densely punctate; clavus and base of corium sparsely punctate; a brownish callous spot occurs near the outer end of the corium; membrane pale bronze, translucent. Connexivum pale yellowish with faint black markings at incisures. Under-surface sulphur yellow with minute black markings laterally in some specimens. Ventral spine reaching the hind coxæ, ivory yellow. Legs rufous; tarsi brown. A black dot occurs at the tip of the osteolar canal and another in front of each eye.

Habits.

The life history of this species has been detailed in the last annual report of this committee. Briefly stated, the imagoes hibernate and appear early in the spring. They attack the larvæ of *Clisiocampa americana* Harr., and after feeding for about a fortnight upon these and other insects, lay their eggs on the under sides of leaves or on twigs. From fifty to sixty eggs are laid by a single female. The eggs hatch in about ten days, and the red and black nymphs feed on the juices of the leaves for about a week, when the first molting takes place. From this time on the insects are predaceous. The second and third molts take place in twelve and ten days respectively; in the last nymph stage the head, thorax and wing-pads are intense pitchy black, the abdomen dark red, margined with a series of black spots, one on each segment. On the dorsum there are four black

spots placed in a longitudinal row. The last molt takes place in about three weeks.

The imagoes of the summer brood appear during July and those of the fall brood in September. While feeding upon the tent caterpillars in the spring this bug is frequently devoured by two spiders, *Epeira strix* and *Phidippus multiformis*, which are common occupants of the caterpillar webs.

The list of insects *P. placidus* is known to destroy includes *Pteronus ribesii* Scop. (Saunders, Can. Ent., 1870, pp. 93, 94), *Euvanessa antiopa* Linn., *Hyphantria cunea* Drury, *Orgyia leucostigma* S. and A., *O. definita* Pack., *Porthetria dispar* Linn., *Clisiocampa americana* Harr., *C. disstria* Hbn. (Kirkland, Report Massachusetts State Board Agriculture for 1896, p. 404.)

Distribution. — Canada, Massachusetts, New York,* Michigan,† Colorado.

Podisus gillettei Uhler. (Plate 1, fig. 6.)

1895, *Podisus gillettei* Uhler, Gillette-Baker, Bull. 31, Col. Agrl. Expt. Station, Hemip. Col., pp. 12, 13.

Prof. C. P. Gillette has been so kind as to send me the type and only known specimen of this beautiful species. Its prominent characters are: —

Length, 14 mm. Body ovate, like *P. placidus*, but much larger. Upper-surface dull olive colored, punctate with black. Head quadrangular, lateral lobes longer than tylus, but not as long as in *P. cynicus*. The sides of the tylus are margined anteriorly with yellowish. The entire upper surface of the head, aside from the preceding, is heavily punctate with black. First segment of antennæ not extending beyond lateral margin of head, yellowish; second segment hardly longer than head, testaceous; third segment two-thirds as long as second; fourth and fifth segments of nearly equal length, each about three-fourths as long as second, and, in common with the third segment, black except at base, which is yellowish. Rostrum of medium size, not as short as in *P. cynicus*, reaching upon middle coxæ. Second segment of rostrum reaching on the fore coxæ; third and fourth segments of nearly equal length; fourth segment piceous.

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* Specimen in Dr. Lintner's collection, labelled "Keene Valley, N. Y., July 4, 1890."

† Specimen in Museum of Comparative Zoölogy collection, labelled "Mich."

Pronotal margins very oblique, with finely incised edges anteriorly, with a broad ivory-yellow band, which diminishes at the humeral angles, which are very obtuse and rounded. The black puncturing on the anterior part of the pronotum is very dense; that on the posterior part less dense, arranged in irregular transverse lines. Scutellum but slightly sinuate, most densely punctured at base, and with a small callous spot in each basal angle. A fine callous line extends longitudinally through the pronotum and scutellum. Corium densely punctate; membrane bronzed, without apical spot. Connexivum ivory yellow, with faint black markings interiorly at segmental sutures. These markings do not reach the lateral edge of abdomen. Under-surface pale yellowish brown, punctate with darker brown. Abdominal spine very short, nearly obsolete. Legs of same color as under-surface, darkening on tibiæ to brown. Tarsi dark brown, hairy.

The stout rostrum indicates that this species has predaceous habits.

Podisus modestus (Dallas). (Plate 1, fig. 9.)

1851, *Arma modesta* Dallas, List, part I., pp. 101, 102.
1856, *Arma modesta* Fitch, 3d Rep. Ins. N. Y., p. 390.
1869, *Arma modesta* Walsh, Can. Ent., vol. II., p. 33.
1870, *Podisus modestus* Stål, Enum. Hemipt., part I., p. 51.
1872, *Arma modesta* Lintner, Ent. Contrib., I., p. 150.
1873, *Arma modesta* Riley, 5th Rep. Ins. Mo., p. 133.
1875, *Podisus modestus* Uhler, Bull. 5, vol. I., U. S. Geol. Surv. Terr., p. 283.
1876, *Podisus modestus* Glover, Manuscript Notes Hemipt. Het., p. 60.
1880, *Podisus modestus* Distant, Biol. Cent. Am. Rhync., vol. I., pp. 38, 39, pl. IV., fig. 4.
1884, *Podisus modestus* Fletcher, Can. Ent., vol. XVI., p. 215.
1885, *Podisus modestus* Fletcher, Rep. Ent. Soc. Ont., pp. 22, 77.
1889, *Podisus modestus* Lintner, 5th Rep. Ins. N. Y., p. 170.
1889, *Arma modesta* Saunders, Ins. Inj. to Fruits, p. 290.
1890, *Podisus modestus* Lintner, 6th Rep. Ins. N. Y., p. 189.
1890, *Arma modesta* Packard, 5th Rep. U. S. Ent. Com., p. 164.
1891, *Podisus modestus* Lintner, 7th Rep. Ins. N. Y., p. 353.
1892, *Podisus modestus* Riley-Howard, Insect Life, vol. IV., p. 123.
1895, *Podisus modestus* Gillette-Baker, Bull. 31, Col. Agrl. Expt. Station, Hemip. Col., p. 13.
1897, *Podisus modestus* Kirkland, Can. Ent., vol. XXIX., p. 115.

Length: male, 9.5 mm.; female, 10.5 mm. One of the smallest of our native species. Upper-surface densely and evenly punctate

with light brick red. Head much longer than wide, nearly truncate in front. The lateral lobes in a few specimens I have examined are a trifle longer than the tylus, but this seems to be an exception; outer margin of lateral lobes embrowned. Eyes very dark brown; ocelli minute, near occiput. First segment of antennæ very short, hardly reaching lateral margin of head; second segment slender, relatively short, but little over three times as long as first; third segment about three-fourths as long as second; fourth segment nearly as long as second; fifth segment longer than third, but a little shorter than fourth; all joints reddish or pale brown. Rostrum stout, reaching upon, sometimes to, posterior margin of hind coxæ; second segment the longest, third and fourth of equal length, the latter dark reddish brown. Pronotum deeply indented at the sides, margined with a fine yellowish white line, within which the puncturing is densely massed; anteriorly on the lateral margins there are several minute teeth; pronotal callosities obscure, thickly punctate outwardly. At the humeral angles the punctures are massed into a reddish spot, the angles being acute but not spinose. Scutellum sinuate, bare at apex, which reaches to the membrane; in nearly all specimens examined there is a minute bald spot at each basal angle of scutellum. Corium and embolium tinged with scarlet at their junction with membrane, which is bronzed and bears a dark-green marking at the tip. Under-surface pale yellowish, punctate with red, and bearing a row of four minute dots on the median line and two rows of similar dots laterally. Ventral spine very short, not reaching hind coxæ. Legs rufous.

Distribution. — Canada, Maine, Massachusetts, New York, Illinois, Georgia, Dakota, Nebraska, Colorado, Mexico.

The only species resembling *P. modestus* is the light variety of *P. serieventris*, which sometimes approaches the darker forms of the former species. The deeply sinuate humeral angles, the red marking at the tip of the corium, the light-colored tergum, the short ventral spine and short second segment of antennæ, — are characteristic of *modestus*, and will serve to distinguish it.

Habits.

This species is very common in May, feeding on tent caterpillars (*Clisiocampa americana* Harr.). At the Museum of Comparative Zoölogy, Cambridge, there are several specimens which were found under leaves by Mr. Jacob Boll in

the winter of 1872–73, thus proving that the insect hibernates as an imago. Different stages of the nymphs have been reared to imagoes at the insectary of the gypsy moth committee; but, owing to the amount of work involved, we have made no attempt to carefully follow the entire round of life, which apparently does not vary materially from that of *serieventris*. The imagoes are abundant in the spring, again in midsummer and also in September and October, and there can be no doubt that the species is here double-brooded. *P. modestus* is less common than *serieventris* or *placidus*, and, so far as my experience goes, is more frequently found on bushes and low-growing plants than on trees. In feeding habits it shows the same voracity as *serieventris*, and preys upon larvæ of all sizes. It has been recorded as destroying *Haltica bimarginata* Say (Lintner, Fifth Rep. Ins. N. Y., 1889, p. 170), *Haltica chalybea* Ill. (Lintner, Sixth Rep. Ins. N. Y., 1890, p. 189), *Hemileuca maia* Drury (Lintner, Ent. Contrib., I., 1872, p. 150), *Clisiocampa americana* Harr. (Kirkland, Can. Ent., 1897, p. 115), *Lygæonematus erichsonii* Hartig (Fletcher, Can. Ent., 1884, p. 215). In Professor Fernald's collection there is a specimen of *P. modestus* taken feeding on a leaf hopper at Amherst, Mass., May 28, 1890.

In September, 1896, Mr. Robert Cooley took a nymph of this bug at Brewster, Mass., feeding on the pupæ of the "yellow-headed fire worm," *Teras minuta*. The imago developed September 20. The writer has found *modestus* feeding on gypsy moth larvæ during the past summer at Saugus, Mass. A minute hymenopterous parasite, *Telenomus podisi* Ashm., has been reared from the eggs of this bug ("Insect Life," IV., p. 123, 1892).

Podisus pallens (Stål).

1859, *Arma pallens* Stål, Freg. Eug. Resa, p. 222.
1870, *Podisus pallens* Stål, Enum. Hemipt., part I, p. 51.
1875, *Podisus pallens* Uhler, Bull. 5, vol. I, U. S. Geol. Surv. Terr., p. 282.

Stål's description of this species may be translated as follows: —

Whitish yellow, somewhat punctate with brownish dots, more finely and less densely (punctate) beneath; antennæ darker towards the apex; posterior angles of thorax produced, subacute; scutellum not punctate at the lowest part of the apex; abdomen with each segment margined with a minute spot above and below at base and at apex, and with spots placed in series on both sides; femora tawny, with an apical dot.

I have been unable to obtain an example of this species and have not included it in the synopsis. The insufficiency of the original description was long ago pointed out by Professor Uhler in the following words: "The small differences in the lateral angles of the pronotum and in puncturing do not seem to me suffiicent to separate this from *P. modestus*."

The specimens from which the original description was prepared were collected in California.

Podisus crocatus Uhler. (Plate 1, fig. 3.)

1878, *Podisus cynicus*, var. *obscuripes* (Uhl. Ms.) Riley, Rept. U. S. Dept. Agr., p. 245.

1884, *Podisus* * *crocatus* (Uhl. Ms.) Hagen, Can. Ent., vol. XVI., p. 40.

1897, *Podisus crocatus* Uhler, Trans. Md. Acad. Sc., pp. 384-386.

Through the kindness of Mr. Samuel Henshaw I have had the privilege of examining several representatives of this species at the Museum of Comparative Zoölogy, Cambridge, Mass. Professor Uhler has also kindly given me a specimen from Vancouver Island. I have nothing to add to Professor Uhler's excellent description of the species. Its prominent characteristics are: —

Length, 15 mm. Body robust, reddish yellow, heavily marked with dark-green punctures. Lateral lobes of head longer than tylus, and bordered outwardly with a fine dark-green line. First segment of antennæ stout, reaching about three-fourths the distance between eye and anterior margin; second segment about three times as long as first; third segment two-thirds as long as second; fourth segment one-third longer than third; fifth segment a trifle longer than third. Rostrum stout, reaching to hind coxæ; first segment thick; second segment but little longer than first;

* Misprinted "Podiscus."

third and fourth segments each nearly as long as first. Sides of pronotum coarsely serrate anteriorly; humeral angles nearly right angled, dark green. Scutellum punctate with dark green, reaching to the membrane. Corium of same color as scutellum; membrane bronze brown, extending beyond tip of abdomen. Connexivum orange, marked with dark green at the incisures. Under-side yellowish, punctate with brick red laterally. Legs amber colored, darkening toward the tarsi. Ventral spine stout, nearly passing the hind coxæ.

In size this species resembles *P. cynicus*, from which it may be distinguished by its orange-colored body with dark-green markings, and humeral angles which are not as acute as in that species.

Distribution. — Vancouver Island, Washington, Oregon, California.

Habits.

In July, 1882, Mr. Samuel Henshaw collected a number of imagoes of this species and three nymphs near Loon Lake, Washington. These insects were feeding on the larvæ of *Neophasia menapia* Feld. Aside from a darker coloration, the nymphs bear a striking resemblance to those of *P. cynicus*. Being certainly an immature stage of a large *Podisus*, taken at the same time and place with the imagoes of *P. crocatus*, there can be but little doubt that they are the nymphs of this species, and may be described as follows: —

Podisus crocatus (?) nymph.

Length, 11 to 14 mm. Body compact, very stout, widest at middle of abdomen. Head and thorax heavily marked with dark bronze green. Abdomen thickly covered with scarlet dots. Head distinctly emarginate in front, edges at least bordered with dark green; a scarlet line extends along the inner margin of the lateral lobes, and also on median line from between the eyes backward to pronotum. First segment of antennæ stout, slightly projecting beyond the lateral margin of the head; second segment nearly as long as third and fourth taken together, these latter being of nearly equal length; all segments dark bronze green. Rostrum very stout, extending to middle coxæ; tip dark brown, horny. Edges of prothorax, scutellum and wing-pads heavily bordered with dark green. Irregular scarlet markings occur on either side of the dorsal groove of the prothorax, on the scutellum and on the wing-

pads; the extent of these markings varies inversely with that of the green ones. One specimen has no red on the scutellum or wing-pads, and but two small spots on the prothorax; while on the other specimens the red predominates. On the dorsum of the abdomen there is a longitudinal row of four transverse dark-green spots, while around the margin at the middle of each segment there is a semi-elliptical spot of dark green; included in each of these marginal spots is a much smaller spot of similar shape, pale buff in color. Under-side pale buff, dotted with scarlet. Femora and tibiæ reddish brown; tarsi dark green.

In a note on the enemies of *Neophasia menapia*, Hagen has written: "*Podisus crocatus* Uhl. (Ms.) is a very eager enemy of the pupa and the caterpillar before pupating, when it is very sluggish. The *P. crocatus* was everywhere common in the devastated forests, and observed in the act of sucking caterpillars" (Can. Ent., XVI., p. 40).

The above, and Riley's record of this species * feeding on *Diapheromera femorata* Say, are the only references to the habits of this insect I have been able to find.

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* Given as *P. cynicus* var. *obscuripes*, which name Professor Uhler writes me he has rejected in favor of *P. crocatus*.

Podisus cynicus (Say). (Plate 1, fig. 7.)

1831, *Pentatoma cynica* Say, Descr. New. Sp. Het. Hemip. of N. A., p. 3, New. Harm., Ind.*
1851, *Arma grandis* Dallas, List, part I., pp. 96, 97.
1856, *Arma grandis* Fitch, 3d Rep. Ins. N. Y., p. 335, pl. 2, fig. 7.
1856, *Arma bracteata*, Fitch, *ibid.*, p. 336.
1857, *Pentatoma cynica* Fitch, 4th Rep. Ins. N. Y., p. 757 (reprint of Say's description).
1859, *Pentatoma cynica* Say, Compl. Writ., vol. I., p. 312.
1867, *Podisus grandis* Stål, Öfvers. Vet. Ak. Förh., p. 497.
1870, *Podisus grandis* Stål, Enum. Hemipt., part I., p. 49.
1870, *Podisus bracteatus* Stål, *ibid.*, p. 54.
1870, *Podisus cynicus* Stål, *ibid.*, p. 54.
1874, *Arma grandis* Glover, Rep. U. S. Dep. Agr., p. 123.
1875, *Podisus cynicus* Glover, Rep. U. S. Dep. Agr , p. 118, fig. 8.
1875, *Podisus cynicus* Uhler, Bull. 5, vol. I., U. S. Geol. Surv. Terr., p. 282.
1876, *Podisus cynicus* Glover, Manuscript Notes Hemip. Het., p. 59, pl. II., fig. 29.
1876, *Arma bracteata* Glover, *ibid.*, p. 60.
1876, *Podisus cynicus* Uhler, Proc. Bost. Soc. Nat. Hist., p. 370.
1877, *Podisus cynicus* Glover, Entomological Index, pp. 8, 58.
1878, *Podisus cynicus* Riley, Rep. U. S. Dep. Agr., p. 245.
1878, *Podisus cynicus* Uhler, Bull. 2, vol. IV., U. S. Geol. Surv. Terr., p 504.
1882, *Podisus cynicus* Lintner, 1st Rep. Ins. N. Y., p. 331.
1884, *Podisus bracteatus* Lintner, Can. Ent., vol. XVI., p. 182.
1884, *Podisus cynicus* Lintner, *ibid.*
1884, *Podisus cynicus* Uhler, Standard Nat. Hist., pp. 291, 292.
1885, *Podisus cynicus* Lintner, Rep. Ent. Soc. Ont., p. 13.
1885, *Podisus cynicus* Riley, 4th Rep. U. S. Ent. Com., p. 97.
1890, *Podisus bracteatus* Cockerell, Can. Ent., vol. XXII., p. 59.
1890, *Podisus cynicus* Lintner, Pop. Gardening, p. 198.
1891, *Podisus cynicus* Lintner, 7th Rep. Ins. N. Y., p. 356
1894, *Podisus cynicus* Fernald, Rep. Mass. State Bd. Agr., p. 260.
1895, *Podisus cynicus* Gillette-Baker, Bull. 31, Col. Agrl. Expt. Station, Hemip. Col., p. 12.
1895, *Podisus bracteatus* Gillette-Baker, *ibid.*
1896, *Podisus cynicus* Kirkland, The Gypsy Moth, Forbush-Fernald, pp. 392, 394, 402.
1897, *Podisus cynicus* Kirkland, Can. Ent., vol. XXIX., p. 115.

Length: male, 14.6 mm. to 17.8 mm.; female, 15 mm. to 18.8 mm. Tawny yellow, punctured with brick red or reddish-brown dots. Head longer than wide; lateral lobes longer than

* This rare pamphlet is in the library of the Boston Society of Natural History.

tylus. Eyes dark brown; ocelli vermilion, in rear of eyes, nearer median line. First segment of antennæ stout, extending about three-fourths of the distance between the eye and anterior margin of head; second segment a little more than three times as long as first; third segment two-thirds as long as second; fourth segment a trifle longer than third; fifth segment of about the same length as fourth. Rostrum very stout, reaching to hind coxæ; first segment wide and thick; second segment one-third longer than first, enlarging at its junction with third segment, which is of about the same length as first; fourth segment a little shorter than third, terminating in a blunt brown point. Pronotum and scutellum of same color as head. Sides of pronotum sinuate, with fine granular teeth anteriorly; humeral angles produced into stout acute spines. The callous spots on the anterior part of pronotum bear one or more small green markings; in some specimens there are small spots of this color at the anterior angles of the pronotum and at the inner ends of the callous spots. Scutellum sinuate behind its middle, reaching slightly upon the membrane. Corium of same color as scutellum; membrane bronze brown, extending beyond tip of abdomen. Connexivum orange, marked with black at the incisures. Under-surface pale yellow, dotted more or less with red. Legs of same color as under-surface, darkening slightly in some specimens towards the tarsi. Ventral spine very stout, reaching to middle coxæ.

Distribution. — Massachusetts, New York, Pennsylvania, Maryland, Illinois, Wisconsin, Dakota, Nebraska, Missouri, Colorado, Arizona.

Podisus bracteatus, as described by Fitch, differs from *cynicus* only in certain small green markings on the pronotum, scutellum and wing-covers. In our collection there is a series of thirty-seven specimens which shows nearly all the variations between the two species as described. Being unable to distinguish between the species, I tried to obtain specimens of *bracteatus* from several sources, but was unable to do so. In this difficulty I wrote to Professor Uhler, and found that he also was not familiar with this species. Since that time he has very kindly gone to the trouble to examine the specimen of *bracteatus* in the Fitch collection at the National Museum, and has decided that it is but a variety of Say's *cynicus*. Glover in 1876 expressed the opinion that *bracteatus* was but a variety of *cynicus* (Manuscript Notes

Hemip. Het., p. 60), an opinion also held by Dr. Lintner (Report Entomological Society, Ontario, 1885, p. 13), but which appears to have been overlooked by later writers.

Aside from the variations in the green markings on the thorax previously referred to, the color of the punctures on the upper-surface ranges from brick red to dark brown. The only aberrations in form that I have seen are two specimens, one of which has both humeral angles blunted off and actually *emarginate*, the other having the right humeral angle normal, the left being rounded. Both these insects were bred from nymphs, and their peculiarities of structure may be due to defective nutrition or to some accident at the time of the last molt, while the body was still soft.

Habits.

The imagoes of this species hibernate under leaves. At the Museum of Comparative Zoölogy, Cambridge, there are several specimens collected by Mr. Boll during the winter of 1872–73. These were sifted out from a quantity of leaves raked from the ground. The eggs and early nymph stages are unknown to the writer. Nymphs in the last stage have been taken frequently during June, July and August, and are known to feed on the larvæ of the gypsy moth. They may be described as follows: —

Podisus cynicus nymph.

Length, 10 mm.; greatest width, 8 mm. Body compact, somewhat elliptical in outline; head deeply inserted in the thorax. Posterior angles of thorax produced for a short distance along the sides of the abdomen. General color of head and thorax pale yellowish brown, sometimes marked with red. A fine dark seal-brown line extends around the margin of the head, thorax and wing-pads, and borders the tylus. From near the middle of the inner margin of each wing-pad a fine dark-brown line extends obliquely outward and backward to the outer margin, enclosing a somewhat diamond-shaped area, and marking the anterior margin of the future wing membrane. The median sulcus of the prothorax and scutellum is bordered with dark brown, and the surface of the thorax is finely punctured with faint brown dots. On either side of the dorsal sulcus of the prothorax there is a short, irregular, transverse black line, extending obliquely backward

toward the lateral margin. Abdomen brick red, bordered with heavy black line. At the middle of the lateral margin of each segment there is a well-defined semi-elliptical yellowish-brown spot, bordered with black. There are four more or less confluent, transverse dark-brown spots on the dorsum. Under-surface of head and thorax amber colored; color of abdomen somewhat lighter than that of the upper-surface. Antennæ four-jointed, black; first segment stout, partially retracted beneath the edge of the head; second segment slightly flattened, widened toward its outer end and four times as long as the first; third and fourth segments of nearly equal length, the latter being constricted at each end. Femora amber colored; tibiæ with three equidistant longitudinal ridges, pale brown and sparsely hairy; tarsi two-jointed, dark brown and hairy.

From the late appearance of the nymphs, it is probable that the species has but one annual brood in this region. Both nymphs and imagoes are rapacious feeders, their stout beak being a very formidable weapon. The insect attacked is impaled by a sudden thrust of the setæ, which hold it firmly, and in a few minutes the body fluids are sucked out. In killing large insects the setæ are sometimes wrested from the rostrum, but are readily replaced by the bug. The setæ can be moved by muscles at their base independent of the rostrum, and are armed with formidable reflexed spines.

The records of insects destroyed by this species include *Diapheromera femorata* Say (Riley, Rep. U. S. Dep. Agr., 1878, p. 245), *Podisus serieventris* Uhl. (Kirkland, "The Gypsy Moth," Forbush-Fernald, 1896, p. 402), *Doryphora decem-lineata* Say (Glover, Ent. Index, 1877, p. 8), *Porthetria dispar* Linn. (Fernald, Rep. Mass. State Bd. Agr., 1894, p. 260), *Aletia argillacea* Hbn. (Riley, Fourth Rep. U. S. Ent. Com., 1885, p. 97), *Pteronus ribesii* Scop. (Lintner, Can. Ent., 1884, p. 182).

Podisus serieventris Uhler. (Plate 1, fig. 2.)

1870, *Podisus serieventris* Uhler, Proc. Bost. Soc. Nat. Hist., p. 94.
1876, *Podisus serieventris* Uhler, Proc. Bost. Soc. Nat. Hist., p. 370.
1892, *Podisus spinosus* Fernald, Rep. Mass. State Bd. Agr., p. 298.
1892, *Podisus spinosus* Fernald, Bull. 19, Mass. Hatch Expt. Station, p. 116.
1892, *Podisus spinosus* Riley-Howard, Insect Life, vol. IV., p. 354.
1894, *Podisus serieventris* Fernald, Rep. Mass. State Bd. Agr., p. 260.
1895, *Podisus serieventris* Gillette-Baker, Bull. 31, Col. Agrl. Expt. Station, Hemipt. Col., p. 13.
1896, *Podisus serieventris* Kirkland, The Gypsy Moth, Forbush-Fernald, pp. 393–403.
1897, *Podisus serieventris* Kirkland, Can. Ent., vol. XXIX., p. 115.

Length: male, 10–11 mm.; female, 11–12 mm. Upper-surface pale yellowish, heavily punctate with dark brown. Head truncate anteriorly, densely punctate on its anterior part. Eyes dark brown; ocelli minute, reddish, in rear of eyes. First segment of antennæ short, blackish outwardly, scarcely projecting beyond the lateral margin of head; second segment spread over with black, slender, dilated at apex, about four times as long as first; third segment a little over half as long as second; fourth segment two-thirds as long as second, and with the third generally spread over with black; fifth segment a little longer than fourth, reddish brown. Rostrum of medium thickness, reaching to hind coxæ; the first, third and fourth segments of nearly equal length, the second the longest, reaching to posterior margin of fore coxæ. Pronotum finely toothed anteriorly, indented laterally, but not as much as in *modestus*. The punctures are massed at the anterior and humeral angles into four blackish spots. Humeral angles acute, but not spinose, often slightly curved backward; on the pronotum of many specimens there are fine transverse wrinkles. Scutellum of same color as pronotum, less densely punctate at tip, which is sometimes whitish; at the basal angles in some specimens there is a small bald whitish spot. Corium more densely punctate than embolium; membrane bronzed, with a dark spot at the tip. Under-surface pale yellowish, marked and clouded with darker shades and sparingly punctate with reddish; on the middle of the last segment there is a round or oval black spot, above which in a longitudinal row there are often three minute black spots; laterally there are two rows of small black spots, occurring as follows: one on the middle of each segment, near connexivum, and one on the anterior margin of the third to

sixth segments inclusive, this latter row being equidistant between the ventral row and the connexivum; there is a large black dot at the tip of the osteolar canal and a smaller one on the pleuræ above each of the coxæ. Legs rufous; femora with two or three black dots near apex. Ventral spine ivory white, reaching upon the hind coxæ.

Distribution. — Maine, Massachusetts, New York,* New Jersey,† Minnesota, Colorado.

Habits.

Perhaps on account of its obscure coloring and active flight this species may be better protected from bird enemies than its congeners. Be that as it may, *serieventris* in this region is by far the most common representative of the genus. Hibernating as imagoes, the insects appear early in the spring, sometimes in April, and by the latter part of May an inspection of the webs of the tent caterpillar will show numbers of these bugs breaking their winter's fast upon the inmates of these webs. After a week or more spent in feeding, mating occurs,‡ and in a few days the female deposits her eggs in two or three clusters on the under-sides of leaves or on small branches. From fifty to sixty caldron-shaped eggs are laid by each female, and in about eight or ten days' time the gaily colored nymphs emerge from the egg-shells and commence feeding on the sap of leaves. If weather conditions are favorable, the first molt takes place in four or five days, and the nymphs wander forth in search of insects. These tiny creatures, not over 4 mm. in length, will destroy caterpillars many times larger than themselves. The second molting occurs about ten days after the first, and the third about six days later than the second. The red and black nymphs feed almost continually during this stage, and boldly attack the largest larvæ. From twelve to seventeen days elapse before the last molt. By midsummer the eggs for a second brood are laid, the imagoes of which appear in August and September. In 1895 the data concerning the times at which the imagoes and nymphs

* In Dr. Lintner's collection.

† Specimens from Prof. J. B. Smith.

‡ These insects frequently mate in the fall ("The Gypsy Moth," p. 403).

appeared seemed to indicate the occurrence of three annual broods. There are certainly two broods each year in this region. The time at which different individuals of this species appear varies to such a degree that imagoes may be taken during every month from April to October, and only by rearing can we get at the actual number of broods. As recorded elsewhere, the writer has reared two broods between the latter part of June and the last of September.

This species is known to feed upon the following larvæ: *Porthetria dispar* Linn. (Fernald, Rep. Mass. St. Bd. Agr., 1892, p. 298), *Euvanessa antiopa* Linn., *Hyphantria cunea* Drury, *Attacus promethea* Drury, *Clisiocampa americana* Harr., *C. disstria* Hbn., *Paleacrita vernata* Pack.; in confinement we have reared it upon *Cimbex americana* Leach, *Datana ministra* Drury, *Attacus cecropia* Linn., *Telea polyphemus* Cram., *Anisota senatoria* S. and A., *Dryocampa rubicunda* Fabr., *Tolype velleda* Stoll, *Rhynchagrotis alternata* Grote, *Noctua c-nigrum* Linn. *P. serieventris* has been known as imago to kill the nymphs of its own species and of *P. cynicus*. In one case it was seen to feed on an imago of *Menecles insertus* Say (Kirkland, "The Gypsy Moth," Forbush-Fernald, 1896, p. 402).

Podisus spinosus (Dallas). (Plate 1, fig. 4.)

1851, *Arma spinosa* Dallas, List, part I., p. 98.
1856, *Arma spinosa* Fitch, 3d Rep. Ins. N. Y., p. 336.
1866, *Arma spinosa* Glover, Rep. U. S. Dep. Agr., p. 43.
1868, *Arma spinosa* Walsh-Riley, Amer. Ent., vol. I., pp. 13, 14, 37, 46, 59.
1869, *Arma spinosa* Riley, 1st Rep. Ins. Mo., pp. 77, 89, 113.
1869, *Arma spinosa* Walsh, Can. Ent., vol. II., p. 33.
1870, *Arma spinosa* Riley, 2d Rep. Ins. Mo., p. 32.
1870, *Arma spinosa* Shimer, Am. Nat., p. 98.
1870, *Podisus spinosus* Stål, Enum. Hemipt., part I., p. 51.
1871, *Arma spinosa* Kridelbaugh, Rep. Ia. State Hort. Soc., pp. 167, 168.
1871, *Arma spinosa* LeBaron, 1st Rep. Ins. Ill., pp. 64, 66, 162.
1871, *Podisus spinosus* Uhler, U. S. Geol. Surv. Terr. (Hayden), p. 395.
1872, *Arma spinosa* Lintner, Ent. Contrib., I., p. 150.
1872, *Arma spinosa* Riley, 4th Rep. Ins. Mo., p. 20.
1873, *Arma spinosa* LeBaron 3d Rep. Ins. Ill., p. 184.
1874, *Arma spinosa* Glover, Rep U. S. Dep. Agr., p. 123.

1874, *Arma spinosa* Lintner, Count. Gent., p. 471.
1875, *Podisus* (*Arma*) *spinosus* Glover, Rep. U. S. Dep. Agr., p. 118, fig. 9.
1875, *Arma spinosa* Riley, The Garden (London), vol. VIII., p. 71.
1875, *Podisus spinosus* Uhler, Bull. 5, vol. I., U. S. Geol. Surv. Terr., p. 282.
1876, *Podisus spinosus* Glover, Manuscript Notes Hemipt Het., p. 60.
1877, *Podisus spinosus* Glover, Entomological Index, pp. 8, 58.
1878, *Arma spinosa* Riley, Rep. U. S. Dep Agr., p. 245.
1878, *Podisus spinosus* Thomas, 2d Rep. Ins. Ill., p. 218.
1879, *Arma* (*Podisus*) *spinosus* Comstock, Rep. U. S. Dep. Agr., p. 289.
1880, *Podisus spinosus* Fuller, Amer. Ent., vol. III., p. 190.
1880, *Arma spinosa* Packard, Guide to Study of Ins., p. 547.
1882, *Podisus spinosus* Lintner, 1st Rep. Ins. N. Y., p. 331.
1884, *Arma spinosa* Murtfeldt, Rep. U. S. Dep. Agr., p. 417.
1884, *Arma spinosa* Osborn, Can. Ent., vol. XVI., p. 151.
1885, *Podisus spinosus* Lintner, 2d Rep. Ins. N. Y., p. 146.
1885, *Arma spinosa* Osborn, Rep. Ent. Soc. Ont., p. 34.
1885, *Podisus spinosus* Riley, 4th Rep. U. S. Ent. Com., pp. 97, 98.
1886, *Podisus spinosus* Riley, Rep. U. S. Dep. Agr., p. 527.
1887, *Podisus spinosus* Riley, Shade Trees and their Insect Defoliators, p. 45.
1889, *Podisus spinosus* Saunders, Ins. Inj. to Fruits, p. 73.
1890, *Podisus spinosus* Lintner, 6th Rep. Ins. N. Y., p. 137.
1890, *Podisus spinosus* Packard, 5th Rep. U. S. Ent. Com., p. 194.
1890, *Podisus spinosus* Riley, 5th Rep. U. S. Ent. Com., p. 252.
1892, *Podisus spinosus* Riley-Howard, Ins. Life, vol. IV., p. 124.
1892, *Podisus spinosus* Riley, Rep. U. S. Dep. Agr., p. 167.
1893, *Podisus spinosus* Ashmead, Bull. 45, U. S. Nat. Mus., Proctotrypidæ, pp. 159, 163.
1893, *Podisus spinosus* Lintner, 8th Rep. Ins. N. Y., pp. 238, 300.
1893, *Arma spinosa* Lintner, 9th Rep. Ins. N. Y., p. 457.
1895, *Podisus spinosus* Gillette-Baker, Bull. 31, Col. Agrl. Expt. Station, Hemipt. Col., p. 13.
1896, *Podisus spinosus* Chittenden, Year Book U. S. Dep. Agr., p. 346.
1897, *Podisus spinosus* Howard, Bull. 5, Tech. Ser., Div. Ent., U. S. Dep. Agr., Ins. Parasitism, p. 8.

Length, 11 to 14 mm. Upper-surface yellowish, so heavily punctured with reddish or dark brown as to give the insect a general dull-brown color. Head nearly truncate in front; in some specimens the lateral lobes are a trifle shorter than tylus; punctures very close together on lateral lobes, more scattering on tylus. Eyes dark brown; ocelli minute, red, in rear of eyes and near the anterior margin of pronotum. Antennæ slender; first segment

short, scarcely projecting beyond the lateral margin of head, pale brown on its outer lateral surface; second segment slender, enlarging at its apex, four times as long as first, rufous at base, darkening toward apex; third segment about two-thirds as long as second, and of same color; fourth segment a little longer than third, similarly colored; fifth segment as long as third, rufous, sometimes tinged with brown at the apex. Rostrum stout, reaching to hind coxæ; first segment thick, half as long as upper-surface of head; second segment one-half longer than first, nearly passing anterior coxæ; third segment a trifle longer than first; fourth segment of same length as first, embrowned at tip. Sides of pronotum indented, with fine granular teeth anteriorly; humeral angles often sinuate posteriorly and produced into long slender spines, which are frequently tipped with dark brown or black. The puncturing is closely massed at each anterior angle of the pronotum and in a small spot at the outer end of the pronotal callosities. A fairly well-defined dorsal line extends from the anterior margin of the pronotum to the tip of the scutellum. Scutellum of same color as pronotum, reaching to the membrane, less densely punctured toward the tip. Corium of same color, generally tinged with red near the cuneus; membrane translucent with a brownish spot at the tip. Connexivum pale orange, with large black markings at each incisure; in the middle of these markings there is usually a minute white spot. Under-side pale yellowish, punctate sparingly with red or brown; on the middle of the last segment there is a large oval black spot, anterior to which on some specimens there is a minute black dot; a small black dot occurs on the third, fourth, fifth and sixth segments; these dots form a row which is equidistant between the median line and the lateral margin; osteolar canal tipped with a black dot. Legs of same color as abdomen, femora generally tipped with two dark-brown dots. Ventral spine slender, reaching upon the hind coxæ.

Distribution. — Canada, Massachusetts, New York, Pennsylvania, Maryland, Virginia, Wisconsin, Illinois, Nebraska, Kansas, Iowa, Missouri, Colorado, Indian Territory, Texas, California. This species is stated to occur generally throughout the south and west; it is rare in Massachusetts.

Habits.

Podisus spinosus has been frequently confounded with *P. serieventris* in the collections I have examined, and in

some series the two species closely approach each other. *P. spinosus* usually reaches a size not attained by *serieventris*. In the latter species the antennæ are generally spread over with brown and the humeral angles are bluntly acute, not produced into slender spines. In *spinosus* there is usually a well-defined sinuation in rear of each spine.

The life history of this species, as briefly given by Riley, is as follows: —

> The eggs of *P. spinosus* . . . are bronze-colored, caldron-shaped objects, with a convex lid, around which radiate fifteen or sixteen white spines. They are attached side by side, in clusters of a dozen or more, to leaves and other objects. . . . The young bug is ovoid, shiny black, with some bright crimson about the abdomen. In the full-grown larva . . . four yellowish spots appear on the thorax, and the abdomen becomes more yellowish. In the so-called pupa, distinguished by wing-pads, the ochre yellow extends still more, and in the perfect insect the black entirely disappears. In the immature stages the shoulders are rounded, not pointed; the antennæ are four-jointed instead of five-jointed as in the adult, and the feet or tarsi have but two joints instead of three.
>
> The diet of the young seems to be principally vegetarian, but we have mentioned elsewhere (Fourth Rep. Ins. Mo., p. 20) instances where the larva has been seen to destroy larvæ of the Colorado Potato beetle four or five times its own size. (Fourth Rep. U. S. Ent. Com., p. 98.)

At the time the Colorado potato beetle was spreading eastward, *P. spinosus* was perhaps its most frequently observed insect enemy, as is shown by its frequent mention in articles on the subject appearing at that time, and its services in destroying this beetle were of sufficient value to call out the commendation of many entomologists. In destroying the cotton worm (*Aletia argillacea*) Riley rates this bug as "the most abundant and effective" of the Heteroptera known to attack the insect. The full list of insects which *P. spinosus* is known to attack is given below: —

Diapheromera femorata Say (Riley, Rep. U. S. Dep. Agr., 1878, p. 245), *Coccinella* sp.? (Walsh, Amer. Ent., 1869, vol. I., p. 13), *Crioceris asparagi* Linn. (Chittenden, Year Book U. S. Dep. Agr., 1896, p. 346), *Doryphora decem-*

lineata Say (Glover, Rep. U. S. Dep. Agr., 1866, p. 43, and many other writers), *Galerucella luteola* Müll (Riley, Rep. U. S. Dep. Agr., 1892, p. 167), *Pieris rapæ* Linn. (Murtfeldt, Rep. U. S. Dep. Agr., 1884, p. 417), *Hyphantria cunea* Drury (Walsh, Amer. Ent., vol. I., 1869, p. 59), *Orgyia leucostigma* S. and A. (Howard, Bull. 5, Tech. Ser., 1897, p. 8), *Carneades scandens* Riley (Riley, First Rep. Ins. Mo., 1869, p. 77), *Aletia argillacea* Hbn. (Comstock, Rep. U. S. Dep. Agr., 1879, p. 289), *Cacœcia fervidana* Clem. (Packard, Fifth Rep. U. S. Ent. Com., 1890, p. 194), *Carpocapsa pomonella* Linn. (Le Baron, 3d, Rep Ins. Ill., 1873, p. 184), *Gymnonychus appendiculatus* Hartig (Glover, Rep. U. S. Dep. Agr., 1875, p. 118), *Selandria barda* Say (Osborn, Can. Ent., 1884, p. 151).

Telenomus podisi Ashm. (Ashmead, Proctotrypidæ, 1893, p. 159) and *Trissolcus podisi* Ashm. (*ibid.*, p. 163) have been reared from the eggs of *P. spinosus*.

Podisus acutissimus Stål. (Plate 1, fig. 5.)

1870, *Podisus* (*Tylospilus*) *acutissimus* Stål, Enum. Hemipt., part I., p. 53.

1875, *Tylospilus acutissimus* Uhler, Bull. 5, vol. I., U. S. Geol. Surv. Terr., p. 283.

1880, *Podisus acutissimus* Distant, Biol. Cent. Am. Rhync., vol. I., pp. 40, 41, pl. II., fig. 22.

1895, *Podisus acutissimus* Gillette-Baker, Bull. 31, Col. Agrl. Expt. Station, Hemipt. Col., p. 12.

Length, 9 mm. Very pale olive yellow, heavily punctate with dark brown on posterior part of pronotum and lower part of scutellum. Head somewhat narrowed anteriorly. Tylus longer than lateral lobes, which are obliquely rounded and margined with dark brown at their outer ends. Between the dark-brown eyes and extending backward to the pronotum are two longitudinal dark-brown markings. First segment of antennæ small, scarcely projecting beyond the lateral margin of head, pale yellow, darkened outwardly; second segment of antennæ slender, dark brown; third segment three-fourths as long as second, reddish yellow, dark brown at base; fourth segment as long as third, testaceous; fifth segment two-thirds as long as fourth, testaceous, darker toward the apex. Rostrum slender, reaching upon middle coxæ; the second segment scarcely reaching the fore coxæ, pale amber colored.

Pronotum with an irregular ivory-yellow callous on the dorsum anteriorly; lateral margins with fine granular teeth. Humeral angles very acute, terminating in slender spines which project anteriorly. A well-marked band of dark-brown punctures extends across the pronotum between the humeral angles, darkening to black at the posterior margin. Post-humeral margins oblique and curved.

There is a large ivory-yellow bald spot in each basal angle of the scutellum, flanked outwardly by a minute brown callous and inwardly by scattering brown punctures which extend in a band across the scutellum. Behind these spots and separated from them by a pale olive-yellow band is a well-defined dark-brown V-shaped marking, posterior to which at the tip of the scutellum there is an ivory-yellow crescent-shaped marking.

Corium pale olive yellow, with a black dot outwardly nearly opposite the apex of the V-shaped marking. Membrane glassy, with a large dark-brown marking. Connexivum olive yellow, without dark markings. Under-surface without conspicuous markings, pale amber colored anteriorly, darkening to olive yellow posteriorly. Ventral spine very long, reaching middle coxæ. Legs amber colored; tarsi pale brown.

Prof. Carl Baker of Auburn, Ala., has very kindly sent me a specimen of *P. acutissimus* from Texas. This species is the most conspicuously colored of any that I have examined, and may be recognized by the V-shaped marking and bald spots on the scutellum, the transverse brown band and sharp, curved spines of the pronotum, the vitta of the membrane and the long ventral spine.

Distant has figured a specimen having a bald spot at the middle of the base of the scutellum (Biol. Cent. Amer. Rhync., pl. II., fig. 22). This specimen, which he states is a typical one, is in the Stockholm Museum. The specimen which I have examined lacks this marking, and it is presumably a variable character. The rostrum is more slender than that of any of our northern species, but is sufficiently stout to indicate predatory habits on the part of the species.

Distribution. — Colorado, Texas, Mexico, Guatemala.

Podisus mucronatus Uhler. (Plate 1, fig. 9.)

1897, *Podisus mucronatus* Uhler, Trans. Md. Acad. Sc., pp. 386, 387.

Length, 9 mm. Head rounded anteriorly, the lateral lobes not extending beyond tylus. General color testaceous, with dark-brown punctures arranged in longitudinal series. First segment of antennæ projecting slightly beyond the lateral margin of head; second segment pale amber colored, slender, two-thirds as long as head; third segment two-thirds as long as second, darkened toward apex; fourth and fifth segments of nearly equal length, pale brown, each three-fourths as long as second. Rostrum of medium size, reaching to hind coxæ. Pronotum ivory yellow, sparingly punctate with brown, and bordered on its anterior lateral margins with pale yellow. Humeral angles produced into slender dark-brown spines, which curve sharply toward the head. Scutellum ivory yellow, very sparsely punctate with brown, and with a large bald spot at the tip and a smaller bald spot in each basal angle. Corium sanguineous, thinly punctate with brown. Membrane dark bronze colored. Under-surface sulphur yellow, tinged laterally with reddish, with scattering pale-brown punctures anteriorly. Ventral spine slender, acute, reaching upon hind coxæ. Legs pale amber colored.

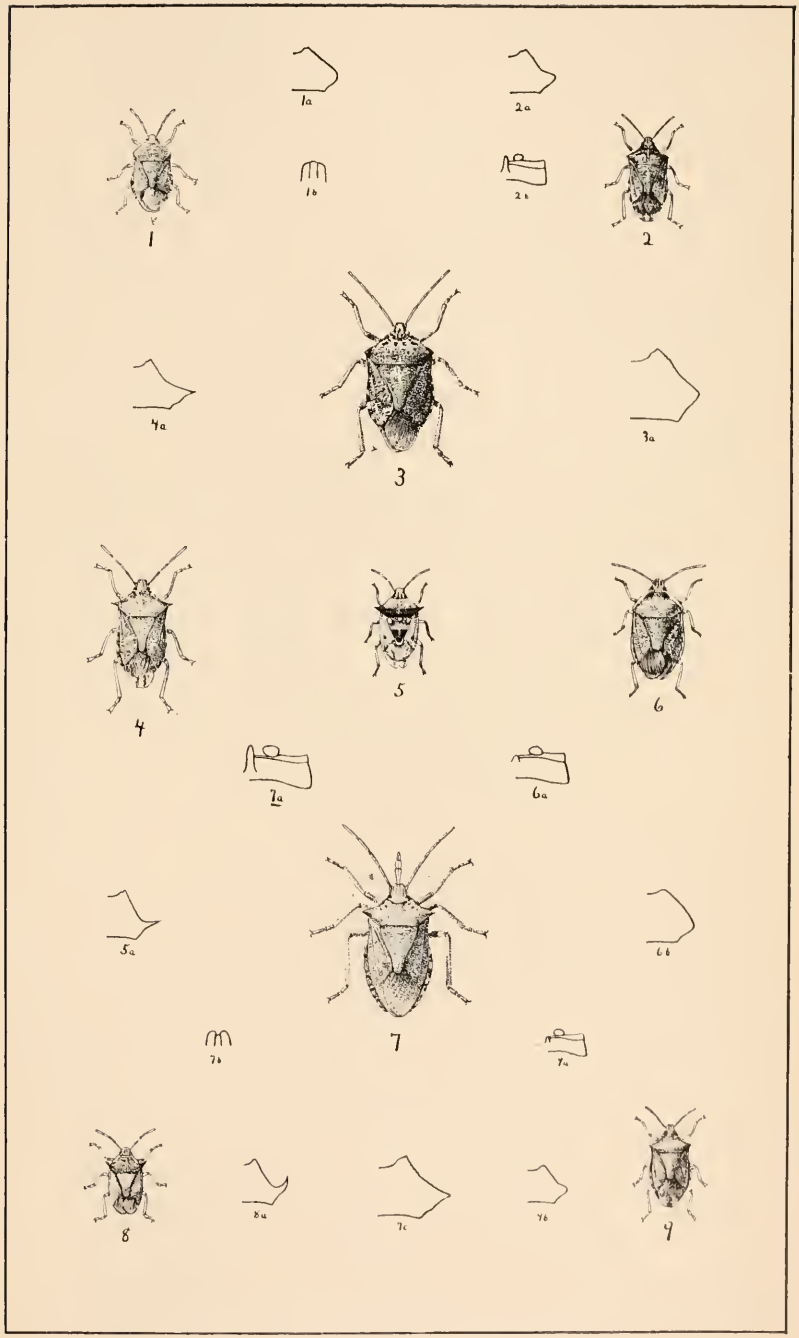
Distribution. — Florida, Cuba.

Prof. P. R. Uhler, to whom I am indebted for many favors in connection with the preparation of this paper, has very kindly given me an opportunity to examine this interesting species.

Explanation of Plate 1.

Figures of insects drawn by J. H. EMERTON; structural details by A. H. KIRKLAND.

Fig. 1. **Podisus placidus**, natural size.
Fig. 1*a*. **Podisus placidus**, right humeral angle enlarged.
Fig. 1*b*. **Podisus placidus**, anterior margin of head enlarged.
Fig. 2. **Podisus serieventris**, natural size.
Fig. 2*a*. **Podisus serieventris**, right humeral angle enlarged.
Fig. 2*b*. **Podisus serieventris**, ventral spine enlarged.
Fig. 3. **Podisus crocatus**, natural size.
Fig. 3*a*. **Podisus crocatus**, right humeral angle enlarged.
Fig. 4. **Podisus spinosus**, natural size.
Fig. 4*a*. **Podisus spinosus**, right humeral angle enlarged.
Fig. 5. **Podisus acutissimus**, natural size (from Distant).
Fig. 5*a*. **Podisus acutissimus**, right humeral angle enlarged.
Fig. 6. **Podisus gillettei**, natural size.
Fig. 6*a*. **Podisus gillettei**, ventral spine enlarged.
Fig. 6*b*. **Podisus gillettei**, right humeral angle enlarged.
Fig. 7. **Podisus cynicus**, natural size.
Fig. 7*a*. **Podisus cynicus**, ventral spine enlarged.
Fig. 7*b*. **Podisus cynicus**, anterior margin of head enlarged.
Fig. 7*c*. **Podisus cynicus**, right humeral angle enlarged.
Fig. 8. **Podisus mucronatus**, natural size.
Fig. 8*a*. **Podisus mucronatus**, right humeral angle enlarged.
Fig. 9. **Podisus modestus**, natural size.
Fig. 9*a*. **Podisus modestus**, ventral spine enlarged.
Fig. 9*b*. **Podisus modestus**, right humeral angle enlarged.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