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EIGHTEENTH REPORT

OF THE

State Entomologist

ON THE

Noxious and Beneficial Insects

OF THE

State of Illinois

SEVENTH REPORT OF S. A. FORBES

For the Years 1891 and 1892

Reprinted by authority of the State of Illinois.

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LETTER OF TRANSMITTAL.

OFFICE OF STATE ENTOMOLOGIST,
CHAMPAIGN, ILL., Dec. 21, 1892.

To His Excellency, JOSEPH W. FIFER, *Governor of the State of Illinois.*

SIR: I have the honor to transmit herewith my seventh report as State Entomologist of Illinois,—the eighteenth from this office,—applying to the years 1891 and 1892.

I have had for some time the intention to present in my entomological reports a complete monograph of all insect injuries to Indian corn, to contain, when completed, not only an abstract of all published knowledge on the subject, but likewise all our own unpublished observations accumulated during the past ten years. Believing that I could at present do the agriculture of this State no other service approaching this in value, I have prepared, as the greater part of this report, a first instalment of this treatise, consisting of a discussion of all insects injuring the planted seed and the roots of Indian corn.

Respectfully submitted.

S. A. FORBES, *State Entomologist.*

GENERAL RECORD FOR 1891 AND 1892.

The economic entomology of the years 1891 and 1892 has presented in Illinois scarcely a single notable feature, all crops having been, on the whole, unusually free from insect injury, and no very serious danger threatening at any time.

The most interesting item of our record was the attack on young corn made in May and June, 1891, throughout the greater part of the State, from extreme Northern Illinois to Bunker Hill, but especially in the central and southern counties, by a small black jumping FLEA-BEETLE, *Chaetocnema pulicaria*, previously wholly insignificant as a corn insect. From five to ten or more of these beetles might sometimes be found on a single blade of young corn not more than five or six inches high, and the damage done was often so great as to give a yellow look to the entire field, due to the deadening of the terminal part of the leaf beyond the spots affected by the microscopic gnawing of those beetles. The injury was magnified by the cold weather of the season, during which the corn made very little growth; and it practically vanished with the advent of good growing weather.

The CHINCH BUG, which in 1889 and 1890 had very nearly disappeared as an important factor in the agriculture of this State, has begun during the two years just passed again to take the upward turn.

The almost uniformly high temperature of the spring and summer of 1890 and 1891 in northern and in southern Central Illinois, combined with light rainfall, amounting in some counties to little less than continuous drouth, favored its development unusually in these sections.

South of Central Illinois, the region affected in 1891 was a belt of counties extending from about the line of the Ohio & Mississippi Railroad northward to the latitude of Springfield, and local injury seemed likely for some distance north of this. In the north, the infested district was a roughly triangular area in the northeastern corner of the State, of which Stephenson county marks the western angle and Kankakee county the southern. The distribution of injury within these limits was, of course, extremely variable, as is shown by the following examples of field notes and correspondence for 1891; first for Southern Illinois, and then for the northern part of the State.

WASHINGTON.—*Nashville*, July 8. "Very destructive to corn in places." Dec. 7. Bugs generally diffused in limited numbers. *Ashley*, Dec. 7. Bugs generally diffused. Injury to wheat slight; corn more hurt.

CLINTON.—*Carlyle*, April 8 and 9. Hibernating in rail fences, corn shocks, etc. Second year here. Corn and wheat suffered some in 1890. Dec. 11. A few bugs. No harm done.

MARION.—*Vernon*, July 1. "Leaving wheat for corn. Threaten injury." *Salem*, Dec. 9. A few bugs in corn. *Odin*, Sept. 27. In large quantities in one field of corn. Dec. 10. Locally abundant.

BOND.—*Greenville*, June 27. "Corn alive with them." Dec. 3. Reported present in limited numbers last season. Effects seen mostly on corn;

some wheat light weight. *Smithboro*, July 10. "Destroying corn." Dec. 4. Report similar to that at Greenville. Chief injury to corn.

Montgomery.—*Litchfield*, May 27. Found bugs in most wheat fields along the road for four miles south of town. Wheat damaged most on corn ground and in the vicinity of places where corn shocks had stood over winter. Eggs abundant; a few young bugs. June 2. Few eggs seen; young bugs very numerous. From ten to fifteen per cent. of wheat in vicinity where corn shocks stood is ruined. July 18. Chinch bugs very abundant in and near woodlands on gray soil. Scarce on black lands north of them. Several rows of corn killed in many fields adjoining small grains. Scattered traces of insect disease, but not sufficient to promise any important aid. Sept. 23. Bugs collected in corn fields. Every field entered contained bugs enough to excite apprehension for next year.

Shelby.—*Herrick*, Aug. 24. Second brood of chinch bugs will seriously damage corn; many stalks completely covered. *Shelbyville*, Nov. 15. Bugs present in considerable numbers. Injuries mostly confined to corn.

Christian.—*Morrissonville*, July 1. "Leaving wheat for corn. Threaten great damage." *Taylorville*, Nov. 17. General diffusion of bugs reported. Some wheat reduced to light weight; corn next wheat fields injured.

Macon.—*Blue Mound*, May 25. Corn and wheat infested by chinch bugs. June 27. Bugs of all ages, mostly young, present. A quart can nearly full of them sent to the office.

In addition to the above list, a general diffusion of chinch bugs was also reported, at this time, with little or no injury, from the counties of Brown, Champaign, Coles, Macon, Sangamon, Effingham, Macoupin, St. Clair, Jefferson, Wayne, Clark, Lawrence, Edwards, White, Hamilton, Randolph, Pope, and Johnson.

St. Clair, Washington, Clinton, and Montgomery counties reported the bugs as being present in small numbers in 1890 also. A noticeable feature of the injury to wheat in this part of the State is that it suffered greater damage in the immediate vicinity of corn shocks, where the shocks were permitted to remain over winter.

In northern Illinois trips of investigation made later in 1891 showed the bugs to have been destructive locally in some nine counties for two years, and in a few places for three. Spring wheat, rye, and barley have afforded them the most acceptable breeding places. Destruction of these grains in areas varying from a fraction of an acre up to two, three, or more, acres was common all through the infested region; and spring wheat was frequently light in weight because of the attacks of the bugs. Oats were quite generally infested, but did not suffer so severely as the other small grains, only now and then a small area showing noticeable injury. Corn next to spring wheat, rye, or barley, suffered considerable damage, several rows next such fields often being almost wholly worthless. Fields at a distance from the small grains contained bugs in limited numbers scattered all through them, but were not commonly damaged noticeably. The situation in these northern counties in the summer and fall of 1891 is shown more specifically in the following brief abstracts of field notes and correspondence:

McHenry.—*Marengo*, Oct. 15. Second year of appearance. Great damage to rye, oats, and corn; some rye and corn not harvested. *Woodstock*, Oct. 16. Abundant all over the county. Wheat, corn, and barley attacked; corn not much hurt. Damage greater than last year.

Boone.—*Belvidere*, Oct. 15. Bugs reported five miles from town, where rye was being plowed up because of them.

Winnebago.—*Rockford*, Oct. 17. Abundant all through this region. Rye not much harmed; barley severely attacked; wheat and corn attacked vari-

ously. One crop of corn reported not worth gathering; another piece was half destroyed; and one field of seven acres of wheat yielded fifteen bushels gr[illegible]. *Pecatonica*, Oct. 18. The bugs are in corn nearly a mile from the nearest stubble. Twenty acres of corn two miles north of town quite spoiled by bugs coming out of rye.

Stephenson.—*Ridott*, Oct. 19. Bugs passed from rye to corn, doing no very marked damage to either. On bottom-land found bugs on corn with no stubble near. *Lena*, Oct. 20. Bugs generally present, but little complaint of injury. One farmer reports bugs in wheat, going thence into corn and damaging it seriously. *Warren*, Oct. 20. Traces of chinch bugs only.

Kane.—*Hampshire*, Oct. 14. Chinch bugs appeared here two years ago last year in greater numbers than the year before. This year, barley, wheat, and corn damaged. Wm. Warrington had three acres of wheat destroyed, and H. Gilkerson had fifteen acres of wheat injured and three acres of corn destroyed. A neighbor of his had three or four acres of spring wheat and two or three acres of corn destroyed.

De Kalb.—*New Lebanon*, June 2. "Abundant in wheat and barley." *Genoa*, Oct. 15. Chinch bugs reported in wheat, Hungarian, and corn. They are also found in the vicinity of *Sycamore*. *Shabbona*, Oct. 20. Chinch bugs common in corn. Somewhat injurious.

Ogle.—*Davis Junction*, Oct. 14. Traces of bugs all along the road from here to Stillman's Valley. *Stillman's Valley*, Oct. 14. A few rows of corn next rye and spring wheat injured. *Paine's Point*, Oct. 15. Bugs went from rye into corn; both damaged some. Barley injured also, one acre of corn destroyed, and seven acres badly damaged. *Oregon*, Oct. 15. Five acres of corn east of town reported destroyed. *Chana*, Oct. 15. Bugs generally diffused between here and Paine's Point. Two or three acres of corn destroyed by bugs coming from rye. *Forreston*, Oct. 15. Bugs were flying thickly about this time last year. Hibernated abundantly in woods. Rye, barley, spring wheat, and corn hurt about as badly last year as this. North of town ten acres of rye was so badly damaged as to be plowed up. Five acres of corn badly damaged; much rye, barley, and spring wheat cut before it ripened to save it from the bugs. Reports from *Mt. Morris*, *Baileyville*, and *Rochelle* show the bugs to be generally distributed over the county.

Whiteside.—*Sterling*, Oct. 21. Chinch bugs few, no important damage.

Warning of possible danger impending was widely distributed by me through the bulletins of the State Agricultural Experiment Station in February, 1892,* accompanied by a brief program of general defence. In the northern part of the State, the presence of insect diseases, especially of the one known as the "white fungus" of the chinch bug, was repeatedly noticed by us in the fall of 1891 and the spring of 1892, but only where local rains gave it an opportunity for development. In Southern Illinois, however, nothing of the kind was found. Singularly in accord with these observations, the chinch bug in Northern Illinois multiplied less rapidly in 1892 than in the southern part of the State, but from both sections numerous calls came to the office for assistance and advice, usually in the form of requests for infected material with which to start "the chinch bug disease." Although convinced by my previous observations of these diseases and by laboratory and field experiments, conducted by us but not yet reported, that there was under the circumstances existing, very little probability of a valuable outcome to these experiments, I did what I could to supply the spontaneous demand by making artificial cultures and sending out both spores and infected insects. Every such sending was, however, accompanied with a

* The Chinch Bug in Illinois, 1891-1892. Bull. Agr. Exper. Station No. 19 (Feb., 1892), p. 44.

warning intended to prevent the recipient from taking the experiment too seriously, believing, as I did, that harm was likely to result from a dependence upon this still problematical method to the neglect of older and more laborious and costly precautions.

Another extraordinary occurrence in a minor field was the appearance in extreme Northern Illinois of two FOREST CATERPILLARS almost unknown to the economic entomology of the State, which occurred in the summer and fall of 1892 upon the oak and hickory in such numbers as to completely defoliate these trees over large areas. My attention was especially called to them by correspondents in Freeport, Rockford, and Argyle, and an assistant was sent from the office to investigate the outbreak. The caterpillars responsible for the injury were *Edema albifrons* and *Halesidota caryæ*. The same injury, due to the same insects, spread widely northward into Wisconsin, but was not heard of by us south of the latitude of Chicago.

An interesting investigation of injuries to books and papers by WHITE ANTS was made in the winter and spring of 1892, in response to a request from the State Department at Springfield. Several rooms in the basement of the State House were found infested; cases in which books and documents were stored were hollowed out by these ants; and in many instances considerable injury had been done to the contents of the cases.

Matters of minor interest and importance were the appearance of small outbreaks of the ARMY WORM in Central Illinois; the occurrence of the MEAL MOTH *(Pyralis farinalis)* in potatoes; the extraordinary abundance in Cook county, for two or three years, of the CECROPIA MOTH, the larva of which does some damage in nurseries by defoliating young apple trees; the excessive abundance during both years covered by this report of an injurious GRASS INSECT, *Crambus caniurellus*, which did noticeable damage to lawns; and the first report of the arrival in the State of the notorious HORN-FLY, which since its advent from Europe had been confined to eastern localities.

The CLOVER SEED MIDGE *(Cecidomyia leguminicola)*, was found abundant in 1891 and 1892 throughout the northern half of the State, from Ogle county to Champaign, and it is very probably still more widely distributed.

Specimens of a large FLEA-BEETLE, *Disonycha pennsylvanica*, sent me from Griggsville, in Pike county, with the information that they were injurious to apples, were confined under a bell jar with cut pieces of apple, upon which they fed very freely. They were, however, proven by experiment to be entirely unable to bite through the skin of uninjured fruit. In the numbers in which they were found at Griggsville, hibernating in the apple orchard under bark, and especially under bands used as traps for the codling moth, they might easily do considerable injury by gnawing and hollowing out specked apples upon the trees.

A Monograph of

Insect Injuries to Indian Corn

PART I

INTRODUCTORY.

For the past ten years the economic entomology of the corn plant has been made a leading subject of investigation in this State by the official entomologist, and in the course of these original studies a large mass of published matter has been scanned and summarized. The present report has been prepared in the hope (1) of finally bringing to bear on the practice of the corn farmer in Illinois all the entomological matter that ought to affect his procedure, and (2) of so massing and condensing the data from which practical and theoretical conclusions are to be drawn as to make it unnecessary for the investigating entomologist to cover the same ground again.

To the first end I have prepared descriptions and classifications of insect injuries to corn which I venture to hope will be found intelligible and practically useful to the actual tiller of the soil as well as to the economic entomologist; and secondly, I have incorporated with this, for the especial benefit of the entomologist, more detailed and thoroughgoing discussions of the insects themselves and of their life histories, habits, and injuries, together with descriptions of the species in all stages as yet recognized. This report is thus written from both the agricultural and the entomological standpoints.

The corn insects now recognized as in some way and to some extent injurious to some part of the plant number 214 species, of which 18 are known to infest the seed, 27 the root and the subterranean part of the stalk, 16 the stalk above ground, 118 the leaf, 19 the blossom,—that is the tassel and the silk,—12 the ear in the field, 2 the stacked fodder, and 24 the corn in store, either whole or ground. The greater part of this long list, which is doubtless by no means really complete, is composed of those whose injuries are now so slight or rare as to constitute a possible menace rather than to cause a serious loss; but the history of economic entomology, and even of the entomology of this one plant, teaches us that we can rarely tell in advance what to expect of any possibly injurious species. In fact, some of the insect enemies of corn now most destructive were not many years ago almost unknown even to the entomologist—the northern corn root worm and the corn root aphis, for example.

The principal insect species infesting this plant are the seed-corn maggot and the wireworms, attacking the seed; these latter insects, the white grubs, the corn root worms, and the root aphis, affecting the roots; the cutworms and root web-worms, the army worm, the stalk-borer, the corn worm, the bill bugs, the chinch bug, the corn flea-beetle, and the grasshoppers, injuring stalk and leaf; the corn worm, the corn root worms, and the grasshoppers, eating the flower structures and the ear; and the meal-moth and the weevils devouring the kernel in the granary or the meal in the bin. Of these, by far the worst at present are the wireworms, the corn root worms, the white grubs, the root lice, the cutworms, the chinch bug, the grasshoppers, and the army worm.

These major injuries have naturally received here the greatest share of attention, but a discussion of the minor and insignificant injuries which at first blush seem to have little or no agricultural importance, will nevertheless be of practical utility as indicating the probabilities with reference to the amount of injury to be anticipated when these minor attacks are noticed.

For convenience of treatment, the general subject of insect injuries to corn will be divided, in discussion, into those to the seed, the root, the stalk, the leaf, the blossom, the ear, and the stored grain, whole and ground.

The most serious ordinary injuries to corn, those which the plant is least able to sustain, are injuries to the seed and root, particularly those occurring early in the year; but they are, fortunately, those against which precautionary or preventive measures may be most readily taken, and with the best effect.

GENERAL INDICATIONS OF INJURY.

Before beginning a description of injuries to each part of the plant, a few practical hints may be given which will aid to a recognition of insect attack from the general aspect of the field or from the appearance of the entire plant.

1. If corn largely fails to appear in due time after planting, the farmer need not content himself with a surmise that his seed was poor or that the weather has been unfavorable, but should examine the seed itself for evidence of the work of one of several insects (*wireworms*, *seed-corn maggots*, *grass maggots*, etc.) attacking it in the earth.

2. If the young plants make an unequal start, some hills appearing earlier and growing more thriftily than others at the very first, the roots should be searched for the *corn root louse;* and even those hills should be examined in which the corn has not yet come up, as this louse sometimes infests the sprouting plant before it appears above ground.

3. The abundant occurrence of ants in the corn field, sinking their burrows among the stalks of the hill, is evidence of the presence of the *corn root louse* in their company.

4. If the growth of the corn is arrested or retarded in patches throughout the field, the leaves turning first yellow and then red, it is likely that the roots are infested by the same *root louse*, to be discovered by carefully digging up the hill and picking or gently shaking off the earth to expose the roots at their origin. If no insect enemy is found, the difficulty is quite likely to be due to a *fungus attack* known as the root blight of corn, a discussion of which does not come within the scope of this article. [See page 46, b.]

5. If single stalks or entire hills are killed or withered when a foot high or less, search should be made among the roots and on the stalk below the surface for the *wireworms* and the *white grubs*.

6. If the corn falls readily in a windy storm and does not afterward rise, and if it may be pulled out easily after the ear has begun to form, it is probable that the roots are infested by the *corn root worms* or that they have been eaten by *white grubs*.

7. If the plant remains green too long, maturing slowly, and if the field contains many sterile stalks or soft, imperfect nubbins, it is likely that the common *corn root worm*, in some of its stages, will be

found in or among the roots if search be made before September 1. If large numbers of grass-green beetles one fifth of an inch in length (about the size of a common red lady bug) are seen on the silks and tassels of the corn, or feeding upon the fallen pollen collected at the bases of the leaves, or upon the blossoms of ragweed or other flowering plants in the field, the crop has suffered from an attack of the *corn root worm*, of which these beetles are the adult, and the ground should be planted to some other crop the following year.

8. A deformed and unequal growth of the foliage, especially of that unfolding from the roll of leaves at the growing tip of the plant, with more or less irregular and ragged injury, when the corn is from one to two feet high, is often due to an attack by the first generation of the *corn worm*, the second generation of which burrows in the kernels of the ear of corn during late summer and early fall.

9. On the other hand, the presence of elongate holes, placed side by side in an orderly manner, in short rows extending across the well-opened leaf, is commonly the mark of an injury done when the corn was smaller by the *corn bill bugs*, several species of which will be described when injuries to the leaf are under discussion.

10. An irregular eating away of the leaves of young corn, and a similarly irregular gnawing of the stalk near the ground when the plant is less than a foot in height, should lead to an examination of the earth about the base of the hill. If fine particles and small lumps of earth are found more or less closely webbed together in a mass approximating the size of a hickory nut, some one or more of the species of *root web-worms* are doubtless at work in the field.

11. The cutting of the young corn at or below the surface of the ground is an injury too well known as the work of the *cutworms* to require more than bare mention here.

12. The appearance in the side of the stalk of a hole about the size of a straw, with a brown moist powder exuding, is evidence of the presence of the *stalk-borer*, an insect which often does a great and practically irremediable damage to young corn in early spring, especially in low grounds, by burrowing the stalk, pushing more or less of its excrement out at the mouth of its burrow.

13. A similar, equally evident burrowing of the ear, the excrement from which escapes by a hole through the green husks or becomes mixed through the silks at the tip of the ear, betrays the presence of the *corn worm* already mentioned under 8.

14. The eating away of the blade of the leaf in late summer and autumn so as to make large irregular holes, which may multiply and increase in size until they finally leave only the stripped midrib and the bare stalk—the injury being commonly very much worst along the edges of the field—is commonly due to *grasshoppers*.

15. In the corn crib or granary the commonest serious mischief is the peppering of the kernel with little round holes, each the diameter of the head of a pin, the first suspicion of which will frequently be aroused by the appearance of fine particles of meal sifting down somewhere within sight. The insect most likely to be responsible for this mischief is the *grain moth;* but various *weevil species* may also be involved.

INJURIES TO THE CORN PLANT AND ITS PRODUCTS.

CLASSIFICATION OF INJURIES.

A. Injuries to the seed in the earth.
B. Injuries to the roots.
C. Injuries to the stalk.
D. Injuries to the leaves.
E. Injuries to the tassel and the silk.
F. Injuries to the ear in the field.
G. Injuries to dry fodder.
H. Injuries to stored corn and meal.

A. Injuries to the seed in the earth.*

Seed corn in the earth may be destroyed by being devoured at once, kernel by kernel; by being bored through from side to side; by being penetrated at some point and hollowed out in a way to leave an empty shell; or by being eaten away gradually from without. It need hardly be said that injuries of the first class are unknown to entomology, birds and mammals being the only corn-field pests which are capable of them.

A kernel which has been smoothly perforated by a cylindrical channel has probably been visited by a wireworm—a slender, cylindrical or flattish, smooth, brown or brownish white, six-legged larva, likely to be found still working on the seed, the roots, or the underground part of the stalk.

One which shows a round or oval hole at the surface, with no exit, will probably be found to contain either the seed-corn maggot—a white, soft, worm-like larva, without legs or distinct head, blunt at one end and pointed at the other—or the black-headed grass maggot—also a small footless white worm, but distinguished by its shining black head.

If the grain has been gnawed away from without, the injury will commonly have begun with the germ or the softer part of the kernel about it, and the insect responsible will frequently be found more or less completely imbedded in the cavity which it has excavated. It may, in this case, be either one of the wireworms, as already mentioned; a small red or yellowish ant; or one of at least three species of small hard-shelled beetles.

If the damage has been done by ants, mealy particles are likely to be strewn through the dirt, as these insects do not devour the substance of the grain, but tear it to pieces merely to lick up the fluids it contains; but injuries due to the various beetles referred to do not differ in a way to suggest the species responsible.

* For Injuries to the Roots, see p. 45.

SYNOPSIS OF INJURIES TO SEED IN THE EARTH, AND ORDER OF DISCUSSION.

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DETAILED DISCUSSION OF INJURIES TO THE SEED.

1. *Injuries by ants (Myrmicidæ), which hollow out the kernel, commonly scattering the meal through the dirt.*

Injuries to corn by ants are of two kinds; one indirect but serious; the other direct, but of little importance because quite rare. The former will be treated in connection with insects affecting the root, since it is by rearing, transporting, and fostering the root lice of corn that ants are most injurious; and the latter is given here in its place as an injury to the seed in the earth.

Occasionally in searching for the causes of the failure of corn to germinate, or to grow thriftily after making its appearance, a kernel may be found wholly or partly hollowed out, the mealy interior being not devoured, but scattered about in the earth, while the cuticle or outer

shell of the seed remains but little disturbed. The agents of this small mischief will frequently be found still buried in the cavities they have excavated—most commonly ants of a minute pale yellow species, a little more than a sixteenth of an inch in length, and very similar in size and general appearance to the minute "red ant" which often infests the pantry. This injury to corn requires no treatment so far as is now known, and, indeed, admits of none; but consistently with the plan of this treatise, which is intended not only to summarize existing knowledge but still more to serve as a basis for future investigation, the two species thus far connected by us with this injury to corn are here briefly treated.

Solenopsis debilis, Mayr.*

(Plate II., Fig. 2.)

This ant is but little known, either to farmers or entomologists, having, in fact, not been discriminated as a species until 1886, in which year it was described by Mayr,† of Vienna, from specimens sent him from North America. His description, with the appended remarks, is the only definite mention of it which I have found in the literature of entomology, with the exception of my own reference (under the name of *S. fugax*) to its injuries to strawberries and kernels of corn in the earth in the Thirteenth Report of the State Entomologist of Illinois, published in 1884 (p. 112). It is, however, probable that a reference under the same name made in 1889 by Mr. F. M. Webster‡ to injuries to corn by ants in Indiana should really be applied to this species.

Mayr reports the species from the District of Columbia, New Jersey, and Virginia, under stones and in a stump under ground, and from Texas and New York. Winged males and females appear in July and August.

It was first found by us June 1-12, 1883, at Normal, Illinois, abundant in many fields of corn, both new and old, and afterwards, May 14-24, 1886, infesting seed corn in the fields at Champaign. In the corn field these ants were usually collected about the kernels in the earth, and frequently more or less hidden in little cavities excavated in the softened grain. May 19, 1887, they were very abundant in a field of corn on sod in Champaign county, eating out the planted kernels. In autumn the same species has been detected by us indulging a similar appetite, but in a way to do no harm. September 11-21, 1893, it was found feeding on and within kernels of corn at the tips of ears, which had evidently been injured previously by crickets and grasshoppers. The solid substance of the grain is not actually eaten by these ants,—a fact which I demonstrated by dissection of the ants—but it is simply gnawed away, doubtless for the sake of the sweetish and oily fluids of the softened kernels. If plants start from seeds thus injured, they are shorter than others adjacent, and have a stunted, weak appearance.

This species has also been several times noticed by us in September in attendance upon the root louse of corn, *Aphis maidiradicis*, sharing with several other species of ants the cares and benefits of this association. It occurs more frequently, according to our observations, at this

* [= *S. molesta* Say wherever used in this report.]

† *Die Formiciden der Vereinigten Staaten von Nord-america in Verhandlungen der k. k. zool-botan. Gesellschaft in Wien*, XXXVI (1886), p. 461.

‡ "Insect Life," Vol. II., p. 257.

season of the year, with the corn root lice infesting purslane than with those upon the corn itself.

Description.—This species of ant, and also the one following, belong to the family Myrmicidæ, in which there are two nodes or thickened joints in the peduncle of the abdomen instead of a single node or scale-like joint, as in the large family of Formicidæ. Solenopsis is readily distinguishable by its peculiar antennæ, terminating, except in the male, in an enlarged club consisting of but two joints, the outer greatly elongate.

The worker, which is the commonest form, is very small, about 1.5 to 1.8 mm. in length, yellow or brownish yellow, the margins of the abdominal segments paler. The antennæ are ten-jointed, and between them are two longitudinal carinæ which end in front in two small teeth. The metathorax is not armed with spines behind. The second joint of the peduncle of the abdomen is distinctly broader than the node of the first, and also much broader in front than behind.

The female is 4.2 to 4.8 mm. in length. General color reddish yellow, the mandibles, head, thorax above, and abdomen, excepting margins of segments, yellow-brown. Antennæ as in worker, but with eleven joints. Frontal carinæ as in worker, ending in two teeth. Metathorax without spines behind. Second joint of abdominal peduncle somewhat broader than first, and twice as broad as long. Abdomen polished. Wings hyaline, with pale veins and stigma.

The male is 3.5 to 3.6 mm. long, shining dark brown, head black-brown; mandibles, antennæ, and legs yellow. The antennæ have a short scape and no distinct club; third joint about one and a third times as long as thick. Metathorax entirely unarmed. Wings hyaline.

Myrmica scabrinodis lobicornis, Nyl.*

(Plate I.; and Plate II., Fig. 1.)

On the strength of a single observation, made in 1887, I mention here a second species of ant as injurious to seed corn in the ground, more commonly known, however, to economic entomologists because of its association with injurious plant lice. This is one of the most abundant of our smaller species, occurring very commonly in the food of the smaller insectivorous birds. It may be at once distinguished from our other very abundant ants by the fact that, like the other members of its family, the stem or peduncle of the abdomen has two distinct, rounded joints instead of one, and by the presence of two conspicuous stout spines or thorns projecting backward from the posterior upper part of the thorax, which is itself finely lined and grooved longitudinally.

This species extends around the world in the northern hemisphere, and it is scattered in North America from ocean to ocean. Its habits in Europe, as reported by Dr. Auguste Forel,† are notably different from those of the same variety in Illinois. There it is subalpine in range, and breeds in July and August; while with us it is universally distributed, and the sexes appear in September and October.

* Determined by Mr. Theodore Pergande, of the United States Department of Agriculture, from a large number of specimens collected in Illinois.

† *Les Fourmis de la Suisse.*

In Champaign, Ill., May 13, 1887, about a dozen workers of this ant were seen tearing off fragments from a kernel of sprouted corn just below the surface of the soil, disposing of them much as does the species mentioned above. Many other grains were found in different parts of the same field similarly injured, being sometimes, indeed, completely excavated. The abundance of this species and the obscurity of the injury suggest that it may do greater mischief than would appear from this statement.

This species, like the preceding, feeds in fall upon kernels of corn at the tip of the ear in the field, most frequently following injuries by other insects, but certainly sometimes hollowing out the grain without their aid.

Its relations to the corn plant louse will be described in another article.

Description.—This is a rather large ant, the worker (Plate II., Fig. 1) being about three sixteenths of an inch in length, reddish in color, tinted above with brownish, or even blackish, especially on the head and abdomen, the legs a little paler. The body is deeply ridged and grooved lengthwise, excepting the abdomen, which is smooth and polished. Long hairs are scattered sparsely over the body. The long first joint of the antenna is bent nearly at right angles near the base, and sharply pointed on the outer side of the angle. The club at the end of the antenna is formed of three large joints. The thighs are thick, and the spurs at the end of the tibiæ have a row of slender teeth on each side. There are two spines projecting backwards from the thorax. The males (Plate I., Fig. 2) and females (Plate I., Fig. 1) are winged, a little larger than the workers, and are similar in size and general appearance. The males are the darker and the more slender, especially as to the abdomen; the ridges on the thorax are also smoother, and run in various directions; and the spines on the thorax are very short and thick. In the wings the large cell adjoining the stigma is invaded from the middle of its further side by the stump of a vein.

The sexes were noticed swarming September 14, 1893, after a rain following upon a long period of drouth. September 21 a nest was found at the foot of a stalk of corn (on which were aërial corn lice attended by this ant), this nest containing eggs, larvæ of several sizes, pupæ, and worker ants, in a chamber about half an inch high and three quarters of an inch in horizontal diameter, placed no more than three and a half inches below the surface of the ground.

2. *Injuries by small beetles* which gnaw away the kernel from without, commonly beginning at the germ.*

Three common beetles have been detected by us and reported by others as engaged in a somewhat noticeable injury to seed corn in the

* Beetles commonly have four wings, the front pair of which are usually hard, thick, and opaque, fitting more or less closely upon the hinder part of the body above, and similar in appearance to the rest of the upper surface. Beneath these, and next to the body, may be found the membranous hind wings, generally entirely concealed except during flight. The segment bearing the hind legs is fixedly attached to the hind body, but by a movable articulation. They also have a biting mouth furnished with two pairs of jaws.

earth, two of them among the most abundant of our Illinois insects, and the third also common, but too small to be noticed frequently by the ordinary observer.

Agonoderus pallipes, Fab.

(Plate II., Fig. 3.)

This oblong, pale brown beetle, with a blackish cloud on the back, is a species of common notoriety (although it has never received an English name) because of its annoying abundance at lights in early spring. Hibernating as an adult, it leaves its winter quarters with the first warm sunny days, and flies abroad at night in countless myriads. Shortly afterwards the eggs are laid in the earth, and a new generation comes forth abundantly in June and July. The adults themselves may be found, however, throughout the year. It is possible that more than one generation occurs in a season. We have noticed, in fact, a disagreeable abundance of these beetles at lights on warm September evenings. The species ranges throughout all, or the greater part, of the United States and Canada.

It was first made known to me as injurious to seed corn in the ground by a note from Mr. Thomas Huber, of Illinois City, Rock Island county, dated June 1, 1883, and accompanied by a specimen of the beetle "found in seed corn, buried in the kernel, eating the germ and part of the inside." In Bulletin No. 12 of the U. S. Department of Agriculture, Division of Entomology (p. 14), Professor Riley reports the receipt of this beetle during the summer of 1885, with the information that it was injuring young corn by gnawing into the seed and by eating the sprouting roots. One of these observations was confirmed by the sending of a specimen together with an injured grain. The exact amount of damage was not stated, but it was said to be quite extensive. Even before these observations I had myself detected this beetle injuring the roots of corn to some small extent:* a point determined by the dissection of specimens taken in corn fields, among the roots. Nearly half the food of these dissected specimens, however, consisted of fragments of chinch bugs, and other insect remains. The character and amount of this injury to corn have not heretofore been such as to call for protective treatment, but if the beetle should become sufficiently destructive to make such measures profitable, it is likely that "a satisfactory remedy will be found in soaking all seed corn for a short time before planting in some arsenical solution, such as Paris green or London purple, in water. Such a course will not injure the germinative quality of the seed, and will probably result in the death of all beetles which attempt to gnaw the seed."†

This species was described by Fabricius in 1792‡, but its economic record did not begin till 1882, when, in treating of the food relations of predaceous beetles in my "Twelfth Report of the State Entomologist" (p. 111), I discussed its food under the name of *Agonoderus comma*. In May, 1883, I also treated the food of the species in an article on the "Food Relations of the Carabidæ and Coccinellidæ."§ Professor Riley,

* Twelfth Report State Entomologist of Illinois, p. 43.
† Bulletin No. 12, U. S. Department of Agriculture, Division of Entomology, p. 15.
‡ Ent. Syst. I., p. 159.
§ Bull. Ill. State Lab. Nat. Hist., Vol. I, No. 6 (1883), pp. 43, 50.

in Bulletin 12 of the U. S. Department of Agriculture, Division of Entomology (1886, p. 11), records an injury to seed corn by this beetle, and figures the beetle and a grain of injured corn. He had previously published the same observation in the "Daily Gate City" of Keokuk, Iowa, for June 28, 1885.

Description.—Length, 6–8 mm., about three times as long as wide, a little depressed. Color black, shining, extensively marked with brownish or reddish yellow; legs, palpi, and base of antennæ pale brownish yellow. Head entirely black, thorax and wing covers widely margined with brownish yellow, the wing covers also narrowly margined on the inner edge, and often in front. Disk of prothorax often more or less brownish yellow. Beneath black, the prothorax and tip of abdomen more or less brownish or yellowish. Mentum not toothed at middle, antennæ with two basal joints smooth. Prothorax a little broader than long, much narrowed behind, hind angles rounded, adjacent impressions feeble and punctate. Wing covers with distinct scutellar striæ, a single hair-bearing puncture on the inner edge of the third interval behind the middle.

Aphodius granarius, Linn.*

(Plate II., Fig. 4.)

The fact that a common small shining black dung beetle, very abundant in stable manure, where it feeds in part on particles of undigested grain, may under favoring conditions transfer its attentions to seed corn in the hill, gives occasion for brief mention of this insect here.

Our only knowledge of this injury comes from Professor C. H. Fernald of the Massachusetts Agricultural College,† who received specimens of this beetle from Lancaster, Massachusetts, with the statement that they had been found destroying seed corn in the ground before it sprouted.

"This insect," he says, "has long been known in America, having found its way here many years ago from Europe, its native country. The different species of Aphodius, while in the larva state, feed in stable manure, and if this be used as a fertilizer in the hills these insects will emerge at the very place where they can do great damage. They are also liable to attack the various kinds of seed grain which have been sown on lands where stable manure is used. In this case, however, the loss is not so noticeable, since the destruction of a few kernels of wheat usually provokes only the remark that 'it did not come up.' But when the manure infested with these beetles is put into hills, and a few kernels of seed only put into each, they may be able to destroy the whole crop.

"It is recommended, when these beetles are troublesome, to soak the seed in water for a short time, and then after pouring off the water

* *Aphodius lutulentus* is sometimes included in lists of corn insects on the strength of the following observation contained in the Report of the Entomologist of the U. S. Department of Agriculture for 1881 (p. 65):

"On January 8, J. G. Barlow, Cadet, Washington county, Missouri, sent specimens of *Aphodius lutulentus* which had been injuring grains of corn contained in cow-dung."

This species may evidently infest corn in the hill under circumstances like those given above.

† Bull. No. 1, Hatch Experiment Station, Mass. Agr. Coll., p. 3.

to stir in with it a mixture composed of one part of Paris green to twenty parts of flour. The reason why we recommend flour instead of plaster, or other substances, as a diluent, is that flour is attractive as food for the beetles, and they will eat the poisonous mixture more readily."

Description.—The beetle is from 4 mm. to 6 mm. in length, oblong and very convex. Color deep shining black, beneath brownish, legs dark reddish brown. The head has three frontal tubercles, very distinct in the male, less so in the female. Clypeus projecting over and concealing mouth parts, front margin broadly emarginate at middle, without angulation. Antennæ nine-jointed, with a three-jointed club. Thorax convex, rather finely and sparsely punctured. Wing covers with closely punctured striæ, intervals feebly convex and with few minute punctures, the first interval broad, a little wider than those adjoining, instead of being distinctly narrower, as in other species of similar appearance. Tibiæ two-spurred, abdomen with six free ventral segments.

Clivina impressifrons, Lec.

(Plate II., Fig. 5.)

This beetle is included among insects injurious to seed corn upon the evidence of a single observation made by Mr. F. M. Webster in Indiana. It is not uncommon in Illinois, and is found from New York and the north Atlantic States to Kansas and Kentucky.

Nothing is known of its earlier stages. Most of our specimens are from electric-light and miscellaneous sweep-net collections, ranging from May 6 to November 15.

The only recorded case of injury to vegetation by this beetle is reported by Mr. Webster in "Insect Life," Vol. III., p. 159. Under date of June 11, 1890, he says, "I received from Whitley county, Indiana, a considerable number of these beetles, with the statement that they were found in a piece of ground which had been broken the preceding spring, the field being swampy and of a black soil, like those infested by wireworms. The beetles attacked the seed grains as soon as the latter became moistened. When received, one of the beetles had burrowed into a kernel of corn in the vicinity of the germ, and was engaged in devouring the substance."

In all probability this species, like others of the family, is essentially carnivorous in its ordinary habits.

Description.—This beetle is 6 to 7 mm. long, and about one fourth as wide. It is rather depressed and elongate, shining dark red in color, tinged partly with blackish. The prothorax is not applied closely to the hinder part of the body, being connected with it by a short peduncle. The fore legs are very thick and strong, and the fore tibiæ strongly toothed. In the row of spines on the outer edge of the middle tibia, is one of double thickness near the tip of the tibia. The prothorax and wing covers are parallel-sided, the former squarish, the latter suddenly rounded off at tip, and with punctured striæ.

3. *Injuries by footless maggots, which bury themselves in the seed grain.*

Two rather common injuries to seed corn in the ground are due to small white maggots without legs, one apparently headless, with much the form and general appearance of a very small blow-fly larva, and the other with a smooth, conspicuous head of a shining jet black color. The first is known as the seed-corn maggot, and infests corn only, as at present understood; and the second is the black-headed grass maggot, normally a grass insect, as its name implies, and injurious to corn only when this follows grass. Both these maggots penetrate the kernel, feeding on the mealy inner part, and leaving the outer shell. The first changes in the course of the summer to a small two-winged fly of the general form of the house-fly, and the second becomes a slender, small black gnat, roughly resembling the mosquito. The fly of the seed-corn maggot is little likely to be noticed in its winged state, but the gnat of the grass maggot is frequently seen in very large numbers on and near the ground in early spring.

The Seed-Corn Maggot.

(Phorbia fusciceps, Zett.*)*

(Plate II., Fig. 6 and 7; and Plate III., Fig. 1 and 2.)

This maggot penetrates the grain commonly after it sprouts but before it appears above ground, killing the germ or the growing shoot and finally hollowing out the interior so as to leave only the harder, outer parts of the kernel. In specimens of injured seed received by us from Altamont, Illinois, the larva had bored a round hole in the grain near the edge, and mined in a circular direction around the germ. In other grains it had entered at the tip of the germ, and in some beside the sprout. In one plant containing a full-grown maggot about two-thirds imbedded in the kernel, a root about three inches long had formed, and a yellowish stalk had grown two inches in height. Still other grains had almost the whole interior eaten out. Unsprouted kernels, softened by lying in the earth, are also frequently penetrated in a way to destroy the grain. Commonly these injuries are trivial in amount, but in at least one instance mentioned by Dr. Riley in his First Report as State Entomologist of Missouri (p. 154), the crop of a field in New Jersey was practically destroyed.

The adult of this insect is a small two-winged fly, not unlike a house-fly in general appearance, but more diminutive and of a lighter form. The species is known at times to do considerable injury over limited areas. It is widely distributed, having been reported from New Jersey and New York to Indiana, Illinois, and Missouri. It was first described under the name *Anthomyia zeas* by Dr. Riley, in his First Report as State Entomologist of Missouri (p. 154), his specimens having been reared from maggots sent him from New Jersey in 1868.

Mr. B. D. Walsh next refers to this species in the American Entomologist, Vol. I., 1869, (p. 224), maggots having been sent him from Eureka, Missouri.

* Much additional information concerning this species has been lately published in Bulletin 78 of the Cornell University Experiment Station, Nov., 1894, p. 499.

In his First Report on the Insects of New York (1882, p. 199), Professor J. A. Lintner gives a brief bibliography of the species and an economic treatment, following Riley; and Mr. F. M. Webster treats the species briefly in the Report of the Indiana Agricultural Society for 1885 (p. 181).

Life History.—The life history of this insect is as yet incomplete, no continuous experimental work having been done upon the subject throughout the year. Miscellanous observations and breeding-cage work at my office give us, however, evidence fairly complete that only a single brood occurs in normal conditions, the larvæ of which have been observed from May 17 to June 13, and pupæ from June 7 to 15, imagos emerging from June 11 to August 7.

Description. Larva. (Plate II., Fig. 6.)—The mature larva is about 6 mm. long and 1 mm. thick at the widest part, which is near the truncate posterior extremity, the body nearly cylindrical from this to near the middle, thence tapering with increasing rapidity to the pointed anterior end. It is dirty whitish or yellowish white in color, the last segment darker. Twelve segments are distinctly seen, the surface of all except the first and last smooth and shining, concave, rising at either end into the sutural line, which is elevated into a ridge, especially thickened and prominent beneath, and provided throughout with numerous short transverse rows of minute scabrous points.

The head is comparatively short and small, white and of a membranous appearance, alutaceous and transversely striated. The vertex is gibbous, but the front is deeply bifid. Each lobe bears at its apex a small sensory area in a dark ring, probably a rudimentary palpus; a short distance back of this is the antenna, which is two-jointed, the first joint tawny, about as long as thick, the second glassy and smaller. Beneath, each lobe ensheathes the basal part of a long and slender black claw-like mouth-hook, curved strongly downwards and a little outwards. The black color of their adjacent bases shows through the skin of the posterior ventral surface of the head. The mouth opening is between the bases of these mouth-hooks. Between the lobes below, and extending forward into the mouth opening is an oblong body, with a small lobe lying parallel to it on each side, suggesting an imperfect labium with its palpi.

The anterior stigmata are situated at the base of the second segment on each side. The peduncle seems to be often drawn into the fold of the suture. It is short, and expands into a fan-shaped transverse dilation, bearing on its outer margin six small globose lobes in a semicircular row. In alcoholic specimens this segment is uniformly more than twice as long on the dorsal median line as on the ventral, causing the head to be directed downwards and forwards.

The last segment is somewhat obliquely and sharply truncate, shorter above than beneath, less smooth than the preceding segments. Below is a large wrinkled dark tawny prominence, surrounding the transversely arcuate anal opening. The truncation is surrounded by twelve small pointed fleshy tubercles, disposed as follows: four equidistant larger ones on the lower margin, the middle pair the largest and trian-

gular; above these four on each side at about equal distances. The upper pair, one on each side, are slender and more distant from each other. Of the remaining three on each side the middle ones are on the margin of the truncation, but the other two are nearer the anterior margin of the segment, and may easily be overlooked. On the ventral surface of the segment are four more: two distant ones just behind the anal prominence, and two placed close together in the concavity just in front of the large middle pair of the marginal series.

The posterior stigmata are situated on a pair of flat-topped tawny tubercles lying near each other, a little above the center of the truncation. There are three slits on each tubercle, radiating outwardly from a point near the inner margin.

Puparium. (Plate II., Fig. 7.)—The puparium is shorter and thicker than the larva, being four to five mm. long and about 1.5 broad. It is fusiform, about equally and narrowly rounded at each end and reddish brown in color. The first two segments of the larval skin form a dark rugose convexity between the two anterior spiracles, which are as in the larva. The posterior tubercles are all present, but shrunken, surrounding the posterior stigmata, which become a little more prominent.

Imago. (Plate III., Fig. 1.)—The following is the description of the female as given by Dr. Riley:

"Length 0.20 [inch (5 mm.)], alar expanse 0.38 [inch (9.5 mm.)]. Antennæ black; style microscopically pubescent; front, fulvous, with a distinct, rather narrow, brownish cinereous margin; face and orbits brownish white; palpi and proboscis black; ocellar area somewhat heart-shaped; thorax and abdomen pale yellow-brownish cinereous, with minute black points at the insertion of the bristles; thorax with an indistinct middle stripe of brown; legs black, tinted with cinereous; poisers pale ochre-yellow; scales small, the upper valve larger than the lower."

The Black-headed Grass Maggot.

(Sciara sp.)

(Plate III., Fig. 3-7.)

When the spring is cool and wet after corn-planting, so that the softened seed lies long in the ground without sprouting, this is especially liable to certain kinds of injury; and it is under these conditions that the black-headed maggot seems most likely to affect it injuriously. Rotting grain is, indeed, undoubtedly preferred by this insect, but it has occasionally been seen to infest kernels which had begun to grow. It lives normally in old sod, feeding chiefly, or perhaps altogether, on decaying vegetation there, and will be found in noticeable numbers in corn fields only where the field was in grass the preceding year. These maggots penetrate and hollow out the kernel, often leaving nothing more than an empty hull. A score or more of them may infest a single grain.

They are also frequently noticed in rich garden ground and among potted plants, where they are accused by gardeners of eating the roots and hollowing out the bulbs.

The species is very common throughout the State, and, doubtless, throughout the country at large, but it has been noticed in its relation to grass and corn only in an article in my Thirteenth Report (p. 57).

No serious attempts have been made to determine the history of this species, but the following data from our scattered notes concerning the time of occurrence of its various stages are worthy of permanent record.

In hothouse and other indoor cultures it may continue to breed and grow the winter through. January 8, 1889, imagos were observed flying about a flower pot in my office which contained growing corn and wheat, and January 18 one fly was found with a string of several eggs yet attached to her ovipositor. On the same day nearly full-grown larvæ and pupæ were found a little below the surface of the earth in the pot. Pupæ were noticed again February 11, these having come from larvæ previously noticed feeding on rotting grains of corn. Feb. 1, 1892, larvæ of this species were received from Mr. Benjamin Buckman, of Farmingdale, Illinois, with the statement that they had mined nearly all his flower bulbs. The adult fly, he says, "seems to be a small fly or gnat, as this has been quite numerous about the pots all winter."

The larva was first brought to my notice as a corn insect in May, 1883, through Dr. Boardman of Stark county, who forwarded specimens to my office with the information that this insect was destroying newly planted corn in that county by eating out the substance of the germ, sometimes as many as three or four larvæ to a single kernel. The field had been to pasture previously—partly blue grass and partly timothy. Other fields of the neighborhood were abundantly infested, but only where the ground had been in grass the preceding year.

May 30, 1883, the same larva was observed at Towanda, McLean county, abundantly infesting corn on old sod, and other similar observations were made to July 10 of that year.

Description. Egg.—Length, .31 mm. Oval, white, smooth, slightly flattened at the ends when they are pressed one against another. Extruded by the female in strings.

Larva.—The larva is cylindrical, smooth, white, except the head, which is jet-black. The body is divided into twelve segments, not including the head, the three anterior of which are shortest, and are frequently somewhat retracted within each other. The terminal segment of the body is bent abruptly downward beyond the middle and constricted before the tip. The body is soft and flexible, and the movements of the maggot are sluggish.

The head, viewed from above, is broad-ovate in outline, narrowing forwards, and somewhat abruptly rounded in front. It is smooth and shining, about as long as the first segment, within which it is frequently more or less retracted. Its width is about three fourths its length. The entire larva is one third of an inch in length when full grown, and about one fortieth of an inch in transverse diameter, and of nearly uniform size throughout, only the first two or three segments being slightly nar-

rower than those succeeding them. It is marked with neither hairs nor punctures, and provided with no locomotor structures whatever.

Pupa.—Length 3.6 mm.; greatest width, one third the length. In general color the pupa is yellowish white, the yellow predominating on the head and thorax. The eyes are black; antennæ tinged with brown, which is darkest towards the base; the front has two rather large prominent brownish tubercles or projections, one on each side of the median line, just above the base of the antennæ. A brownish bristle arises from each of the tubercles. Prothorax and anterior margins of the wing pads tinged with brown. The anterior stigmata are on the sides of the thorax, over the eyes, the antennæ intervening in a broad transparent tubercle which contains in the center an oblong elevation with four elongate transverse black spots. Dorsum of thorax and abdomen with microscopically minute brown points. The penultimate segment has a lateral plication on each side, and the last segment is bilobed beneath, with a pair of conical prolongations, thickly beset with scabrous points, extending backward from each side.

Female.—Length 3 mm. exclusive of ovipositor, which is about .6 mm. in length. General color blackish. The head is black; antennæ brownish black, with sixteen cylindrical joints united by very short pedicels, and covered with short white pubescence; occiput and front black; palpi and proboscis dusky yellow. Thorax black and moderately shining; pleuræ brownish black; halteres pale yellowish; legs yellow, with black hairs; coxæ with golden hairs; femora with black spot on the under side at base, tips of tibiæ and tarsi dusky, hinder tarsi almost black; middle and hind tibiæ with yellow spurs at tip; wings hyaline, veins brownish yellow, branches of fork almost equally curved. Abdomen dusky blackish, paler on ventral surface. Ovipositor dusky, with two pale yellowish lamellæ at tip.

Described from alcoholic specimens.

4. *Injuries by six-legged larvae which gnaw or bore through the kernel.*

The six-legged insect larvæ which infest corn in the earth are of very unequal importance, the so-called wireworms being found more injurious to seed corn than all other insects taken together, the larva of the banded Ips being only occasionally reported to infest corn in the earth, and the other—that of the pale-striped flea-beetle—having been seen but once in this situation. Probably ninety-nine per cent. of the six-legged kernel-eating insect larvæ will be found to be wireworms of one or another species; and the greater part of these will usually belong, in Illinois at least, to a single species *(Melanotus cribulosus)*, which may well be called the *corn wireworm.*

Pale-striped Flea-beetle.

(*Systena taeniata*, Say.)

(Plate III., Fig. 8; and Plate IV., Fig. 1 and 2.)

The larva of the pale-striped flea-beetle is a stiff, sluggish insect, slender and small, less than a fourth of an inch in length and about one eighth as wide, dull, of a very pale yellowish color, minutely roughened

and hairy, the thoracic segments with a regular geometrical pattern of longitudinal depressed lines. It is also distinguished by its peculiar form, which narrows noticeably from behind forward, the head being very small.

In the only case in which it was found infesting growing corn (Champaign, May 17, 1886)* the larva had partly buried itself in the kernel beside the sprout. This and others of the species found among the roots were bred to the beetle stage on sprouting corn, pupating May 26 to June 7 and emerging as adults on the 17th of June. The great abundance of this insect in the beetle stage—so common as often to keep the leaves of the cocklebur peppered with small holes where these beetles have fed—makes even so slight a hint of its capacity for mischief both interesting and important. The adult insect also feeds on corn, as reported by Glover† on the authority of a correspondent, according to whom these beetles nearly destroyed a field of corn at Chambersburg, Pa., eating the leaves and leaving the bare stalks standing. The edges of the leaves may be gnawed away, sometimes nothing but the midrib being left, or the leaf may be riddled with small holes.

The agricultural injuries of the beetle are not confined to the corn plant, however, but it has been found by various entomologists to feed on beans, potatoes, beets, clover, strawberry and blackberry leaves, and the muskmelon, among useful plants; and also on purslane, cocklebur, plantain, ragweed (Ambrosia), pigweed (Amarantus) and lamb's-quarters (Chenopodium).

Adults of this species have been taken by us at frequent intervals from April 8 to September 2, much the most abundantly in June and July. Our substantial knowledge of its life history depends, however, on the single breeding experiment already mentioned. Four larvæ were collected May 17, 1886, and placed at once in breeding cages with sprouting corn. May 26 a pupa was found lying on the earth in the cage. June 7 another pupa was noticed yet in the earth, and on the 17th of June three adults had emerged, and one pupa about mature was taken from the cage.

Description. Larva. (Plate IV., Fig. 1 and 2.)—Length 5 mm., greatest width about .6 mm. Slender, widening gradually to the 11th segment, thence tapering quite rapidly. General color pale yellow or brownish yellow, paler towards the posterior end. Head yellowish brown, with numerous stiff hairs; jaws darker brown. Antennæ three-jointed, pale, short, and thick. The thorax and abdomen are darkest on the dorsum, fading to paler on the margins and ventral surface, and the latter very pale yellowish at the end. The first thoracic segment has two longitudinal curved impressed lines on the dorsum; segments two and three have longitudinal impressed lines on each side near the border, between which is a transverse curved line crossing each segment near its anterior margin, from which two oblique straight lines extend to the posterior margins of the segments. The legs have stout, blunt, spine-like processes on their anterior surfaces, and stiff hairs on the posterior. The abdominal segments are transversely wrinkled on both anterior and posterior margins. The skin is shagreened, and the whole body is sup-

* "Canadian Entomologist," 1886, Vol. 18, p. 177; "Entomogica Americana," Dec., 1886, Vol. II., p. 174.

† Rep. Com. Agr., 1873, p. 152.

plied with stiff, spine-like hairs of various lengths. The anal segment has a single fleshy proleg. When seen from above this segment rapidly narrows to midway its length, the posterior half forming a rounded, lobe-like projection of about one half the width of the anterior portion of the segment. On the projection are four long, stiff, spine-like hairs and a marginal crown of shorter spine-like processes, each of which ends in a fine, curved, hair-like lash. (Described from two specimens.)

Pupa.—The pupa is 3.5 to 4 mm. in length. It is pale yellowish in color, naked, and furnished with scattered stiff hairs of considerable length. The wing-pads, antennæ, and legs are folded obliquely over the ventral surface. The abdomen ends in a pair of rather long, tapering, brown spines, which are very thick at the base. In the older specimen the black eyes and dusky marking of the wing-covers show through the thin pupal skin. (Described from two specimens.)

Imago. (Plate III., Fig. 8.)—Length 3–4.5 mm. Elongate oval in shape, with a shining surface. Color very variable, ranging from almost black to entirely pale brownish, the pale variety being the common form in Illinois. The head is dull rufous, with a few punctures; antenna black. The thorax is pale, with a few faint punctures on the surface, a distinct posterior transverse impression, not limited at the ends.

The legs are dull reddish or testaceous, the hind legs fitted for leaping. The wing-covers are finely densely punctured, not striate, and each has a whitish longitudinal stripe on the middle, extending nearly to the apex. These stripes are visible on even the palest specimens. The variety *blanda* has the under side of the body and the sides of the thorax narrowly piceous.

The preceding descriptions of larva and pupa were drawn up by an assistant, Mr. John Marten, from the office specimens, not accessible as I write.

The Banded Ips.

(*Ips fasciatus*, Oliv.)

(Plate IV., Fig. 3-5.)

Among the insects attacking the kernel in the earth, is the hitherto undescribed larva* of a beetle, *Ips fasciatus*, which in the adult state is abundant everywhere, feeding upon a great variety of vegetable substances, fresh or in a state of decay. The adult beetle has long been known as occasionally and slightly injurious to corn in the ear; but the fact that the larva may infest seed corn after planting, although first noted by us in 1883, has not hitherto been published.

My first observation to this effect was made at Normal, Ill., June 18 of the above year. In a field of corn a part of which had been in pasture for fifteen years preceding, while the remainder had grown turnips the year before—which, however, had not been removed from the ground—large numbers of these larvæ were found in and about the seed kernels.† From the first, stalks were growing fully two inches high. Occasionally a larva was seen in the space between the rows, but

* Although the larva of this beetle was rudely figured many years ago (Packard's Guide to the Study of Insects, p. 444), the immature stages of the species have not anywhere been described.

† The field had been twice planted because of a partial failure of the first seed, and the kernels of both plantings were infested.

nearly all were concentrated in the hills of corn. Considering the ordinary habit of the species, it is quite likely that the beetles were attracted to this field by rotten turnips remaining in the ground.

June 16, 1885, larvæ were very abundant at Mt. Pulaski, in Central Illinois, in the kernels of ears left in the field which had been turned under by the plow and had commenced to grow. May 16, 1887, a number were taken in a similar situation from a mass of sprouting corn at Urbana, Ill.

As an adult, this species was reported by Walsh in 1867,* on the testimony of an anonymous correspondent, to have done an extensive injury some years before to sweet corn in Minnesota by burrowing in the ear; and Dr. John Hamilton, of Toronto, Canada, says† that it is often found in the green ears of maize, but only in such as have been injured by birds or other animals. September 13, 1893, it was brought to my office by an assistant, Mr. Marten, with several injured kernels of corn, from the exposed tip of the ear, which the beetle had burrowed into or eaten away irregularly. In one other case reported under this same date it was found burrowing into doughy grains beneath the husk, more than an inch from the nearest exposed kernels, the natural inference being that the grains had not been previously injured. This very common species must consequently be classed as one of the minor insect enemies of corn, which it injures both as larva and adult—much more seriously, however, in the former stage.

Injuries to other valuable plants and fruits were first reported by Walsh in 1867,‡ to whom a correspondent sent the beetle with the statement that it had eaten into apples and pears, apparently burrowing in holes made by some other insect or a bird, as many as ten or twelve occurring in a single hole. A similar report as to the pear was made in 1870 by a correspondent of Dr. Riley, who found the beetle entering the fruit by way of the calyx.§

By Dr. Cyrus Thomas, State Entomologist of Illinois, it is said**—again on the authority of a correspondent—to have injured apples in 1876—principally the early varieties, puncturing the skin, and eating its way to the center, dozens of them being sometimes found in a single apple. By one of my most valued correspondents, Mr. Benjamin Buckman, of Farmingdale, Ill., this beetle was reported to me July 14, 1884, as a "never-ending nuisance from eating into ripe apples, pears, raspberries, blackberries, etc.," on his place.

By Packard it was said in 1883 to occur in the roots of the squash, seemingly in both larva and imago states;†† and Dr. Lintner, State Entomologist of New York, mentions in his Sixth Report (p. 188) the receipt from Prof. C. H. Peck of several examples of this species taken July 4, eating into squash vines. Other foods of the adult are decaying corn stalks, cabbage, and other plants, the oozing sap of trees, the blossoms of composite plants, and the pollen and anthers of corn. It frequently follows the corn worm and other burrowing larvæ into corn and other vegetation, feeding probably upon exuding sap and excrement;

* Prac. Ent. Vol. II., p. 56.
† Can. Ent. Vol. XVII. (1885), p. 46.
‡ Prac. Ent. Vol. II., p. 56.
§ Amer. Ent. Vol. II., 1870, p. 308.
** Sixth Rep. State Ent. Ill., 1875-76, p. 91.
†† Guide to Study of Insects, 1883, p. 445.

and it occurs in the apple in the burrows of codling moths. It is also an occasional pest in the pantry, infesting bread and other cooked foods.

The feeding habits of the larva are much less known, the single doubtful statement of Peck as to its occurrence in squash vines being the only published record I have seen. Our own notes show, besides its occurrence in corn, that the larvæ breed in rotten apples, specimens having been reared by us from crab apples in 1885.

The annual number of its generations has not been determined, but our breeding notes tend strongly to establish the occurrence of more than one brood in a year. Adults have been collected by us as early as March 10 to 14 (1885), at which time they were hibernating under leaves, and as late as November 15 (1884), when they were taken from piled-up driftwood and leaves near a slough. In both cases the beetles were evidently in winter quarters. Our numerous collection records show that the species is common in the adult stage in Central Illinois through April and May and until about the middle of June. May 16 is our earliest date for the observation of the larva, other examples occurring from June 16 to 20. By the middle of July the beetles again become abundant, continuing common throughout the remainder of the year, our dates of capture at this season ranging from July 10 to November 15. Larvæ of what is probably a different generation from those mentioned above were collected by us in crab apples and transferred to a breeding cage. October 6 larvæ, pupæ, and imagos were taken from this cage, and by the 16th others had completed their transformations, and still others by the 21st.

It appears from these observations that the species hibernates as an adult, and that it gives origin during the year to at least two generations,* breeding in corn, apples, and doubtless other vegetable substances.

The larva enters the earth to transform, making a friable earthen cell.

Description. Larva. (Plate IV., Fig. 3.)—Length 5 to 6 mm., width slightly less than 2 mm. Elongate, oblong, depressed, sides nearly parallel; general color brownish testaceous, surface minutely granulate, the more exposed portions above and below finely punctate; covered with dense short grayish pubescence except the head and the greater part of the first and last segments, which are smooth. Twelve distinct segments besides the head.

Head four fifths as wide as the first thoracic segment, and four fifths as long as broad, dark red-brown. Front with two sulci arising at the bases of the mandibles, converging slightly posteriorly, and united behind by a transverse sulcus. Four shallow impressions are grouped about the center of the space included by the sulci. The clypeus is indistinctly separated from the front, deeply impressed at middle; the labrum transverse, concave, elevated at sides, emarginate in front, it and the clypeus with a setigerous puncture on each side. The mandibles are rather long and not strongly curved, broadly emarginate near middle of exterior margin. The maxillary palpi have three nearly equal joints, about as long as thick, except the last, which is a little longer

* See also Caulfield, Can. Ent., XX., p. 198.

and slenderer. The maxillary lobe is short and thick, the end rounded, fringed with a dense brush of short erect hairs. The ligula is small and short, the labial palpi small, of two joints, the first short and thick, the second more slender, nearly three times as long as thick. The gular sutures, mentum, and base of maxillæ, are usually outlined in darker color. The antennæ are four-jointed, the first short and very broad at base, the next two about equal in length, the second a little longer than thick, the third more slender, the fourth subulate, shorter, borne at the upper side of the apex of the third, which also bears below this a small accessory article about half the length of the fourth. Eyes wanting.

First thoracic segment reddish brown, with the posterior border minutely rugose-granulate, extending forwards in a point upon the median line; anterior margin narrowly rugose, remaining surface smooth and shining; one half longer than the next segment on mesal line; this latter and the following segments, except the last, similar in size and vestiture. The surface of the abdominal segments is varied by naked impressed lines, finely transversely ridged, as follows: a dorsal row of V-shaped impressions, one at the anterior edge of each segment; a subdorsal row of oblique impressions; and a lateral impressed line, interrupted at the sutures. Beneath is a similar pattern of sculpture. The spiracles are raised upon short subcylindrical shining tubercles. The first pair are at the extreme anterior lateral angle of the second thoracic segment. The remaining nine pairs are upon the abdominal segments, a little higher upon the sides. The first ones are nearer the anterior margin of the segment, but posteriorly they approach the hind margin, and those on the penultimate segment are longer and project backwards beyond the posterior margin of the segment. On the last segment they appear as two slender black-tipped tubercles on the upper surface. Beneath the tubercles, and nearer the hind margin of each segment, is a pubescent tubercle. The last segment is about two thirds as wide as the preceding one, semicircular, shining, colored like the head, bearing posteriorly a pair of stout hooks projected backwards and curved upwards, with a strong inner seta-bearing tooth near tip, not as long as the tip itself, which also bears setæ. Legs rather short, four-jointed, with a single claw. Anal proleg short, cylindrical.

Pupa. (Plate IV., Fig. 4.)—Length 5 mm., greatest width 2.2 mm. Elongate-oval, tapering posteriorly, brownish testaceous: head, wing-pads, and legs usually paler. Surface subopaque, minutely and densely punctate, and very minutely pubescent, with smooth spaces at bases of wing-pads and on metathorax.

Vertex of head with a pair of large spines on each side. Just over each eye is a pair of minute spines, and in front of these another pair on each side. The labrum is rather strongly notched.

Prothorax with four spines on the anterior margin, the inner largest of all; four spines on each side, one at each angle, and the remaining two nearer the angles than to each other. Within the line of marginal spines are three smaller ones on each side of the disk. The scutellum is three fourths as long as the metathorax, which is as long as the first three abdominal segments, and is longitudinally sulcate at middle. The elytra reach to the hind knees, and the hind tarsi reach

the posterior margin of the fifth segment. The wings attain the middle of the sixth segment.

Each abdominal segment bears on each side a long spine on its lateral edge, situated near the middle on the first seven, and at the posterior angles of the last two, pointed directly backwards on the last segment. The spiracles are rather large, circular, slightly elevated on broad tubercles, darker colored and conspicuous on the first five segments, indistinctly visible on the remainder. Just above these on each segment, is a strongly elevated carinate ridge, also bearing a spine, except on the last segment. The spines are small, except on the seventh and eighth segments, where the ridge becomes enlarged and overhanging, and the spines large. The first four segments are short, nearly equal, about twelve times as wide as long; the fifth and sixth are each about twice as long as the second, the sixth a little the longest. The seventh segmenth is subtrigonal above, with curving sides; the eighth consequently arcuate and narrow, obtusely pointed behind at middle; the ninth a little longer, less than half the width of the seventh, and truncate posteriorly. Beneath, the seventh segment is the longest, and the eighth is very short, especially at middle.

Adult. (Plate IV., Fig. 5.)—Length 5 to 6 mm. Body elongate-oval, smooth, moderately shining, black, evenly and finely, but not densely, punctured. Wing-covers with four yellowish spots, one at the base and one near the tip of each. These vary in extent and color. The wing-covers are subtruncate at apex, exposing the tip of the abdomen above.

WIREWORMS.

(Elateridæ.)

Failure of the seed to start, or a sudden withering of the corn plant when a foot or two in height, especially if the field was broken up from grass one or two years preceding, are always sufficient to warrant a suspicion of injury by wireworms. These hard, smooth, shining, reddish or yellowish brown cylindrical six-legged larvæ* are indeed much more destructive to seed-corn, under ground, in Illinois than all other insects taken together. They may begin their injuries to the seed almost immediately after planting, commonly burying their heads in it at first, sometimes eating entirely through the kernel, and even devouring it completely. If they attack the growing plant they are likely to eat the smaller roots, or to penetrate or bore through the larger ones, dwarfing or killing the corn; and later, when the young plant is several inches high, they frequently kill it outright by boring their cylindrical channels directly through the underground part of the stalk. They are far the commonest in corn on ground which has lain for several years in grass, and are much more likely to do serious mischief the second year after the breaking up of the sod. They should be sought for diligently on such lands whenever the seed fails to grow, or when the sudden withering of the plant hints at a serious damage to it under ground. At such times practically all the wireworms in the field will be found in the hills

* This general description of the wireworms does not apply to one very peculiar form (Cardiophorus) taken but once in Illinois, and described on pages 28-29.

of corn or in their immediate vicinity, sometimes as many as ten or a dozen in each hill.

Although wireworms are rarely distinguished by farmers as of different kinds, there are no less than one hundred species of these insects known to occur in Illinois in the adult, or beetle, stage, and eight species of the larvæ (the so-called "wireworms" themselves) have been found by us here injurious to corn. These corn wireworms have, however, so strong a family resemblance that they are little likely to be confused with any other insect by the fairly good observer who has once learned to recognize any one of them. They vary in length, when full grown, from half an inch to an inch and a quarter, but agree in their hard, crust-like surface, nearly destitute of hairs; their brownish color, varying from yellowish to reddish; their slender bodies, distinctly segmented, and of about equal diameter throughout their length; their flattened heads, with jaws borne in front and extending horizontally forward; the six pairs of short, stout, jointed legs on the three segments following the head; the absence of legs of any kind on the eight segments thereafter; and the single sucker-like proleg on the under surface of the last segment of the body—the thirteenth, counting the head as one. This terminal segment is often peculiarly finished above—concave or convex, notched, toothed or lobed at the sides and end, or, in one species, with a pair of conspicuous round openings on the upper surface. Taken in the fingers, the wireworms bend and wriggle with surprising strength, and easily slip out of the grasp.

They live regularly and normally in grass lands, feeding on roots of grass, where, however, their numbers are rarely sufficient to produce any notable effect upon the sod. It is only when concentrated in the comparatively scanty vegetation of a field of young corn in spring, or occasionally in young wheat or other small grain, that they do any very marked or important harm. They are to be found in grass of every description, from prairie sod and the coarse and rank sedges along the borders of marshes, to the cultivated grass of our pastures and meadows.

The commonest form of attack on the corn, as seen by the farmer, is, perhaps, the burrowing of the worm into the seed kernel, either before or after it has sprouted. All the species treated in this paper have been seen with their heads buried in the kernels, either in the field or in breeding cages. Frequently attacks in the field have been so severe, particularly the first or second year after the sod has been broken, as to require planting a second or third time. *Drasterius elegans* and *Melanotus fissilis* have been taken in the act of perforating stalks just above the root. In a field at Peru, Illinois, examined in July, 1883, as much as six per cent. of the corn in the field had been killed in this way, sometimes two or three larvæ being found in a single stem.

The roots of the corn are also eaten to a greater or less extent by all the species, the damage from this cause being sometimes quite considerable. A field in Alexander county visited in June, 1886, had spots of one hundred to two hundred hills not more than a foot high, while the balance of the field was four or five feet high. Many hills in these spots were gone. In the smaller hills many, small, slender, peculiar-looking larvæ of an unknown species of Cardiophorus were found. In

some instances they had almost completely destroyed the roots of the corn; in others the roots were bored through and the outer surface eaten away so as to almost destroy their usefulness.

Agriotes mancus is so destructive to wheat as to be known as the "wheat wireworm." *Drasterius elegans* is also known to infest this crop, as do other species as well. Rye, barley, and oats also suffer from wireworm attacks. Dr. Fitch also found them burrowing in timothy bulbs. Larvæ taken from a dense clover sod and placed in our breeding cages, where they were supplied only with grass and clover, gave us imagos of *Asaphes decoloratus*.

Among root crops, potatoes often suffer from being bored into and by having the surface gnawed and corroded by the worms; but turnips, it is said, appear to be more infested by them than any other root crop.

Besides the crops already mentioned Dr. Fitch names the following, which the wireworms are known to attack or are recorded as attacking: mangel-wurzel, cabbage, carrots, beets, onions, lettuce, rape, hops, strawberries, pinks, carnations, dahlias, lobelias, and numerous other garden flowers. They have also been reported to me by a horticultural friend as destroying planted peach pits in the earth.

The injurious species agree fairly well in the main features of their life history, changing to the dormant pupæ in the earth in July or sometimes in August, and changing again some three or four weeks later to the brown or reddish beetles commonly known as "click beetles" or "jumping jacks"—hard, somewhat hairy insects, of slender oval form, distinguished at once by their peculiar habit of springing into the air with a sudden click when placed upon their backs. A large part of these fully developed beetles remain under ground until spring, enjoying there the protection of the oval earthen cavity or cell formed by the larva as a preparation for pupation. A part, however, come forth from the ground in fall, passing the winter in sheltered places, and the remainder emerge in spring, laying their eggs most commonly in grass lands in the earth. Of their subsequent life history little is yet definitely known. It seems certain that all live more than one year as wireworms in the earth, and observation of the various sizes of larvæ of the same species to be found in the field at once, usually supports the common impression that the period of life in the larval stage does not extend beyond two years: a fact which, taken in connection with the death and decay of grass roots the first year after breaking up the sod, serves to explain the greater damage done by wireworms the second year the ground is in corn. The number of wireworms having been little diminished since the crop was changed, and their original food having practically disappeared, they are compelled to concentrate upon the corn —either the newly planted seed or the young plant while it is still very small.

The species of wireworms have by no means all been identified by breeding, but a good beginning has been made in this useful work at my own office and at the Cornell University Experiment Station. As a present aid to discrimination of forms I here present an outline of distinctive characters drawn up by my office assisstant, Mr. C. A. Hart.

GENERIC SYNOPSIS OF WIREWORMS.

It is not surprising, in view of the slight differences which separate some of the larger groups of Elateridæ, that their larvæ should fail to fall naturally into the same grouping; and it is probable that a fuller knowledge of larval characters will show that the natural relationships of several genera are different from those now accepted. The larvæ of Elateridæ do not all have the same habitus. Those of the Eucneminæ so far as known resemble larvæ of Buprestidæ. Melanactes is also quite unlike a wireworm, and the Cebrionini, as represented by Cebrio, have peculiarities which distinguish them from typical wireworms. Excluding these forms, the Illinois genera whose larval history is known may be grouped as follows:

The genera related to Alaus, and also some of the Elaterini, possess a pair of curved hooks, one each side of the anal proleg, called the scansorial hooks, which are absent in the other Elaterini; and the last segment usually bears two backward prolongations, or *cerci*. In Elater and related genera, also in Agriotes, the last segment is more or less rounded-conical and pointed, without cerci. In Melanotus it is flattened above and pointed. In the remaining Corymbitini, except Melanactes, the cerci are well developed. The following table can only be regarded as provisional until a greater number of species are studied.

Scansorial hooks present.
  Cerci present.
    Anal proleg denticulate each side.
      Muscular impressions* conspicuous on thorax and abdomen, ovate on the latter.....*Chalcolepidius.*
      Muscular impressions obsolete on thorax, narrow and curved on abdomen .....*Alaus.*
    Anal proleg unarmed except with the scansorial hooks.
      Abdominal muscular impressions obovate, last segment bearing minute setigerous tubercles above.....*Agrypnus.*
      Abdominal muscular impressions linear, last segment rugose above, without setigerous tubercles, apical notch acute .....*Drasterius.*
  No cerci, larva long and moniliform.....*Cardiophorus.*
Scansorial hooks absent.
  No cerci.
    No black pits at base of last segment.
      Muscular impressions linear, indistinct, not striate, last segment conic, terminated by an acute point.....*Dolopius.*
      Muscular impressions distinct, sharply striate.
    Last segment ovate-conic.
      Smooth, tip of last segment rounded.....*Ludius.*
      Punctate, tip of last segment with an acute point..*Elater.*
    Last segment flattened, and with a subdentate margin apically .....*Melanotus.*

* Small, striated areas, a pair to each segment, above the spiracles, near the anterior margin, usually oblong in shape, and each marked with equal, parallel ridges and grooves, extending in the direction of the long axis of the segment.

A pair of black pits at base of last segment, which is ovate-conic and pointed ..... *Agriotes.*

Cerci present..... *Athous, Corymbites, Asaphes, Cryptohypnus.*

We have recognized five or six species of Melanotus larvæ, two of which are definitely identified, and may be separated by the following key. Both have the body very finely and sparsely punctate, and the last segment finely tuberculate.

Last segment finely, sparsely, and indistinctly punctate above, 5-dentate apically, striæ of muscular impressions at middle of body 12-14, sometimes fewer in younger specimens (Pl. VI., Fig. 4, 5) ..... *communis.*

Last segment distinctly and rather coarsely punctate above, triangulate or feebly tridentate apically, striæ of muscular impressions at middle of body 4-5, rarely fewer (Pl. VI. Fig. 6, 7, 8) *cribulosus.*

A larval skin like that of *cribulosus,* but with the apical teeth more narrow and prominent, especially the median one, was found in a pupal cell with a fine male *M. americanus.* Another species frequently found in rotten wood, has the surface strongly punctate.

Cardiophorus sp.

(Plate IV., Fig. 6.)

A very peculiar long and slender elaterid larva, quite unlike a wireworm in general appearance, although belonging to the same family and doing the same mischief in the corn field, was found by me in 1886 mining and perforating the roots of corn in the sandy soil along the Mississippi in Alexander county, Illinois, with the effect to greatly delay the growth and permanently dwarf the corn. Although known only as a root insect, it probably attacks the kernel earlier, and its description is given here with that of other members of its family. It may be distinguished at once from any other larva likely to occur in the same situation by its very long and slender form, and by its nodulated appearance, due to the expansion of a part of each segment.

It is evidently capable of very serious injury to corn, channeling and burrowing the roots in every direction, and often causing decay—much more serious than the immediate mechanical injury of their mining. The perforations through the surface of the root were in some instances so numerous and close as practically to deprive the plant of all use of its roots.

The number of larvæ found in a hill varied from one or two to ten or twelve, and their great activity in the ground—through which they moved with ease—suggested the probability of their going from hill to hill, as their necessities required. This genus has never been reported in the larval state in this country except on the occasion mentioned, and then on no other plant except corn. Search among the roots of other plants in the infested field,—pigweed (Amarantus), purslane, pigeon-grass, cocklebur, etc.,—failed to discover them.

Description.—It is nearly an inch long when full grown, and scarcely a millimeter (.04 inch) wide, whitish in color, becoming yellowish

on the thorax and darker yellowish brown on the head, sparsely clothed with long hairs. The head, including the mouth parts, is nearly three times as long as wide, with the sides almost straight. The clypeus is greatly elongated, the posterior portion linear and tapering almost to a point behind, the anterior part (epistoma) rectangular, one third longer than wide, behind marked off by an impressed line, in front notched at middle, bearing a fringe of short hair each side of the notch, and emarginate behind each antenna. The antennæ are robust, flattened above, the first joint subtriangular, but little longer than wide, the second oblong, twice as long as the first, its apex obliquely truncate, making the outer side the shortest. At the inner angle of its apex is attached the very small third joint, which is directed obliquely outward; and near the outer angle is placed an accessory joint. No trace of ocelli appear. The mandibles are about half as long as the head, dark brown, vertically flattened, deeply grooved, cleft half-way to the base into two branches, one above the other, parallel and nearly straight, their apices slightly curved outwards. The upper branch bears on its inner edge three sharp teeth directed mesad, with a small denticle on each side of the proximal one. The maxillæ are slender at their bases, which are provided with numerous long hairs, and are scarcely separated by the very slender labium. The prominent excurved four-jointed maxillary palpi are inferior, and the inner maxillary lobe with its brushes of long yellowish hair is superior. Between the maxillæ extends the very slender distal portion of the labium, with diverging two-jointed palpi at tip. Thoracic legs rather stout and long, and furnished with long hairs on the coxæ and femora, the latter with about three small spines on the under side towards the apex. The tibiæ each have one or two small spines below, and several short brown spines at the tip.

The first eight abdominal segments are similar, and consist of three divisions each, except that the first division of the first abdominal, and the last division of the eighth, are wanting. The middle division is wider and subglobose; the other divisions are narrower and subcylindrical, the anterior short, the posterior as long as the middle portion. All the abdominal segments are marked below with seven longitudinal sulcations, the median smaller than the rest on the posterior division, and reduced to a fine impressed line on the anterior division, on which the inner pair of sulci are lacking. The outer pair are lateral, and narrower, except on the middle division, where they contain the concolorous spiracles. On the middle portion of each segment beneath, in the pair of sulci next to the median one, is a pair of plicated oblong prominences used in crawling. The ninth segment is two fifths longer than the eighth, and the climbing hooks which accompany the prolegs are quite prominent. This segment ends in a rounded lobe-like projection clothed with long hairs.

Drasterius elegans, Fabr.

(Plate V., Fig. 1-3.)

This wireworm, the smallest of the species infesting corn, was reported as exceedingly abundant and injurious to young wheat in Indi-

ana in 1889.* The first mention of it as an insect injurious to corn which has come to my notice, is contained in the Report of the United States Entomologist for 1887, p. 151, in the nature of a note by Mr. Webster to the effect that he had twice surprised larvæ of Drasterius, supposed to belong to this species, with their heads inserted in the stems of young corn. Mr. Wm. H. Ashmead also reports† that the corn fields of certain counties of Maryland were found to be badly infested by two insect larvæ, one of which he considered as possibly that of *D. elegans*.

It was first found by me in corn fields August 18, 1882, at Elmira, Illinois, in the course of a field study on the corn root worm (*Diabrotica longicornis*). It was taken again from the roots of young corn at Normal, Illinois, June 17, 1884, and also in Champaign county June 11 of the following year, and June 5, 16, and 29, 1886. June 26 of the last year it was collected from growing corn at Cairo, Illinois, where it was associated with great numbers of another and more injurious wireworm (Cardiophorus). An individual was seen May 16, 1887, at Champaign, Illinois, among the roots of corn, eating a kernel of sprouting corn; and another was taken a few days later among the roots of corn, following sod, in such connection with an injured kernel as to leave little doubt that it had been eating it. It occurred again in corn-field collections from the earth, made at Champaign May 29 of that year, and in others made June 20, 1888. The extent and amount of its injuries are as yet unknown, the data collected serving merely to show its presence and injurious habits in corn fields following grass.

This is the smallest of the wireworms, measuring when full grown less than half an inch in length. It was first identified by breeding by Comstock and Slingerland in 1891, as reported in their Bulletin 33 of the Cornell University Agricultural Experiment Station, published in 1891.

Description. Larva. (Plate V., Fig. 2 and 3).—"The larvæ are small, 9 mm. to 12 mm. in length, sparsely hairy, and considerably flattened in form, tapering slightly toward the extremities. The body is of light waxy yellow color, with the head and following segment considerably darker. A deep linear mesal impression extends along the dorsum. The mandibles are rather large and not toothed. The caudal segment is much flattened, and has a nearly heart-shaped caudal notch formed by two short, broad projections that curve upward, each of which terminates in two short, blunt, horny, diverging tubercles. The dorsum of the segment is bounded by a narrow ridge which, at the sides of the segment, bears five or six short, horny tubercles. The oval area bounded by this ridge is strongly convex cephalad, and deeply concave caudad. This area is marked by two distinct linear impressions diverging slightly cephalad from which many fine wavy wrinkles radiate. The proleg is large, hairy, and has no raised ridge around its base, but the segment is deeply excavated just back of it."‡

* F. M. Webster in Bull. 22, Div. Ent., U. S. Dept. Agr., p. 52.
† "Insect Life," Vol. III (1890), p. 54.
‡ Comstock and Slingerland, in Bull. 33, Ent. Div. Agr. Exper. Station, Cornell Univ., p. 267.

Adult. (Plate V., Fig. 1.)—The beetles are small, from 6 mm. to 7 mm. in length. General color rusty red with black markings. The body is closely punctured and covered with fine short yellowish hairs. The head, a fusiform spot on the thorax, an oblong spot near the base of each wing-cover, and an irregular larger band crossing both wing-covers behind the middle, and the under side of the abdomen are black. The legs are brownish yellow.

Notwithstanding the abundance of this species, comparatively little is yet known of its life history. Larvæ placed in breeding cages by Professor Comstock April 24 were found July 4 to have reached the beetle stage in earthen cells in the sod. Comstock and Slingerland were not able to say, however, whether the beetles soon emerged after this transformation or whether they hibernated in the earth. Our own records show so large a number of collections of hibernating beetles of this species made from a variety of situations, that there can be little doubt that free hibernation is their habit. For example, November 1, 1883, they were taken under boards lying upon the ground. On the 7th of November, 1884, they occurred with other hibernating insects at Normal, Illinois; and on the 14th and 15th of the same month they were collected from driftwood along the Mississippi River near Quincy. December 3, 1884, they were found in hibernation under leaves and rubbish in strawberry fields, December 2, 9 and 16, 1889, they were under boards on grass lands, and December 4 under leaves of dock and other plants in corn fields. December 23, 1891, and February 25, 1892, they were taken by us in the woods under leaves; and April 8, 1890, from roots of old corn and from under boards. March 31 and April 24, 1884, they were still in hibernation in strawberry fields, but by April 27, 1892, specimens were taken on the wing at dusk. They are much the commonest in our collections made in May and July.

Comstock found the larvæ quite abundant in April in sod-land on the Cornell University farm.

The larvæ of eighteen small lots collected by office assistants in Illinois, divide readily into two well-distinguished sizes, and only two. Those of the smaller size, 6.2 mm. long, were taken March 26, June 5, 11, 26, and 29, and in November, without date specified; and those of the larger size, averaging 8.8 mm. in length, were found May 19, 29, and 30, June 16, 17, and 20, July 8, August 18, and October 26.

From these data it seems probable that this species emerges in summer and early fall, probably laying its eggs in part the same season, as indicated by my small larvæ taken in November, and also, from timothy sod, the 26th of March; that it hibernates in sheltered places and continues abundant until June of the following year, doubtless breeding meanwhile, as shown by the number of young larvæ occurring in June; and that it lives two seasons in the earth before pupation—a supposition necessary to account for the distinction in size noticeable in larvæ collected together at various dates, practically throughout the entire year.

It follows from the foregoing that late fall plowing, commended as a general defence against wireworm attack, would probably be substantially without effect against this species. Breeding experiments

with respect to the habit of hibernation in the pupal chamber are, however, needed to determine the value of this economic method for *Drasterius elegans*.

The Wheat Wireworm.

(Agriotes mancus, Say.)

(Plate V., Fig. 4-6.)

This larva, commonly known as the wheat wireworm, is injurious to corn as well as to small grain. It is a cylindrical pale brownish yellow species, readily distinguished from any other wireworm (except another species of the same genus, doubtfully separate) by the smooth outlines of the last segment of the body, (which is slightly pointed at the tip), and especially by two conspicuous black circular pits upon the upper surface of this segment near its front border.

It was first found by me in corn fields July 1, 1883, in a field near Peru, Illinois, which had been broken up the preceding year from sod. Specimens collected here were devouring the roots of the corn and perforating the stems just above the roots, the plants being at the time from eight to twelve inches high. The effect of this attack—especially of the perforation of the stems—was shown by the sudden withering of the infested stalks. About six per cent. of the corn in the field had already been killed in this way. It was further obtained by us April 27, 1886, in an old corn field among specimens collected by following a plow.

July 4, 1889, it was sent to us from Prophetstown, Illinois, with a report of serious injury to corn and potatoes, plants of which withered and died under the attack. A field of one hundred acres over which they seemed well distributed, was reclaimed swamp land, recently brought under cultivation. Finally, I found it near Sycamore, Illinois, on the 11th of July, 1889, in a field tiled and drained the year before and broken up in September from a marshy sod. In this field it had completely killed the corn in small patches, and notably crippled its growth in others.

The larva has further occurred in our collections from pastures and meadows at Champaign. It is not nearly so abundant in Illinois as some other wireworms, only about one eighth of our office collections representing this species. In New York, however, it seems to be the commonest wireworm known, making ninety-one per cent. of some 10,000 larvæ sent to Professor Comstock, of Cornell University, for experimental uses.

It has been published as a corn insect only in a brief note in "Insect Life" (Vol. III., p. 246), by Mr. C. A. Hart, an assistant of this office, whose statement was based upon our breeding-cage work and collections.

Its injuries to wheat, though doubtless occurring in Illinois, have not come to the notice of myself or my assistants. It has, however, been reported from wheat fields in Indiana by Mr. F. M. Webster,* infest-

* Rep. U. S. Dept. Agr., 1887, p. 153.

ing there lands of various previous history. An older article by Mr. J. Pettit* gives a full acount of its attack on wheat.

The length of time passed by this species in the larva, or wireworm, state cannot be given with certainty. Mr. J. Pettit, of Ontario, who was the first to rear it from the larva to the adult, was of the opinion that the larval state did not last longer than three years.† Messrs. Comstock and Slingerland, in their work on wireworms at the Cornell University Experiment Station, 1889–1891, from extensive and careful breeding-cage experiments—one at least of which continued through two years and two months—arrived at the same conclusion. They also ascertained that as the summer advanced the larvæ became gradually less destructive, and that by November 1 (probably earlier in the fields) they cease feeding and go deeper into the ground, where they remain without food for five or six months. It is early in spring, when they begin to eat again after this long fast, that the greatest damage is done to crops.

Larvæ become full grown and pupate in July, in earthen cells. The change occurs a few days after these cells are formed, and pupæ are most abundant about the middle of July. Adults may be found by the end of this month, and by about September 1 all the pupæ have changed to beetles. For a few days after the change they are yellowish white in color, and nearly as tender as pupæ. Before winter, however, they have become hard and normally colored. In Comstock's experiments, the beetles passed the winter in their earthen cells, none coming to the surface the same fall unless their cells were injured. Adults thus disturbed did not form new cells, but worked their way to the surface and soon died. In April the greater number of the beetles emerge from the earth, though we have taken them almost continuously from March 22 to the middle of July. They are most active in the evening or at night.

Description. Larva. (Plate V., Fig. 5 and 6.)—"The newly hatched larvæ must be very small, and, according to European writers, they grow very slowly. The smallest larvæ of the wheat wireworm we have seen were about 4 mm. in length. All variations in size occur at the same time up to a full grown larva, which measures from 16 mm. to 19 mm. The larvæ are quite slender, cylindrical, somewhat flattened on the venter, sparsely hairy, and of a waxy yellow color, lighter at the sutures. The anal segment tapers gradually to a subacute brown point, and bears on the dorsal aspect, near the cephalic border, two large conspicuous, brown, eye-like depressions resembling the breathing pores. By these, the wheat wireworm of any size may be readily separated from any other species which we have found infesting fields."‡

Pupa.—"The pupa resembles the imago in many of its characters, being, however, about one fourth longer, and in the abdominal region more slender, the only differences of moment being the following:

* Can. Ent., Vol. IV. (1872), p. 3.

† "Description of the Wheat Wireworm." Can. Ent. Vol. IV. (1872), pp. 3-7. This article contains figures and descriptions of the larva and pupa by Dr. Horn, from specimens reared by Mr. Pettit.

‡ Comstock and Slingerland, in Bull. 33 Ent. Div. Agr. Exper. Station, Cornell Univ., p. 252.

"Thorax at each angle with a stout bristle-like appendage more slender towards the tip, about a sixteenth of an inch long. That at the anterior angle is supported on a small papilla, the posterior being prolonged from the tip of the angle. Terminal abdominal segment above subquadrate, emarginate at tip, angles acute and divergent, beneath with a deep sinuous groove on each side and a median shallower groove.

"Abdomen above and beneath of nine segments, the first very narrow, distinctly visible above, beneath visible only at the sides; second slightly broader, beneath nearly entirely concealed. The remaining segments are distinctly visible both above and beneath, the distal angles being slightly prominent, giving the sides of the abdomen a dentate appearance." (GEO. H. HORN, Can. Ent. IV., 1872, p. 6.)

Larva. (Plate V., Fig. 1.)—Robust, color piceous to brown, elytra often paler, surface moderately pubescent. Head and thorax very convex, the mouth inferior, mandibles broad and chisel-shaped at tip; surface of head and thorax densely and coarsely punctate; striæ of elytra deep, punctate, interspaces nearly flat, rugose, and punctulate, antennæ and feet rufous.

Length 7–9 mm.

Agriotes pubescens, Mels.

(Plate VI., Fig. 1.)

This species, closely related to the foregoing, is not separable from it in the larval stage, and as the two occur in about equal abundance in corn fields and have a similar life history, they may best be treated—at least until more is known of them—as a single economic species.

Melanotus communis, Gyll.

(Plate VI., Fig. 3-5.)

This species is one of the most abundant of our click beetles, and the wireworm descended from it has been taken by us in about equal numbers with that of the following species (*M. fissilis*). The two together make about twenty-eight per cent. of the wireworm collections of this office. The species is widely distributed, ranging at least from Nebraska to New Jersey and Canada. The wireworm of *M. communis*,* though so abundant generally, has not been especially common in our collections from corn fields, only eight out of forty-five lots collected by office assistants having come to us from such situations. These were taken respectively June 30, 1883, from about the roots of corn near Milan; from corn fields at Champaign, May 25, 1885, and May 16, 1886; from roots of corn after prairie sod at Mendota, July 17, 1884; from corn fields near Peoria, July 1, 1883, from sod corn at Mt. Pulaski, June 16, 1885; from corn at Urbana, May 7, 1888; and from a corn field on the University premises at Urbana, November 25, 1890.

Life History.—The length of the larval period is not definitely known, but is not less than three years. According to the account of Comstock and Slingerland (with which our own breeding-cage results agree), pupation occurs during July, and about one month later the change to the adult state has taken place. The beetles under observation

* The larva of *M. fissilis*, the species following, is quite possibly included here.

did not leave the cell in which they had undergone their transformations in the breeding cages, until the following spring, which would indicate that they normally pass the winter in the ground. Harris says, however, that they are found under the bark of trees, where they pass the winter, having completed their transformation in the previous autumn. Dr. Fitch says that the beetles are most abundant during the months of April, May, and June. Their numbers then diminish, and only a few are to be found in August, but they are again quite numerous in September and the following months.

In the collections of the office the beetles have been most abundant in April. Electric-light collections of Melanotus were made in May and June; and in November, December, and February, *communis* has been taken in crevices of decaying logs and under bark in the woods.

Description.—The larvæ vary considerably in size at maturity, but may be from 20 to 25 mm. long.

"They are subcylindrical in form, nearly smooth, shining, and of a light brown color, with the head, thoracic and last segments considerably darker, and the venter and margins of the segments lighter in color. Body sparsely hairy, and each segment marked on the sides just dorsad of the spiracles with a linear impression. The cephalic border of the segments is slightly elevated and rendered distinct from the rest of the segment by a wavy dark border. Touching this border on each side of the dorsum of the segments, is a large, dark, elliptical, striated muscular impression. The caudal segment is much flattened, has no caudal notch, but ends in a short, blunt, horny tubercle. On each side of this tubercle the margin is very obtusely notched, forming two wave-like projections. The dorsum of the segment is much roughened and marked by four linear impressions near the cephalic border, and a similar mesal depression on the dorsum near the caudal extremity.

"The change to a pupa takes place during July. The mature larva forms an earthen cell similar and probably made in a similar manner to the cell of the wheat wireworm. This cell is about three fourths of an inch in length and three eighths of an inch wide. Soon after the cell is finished the skin of the larva opens at the sutures on the top of the head and along the median line on the dorsum of the following three or four segments. The white and tender pupa then works itself out, leaving the cast larval skin crowded into one end of the cell. The wing-pads, legs, and antennæ of the pupa are folded closely on the breast. In other respects it resembles the beetle, but is nearly one fourth longer, and the nine segments of the abdomen are distinctly visible. It is much larger than the pupa of the wheat wireworm, and in addition to the long sharp bristle at each angle of the thorax it has two similar shorter ones, one each side of the mesal linear depression near the caudal border of the thorax."

"The change to a beetle takes place in about one month. The rather slender, glossy, dark brown beetle varies from 11 mm. to 15 mm. in length, and its body is closely punctured and clothed with fine, short, incumbent grayish hairs. The wing-covers are striated by deep oblong punctures, the intervening spaces flat and minutely punctured. The mouth parts are on the anterior portion of the head, and the front is slightly flattened but distinctly margined back of the labrum. The an-

tennæ are reddish brown and serrate. A smooth, shallow, impressed line extends along the mesal portion of the thorax. The tarsi are not lobed beneath and the claws are pectinate."—Comstock & Slingerland.

Melanotus fissilis, Say.

(Plate VI., Fig. 2.)

This species is, according to Le Conte, abundant throughout the Middle and Southern States, and it also extends northward into Canada. The larvæ and beetles are associated with those of *M. communis* throughout Illinois, but in the southern part of the State this is the more abundant of the two.

The larva has not been separated by us from that of *M. communis,* and the two are quite possibly indistinguishable.

The beetle is from 12 mm. to 15 mm. in length, a dark reddish brown in color, with the body closely punctured and covered with fine, short, pale yellowish or grayish hairs. The wing-covers are striated with deep punctures and the flat intervening spaces are minutely punctured. The thorax in *fissilis* is without the smooth median longitudinal impressed line found in *communis*, otherwise it is difficult to distinguish these species.

Life History.—The life history of this species is probably parallel with that of *M. communis*, pupæ being found by us July 12, 1886, and August 12, 1889, as in that species. A pupa introduced accidentally, in blue-grass sod, into a cutworm cage in 1889, probably had its cell broken in moving the sod, and August 20 it was found lying on the surface. August 22 the beetle cast off the pupa skin and appeared to be none the worse for its strange experience. Larvæ that had already formed cells May 26, 1890, in the breeding cage, about six inches below the surface, had pupated July 26. From a stock-cage of wireworms collected at various times for experimental use during the spring of 1889, we obtained September 21 several specimens of this species, with hardened crusts and fully developed color, as if their final transformations had been completed some little time before. They were still in their pupal cells, where they would probably have passed the winter if they had not been disturbed.

Our collections of imagos have been made at substantially the same times as those of *communis.* In November, December, and February, numbers of adults were found in crevices of old logs, sometimes as many as a dozen to thirty or more within a few square inches.

Melanotus infaustus, Lec.

A single specimen of this beetle was bred in 1889 from a lot of larvæ kept in a stock cage and fed upon corn, the others giving us *M. fissilis.* All were collected in a corn field near Champaign, and after being placed in the breeding cage were not disturbed until September 21, 1889. They were then found to be well-colored adults lying snugly in the pupal cells, and apparently prepared to pass the winter there.

The adult is 11.5 mm. in length, of a dark brownish color, rather slender, and covered with grayish hairs. The thorax is longer than wide, with straight, diverging sides, and the posterior angles have only a single carina. It is rounded in front, and is very sparsely punctate.

The form of the thorax clearly distinguishes this species from the others attacking corn. The legs and antennæ are chestnut-red.

The Corn Wireworm.

(*Melanotus cribulosus*, Lec.)

(Plate VI., Fig. 6-8; and Plate VII., Fig. 1.)

This is without doubt by far the commonest wireworm in corn fields in Illinois. Larvæ referable to it make not less than one third of the wireworm collections of this office, and fully half of these were taken in corn fields at dates from April 27 to June 28, that is to say during the time when wireworm injury to corn is generally commonest and most serious. On the other hand, the adult is far outnumbered by *M. communis* in miscellaneous collections, being, indeed, rather rare with us except among insects obtained from corn fields or bred from larvæ infesting corn. Le Conte found the species in Nebraska, and Smith's Catalogue of the Insects of New Jersey credits it to that state.

Little has been added to our knowledge of this species since I published in 1886 a brief account of its life history in my Miscellaneous Essays on Economic Entomology (p. 17). The statements of that article were based chiefly upon observations made in 1885 in a field of corn in Champaign county which had lain in pasture for many years before.

The injury to which corn is liable when the ground is infested by this species was well illustrated by the condition of this field, where I estimated that wireworms averaged three to a hill for the entire area, the number ranging from two to six or eight. Only about one hill in fifty was found free from them in the higher, more sandy, parts of the field, although on the lowest ground there were no wireworms at all in several hills examined. They had attacked only the kernels as yet, but would later, of course, have eaten the roots and burrowed the underground portions of the stalk. All the wireworms in this field were concentrated in the hills of corn, not a single one being found during protracted search made elsewhere. Even the few remaining tufts of sod of the preceding year were free from them where the hills around were badly infested. The ground had been in corn the year before, and had then been considerably damaged, but not nearly as much so as at the time of my visit. It had, however, been replanted about June 1 (1884), and the owner was plowing up the first planting May 25, 1885, with a view to planting again.

The wireworms taken from this field were easily assorted in two lots, and only two, according to size. Placed in breeding cages May 25, they were still living as larvæ June 13 and July 12. By August 3 pupation had begun, the pupæ being enclosed in elongate cells in the earth, and on the 22d pupæ were again found, but no imagos, while September 12 pupæ, recently transformed imagos, and others of a color and consistency to indicate that they had changed at least a few days previously were found still in the earth. None of the beetles came out of the earth in the cage during early fall or winter, but February 17, 1886, all were found dead in their pupal cells, badly infested by mites. The larvæ of the smaller size were not bred in this experiment, but only those seemingly full grown. All the specimens reared were *cribulosus*,

except a single *communis*, which may not impossibly have been introduced with the sod. The earth in the breeding cages was mixed with soaked corn kept covered with fresh sod.

A similar but smaller experiment was made the following year, with a like result, wireworms placed in a breeding cage in May yielding the adult of this species by September 17.

From these experiments it is evident that the larval life of *cribrosus*, and clearly of *communis* also, is completed during the latter part of the summer, and that the transformation to the imago begins in early autumn. It is probable that the imagos emerging pass the winter in their pupal cells, although the death of our specimens in the earth makes the evidence on this point incomplete.

The hibernation of this species above ground anywhere outside its pupal chamber has not been positively ascertained by us. The only collections made from the office which could possibly bear this interpretation are five obtained in April from the 8th to the 28th of the month. Three of these were from ground being plowed, and both the other specimens came from corn fields—one from about the roots of old corn of the preceding year.

Description. Larva. (Plate VI., Fig. 6-8.)—Length about 20 mm., width 2 mm. Subcylindrical, slightly depressed, yellow-castaneous, extremities darker, surface glabrous and shining, minutely and very sparsely punctate.

Head flattened; clypeus with a rather sharp black tooth at middle, and a shorter tooth each side. Exterior to these, the front margin bears a brush of long, golden yellow hair. Four sulci extend back from the front margin, the outer pair ending in a setigerous puncture. The posterior clypeal prolongation widens slightly behind the constriction and usually tapers a little posteriorly, but does not become narrower than at the constriction. Labrum invisible. Mandibles black, toothed internally. Maxillæ and labium as usual in wireworms, the palpi short and stout. Antennæ short, the penultimate joint obtusely toothed beneath, the last joint hemispherical, whitish.

First thoracic segment about as long as the other two combined. Abdominal segments about two thirds as long as the prothoracic, except the first, which is shorter, and the last, which is nearly twice as long as the one preceding. Each segment bears an elevated border in front, limited by a sharp darker edge posteriorly, which is obsolete at the middle on the thoracic and first abdominal segments. This edge curves suddenly backward in front of the spiracles. These are oblong ovate, not far from the anterior margins of the segments, one on each abdominal segment except the last, and the thoracic pair on the mesothorax below the lateral margin. Above the spiracles, close to the elevated border, is a transverse longitudinally striated oval muscular impression, and between them and the spiracles originates an impressed line which extends backwards partially across the segment. The striæ of the muscular impressions are light colored, and they are separated by dark brown flat intervals. On the middle segments of the body there are usually five striæ in each impression, sometimes fewer, and in one specimen none. On the terminal segments the number may reach ten or twelve; and on the prothorax there are usually more than five. The legs

are stout, and armed with brown spines. The last segment is characteristic of the species. Anteriorly it is quite convex, and marked with four longitudinal nearly parallel impressed lines, the inner pair diverging anteriorly; posteriorly it is flattened a little, especially at the tip.

The surface is covered, as usual in Melánotus, with small tubercles, more numerous near the tip, and is also rather coarsely punctate over the posterior two thirds, more closely near the tip. In *M. communis* the punctures are finer, sparser, and much less conspicuous. At the tip of the segment is a short, feebly elevated margin, ending on either side in an angle or blunt tooth, and bearing a third angle or tooth at middle; the outline between the teeth often scarcely concave. The sides of the segment are rounded, not evidently margined or angulate.

Imago. (Plate VII., Fig. 1).—Length 9-11 mm. Pubescent; color brownish fuscous, lighter than in *communis,* and tapering less posteriorly. The front is not concave or margined. The thorax above coarsely and rather densely punctate, shining; sides nearly straight in male, rounded in female; posterior angles unicarinate. Claws pectinate as usual in Melanotus.

Asaphes decoloratus, Say.

(Plate VII., Fig. 2-4.)

This widely distributed species, occurring through all the Northern States east of the Mississippi River, is fairly abundant in our collections, nearly one third of them coming from corn fields. Otherwise the larvæ have been collected in meadows and pastures and freshly plowed sod, from oats fields (twice) and clover, and once from woodlands.

Of the frequency and amount of its injuries to corn, as compared with other species infesting that crop, we have no very precise information. The general drift of our observations is, however, to the effect that it is of little significance as a corn insect; a conclusion of some interest, since its life history differs from that of the other species in a way to render it less subject to destruction by fall plowing—almost the only preventive measure hitherto found practically useful for wireworms. Indeed, the early date at which larval activity ceases, makes it unlikely that injuries by this species will be as serious as those whose period of pupation comes later in the season.

Life History.—Shortened larvæ enclosed in oblong oval cavities were turned out by the plow in a corn field in Urbana April 20, 1886. They were placed in a breeding cage, and by May 15 one of them had pupated on the surface of the earth. June 7 one beetle of the lot emerged, and another partially escaped from its pupal skin, but died before completing the transformation. In other breeding cages larvæ were found to have pupated May 16 and June 13, 1886, and a beetle was obtained from the earlier one on June 2. On May 16, 1887, a pupa was turned out by the plow in a corn field, and the beetle from it appeared May 25. In a cage containing larvæ taken in a clover field, both larvæ and pupæ were found July 19, 1887. Again, larvæ kept in an insecure cage outdoors had formed cells as late as June 17, 1890, but they had not pupated on July 1. Subsequently, when the cage was examined, all had escaped.

The experience of Comstock and Slingerland was to the same general effect, except that preparations for pupation did not begin with them until the latter part of May or the first of June. Adults had emerged, however, from their pupal cells by June 27, in about six weeks after the larvæ had been placed in their breeding cages. With us, it will be noticed, preparations for pupation began April 20, the first pupæ were found May 15 and 16, and the beetles appeared as early as May 25. The pupal stage was of about three weeks duration.

Description. Larva. (Plate VII., Fig. 3 and 4.)—"Subcylindrical in form; considerably flattened; dorsum slightly more convex; and lateral fold prominent. Length, when full grown, 20 mm. to 25 mm. Color dark waxy yellow; mandibles and cephalic margin of head black shading gradually into the dark brown color of the head. Head flattened, and with long brown hairs arising from the pits on the sides. The clypeus with the caudal portion fusiform, the cephalic part of this portion *narrower* than the caudal part; cephalic margin of clypeus with a large, prominent, three-toothed lobe on median line; the mesal tooth of this lobe is larger and longer than the others; on some specimens these teeth are more or less worn off. Labrum apparently wanting, being entirely within the cavity of the mouth. The mandibles are large, arcuate, and bear a short curved median tooth on the mesal side. The maxillæ have the cardo strongly bilobed; the stipes very slightly diminish in width toward the proximal end, which is truncate. The sides of the gula are nearly parallel, this part being but slightly narrowed towards its base; the base is rounded, with one long hair arising from a deep excavation near each lateral angle. Prothoracic segment subquadrate and nearly as long as the other two thoracic segments. The remaining segments of the body of nearly uniform length, slightly constricted at the sutures, and almost twice as wide as long. The caudal segment is considerably flattened, and has a large oval caudal notch formed by two rather long flattened projections, each of which curves slightly dorsad and terminates in two short, blunt, horny diverging tubercles; the two inner tubercles project dorso-mesad, with a small hair-bearing tubercle arising from the lateral aspect; the outer tubercles project nearly directly dorsad. The dorsum of the segment is bounded by a narrow ridge which on the sides of the segment bears four short, distinct, blunt, horny tubercles, the more caudal one being considerably larger. The area bounded by this ridge is convex cephalad, slightly roughened, bears no hairs, and is marked by a deep, roughened, linear depression on each side and a short mesal linear impression extending from the middle of the area to the caudal notch; ventral portion of the segment slightly wrinkled; the semicircular fold around the anal proleg extends upon the base of the leg in the form of a thin finely striated margin; the distal margins of the joints of the leg are similarly striated The prosternum is triangular, and acutely wedge-shaped caudad. The thoracic legs are short and stout.; each joint armed with short brown spines. Spiracles large, elongate oval, brown; there is a single thoracic pair situated on the second thoracic segment on the inflexed portion just in front of the coxæ; there are eight abdominal pairs, each situated near the cephalic border of the segment. Surface of the body shining.

nearly smooth on the thoracic segments and on the venter; the dorsum of the abdominal segments is marked with numerous shallow transverse notches, and a slight dark ridge which crosses the segment near the cephalic border, then curves suddenly, extends obliquely caudo-ventrad on each side and nearly meets the faint impressed line extending across the segment. The caudal and cephalic margins of the first thoracic segment, and the caudal margin of the other segments, except the first and last, are marked by numerous fine longitudinal striæ. A linear mesal depression ending abruptly near the caudal border of each segment, extends along the dorsum. Body sparsely clothed with long yellowish brown hairs; a row of from 18 to 22 hairs extends around the body from one subdorsal line to the other near the caudal border of each segment except the head and last segment; two similar hairs arise near the cephalic margin of the segments, one dorsad and the other ventrad of each spiracle; the lateral and caudal tubercles on the anal segment have one or two hairs arising from their sides, and other hairs arise from the proleg and from small tubercles on the venter of the segment."—Comstock & Slingerland.

Imago. (Plate VII., Fig. 2.)—"Piceous black, shining, surface often with æneous tinge, elytra often pale, legs pale rufous; surface sparsely clothed with grayish pubescence. Thorax moderately, not densely, punctured, hind angles divergent, carinate, the carina diverging from the margin; flanks moderately densely punctured in front, a large smooth space posteriorly. Elytra moderately deeply striate, striæ punctured, intervals convex and punctulate. The prosternal mucro is horizontal, the mesosternum is however not prominent. Length 9-15 mm."—Geo. H. Horn. (Trans. Am. Ent. Soc. VIII., p. 73.)

The female differs from the male in having the thorax shorter, its disk more convex and punctured, the sides more arcuate, and the general form stouter and more convex

NATURAL ENEMIES OF WIREWORMS.

A single parasitic fly has been bred by us from a wireworm, which because of its condition when found, could be only doubtfully referred to *Melanotus fissilis*. Comstock and Slingerland frequently found larvæ killed in their breeding cages by a fungus determined by Professor Roland Thaxter as probably *Metarrhizium anisopliæ*. Larvæ killed by this disease have the body filled by the growth of the fungus, and assume a woody appearance. An Asaphes larva turned out by the plow at Champaign May 10, 1886, was infested by a parasitic fungus of another genus, very much like Cordyceps.

In my work on the food of birds,* I found that some seventeen species eat to some extent "click beetles," or their larvæ, the wireworms. These insects constitute about two per cent. of the food of five species of the thrush family—the robin and the brown, the hermit, the wood, and the Alice, thrushes. The examination of the food of these birds continued throughout the year, and the proportionate amount of these beetles eaten was found to be greatest during the months when they

* Bull. Ill. State Lab. Nat. Hist., Vols. I and II.

were most numerous; but even then the quantity destroyed was scarcely sufficient to affect materially their average numbers. Mr. E. V. Wilcox,* while studying the food of the robin, at the Ohio Agricultural Experiment Station, found in the stomachs of twenty-seven of these birds, shot in April and May, Elateridæ amounting to three and one half per cent. of their food. Of the remaining species of birds known to eat them, none take enough to make more than a fraction of one per cent. of their food, except, perhaps, the crow. Dr. Fitch says that "wireworms and their progenitors, the snapping beetles, constitute the favorite food and principal sustenance of these birds [crows]."†

PREVENTION AND REMEDY.

Probably no class of agricultural insects has had prescribed for it a longer list of artificial remedies than the wireworms, and certainly no such list has been of less practical value. After many generations of experience with their work in this country and in Europe their injuries continue at present practically unchecked by any treatment consistent with the methods of American agriculture.

Even poisons of the most deadly sort applied to corn previous to planting, or to food lures distributed through the ground for the purpose of drawing off the attention of these insects from corn, have proven almost entirely valueless, both in my experience and in the more elaborate trials made by Comstock and Slingerland in New York. Late fall plowing, breaking open the pupal chambers within which the recently transformed adults pass the winter, will probably have the effect to diminish generally the number of these beetles during the following year. Comstock and Slingerland have also ascertained that the adult beetles are susceptible to certain poisons judiciously distributed with certan attractive kinds of food; and I have to suggest a systematic rotation intended to interpose between grass and corn a crop not vulnerable to the wireworm. Otherwise we are substantially without a hint of any means of diminishing the ravages of these insects other than the time-honored resource of the corn farmer, namely, late planting of his corn the second year after sod, and late replanting if the first planting is destroyed. In the latter case it is well to plant between the rows, allowing the first corn to stand as long as is consistent with a proper cultivation of the field. All the wireworms being at the time concentrated in the old hills of corn, if these be destroyed when the field is planted the second time, the wireworms still active in the earth are forced to attack the freshly planted kernels as their only food resource.

The first experiments with poisons for the wireworms of which we have definite record, were made at my office in 1885, and reported briefly in my "Miscellaneous Essays on Economic Entomology" (p. 18), printed the following year.

Later, in May, 1888, we fed thirty-seven wireworms on corn soaked for seven days in a mixture of water and Paris green. The corn was covered with a coating of the green poison, and was eaten freely by some of the worms without killing them. Twelve wireworms fed on corn

* Bull. Ohio Agr. Exper. Station, No. 43, (1892), p. 127.
† Eleventh Rep. (Trans. N. Y. State Agr. Soc., (1866), p. 542.

soaked in Fowler's solution diluted with an equal quantity of water were not affected, although a portion of the corn was eaten. Twelve others fed on corn soaked in an alcoholic solution of arsenic, were not injured by the poison, though feeding freely on the corn. Experiments in June and July, when wireworms were fed on corn soaked in a solution of arsenic in boiling water, were less satisfactory because the larvæ were so near pupation that they ate little or none, pupal cells being formed five days after the experiment began. Corn soaked in a solution of strychnine—four grains to a half pint of water—over night, and fed to seven wireworms June 8, 1888, had not affected them by July 5, although the corn was slightly eaten. Twelve worms supplied with corn soaked twenty-four hours in an alcoholic solution of corrosive sublimate June 27, 1888, did not eat the corn.

A repetition of these experiments in June and July, 1891, by a different assistant and under somewhat different conditions, gave substantially the same results. June 7, 1891, corn was soaked in a saturated solution of potassium cyanide and fed to three wireworms. July 3 one grain of corn was slightly eaten, and July 10 one grain was badly eaten and one worm missing—probably eaten by mice that had obtained access to the cage. July 20 several grains were badly eaten; July 27 the remaining two worms were active, but the corn was untouched; and the experiment ended without effect.

In many of the experiments, particularly when alcoholic solutions were used, or where the corn was soaked for a considerable length of time in arsenical solutions, it failed entirely to germinate; while in experiments where the grain was simply wet and rolled in the arsenites, or soaked for only a few hours, it grew almost as freely as did untreated corn in check lots.

These experiments with the arsenical poisons and strychnine agree substantially with those of Messrs. Comstock and Slingerland, published in November, 1891, and show that it is not practicable to protect the corn by means of them, even were it possible to use them without retarding or preventing the germinating of the seed.

Coating the kernels with tar and soaking them in a solution of salt, a solution of copperas, a solution of chloride of lime and copperas, in spirits of turpentine, and in kerosene oil, have been tried by Comstock and Slingerland without encouraging results.

Applications of kerosene emulsion and pure kerosene made to the worms in the earth were found by me in 1885 practically ineffective, any strength sufficient to kill the larvæ killing vegetation also. Similar results were obtained by Comstock and Slingerland, who, after using crude petroleum, an emulsion of the same, and a common kerosene emulsion, concluded that the last is more promising than the others, but that it cannot be profitably applied on a large scale. Experiments made by them show also that even a clean fallow for an entire season will not starve out the worms; that neither buckwheat, mustard, nor rape crops —frequently recommended to clear the earth of wireworms—will accomplish the desired result; and that salt applied at the rate of 1,600 pounds to the acre—a heavy dressing—neither drives the wireworms

deeper into the soil nor causes them to migrate to any appreciable distance; that kainit used as a fertilizer, even in very large quantities, had little if any effect on the wireworms;* that muriate of potash—four to six tons to the acre (an excessive amount)—is but slightly effective; that lime at the rate of even two hundred bushels per acre does not injure wireworms; that chloride of lime must be used in impracticable quantity to produce any marked effect; and that gas-lime, although capable of destroying the wireworms, must be applied in such great quantities that its use is impracticable on large areas. Bisulphide of carbon poured into a hole in the earth near the infested hill destroys the wireworms, but at an excessive cost.

The most promising remedy for wireworms, in my judgment, is one which has unfortunately not been experimentally tested, but which is, nevertheless, precisely based upon our knowledge of the life history, food, and habits of these insects. It consists of a rotation in which clover follows always upon grass and is itself followed by corn. According to this plan pastures and meadows of grass might lie unchanged for several years, being plowed, when broken up, in late summer or early fall and sown to clover in the spring—either with oats, or on winter wheat or rye sown the fall before. The clover should be allowed to stand a second year, and might then be followed with corn with positive assurance that the wireworms originally in the sod would by that time have entirely disappeared. From the regular rotation for grain lands, grass would thus be excluded. In such a rotation corn might be followed by small grain, this by clover, and this by corn. While the wireworms might produce some visible effect on the small grain the first year after grass, this would usually be much less serious, at any rate, than the damage to corn.

The general entomological effect of some such management could not fail to be beneficial, since it would apply to cutworms and white grubs as well as to the wireworms now under discussion. The system of rotation now common in Central Illinois is, indeed, seriously defective in the fact that the plants composing it—Indian corn, small grains, and grasses—are all of the same botanical family and consequently subject in large measure to the same enemies. Any variation of this system which will introduce as a regular link in the chain a crop belonging to some other and widely different family of plants, will serve the general purpose of that here proposed.

* These results are inconsistent with those reported by Prof. J. B. Smith in the 12th Ann. Rep. N. J. Agr. Exper. Station (for the year 1891), p. 412. Here Professor Voorhees, Chemist of the Station, is said to have applied kainit and muriate of potash separately to two sections of a fourteen-acre piece of corn on ground always badly infested by wireworms and cutworms, leaving a strip between these sections without treatment. Care was taken that the sections should be similar with respect to quality of land, situation, etc. As a consequence, the kainit section was reported as almost entirely exempt from injury by insects, the muriate section as but little infested, and the intermediate strip as almost destroyed. It is evident from the context that this experiment had been made some years before, apparently not under the inspection of an entomologist.

B. Injuries to the roots.

Injury to the roots of corn in spring and early summer may be indicated to the close observer by the aspect of the growing crop. If the corn fails to appear in spring, the difficulty may not be due to poor seed or to injuries to the kernel, but may be caused by an early insect attack upon the young roots, which may even kill the plant outright before the sprout has broken ground. The root louse of the corn and the wireworms are most likely to be concerned in this form of injury.

Later in the season, when the plant is a few inches high, the uneven growth of the corn will often attract attention, patches here and there advancing slowly in comparison with parts of the field adjacent, and in a way not to be accounted for by differences of soil. In such cases, white grubs, wireworms, corn root worms, or plant lice should be sought for. Combined with this uneven growth, or possibly in times of drouth without it, the farmer may notice yellow patches in his field, the color being most pronounced upon the lower leaves. The root louse of the corn will be found responsible in most cases for this partial discoloration, but any of the species just mentioned may produce a similar effect,* or it may be caused on the lower part of the stalk by the chinch bug.

An especially significant symptom of more or less serious mischief is the presence in the field of numerous burrows of ants, commonly placed in or immediately near the hills of corn, and most conspicuous shortly after rains. This invariably indicates the presence of root lice in the field, although if the corn be small a careful search may fail to detect them at the time. The nature of the association between the ants and the root lice is such that the former prepare the way for the latter early in the season by sinking their burrows among the corn roots, thus giving the lice access to them.

If at about the time the ear is beginning to form, and from that time onward, the stalks of corn are easily prostrated by wind and rain, and do not readily rise again, it will commonly be found that the hold of the plant upon the earth is abnormally slight, so that the hill may be pulled up too easily. This condition of the plant is due to a loss of roots, usually to be attributed to one of the corn root worms, or, more

* A condition of the corn very similar to that just described is not due to insect attack at all, but to a bacterial disease of the roots known as the *corn root blight*, fully described by Prof. T. J. Burrill in Bulletin No. 6 of the Illinois Agricultural Experiment Station (August, 1889). In this disease the corn stops growing in patches, becoming yellow and usually slender, and sometimes dying while young. The yellow color is most pronounced upon the lowest leaves. On pulling up the plant, the oldest and the lowest roots are seen to be injured and usually dead, the bottom part of the stalk to which these roots are attached being similarly affected. If split through the middle, the inner tissue of this lower part is seen to be of a uniform darker color, and a slight discoloration, becoming less and less pronounced above, appears in the next succeeding joints, while the parts between them are seemingly healthy. On the surface, when carefully cleared of dirt, brownish corroded spots may be found, sometimes covered with a firm gelatinous material.

rarely, to the white grubs. Sometimes, however, a similar appearance is given late in the season to a field infested by the chinch bug, which by abstracting sap from about the base of the stalk just beneath the surface of the ground will often prevent the shooting forth of the so-called "brace-roots," which serve to anchor the top-heavy stalk more firmly in the earth.

SYNOPSIS OF INJURIES TO THE ROOTS, AND ORDER OF DISCUSSION.

1. Roots deadened, hardened, or dwarfed, without apparent loss of substance. Page 48.
   a. Small brown or yellowish ants abundant in the hills, and bluish green or whitish root lice on the larger roots. Page 48.
      Plant Lice and Mealy Bugs: Page 48.
      Aphis maidiradicis (The Corn Root Aphis). (Plate VII., Fig. 5 and 6; and Plate VIII., Fig. 1-5.) Page 50.
      Schizoneura panicola (The Grass Root Louse). (Plate VIII., Fig. 6; and Plate IX., Fig. 1.) Page 75.
      Trama erigeronensis. (Plate IX., Fig. 2.) Page 82.
      Forda occidentalis. (Plate IX., Fig. 3.) Page 84.
      Tychea brevicornis. (Plate IX., Fig. 4.) Page 86.
      Geoica squamosa. (Plate IX., Fig. 5 and 6; and Plate X., Fig. 1, 2, and 3.) Page 87.
      Rhizobius spicatus (The Woolly Grass Root Louse). (Plate X., Fig. 4.) Page 92.
      Dactylopius sorghiellus (The Corn Mealy Bug). (Plate X., Fig. 7 and 8.) Page 94.
      Ants: Pages 57 and 72.
      Solenopsis debilis. (Plate II., Fig. 2.) Page 57.
      Myrmica scabrinodis lobicornis. (Plate I. and Plate II., Fig. 1.) Page 57.
      Lasius niger. Page 72.
      Lasius niger alienus. (Plate X., Fig. 5 and 6; and Plate XI., Fig. 1.) Page 72.
      Lasius interjectus. Page 57.
      Formica schaufussi. (Plate XI., Fig. 2.) Page 57.
      Formica fusca. Page 57.
   b. No notable number of insects present. The lowest roots dead; surface of underground part of stalk with brownish corroded spots, interior of this part darker, at least at the joints, while the spaces between may be seemingly healthy. (Root blight of corn, a bacterial disease; not entomological.) Page 45.

2. Roots evidently injured or destroyed by perforations, gnawing, burrowing, decay, or other loss of substance. Page 96.

a. Roots eaten away, not burrowed or perforated, and without rotten or withered tips; tap-root commonly gone or decayed. White grubs in soil among or beneath the roots. Page 96.

White Grubs. Page 96.

Lachnosterna rugosa. (Plate XII., Fig. 1-3.) Page 122.

Lachnosterna fusca. (Plate XII., Fig. 4 and 5.) Page 121.

Lachnosterna inversa. (Plate XII., Fig. 5.) Page 121.

Lachnosterna hirticula. (Plate XII., Fig. 3.) Page 122.

Lachnosterna gibbosa. (Plate XII., Fig. 6 and 7.) Page 122.

Cyclocephala immaculata. (Plate XII., Fig. 8; and Plate XIII., Fig. 1 and 2.) Page 121.

Allorhina nitida (The Green June Beetle). (Plate XIII., Fig. 7.) Page 127.

Prionus laticollis. (Plate XIII., Fig. 4.) Page 128.

Prionus imbricornis. (Plate XIII., Fig. 3.) Page 128.

b. Roots penetrated, perforated, irregularly burrowed, and more or less eaten off and eaten up. Underground parts of stalk also usually similarly injured. Page 129.

Wireworms in soil among the roots. Page 24.

Wireworms. Pages 24, 41, 42.

Cardiophorus sp. (Plate IV., Fig. 6.) Page 28.

Drasterius elegans. (Plate V., Fig. 1-3.) Page 29.

Agriotes mancus (The Wheat Wireworm). Plate V., Fig. 4-6.) Page 32.

Agriotes pubescens. (Plate VI., Fig. 1.) Page 34.

Melanotus communis. (Plate VI., Fig. 3-5.) Page 34.

Melanotus fissilis. (Plate VI., Fig. 2.) Page 36.

Melanotus infaustus. Page 36.

Melanotus cribulosus (The Corn Wireworm). Plate VI., Fig. 6-8; and Plate VII., Fig. 1.) Page 37.

Asaphes decoloratus. (Plate VII., Fig. 2-4.) Page 39.

Small, slender, soft-bodied, yellowish white grubs in the roots and earth. Page 129.

Diabrotica 12-punctata (The Southern Corn Root Worm). (Plate XIV., Fig. 1-5.) Page 129.

c. Roots visibly penetrated and perforated scarcely at all; sometimes decayed at tips, but not eaten away. Principal injury interior, in form of minute burrows which are commonly longitudinal, discoverable on peeling or splitting the root, the burrows sometimes containing minute slender white six-legged larvæ, with brown head and neck and brown patch on last segment. Page 135.

Diabrotica longicornis (The Northern Corn Root Worm). (Plate XIV., Fig. 6-8; and Plate XV., Fig. 1-8.) Page 135.

DETAILED DISCUSSION OF INJURIES TO THE ROOTS.

1. *Some of the roots deadened, hardened, or dwarfed, without loss of substance.*

   a. Small brown or yellowish ants abundant in the hills, and very small, bluish green or whitish, oval, thick-bodied root lice on the larger roots.

PLANT LICE AND MEALY BUGS.

(APHIDIDÆ AND COCCIDÆ)

Associated with ants in hills of corn, the observer may find any one or more of eight species of minute, soft, thick-bodied, six-legged insects, sometimes winged, but usually without wings, and always of very sluggish habit and slight power of locomotion. When exposed, they may show little or no signs of disturbance, but if shaken off the roots into which their stout jointed beaks are thrust, they will probably crawl slowly and clumsily about, making movements almost too sluggish and aimless to look like efforts to escape. The ants which have nested in the hill will, however, commonly seize these little insects in their mandibles and hurry away with them into concealment.

By far the greater part of those answering to the above description to be found in the corn field, will usually be plant lice (aphides); and will mostly belong, in fact, to a single species, the corn root aphis; but a few may be "mealy bugs" (genus Dactylopius, family Coccidæ), recognizable as such by their general resemblance to the kinds of "mealy bugs" common in greenhouses. They may be readily distinguished from the plant lice by their thicker, clumsier bodies, and by the almost rudimentary size of their legs and antennæ. They are always covered with a mealy or powdery excretion of minute particles of wax, and never have honey tubes, or cornicles, on the back of the abdomen—both characters in which they agree, however, with some of the lower plant lice. From all the corn-infesting plant lice they may be technically separated by the fact that their tarsi are single jointed, and bear a single tarsal claw, while the plant lice of this group have two tarsal joints and a pair of tarsal claws.

Plant lice are among the most prolific of insects,* producing several generations annually, but they are commonly held severely in check by climatic, meteorological, and biological conditions; that is, by season, weather, and plant or animal parasites. They are, consequently,

* Slingerland has bred twenty-five generations of a plant louse (*Myzus achyrantes?*) in a single year (Science, Vol. XXI., 1893, p. 48); and Buckton shows (A Monograph of British Aphides, Vol. I., p. 80) that a single rose aphis (*Siphonophora rosæ* might give origin, at its normal rate of unchecked multiplication, to over thirty-three quintillions of plant lice in a single season, equal in weight to more than a billion and a half of men.

capable of rapid and enormous increase when any of these checks are temporarily weakened to any considerable degree. As they affect the plant by abstracting the elaborated sap upon which its vital activity depends, the injury done is usually general, and especially is this true if the root be the part infested. Some species, however, in addition to the general drain upon the life of the plant, cause a distinct local deformity to root or leaf in the nature of a gall, which protects them at the same time that it secures them food. Any crop liable to their attack in force is never long free from danger, but, on the other hand, a seemingly irresistible outbreak may disappear as quickly as it came, a slight and almost imperceptible change of conditions often taking tremendous effect on these delicate insects.*

Economically, plant lice may be divided, according to the peculiarities of their life histories, into several groups or classes. Some generation, or some part of some generation, may grow wings, fitting them for rapid dissemination, or the species may be without winged representatives. They may live through the whole season of their active life above ground, on exposed parts of the plant; they may spend the whole season under ground, upon the roots; or they may alternate, spreading each year from roots to stalk and leaves and back again. Whatever part of the plant they infest, they may live on a single host species, they may spread indefinitely from one to several others, or they may migrate definitely, by means of a fixed generation, from one species to another, requiring thus for their continuance two plant species often extremely unlike.†

Finally, the sexual, oviparous generation (commonly the last to appear in fall) may leave its eggs on the exposed parts of the plant last infested, or it may deposit them in the earth among or on the roots of its host. In the former case the destruction of the plant, or of its remains, will destroy the lice; in the latter, the eggs rest like a seed in the earth to stock the ground the following spring with a horde of young, ready to infest the succeeding crop if suited to their tastes and habits.

All the plant lice of our present list of species infesting the roots of corn are, so far as known,‡ subterranean only, producing no galls, but leaving their eggs in the earth over winter. They infest more than one plant, spreading from one to another species in an indefinite manner, not definitely migrating. The corn and grass root lice *(Aphis maidiradicis* and *Schizoneura panicola)* develop early in the season winged forms by which they easily spread from field to field.

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* A marked illustration of this fact is afforded by the somewhat recent history of the grain louse *(Siphonophora avenæ)* in Illinois. (See Seventeenth Report State Entomologist of Illinois, p. X.)

† The apple louse *(Aphis mali)*, for example, passes from the apple to various grasses in midsummer, returning to the apple leaf in fall, and leaving upon the twigs eggs from which young hatch the following spring. The hop louse *(Phorodon humuli)* alternates in a similar manner between the hop and the plum; and a grass root louse *(Schizoneura corni)* between the grasses and the dogwoods.

‡ It has long been a general opinion that the corn root louse, presently to be discussed, is a subterranean form of the leaf louse (*Aphis maidis*), a surmise which I have failed to verify after many efforts extending through several years, and so have declined to accept.

Seven species of plant lice belonging to as many different genera,* have been found by us habitually infesting corn roots in Illinois. They are *Aphis maidiradicis, Schizoneura panicola, Trama erigeronensis, Forda occidentalis, Tychea brevicornis, Rhizobius spicatus,* and *Geoica squamosa.* By far the most important of these is the first mentioned, commonly known as the corn root aphis. This is, in fact, the only one on the list which infests corn primarily as a principal food plant, the others being essentially species of the meadow and pasture, attacking corn but lightly, and most commonly only when it follows grass.

The association of all these species with ants, which care for them in many ways, some of them indispensable, and feed in turn on excretions of their insect charges, is a fact of special economic significance, since the ant most active in preserving the plant louse species must be taken into account as a factor in the economic problem.

The Corn Root Aphis.

(Aphis maidiradicis, Forbes.)

(Plate VII., Fig. 5 and 6; and Plate VIII., Fig. 1-5.)†

No insect affecting corn is more deserving of the attention of farmers and entomologists at the present time than the corn root aphis. It ranks as a corn pest with the chinch bug and the army worm, less injurious at any one time than these are locally and occasionally, but overtaking them, on the other hand, by its general distribution and the constancy of its attack. Although it lives upon the roots throughout the life of the plant, the principal damage is done at the same time as that caused by wireworms—while the corn is still small. It contrasts with the corn root worms with respect to the time of its most injurious activity, the latter coming in at about the time when the aphis generally begins to loosen its hold; but the two agree in the fact that they make their first appearance in spring only on ground which has been in corn for at least a year preceding. The common root worm is confined throughout the season to the field in which it hatches, while the aphis presently scatters abroad, more or less freely according to the percentage of the second and succeeding generations which develop wings. On

* The following brief table may serve in a general way to indicate the correct genus and species of each of our corn root lice:

Cornicles well developed.....*Aphis maidiradicis.*
Cornicles reduced to dark rings.....*Schizoneura panicola.*
Cornicles wanting.
  Last two joints of beak not longer than basal portion.
    Anal plate subglobose, strongly prominent.
      Third antennal joint about as long as first two combined, an additional joint usually more or less distinctly formed from it, making the antennæ 6-jointed.....*Trama erigeronensis.*
      Third antennal joint very long, nearly twice as long as first two combined, antennæ uniformly 5-jointed.....*Forda occidentalis.*
    Anal plate short, transverse, not at all prominent.
      Antennæ normal, as large as rostrum, third and fifth joints more than twice longer than thick.....*Tychea brevicornis.*
      Antennæ minute, much smaller than rostrum, joints less than twice as long as thick.....*Rhizobius spicatus.*
  Last two joints of beak much longer than basal portion, anal plate retracted into dorsal segments.....*Geoica squamosa.*

† A colored plate of the oviparous females, and of winged, wingless, and pupa forms of the viviparous female of this species, was published in the 17th Report of this office.

the other hand, although its worst mischief coincides with that of the wireworms, it is not commonly the case that both are especially injurious in the same fields, the wireworms following grass of the first and second year preceding, and the plant louse most commonly infesting corn on old corn ground only. As lands recently in grass are most likely to contain the white grubs also, it is not a common thing to find the corn root aphis early in the spring in grub-infested fields.

Its life history is now probably very well understood, but thoroughly effective remedial measures, I regret to say, are not yet certainly known. Rotation of crops will often greatly decrease or even prevent injury by dispersing the attack, but we have no conclusive proof that this measure diminishes to any considerable extent the number of root lice in the country during any one year. It is therefore probable that this insect is increasing slowly in average numbers from year to year, and it may yet bring serious disaster to agriculture throughout the whole region best adapted to the culture of Indian corn.

Although I have no data for a precise account of its distribution, it has been recognized by us in all parts of the State from Cairo to the extreme northern limit, and has been definitely reported outside Illinois, from Maryland, New Jersey, Indiana, Ohio, Kentucky, Minnesota, and Nebraska. It is altogether likely that it occurs in larger or smaller numbers throughout the whole corn belt.

INJURY TO CORN.

The corn root louse is a suctorial insect, taking only fluid food through a stiff beak, which it thrusts into the tissues of the plant it feeds upon, producing thus no external injury, nor, indeed, any local internal effect discoverable by ordinary methods of observation. Indications of injury by this insect are consequently all of a general character, affecting the entire plant, and do not materially differ from those caused by severe drouth, except in the fact that they are likely to be unequal in different parts of the same field in a way to indicate no connection with the amount of retained moisture in the soil.

A noticeably greater abundance in early spring in the lower parts of an infested field seems to be due to the greater abundance there of young weeds on which the corn root aphis feeds at first. As soon as the corn starts to grow it may become infested, and even be killed outright before it appears above ground. We have, in fact, found the root louse on the plant as early as May 9, only four days after the field was planted.

The dwarfing of the plant, especially in patches here and there, with a yellowing or reddening of the leaves—beginning of course with the lowest ones—and a general apparent lack of thrift and vigor, are sufficient to cause suspicion of injury by this louse, a suspicion which will be confirmed in part if numerous burrows of ants are seen in or near the hills of corn. The presence of ants in the field may be overlooked after the ground has been recently cultivated, but can scarcely escape attention shortly after a rain, when these little insects actively open up their burrows, heaping up the little pellets of earth about the openings of their nests.

The appearances described may, nevertheless, be due either to the corn root blight—a disease not caused by insects, and hence not treated in this report—or to the grass root louse, a species likewise attended by ants, but far less injurious to corn than the aphis under discussion. If the damage be due to the root blight, the root lice themselves will be few or wanting;* and if to the grass louse, the fact may readily be ascertained by an examination of the roots of the corn.

The root aphis of the corn is of a bluish green color, slightly whitened by a waxy bloom. The form of the body is oval, and on the hinder part of the back are two short, slender, but conspicuous, tubes, standing erect or projecting slightly backwards, which may be seen by the glass to have open ends externally. These are called the cornicles of the aphis, or, sometimes, the "honey tubes," it having been formerly supposed that they were the source of the abundant excretion upon which the ant attendants of the lice eagerly feed. The grass louse, on the other hand, is white in color, with a blackish head and other blackish markings, but without any tint of green; and it has no trace of cornicles, their place being taken by two minute openings in the corresponding segment of the body, each surrounded by a delicate brownish rim.

The evidences of serious injury by the corn root aphis are, in short, an unusual dwarfing and discoloration of the corn, an abundance of small brown ants in the field, nesting among the hills, and, finally, the presence of the bluish green insects themselves upon the larger roots of the corn, especially near the base of the stalk.

The amount of injury may vary from a scarcely noticeable check upon the growth of the plant to a total destruction of the corn over considerable patches, up to half an acre or more. This more serious effect is, however, rarely, if ever, produced by the root louse alone. Like most insect enemies,—especially those of suctorial habit, which abstract the sap of the plant they feed upon,—the corn root aphis serves to intensify the effect of drouth and other unfavorable influences, and it is often difficult to say how much is to be ascribed to the action of the insect pest and how much to other causes coöperating.

There is some evidence to the effect that a too serious check to the growth of the corn results in the early evolution of a great number of winged plant lice of the second spring generation, whose escape from the fields in which they start so breaks the force of the attack that in a favorable season very badly damaged plants may rally and make good corn; but if the insect injury is followed or reinforced by drouth, the corn may grow sluggishly the whole season through, and either fail to ear, or bear small imperfect nubbins only. Sometimes a field not infested the year before is permanently damaged in June, or even late in May, as the result of an early accidental concentration of the winged lice originating in other fields.

INJURY TO OTHER PLANTS.

No other crop plants are especially liable to injury by this aphis, unless possibly we should except broom corn and sorghum. Although not at all uncommon on these plants, it does not commonly thrive on

* See also page 46, b.

them, and so far as my observations have extended, can scarcely be called injurious to them. It has been observed in the field, however, or bred in the insectary, on the roots of a number of other species of plants, some of which are, in fact, important to its maintenance. Many of the first generation hatch from the egg in the field before the corn is ready to receive them, and at this time young smartweed plants and foxtail grass (Polygonum and Setaria) are their principal resource. These plants harden early and lose the succulence which makes them especially desirable to plant lice, a fact which accounts in part no doubt for the early transfer of the lice to corn; but in fields of small grain, Setaria and Polygonum may continue to support the corn root louse at least until the second generation is well matured. Indeed, I have found this insect on the roots of smartweed more than a foot high as late as June 17. Crab-grass (Panicum) also becomes infested, but less abundantly than the Setaria, and from the latter part of June throughout the rest of the season the aphis breeds abundantly on the common purslane *(Portulaca oleracea)*. We have occasionally found it so abundant on purslane plants far removed from corn fields—besides paths in lawns and in other similar situations—that one might well regard this as a purslane aphis, if it were not for the fact that this weed starts too late in the season to serve as food for the earlier generations.

We have, further, experimental evidence that the corn root aphis can live on roots of ragweed (Ambrosia), having transferred May 8, 1889, half-grown young of the second generation from smartweed roots to this plant, where they lived and fed until they acquired wings, five days later. The fall oviparous generation and the one preceding it have been repeatedly reported by my field assistants—who were constantly dealing with the root aphis and knew its characters perfectly—to have abundantly infested dock *(Rumex crispus)*, fleabane *(Erigeron canadense)*, mustard *(Brassica nigra)*, sorrel *(Oxalis stricta)*, plantain *(Plantago major)*, Hungarian grass *(Setaria germanica)*, pigweed *(Amarantus hybridus)*, and squash; but as these statements were not verified by successful transfers from these various plants to corn, they rest only on determinative evidence, notoriously unreliable with respect to the plant louse species. Indeed, an attempt at transfers of the supposed corn aphis found on squash, sent me from Ohio by Prof. C. M. Weed, entirely failed. A similar result was reached in an attempt to transfer known corn root lice from corn to wheat and oats, begun April 22, 1889. Insects placed on roots of wheat in breeding cages April 22 continued to live there until May 5, but without producing young. May 11, however, all had left the plants. An earlier experiment, begun April 10, had a like ending, and a precisely similar result was obtained in a parallel experiment with oats.

The repugnance of this insect to the roots of small grain was repeatedly shown also by field observations. Fields of oats and wheat on old corn ground, sometimes known to have been badly infested by the root aphis the preceding year, often contained in April and May large numbers of these root lice and their associated ants, the former feeding on the roots of smartweed and pigeon-grass growing with the grain, but

never being seen on the roots of the grain even where these and the grass roots were closely interlaced.

The relation of this louse to other plants than corn has an important economic bearing. For example, in fields on old corn ground, the first generation of plant lice are very noticeably more abundant early in spring in the lower parts of the field than elsewhere, especially in those parts so situated as to receive the wash from the remainder. I can at present only account for this unquestionable fact by the very much greater abundance here of young smartweed plants, doubtless due to the washing down of the seeds left on the ground in fall. This seems especially likely to be the true explanation, since the difference in the number of plant lice on low and high ground in the same field diminishes greatly or entirely disappears with the advent of later generations and the scattering of the winged lice abroad.

LIFE HISTORY.

General Statement.—The corn root aphis passes the winter as an egg in the earth, in corn fields or, rarely, in other grounds where purslane grows late in fall, always, so far as known, only in the nests of a small brown ant about an eighth of an inch long, known to science as *Lasius niger* or its variety, *L. niger alienus*. This ant is the constant companion of the root louse throughout the year, living in burrows among the roots of the corn. The aphis eggs begin to hatch about the time of the opening of the seed leaves of the smartweed or heartweed (*Polygonum persicaria*), abundant in cultivated ground. This first of the spring generations is readily distinguished by characters of form and color from all that follow. Appearing usually before the corn is planted, it is dependent at first, in our region, almost wholly upon the young smartweed plants. The roots of these are laid bare by the burrows of the ants, and upon these roots, within their narrow tunnels, the lice will usually be found thickly clustered. Later, if the field be not planted to corn, our common species of pigeon-grass (Setaria) divides the attention of the lice, offering in fact, for a little time, a more succulent herbage than the rapidly growing smartweed.

The second generation begins to appear about the 1st of May,—we have one breeding-cage record of the 28th of April,—and by the middle of that month may be itself mature. Many of this generation are winged, while others are without wings,* the winged form first occurring about May 10.† These "migrant" root lice may live at first, like those of the preceding generation, upon smartweed and pigeon-grass, but more commonly they are transferred to corn by the little brown ant already mentioned, either in the same field or after they have flown to another. These ants not only carry from weeds to corn the root lice already in their possession, but burrow hills of corn in advance, eagerly seizing and conveying to their subterranean galleries winged root lice which come their way.

* Two young of this generation, born of the same mother in a glass tube enclosing a corn root, were kept by us until adult, when one proved to be a wingless aphis and the other winged.

† This generation is at its best from May 15 to 20 in average years in Central Illinois.

The succeeding generations are not of special economic interest with the exception of the last to occur—the autumnal, bisexual brood, by which the eggs are laid. Both males and females of this brood are wingless, and live in the earth like their parents, occurring there from the middle of September to the middle of November. The eggs which they lay are taken in charge by their attendant ants and cared for during the winter.

Number of Generations.—The eggs of the corn root louse begin to hatch as early as April 10, this process continuing, according to our observations, until May 2. The adults of this earliest generation, the so-called stem mothers, were first seen by us April 28, and the last appeared in our collections exactly one month later. The first of the second, or so-called migrant, generation originating in our breeding cages was born April 28, and the last on the 21st of May. Migrant pupæ were first observed May 10, and winged adults May 11. The evolution of winged forms of this second generation has continued unquestionably until June 2, and possibly until June 8. Our earliest date for the bisexual brood is September 12, when an oviparous female was found in a breeding cage. The first male was observed September 16; and male and female were seen *in copula* October 1. Living females of this brood have been taken by us from ants' nests as late as December 11 (1893). Our autumnal dates for the collection of eggs are October 21, November 5 and 20, and December 11.

Our numerous breeding cage experiments, although not one of them is continuous throughout the year, enable me nevertheless to give a fairly full account of the number and succession of generations. Stem mothers very young when taken (together with eggs), April 25, and probably hatched the preceding day, gave birth to young May 15, making the period of this generation twenty-one days. Young of the second or migrant generation born May 9 became winged adults May 28, thus requiring for their growth a period of nineteen days.

In another case, young of the same generation born May 17 acquired wings June 4, the interval being eighteen days. Descendants of this migrant generation (the third of the series consequently) born June 8, were adult June 19 (eleven days), giving origin on that date to young of the fourth generation, which became adult on the 30th of June—again an interval of eleven days. Examples brought in from the field June 22 (probably of the third generation)* gave birth to young June 24—probably of the fourth generation. From this start a continuous series of generations was bred† to September 5, all adults of each generation being in every case removed and destroyed by us before their young had begun to breed. Assuming that this experiment began with the fourth generation, the first of the fifth were born July 3 (nine days); of the sixth, July 10 (seven days); of the seventh, July 24 (fourteen days); of the eighth, August 5 (twelve days); of the ninth, August 15 (ten days); of the tenth, August 25 (ten days); and of the eleventh, September 5 (twelve days). On the 16th of September males of the

* Other observations and collections show that these specimens may have belonged to the fourth or even the fifth generation. They can hardly have been of earlier date than the third.

† These root lice were maintained thus continuously on the *leaves* of the corn, for greater convenience and accuracy of observation.

autumnal generation appeared, belonging probably to the twelfth generation from the egg.

From the above account it will be seen that while the first three generations have an average life of nineteen days, the fourth to the twelfth followed each other at an average interval of precisely eleven days. Many of our observations show that a much earlier start and a more rapid growth are common, and that a greater number of generations may consequently occur. Thus, although in the above account the stem mothers hatched April 24, we have collected young of this generation as early as April 10; and our breeding records show that adults of this first generation may mature and young migrants may be born by April 28, a date more than a fortnight earlier than those used above. Adult (winged) migrants have been seen by us May 11—again more than a fortnight earlier than the corresponding date just mentioned. Further, we have had young of the third generation May 13, if we may trust an unverified report of Mr. F. W. Mally, who assisted me on this work in 1890. On the other hand, as I have counted generations from first-born to first-born, the life of a generation is here made too short for the average.

No special attempt was made to determine the number of individuals a single female may produce or the relative productiveness of the various successive generations. The fact is however worthy of record that a single stem mother placed on a corn root in a breeding cage May 4, brought forth her first young May 6 and her *twelfth* and last May 15. At this time the first-born was a pupa, acquiring wings on the 19th. The stem mother lived until the 22d, and was then placed in alcohol. Another female of a midsummer brood brought forth fifteen young.*

According to the results of experiments conducted for the purpose of determining the number of moults of the corn root aphis, and the intervals between successive moults, we find that this species moults four times, at average intervals of three or four days. Our most successful observations upon this and several other nice points of individual life history were made on isolated specimens, each placed upon the root of a potted plant which was then passed through a small glass tube and covered with earth except where the tube enclosed it. To prevent the escape of the plant louse the ends of the tube were lightly plugged with cotton-wool.

Migration to Uninfested Fields.—The last autumnal brood of the corn root aphis lives, so far as known, only upon roots of corn and purs-

* As an effective illustration of the pressure which this plant louse species brings to bear upon the natural limitations on its increase, it may be worth while to say that assuming the correctness of the figures here given as to the normal rate of multiplication and the number of generations produced in a year, and further supposing that all the plant lice descending from a single female hatched from the egg in spring were to live and reproduce throughout the year, we should have coming from the egg the following spring nine and a half trillion young. As each plant louse measures about 1.4 mm. in length and .93 mm. in width, an easy calculation shows that these conceivably possible descendants of a single female would, if closely placed end to end, form a procession seven million eight hundred and fifty thousand miles in length; or they would make a belt or strip ten feet wide and two hundred and thirty miles long. Since the natural checks upon multiplication keep this insect species within limits of relative insignificance, the above statement would have no practical value if these checks were uniform in action. It is because they are highly variable that the aphis species, capable of reproduction at a rate so enormous, able consequently to take rapid and great advantage of any circumstance even slightly favorable, are a constant and often hideous menace to agriculture.

lane, the latter being usually infested in corn fields only, and in these situations, consequently, the eggs are left from which young hatch the following spring.* This first spring generation being always without wings, the root aphis is practically confined for a little time to fields previously in corn. As a considerable part of the second generation acquires wings, a general dispersal of adults begins almost as soon as the corn is out of the ground. These winged root lice do not, however, become sufficiently abundant for a considerable time thereafter to noticeably affect fields not in corn the year before. Previous to the first of June this distributed attack can scarcely be detected, and not until July 1 have we found it really serious anywhere.

The first winged migrant was reared in our breeding cages May 11, and May 12 of another year an example was seen in the field. From this date forward, breeding-cage and field observations of the winged lice or migrants of this second generation were an almost daily occurrence to May 28, and were occasional for a few days thereafter.

Many scores of field observations of root lice on corn include no case of their occurrence in other than old corn ground previous to May 19, on which date, in 1887, a single winged louse was found on corn after sod. This was on one of the upper roots, along which the small brown ant had mined for a considerable distance. Many other hills in this field were similarly mined by ants but contained as yet no plant lice. Next, May 21, 1886, a single winged female was found on corn roots in an ants' nest, the only aphis in the hill. This female began to produce young the next day. May 28, among many hills searched in a field of corn following upon grass, two were found with winged root lice, one of which had just produced a single young louse; and May 31 two winged lice were again found in corn planted on sod. In the month of June but three such observations are recorded in our notes, and these refer to small numbers only. Not until July 1 have we found winged and wingless root lice (generations two and three) sufficiently abundant in ground not previously in corn to be worthy of special attention.

The evolution of winged root lice is not confined to the second generation, above mentioned, but continues throughout the season in numbers varying according to some law not yet ascertained. It is to be noted, however, that we have taken the winged form in August but once, although our collections of wingless specimens were made on twenty-seven days within that month. In September also the winged louse is relatively rare, occurring but three times in twenty collections made on as many different dates. By November the viviparous generations are all dead, as a rule, and the species is thereafter represented only by the sexual generation and the egg.

RELATION TO ANTS.

Seven kinds of ants have been found by us fulfilling the relation of host, guardian, and nurse to the corn root aphis; viz., *Formica fusca*, *Formica schaufussi*, *Lasius niger*, *Lasius niger alienus*, *Lasius interjectus*, *Myrmica scabrinodis*, and *Solenopsis debilis*. The occurrence in

*Among more than fifty lots of "stem mothers" of the corn root aphis collected by us in the field, every one was found in ground which had borne corn for at least the year immediately preceding.

this relation of all but the third and fourth just mentioned* is, however, so rare that they need receive here no more than this passing mention, especially as their services to the aphis are, so far as observed, the same in character and value as those of the much more abundant species.

The fact has already been mentioned in this paper that the sexual egg-laying generation of the corn root aphis—the last to appear in fall—is born in the galleries of the nests or homes of ants, and that here the sexes pair and the females drop their eggs. As one explores these nests in November, when the root louse eggs are being laid, he is struck with the relative independence of these oviparous adults, which are allowed to wander unattended through the burrows of their hosts as far as a foot or more from a corn root. We have found them, however, still feeding as late as November 5, and laying eggs November 21. These eggs, which are yellow when first deposited, but soon become shining black, and turn green just before hatching, are at first scattered here and there, as it happens, but are finally gathered by the ants for the winter in little heaps and stored in their galleries, or sometimes in chambers made by widening the gallery as if for storage purposes. If a nest is disturbed, the ants will commonly seize the aphis eggs—often several at a grasp—and carry them away. In winter they are taken to the deepest parts of the nests (six or seven inches below the surface in some cases observed) as if for some partial protection against frost; but on bright days in spring they are brought up, sometimes within half an inch or less of the surface, sometimes even scattered about in the sunshine, and carried back again at night—a practice probably to be understood as a means of hastening their hatching. I have repeatedly seen these ants in confinement with a little mass of aphis eggs, turn the eggs about one by one with their mandibles, licking each carefully at the same time as if to clean the surface. These anxious cares are of course explained by the use the ants make of the root lice, whose excreted fluids they lap up greedily as soon as the young lice begin to feed. They are not, however, wholly dependent on this food supply, at least in early spring, as I have seen them kill and drag away at that season soft-bodied insect larvæ, doubtless to suck their juices out as food. This has been a somewhat rare occurrence, however, and has rarely been noticed by us among ants which had plant lice in their possession. Once, however, ants of this species occurring abundantly in corn fields were observed September 22 to carry bits of dead insects into their burrows, together with a living corn root louse.

That the young of the first generation are helped by the ants to a favorable position on the roots of the plants they infest is quite beyond question. It is shown (1) by the fact that in many cases the aphis could not get access to such roots unless these had been previously laid bare by the tunneling of the ants, and (2) by the behavior of ants with mines already constructed, when the root aphis is offered to them. We have repeatedly performed the experiment of starting colonies of ants on hills of corn in the insectary and exposing root lice from the field to their attentions, and in every such instance, if the colony was well established,

* Typical *Lasius niger* and its barely distinguishable variety *alienus* are almost equally at home in the corn field, and do not differ noticeably in their relations to the corn root aphis.

the helpless insects have been seized by the ants, often almost instantly, and conveyed under ground, where we would later find them feeding and breeding on the roots of the corn. In many cases in the field, we have found the young root aphis on sprouting weeds (especially pigeon-grass), which have been sought out by the ants before the leaves had shown above the ground; and, similarly, when the field is planted to corn, these ardent explorers will frequently discover the sprouting kernel in the earth, and mine along the starting stem and place the plant lice upon it.

We have also abundant evidence that ants excavate hills of corn in very early spring, when they have as yet neither eggs nor plant lice in their possession, and some days before the possible appearance of the second or winged generation. I can only account for this practice on the supposition that these ants expect later to obtain eggs or young with which to stock their burrows, made ready in advance. Certainly this is true with respect to the second generation of the root aphis. When winged lice of this brood begin to appear, it is a common thing to find the small brown ant scattering far and wide over fields not previously in corn, and containing consequently no plant lice in any stage, burrowing there the hills of corn, and carrying underground such corn root lice as come within their range. For example, a corn field on sod near Polo, Ill., was searched May 18 of a backward spring, after a period of frequent cold rains which had greatly retarded the work of the ants and the development of the corn root aphis. A few of the hills already burrowed by the ants were found with the grass louse only (*Schizoneura panicola*), and one with a single mealy bug (Dactylopius), while twenty contained no insect whatever except the little brown ant, which was in full possession. May 28 two long rows of a field likewise on sod were searched carefully. Many hills were burrowed by ants, but only two contained the corn root louse, and in these were winged adults—one specimen in one hill and two in the other, the latter with a single young one but just born. Our records are full of notes of observations made during the latter part of May in several years according to which ants were just beginning to mine corn hills on sod, no lice of any kind yet occurring in their burrows. Occasionally, in fact, an ant has been seen to seize a winged louse in the field, commonly by the wings themselves, and to carry it down out of sight. In one instance such a winged adult was found in a corn hill with its wings gnawed away near the body, as if to prevent its escape from the earth; an operation to which ants are well known to subject their winged captives of the migrant generation. Confirmation of this practice is furnished by an observation made September 22, 1884. A winged corn root aphis placed near an ant in the field was seized by the latter and carried about four feet to a newly opened formicary, and was then laid down while the ant went inside. An ant coming out of the nest afterwards carried the aphis into the earth.

I need hardly say that the relations above described between the corn root aphis and these ants continue without cessation throughout the year, the succeeding generations being quite as useful to the ants

as those whose history I have thought it worth while to follow in detail. In order to determine more precisely the value of the services performed by their guardians, I arranged in several years a series of experiments designed to show to what extent the plant lice could help themselves if left unattended. Owing to the waywardness of the ants, which in most cases refused to content themselves in confinement, but one of these experiments came to a successful issue. April 13, 1889, corn root aphis eggs were placed in the earth among smartweed roots to test the ability of the young lice hatching to find the roots for themselves. A check experiment was started at the same time with eggs placed in artificial cavities beside smartweed roots. April 25 no insects could be found on the plants of the first experiment, while the cavities made in the second experiment contained young lice upon the roots in fine condition.

RELATION TO THE CORN LEAF APHIS.

Ever since Walsh, in 1862, doubtfully connected a leaf louse of corn, first reported by him,* with the root aphis described by Fitch from the roots of corn under the name of *Aphis maidis*,† the relations of these insects has been a moot point. There has never been any evidence, however, of their connection as simply different forms of the same species other than the facts that they belong to the same genus, that they resemble each other more or less closely in specific characters, and that they infest different parts of the same plant in the same territory, and often at the same time. On the other hand, the differences of specific character are such that they may very well belong to different species, and should, indeed, have been held to be distinct until their identity had been demonstrated. They do not by any means vary together in abundance either in time or in place; neither do they by preference infest the same species of plant. The corn leaf aphis occurs much more abundantly on sorghum and broom corn, especially the former, than it does on Indian corn itself; while the root louse occurs but rarely on those plants. Many other species whose roots are infested by the root aphis have not been known to support the corn leaf aphis at any time. The bare possibility, however, that these two forms may nevertheless alternate in such a manner that the one may be derived from the other throws some doubt on all propositions for an economic procedure, since if this is the case, both leaf and root louse must be taken into account in any measures intended to arrest the multiplication of either.

On account of the economic importance of this point, elaborate experiments have been made necessary with both root and aërial lice. The distinctness of the two can only be shown by tracing the life history of each throughout the entire year under conditions such as to insure the production of the one from the other if such production be possible. Even then the demonstration would be incomplete unless both root and leaf lice had been followed generation by generation throughout the entire season from the egg of one year back to the sexual generation and the egg of another year. These experimental conditions have now been sub-

* Proc. Ent. Soc. Phila., Vol. I. (1863), p. 300.
† Rep. Ins. N. Y., II., p. 318.

stantially fulfilled for the root louse only, as will be seen from what is presently to follow. The leaf louse, on the other hand, although it has been carried through the greater part of the year, including the entire fall and winter season, has never yet been seen to produce a sexual generation or an egg. Some experimental evidence has been obtained by attempting to bring the leaf aphis out of the root form by breeding the latter for many successive generations upon the corn leaf, and by similar attempts to rear the root louse from the winged leaf louse transferred to the roots of corn. These attempts have not thus far succeeded, and as the case stands at present, there is no satisfactory evidence of the specific identity of these forms, but a considerable body of proof to the contrary. The economic recommendations of this paper are therefore based provisionally upon the theory of a specific distinction of the root and leaf aphides of corn.

Observations and experiments on the leaf aphis were directed especially to the time and circumstances of its earliest appearance in the fields, and to the time and method of its disappearance in fall; to the first with a view to learn whether it originates in migrants from the roots; and to the second in the hope of finding the sexual generation, and thus determining the place of deposit of its eggs. A few additional experiments in transferring the leaf aphis to the roots of corn and other plants were made to see whether we could thus demonstrate the possibility of a migration downward from leaf to root and the origin of the root louse from that of the leaf.

Earliest Appearance of the Corn Leaf Aphis.—The earliest date at which the leaf louse has been found by us is July 23 (1883), at which time it was common in a field of sorghum near Champaign. It occurred there in all stages of winged and wingless adults, pupæ, and young, in association with the yellow sorghum louse *(Chaitophorus flavus)*. It had doubtless started there as early as July 15.

Our next earliest date for the leaf aphis is July 28 (1884), when *wingless* females were found by Mr. H. Garman at Normal, Illinois,—the first specimens of the year,—beneath the lower leaves of small corn in the field. Many stalks were searched, but the aphis was found in only two. Again, July 31, 1888, *winged* examples of *Aphis maidis* were common, crawling about on stalks and leaves of corn in a field near Urbana, Illinois.

Protracted and most careful search in corn fields which were heavily infested by the root aphis, made by Mr. C. M. Weed during the latter days of June, 1887, and by Mr. John Marten early in July, 1889, failed to discover a single leaf louse, although Mr. Weed found the winged *root* louse on corn leaves June 23, 24, 27, 29, and 30. In several cases these winged lice had made themselves at home upon the leaf, and were producing young, from one to five occurring with a single female. June 30 several winged root lice were detected on the rolled corn leaves at the tip of the stalk. Indeed, numerous earlier observations of winged root lice on leaves of corn are recorded in our notes; one by Mr. Garman as early as June 6, and others June 9 and June 11. On the last date, after tearing open the terminal tufts and rolled leaves of some

thirty growing plants, Mr. Marten found a single root aphis dead on the inner surface of the leaf.

Transfer of Root Aphis to the Leaf.—This spontaneous appearance and breeding of the winged root aphis on the leaves of corn was strongly suggestive of a permanent and regular migration, and of a possible transformation there into the ordinary *Aphis maidis* in late June or early July. This hypothesis was tested by a series of experiments made in 1890 and 1891, the most conclusive of which was begun June 22 of the latter year. Corn growing in a trench in the insectary was stocked with root lice from the field, several "adult females" being confined to the leaf in a bag of Swiss muslin.* From this beginning, the successive generations were bred, specimens of each generation being transferred to a new leaf, until September 16 (at which time the sexual generation appeared) without the slightest approximation in any generation to the characters of the aërial *Aphis maidis*. Several similar experiments made with sorghum plants instead of corn were even less successful, transferred root lice, though living and breeding for a short time, all dying, nevertheless, in from ten to sixteen days without more definite result. From these experiments we may conclude with some confidence that the corn leaf aphis does not originate in a migration of *wingless* lice from the roots.†

Another class of experiments, less precise but less artificial, points to a similar conclusion concerning the *winged* root louse also. In these experiments large rectangular frames covered with cheese cloth were used to enclose tightly entire hills of corn in the field, as well as specially planted hills in a plot of ground adjoining my insectary. In the field experiments these screens were made without doors, the hills being plentifully stocked with corn root lice in the beginning, and with their attendant ants, before the screens were set. In these cases the corn was left to itself until a sufficient time had elapsed, when the cover was removed and the plant searched for the corn leaf louse. In the small garden plot a screen was built large enough to enclose four hills of corn at once. At first the mistake was made of using too small a frame, and our results in 1889 were vitiated by the discovery that winged *Aphis maidis* from the fields would sometimes settle on the cheese cloth cover where the corn leaves pressed against it, and there extrude their young, which were small enough to pass through the meshes of the cloth. Thereafter the enclosure was made so large that no part of the plant could touch it, even when full grown, access to the plants being given by means of a closely fitting door. The chief experiments of this series were the following: Six corn hills were covered in the field June 28, 1889, selected because already stocked with the corn root aphis and the small brown ant *Lasius niger alienus* attending it. July 15 one hill was opened up and found unchanged, except that the ants had burrowed under ground and come to the surface far outside the space enclosed, thus

* On account of a deficiency in the notes of this experiment, it is now impossible to say whether any *winged* females were included in this lot.

† Our notes of breeding-cage work and observation in the field show, nevertheless, an occasional appearance of the wingless root form above ground on corn, in one case on the stalk, a few inches above the surface, and in another upon the leaves at a much greater distance, where young were being produced.

providing for themselves and their charges a ready means of escape from confinement, as well as a passageway for the possible introduction of other plant lice from without. July 25 and 30 two other hills were opened and found unchanged. From a fourth hill, examined August 2, and a fifth, opened September 2, everything had escaped, neither ants nor plant lice remaining; while the sixth, opened September 11, contained an abundance of the root aphis (winged adults and young) as well as the usual ants. In all these cases a critical examination of the entire plant above ground showed beyond question the absence of the aërial aphis.

In the large breeding cage near the insectary, corn was planted early in May, 1890, and the hills were stocked June 3 and 4 with ants, ant larvæ, and root lice, others being added to the original stock June 13, July 1, 10, and 16, August 2 and 18, and September 15. These repeated additions were made necessary by the gradual disappearance of the root lice from the plants, which did not thrive perfectly at first, owing apparently to the shade of the screen. No aërial lice appeared in this cage at any time during the progress of the experiment. This was terminated October 5, at which time root lice were still present on the corn.

In another experiment, made June 16, 1891, by transferring the same species to hills of planted corn in the enclosure above described, the same results appeared. Root lice were reared on all the hills throughout the entire summer, but there was no appearance of aërial lice at any time up to September 16, when the experiment closed.

In 1891 both corn and sorghum were grown in this enclosure for experiment, and the plants were first stocked June 16. Additional specimens of both the root aphis and the small brown ant were introduced June 27 and 29 and July 17, and ants alone, including their pupæ, larvæ, and eggs, July 24. By exposing single roots in little cavities in the earth and covering these with glass, it was easy to watch the behavior of the insects after they had been put in place, and it was thus learned that the sorghum hills were deserted almost at once. Consequently no root lice were found on the sorghum roots when the plants were dug up July 13 and September 16. On the corn, however, the root aphis continued until the experiment was closed at the date last mentioned, but no aërial lice appeared at any time on either kind of plant.

Another smaller experiment was tried with a hill of sorghum only, transplanted to a box July 3, stocked with the root aphis and with ants of all stages, and covered with Swiss muslin. July 10 and August 1 more root lice were added, and July 17 both lice and ants. Ants were observed at work in this enclosure July 11, 18, 20, 22, and 30, August 5, 7, 10, 15, and 18, and September 1 and 16; but no aërial corn lice appeared at any time, and no corn root lice were seen after August 5. August 18 the common yellow sorghum louse *(Chaitophorus flavus)* had become abundant on stalks and leaves of the plant in the cage with the ants, and this condition of things continued until September 16, when the experiment was dropped. Apart from the negative result of this attempt to bring the corn leaf aphis out of the root louse, we get additional evidence that the latter does not thrive on the sorghum root.

The above evidence is, of course, negative only, and it is not at all certain that the conditions present were such as to favor the migration of the root lice to the leaves, if this were ever possible. Until further and much more numerous attempts are made to breed the leaf louse from the root form, and especially until such attempts are made by confining winged root lice of several generations on the leaves and tassels of corn and sorghum, the relations of these two corn aphides must remain somewhat in doubt.

Disappearance of Corn Leaf Aphis in Fall.—To determine the autumnal history of the leaf louse of corn, two lines of investigation were open; the first that of careful and continuous observation of the course of events in the field as the season closed and the plant lice disappeared, and the second that of insectary and breeding-cage experimentation continued through the fall and early winter. Both these lines have been carefully worked out under my direction; the first by Mr. Garman in 1884, and the second by Mr. J. S. Terrill, followed by Mr. Marten, in the fall and winter of 1888 and 1889. Mr. Garman's observations extended from October 6 to November 20, and were made almost daily in corn fields either at Champaign or Normal. As they related to the usual life history of the insect, they will be fully summarized under the head of *Aphis maidis* itself, and it need here only be said that a careful following of the stages of the autumnal disappearance of this plant louse, as its food dried up and successive frosts destroyed the lingering remnants of the summer horde, gave no trace whatever of the presence of eggs, or of the occurrence of an oviparous generation. This conclusion was verified by hundreds of dissections made under the microscope, —all of which showed the presence of embryos in the abdomen,—and also by observations made upon small lots kept alive in the house. The experiments of 1888 and 1889, being of an artificial character and relating to the history of the plant louse under abnormal conditions, may properly be given here in full.

October 9, 1888, adult specimens of *Aphis maidis* were transferred from broom corn to growing Indian corn in pots in the insectary, and eight of the lot finally settled upon the corn. Young appeared continuously, both wingless and winged forms, the latter, however, showing a disposition to leave the plant. By October 24 all the plants which had not been covered by bell jars were completely deserted by the lice, and under the bell jars the winged lice were evidently disposed to scatter and escape, many of them sticking to the glass in the film of moisture which covered it within. October 30 these leaf lice were still breeding freely on the corn, and likewise on wheat plants exposed to them under the same cover, producing both winged and wingless individuals. These conditions remained substantially unchanged, the lice breeding freely in all the inclosures in the insectary until March 19, 1889, when the experiment was discontinued with a considerable supply of these aërial lice still in our possession. February 14 one lot under a bell jar was placed outdoors to determine the effect of a change of temperature. This lot was not examined again until March 4, when all were dead, with no trace of eggs, however, on the plants. Between September 11 and

March 11 eight successive generations apppeared—practically eleven days to each generation.

Transfer of Leaf Lice to Roots of other Plants.—A few experiments of this sort, made in October, 1887, and in September, 1890, were quite without result, the plant lice neither feeding nor breeding at that season of the year on roots of purslane or corn. They simply tried to escape, and died if prevented. A similar experiment tried with purslane in October, 1888, had a similar issue.

NATURAL ENEMIES.

Although various insect species, mites, ground beetles, and the like, have been found in more or less suspicious relation to the corn root lice in our breeding cages, and even in the fields, no known case has occurred to us of destruction by an insect enemy. It is, indeed, a remarkable fact that not a single hymenopterous parasite has ever been bred from the corn root aphis in all our long experience with that insect. It is true that root lice are much less parasitized than those feeding in more exposed positions, but they are nevertheless by no means commonly free from parasitic attack.

The only natural check upon the increase of this root aphis which has come immediately to our notice is a parasitic fungus, *Entomophthora fresenii,* detected October 16, 1889, infesting sexual individuals of this species found on roots of the curled dock *(Rumex crispus)* at Champaign, Illinois. Affected specimens were of a creamy or whitish color, and were literally crammed with the small oval granular spores of the Entomophthora. These so-called spores (properly "conidia") are commonly of a smoky tint with a clearly distinguishable cell wall and granular contents. They measure 18-20 microns in length by 15-18 in width. They are nearly spherical to short ovoid, and often have a short truncate, or slightly papillate, base. The fatal disease characterized by this fungus was generally distributed among the corn root lice in the field in which it was observed, nearly every lot of root lice detected there giving us examples of it, but it was not detected elsewhere, and an attempt to extend it by contagion to the corn leaf aphis *(A. maidis)* resulted unsuccessfully.

This fungus parasite is, so far as known, confined to the species of plant lice, of which it infests a great number. It is reported by Thaxter, in his "Entomophthoreæ of the United States,"* to occur in Maine, Massachusetts, North Carolina, and Europe.

ECONOMIC PROCEDURE.

Our present knowledge of the life history of the corn plant louse suggests four possible methods of attack. (1) We may try the effect of a change of crop after any notable plant-louse injury to corn, in the expectation that corn planted on ground which contains no plant-louse eggs will become so slightly or so slowly infested, if at all, that no harm need be anticipated. (2) We may resort to fertilizers and other applications made to the young corn hill in spring in the hope of killing the lice outright or of supporting the plant against their attack at a

*A full account of this Entomophthora is given in the paper cited. (See Mem. Bost. Soc. Nat. Hist. Vol IV., No. 6, p. 168.)

time when this is likely to be most injurious. (3) Since the small brown ant cares assiduously for the eggs in winter and spring, we may assume provisionally the necessity of such care and strive to find means of so disturbing the nests of the ants or of breaking up and dispersing their contents in late fall or in winter that their stores of aphis eggs cannot be recovered by them, and so shall be left to perish. (4) Taking account of the early hatching of the eggs in spring,—several days, as a rule, before the usual time for planting corn,—and the dependence of the young lice for food at that time on sprouting weeds in the field,—especially smartweed and pigeon-grass,—we may seek to handle the ground in such a manner that there shall be no sufficient start of vegetation to keep the lice alive. We may also delay somewhat, if necessary to this end, the planting of the field to corn.

Rotation of Crops.—There can be no doubt that a judicious rotation of crops has the effect at least to diminish injury by the corn plant louse by distributing its attack: and there is also considerable reason to believe that it must result in the destruction, direct or indirect, of a certain proportion of the insects themselves. Corn planted on ground not previously stocked with plant-louse eggs must escape at any rate until invaded from without by winged individuals of the second generation, and then, as a rule, it will be no more subject to injury than the other fields in its neighborhood. On the other hand, as the corn root aphis has never been known to infest to an injurious extent any other crop following corn, there is very little probability that the escape of the corn will be balanced by damage to other crops.

We have many observations going to show that wheat and oats and the smaller grass-like plants in general are commonly soon deserted by such corn root lice as commence to breed on them—a fact which indicates that these plants are less suitable than corn to the maintenance and multiplication of these insects. We have also considerable reason to believe that many winged plant lice flying about in search of feeding and breeding grounds must be destroyed by some of the innumerable accidents to which these feeble and helpless insects are necessarily exposed. This measure of rotation may consequently have the effect to diminish to an important extent the number of corn root lice in later generations. Precise proof on these points is, however, very difficult to secure. Artificial breeding experiments are altogether too variable in result to serve the purpose, as our own attempts at a solution of this question show; and evidence must be sought in the field especially by making detailed comparative observations of parts of the same previously infested fields, planted here to corn and there to small grain. The relative abundance of the lice late in May and early in June will go far to show the comparative utility of these crops as a food resource to the corn root aphis.

Applications of Fertilizers and Insecticides.—Various field observations have given us reason to conclude that fertilization of the soil will serve to support corn under the drain of aphis injury, especially by enabling a stunted plant to rally more rapidly and completely after the insects have begun to scatter. The rapidity and vigor with which, in rich ground and in a fairly favorable season, corn will outgrow an apparently fatal injury by the root aphis is, in fact, often quite sur-

prising. Apart from this general statement I have only to report the result of a single series of plot experiments tried in 1891 with various fertilizers mingled with petroleum, crude and refined, as an insecticide, and with applications of salt, wood ashes, and lime.

A plot of ground ten hills square, containing ninety-seven hills of corn, was selected on the University experimental farm at Urbana June 18, 1891, and surrounded by a continuous line of six-inch boards sunk about three inches into the ground, with close-fitting joints, and with the earth well tramped both outside and in. The upper edge of the boards was thickly covered with coal-tar, subsequently kept fresh by repeated applications. These measures were intended to prevent all interference with the experiment, either by escape of the insects within the plot or by invasion from without. June 26 this enclosure was enlarged to contain twenty-three hills more. Fertilizers, and mixtures of fertilizers and petroleum, were applied to the hills of corn June 18 and 23, being worked into the soil about each hill; and on the 26th lime, ashes, and salt were similarly applied. Of the ninety-seven hills in the first enclosure, forty-eight were found in the beginning to contain root lice and ants, and of the twenty-three hills in the second lot sixteen were similarly infested.

Three fertilizers were applied: superphosphates, muriate of potash, and sulphate of potash; each at the rate of three pounds to twenty hills of corn, and in each case half the hills under experiment were treated with the pure fertilizer and the other half with a mixture of fifteen ounces of petroleum to three pounds. One third of the above amounts were applied June 18,—the petroleum in these cases being the crude Lima oil,—and the remaining two thirds, June 23, when refined petroleum was used. The following notes are condensed from the memorandum filed at the time by the assistant* in charge of the experiment:

Experiment I., Superphosphates. Experiment II., Superphosphates and Petroleum.
June 29, I. Ants and root lice numerous.
" 29, II. Both insects present, but less numerous than in I.
July 1, I. Ants and lice abundant.
" 1, II. Ants present but no lice.
" 7, I. Ants and lice abundant.
" 7, II. A few ants but no lice.
" 15, I. Ants and lice comparatively abundant.
" 15, II. Ants and lice both present but fewer than in I.

Experiment III., Muriate of Potash. Experiment IV., Muriate of Potash and Petroleum.
June 29, III. A few ants and lice found.
" 29, IV. Dead plant lice discovered in one hill, both ants and lice occurring generally but not abundantly.
July 1, III. A few ants but no lice.
" 1, IV. Ants alone discovered on roots about one foot from the hill, just outside the fertilized area.
" 7, III. Ants and root lice found.
" 7, IV. Ants but no lice.
" 15, III. Ants plentiful; lice common.
" 15, IV. Few ants and lice detected.

Experiment V., Sulphate of Potash. Experiment VI., Sulphate of Potash and Petroleum.
June 29, V. Ants present but no lice.
" 29, VI. A few ants present but no lice.
July 1, V. Neither ants nor lice were found.
" 1, VI. A few ants and lice in one hill.
" 7, V. Ants and lice numerous.
" 7, VI. Both insects present.
" 15, V. No ants or lice detected.
" 15, VI. Small colony of ants and a few lice in one hill.

*Mr. J. S. Terrill, now of the Agricultural Experiment Station of Kentucky. The work was, however, done under the immediate supervision of John Marten, one of my present entomological assistants.

The weather during the period covered by the above experiment was generally dry, but abundant rains occurred June 20 and 21, which seemed to dissolve the fertilizers and wash them into the ground.

The lime, ashes, and salt experiments were entirely without effect, ants and plant lice occurring abundantly in all parts of the plot treated throughout the entire period of observation to July 28. This plot served consequently as a check upon the preceding experiment.

Although the effect of the other applications seems from the above notes to be quite marked, the experiment is nevertheless indecisive, since the hills treated were not dug up when examined from time to time, but only searched as carefully as was possible without injuring the plants. July 28, when all the hills were removed they seemed, according to Mr. Marten's report, to be about equally infested, all appearance of difference having then vanished. It will thus be seen that these experiments have little value except as hints towards future work. The differences observed may nearly all have been due to a repellant effect of the substances applied, in consequence of which the ants withdrew their charges deeper into the earth, with little diminution perhaps of the injury to the corn.

Breaking up Nests of Ants.—In one experiment, begun November 25, 1890, a strip of corn stubble three rods wide and ten rods long near the University premises at Champaign, was plowed six inches deep, half the strip being thoroughly harrowed also. The ants' nests among the corn hills were thus turned out and thoroughly broken up, except that in a few cases the plow did not go the full depth of the nests, but left the bottom undisturbed. The harrowing knocked the dirt out of the roots of the corn and broke up the fragments of the nests remaining in the clods. April 18, 1891, when the ground was again plowed, five ants' nests were found in this plot and thirteen in an equal strip beside it. All of these outside nests contained ant larvæ of various sizes, while those inside the strip contained no ants but worker adults. Ten of the former lot of nests and three of the latter contained root lice also, on smartweed roots.

In another precisely similar experiment, begun upon the same day in an adjoining field, a strip was plowed two and a half rods wide by twelve rods long, half of this being thoroughly harrowed, as before. The plowing averaged six inches in depth, but the plow ran considerably deeper under the corn rows, and the ants' nests were well broken up and scattered. April 17 of the following spring the ground was plowed for corn and thoroughly examined to determine the result of the experiment. The part which was harrowed contained three ants' nests, the remainder six; while on an equal strip adjoining, thirty were found. None in the strip plowed in fall contained young ants, while every one of those outside contained them. Several wingless females were seen in the nests, one of them in the plowed strip.

Neither the weather at the time nor that of the following winter was especially favorable to the success of such an experiment, the mercury reaching a maximum of 49° F. on the day the experiment began; and the winter following—that of 1890–91—being unusually open and

warm. Further, there had been more than a week of warm spring weather previous to April 18, the mercury reaching 72° on the 9th, 75° on the 13th, and 77° and 78° on the 17th and 18th respectively—temperatures at which ants as active as the little *Lasius niger alienus* might well disperse themselves and begin new colonies in unoccupied ground.

These experiments afford, perhaps, scarcely a sufficient basis for a final conclusion as to the economic value of this method, but so far as they go they are most encouraging. If we compare the treated plots with the check plots beside them, we find (1) that the ants' nests in the former were less than a third as many as in the latter; (2) that all in the plowed and harrowed plots were destitute of ant larvæ while in the check plots all without exception contained such larvæ; and (3) that in the single plot first mentioned the ants' nests containing lice were less than a third as numerous as those in the plot outside.*

From the above we can only infer the disastrous effect of this late fall and winter plowing upon the ants themselves, and, presumably, also upon the plant louse eggs they have in charge. It seems also quite probable that some, if not all, of the nests found April 18 in the experimental plots had been established there by worker ants in spring, and were not remnants of the nests previously broken up, and if this were the case the root lice found in them had doubtless been brought in from without.

Starvation Experiments.—April 15, 1889, twelve young root lice recently hatched were placed in a cavity in the moist earth, which was covered with a glass slip so placed as to allow an examination of the interior. April 20 two of these root lice died; the next day half of the lot were dead; April 22 only two were living; April 23 but one; and on April 24, nine days from the beginning of the experiment, all were dead.

May 14, 1888, a number of corn root lice of various ages, taken from the roots of young smartweed in the field, were placed in a glass vial with moist earth, the mouth of the vial being covered with gauze. On the 18th all were still alive, but by the 20th all had died, the earth in the vial still remaining moist.

April 30, 1890, a number of eggs were placed in a cavity in sterilized earth and left to themselves. May 1 one young louse appeared from the only egg of the lot which hatched, and May 3 this was dead. It appeared from the foregoing that young of this species hatching in the earth and kept without food would die in from two to nine days.

As a field application of this fact, an attempt was made April 16, 1889, to starve the young lice in the ground by keeping down the growth of young weeds. A piece of ground was thoroughly harrowed in two directions with a cutaway disk harrow, and the weedier parts of the plot, several times additional. April 20, however, ants and lice were found both within and without the harrowed strip; but the ants had no plant louse eggs in their possession where the ground had been harrowed. The result of this treatment was not especially encouraging,

* By an unfortunate oversight no mention was made in the notes on the second experiment, of root lice in either the plowed strip or check.

the young weeds sprouting so freely and abundantly in the moist earth, to a depth of four or five inches, that it seemed impossible to reduce the food supply of the lice to any considerable extent by mechanical methods.

Our present knowledge of effective economic procedure for the corn root aphis may be summarized in the form of the following recommendations: (1) that the fertility of the ground should be maintained as a general safeguard, and that cultivation should be so managed—especially that of the lower parts of the field—as to prevent so far as practicable the seeding of pigeon-grass and smartweed among the corn; (2) that infested fields should be plowed deeply and thoroughly harrowed late in fall or during some suitable early winter interval; and (3) that a somewhat rapid rotation of crops should be systematically followed, corn usually being allowed to grow on the same ground but two years in succession. While some work remains to be done with reference to the precise value of these methods in practical application, there is no longer any doubt of their substantial usefulness, at least as a means of holding in check the injuries of the corn root aphis.

DESCRIPTION OF CORN ROOT APHIS.

Wingless Viviparous Female (Plate VIII., Fig. 1).—Body broad-oval. Head and prothorax blackish, remaining segments pale green, the first three with a transverse dusky mark at middle. Abdomen with blackish marginal patches on the second, third, and fourth segments, also numerous smaller spots of variable number and extent. The seventh and eighth segments have transverse blackish marks at middle. Antennæ dusky towards tip and slightly so at base. Cornicles black, cauda and anal plate dusky. Beneath nearly uniform pale green, except the usual oblong transverse chitinous plate on the seventh segment; beak black at base and tip; coxæ, most of femora, tips of tibiæ, and tarsi black. Antennæ rather short, reaching about to the hind coxæ, I and II short and thick, both combined about two thirds as long as III. IV, V, and basal part of VI about equal, the latter about three fifths as long as the spur, IV and V combined about equal to III. Four outer joints imbricated throughout, more distinctly on the spur, a group of sensoria on VI at the base of its spur, and one near the tip of V, as usual, rarely also one near tip of IV or III. Beak passing middle coxæ, usually attaining hind coxæ. Lateral thoracic tubercles large and distinct, directed somewhat forward. Similar conical tubercles occur on the abdomen, each surrounded by a dark ring; one on each side of the first segment, between the first two spiracles, and another pair on the seventh segment, each side of the chitinous plate. The cornicles are about as long as the third joint of the beak, rather slender and nearly cylindrical, often broad at base, the outlines straight or concave. The cauda is a little longer than its breadth at base, where it is widest, tapering to apex, which is broadly rounded.

Length 1.4 mm., width .93 mm., antennæ .57 mm., cornicles .10 mm. The young are paler in color, and have proportionally longer beaks and shorter cornicles. The chitinous space of the seventh segment is almost wanting, and the cauda is shorter and broader, as in the pupa.

Pupa of Winged Viviparous Female (Plate VIII., Fig. 3).—Head obscure dusky, thorax pale reddish brown, abdomen dull pale green, without marking; beneath greenish. Cornicles blackish, cauda subtriangular, dusky. Beak dark at base and tip; tarsi and tips of tibiæ dusky. Antennæ short and pale, last joint darker and proportionately longer than in the wingless female. Beak and tubercles as usual.

Length 1.61 mm., width .8 mm., antennæ .48 mm.

Winged Viviparous Female (Plate VIII., Fig. 4 and 5).—Head black, thorax brownish black, abdomen pale green, with black marginal blotches on the second, third, and fourth segments, and around base of cornicles. Several transverse dusky marks in front of the cauda. Beneath, thorax chiefly dark, with pale spaces about base of legs; abdomen pale green, seventh segment as in wingless female. Antennæ dark, pale at the articulations, length and proportions about as in wingless form, imbrication of joints III-VI distinct, III with six to eight mostly large sensoria in a nearly straight line, fourth segment with one or two sensoria, sometimes none, V and VI as usual. Beak, abdominal tubercles, cornicles, and cauda, as in wingless form. Thoracic tubercles more outwardly directed.

Length 1.8 mm., width .9 mm., antennæ .7 mm., cornicles .12 mm., fore wing 2 mm.

Wingless Oviparous Female (Plate VII., Fig. 5).—Body dull green, with a glaucous bloom. Head dusky, prothorax chiefly dusky, three succeeding segments with a median transverse dusky blotch. Other small spots in series on dorsum. Beneath, head and prothorax dusky, two dark spots outside middle coxæ, and dusky line before each of the hind coxæ. The usual dark patch on the seventh segment. Antennæ relatively shorter, not reaching hind coxæ, proportions as in the pseudogyne; basal two joints and apical portions of the others dusky. Beak dusky, attaining middle coxæ. Legs blackish, femora paler at base, anterior and middle tibiæ paler except at tips; hind tibiæ greatly swollen and thickly covered with small sensoria. Tubercles smaller than in the pseudogynes. Cornicles and cauda as in the other forms.

Length 2.3 mm., width 1.2 mm., antennæ .8 mm., cornicles .2 mm.

Egg.—Length .7 mm., width .3 mm. Yellow when first laid, becoming black during winter and changing to green just before hatching in spring.

Wingless Male (Plate VII., Fig. 6).—Body narrower than that of pseudogyne, greenish black with a glaucous bloom, head black, thoracic segments each with a transverse black band, narrow on the prothorax, wider on the mesothorax, both attaining the lateral margins, that on the mesothorax narrow and short, not reaching the margins. Similar short bands on the first and the last three abdominal segments, other smaller spots present. Antennæ, legs, and cornicles blackish. Thorax beneath blackish, abdomen dark green, with the usual dark patch on seventh segment. Antennal lengths as in the pseudogyne, the joints thicker, joint III with two or three large sensoria near the middle, usually in line, and about ten very small ones irregularly distributed, grouped especially near the apex; IV with 5—7 sensoria, one often

large, the rest very small; V with two or three very small ones and the usual large subapical one, and VI with one large and several small ones in a group at base of spur, as usual. Tubercles as in the females, the thoracic directed outwardly, the cauda as in the females.

Length 1.4 mm., width .7 mm., antennæ .9 mm., cornicles .08 mm.

This species is sufficiently distinguished from *Aphis maidis* by the breadth and large size of the thoracic and abdominal tubercles, which are slender and minute in *maidis;* by the longer beak, which passes the middle coxæ and usually attains the hind pair, while that of *maidis* seldom reaches the middle coxæ; by the cornicles, which have a broad base, the sides tending to be straight or concave in outline, while in *maidis* the base is narrower, and the outlines more or less convex, these varying somewhat, however, so as to mislead in isolated examples; by the cauda, which in the adults is uniformly broadest at base, the sides tapering, while in *maidis* it is somewhat spoon-shaped, broad near middle, and narrower between middle and base; by the adults of *maidis* being much more elongate and narrow than adults of this species; and, in the winged individuals, by the number and armament of the sensoria of the third antennal joint, which are larger than in *maidis* and rather uniform in size, six to eight in number, and arranged in a fairly straight row, while there are thirteen to sixteen visible in *maidis*, of variable size and irregularly distributed along the under side of the joint.

The oviparous female may be easily recognized by the swollen hind tibiæ, covered with numerous minute sensoria; and the male differs from all the wingless individuals in the presence of a few large, and numerous minute, sensoria on the antennæ.

ON THE ANTS ATTENDANT UPON THE CORN ROOT APHIS.

Lasius niger and its variety *alienus** are so far the most abundant of the seven species of ants which we have found in attendance upon the corn root aphis that a discussion of the economics of this relation need scarcely take account of any other species; but as the most promising protective measures against this aphis are based on our knowledge of the life history and habits of this commonest corn-field ant, an accurate account of the latter is to be desired. Our notes on this subject cover the entire period since 1883, and enable me to give a fairly complete history of this species throughout the year.

Life History.—The winged sexual forms, male and female, of this ant begin to appear each year, as early as the latter part of June (the 21st to the 27th), hatching from pupæ which may have formed late in May (27 and 28, by our notes). The emergence of males and females from the pupa continues throughout the season, certainly into October and probably to November, but the males perish before the winter. The females, however, having been fertilized and deprived of their wings, begin their separate excavations in fall, or continue with the workers in nests already established. There they hibernate, sometimes, at least, commencing to lay their eggs in fall, and living in spring through April and May.

* [= *americanus* wherever used in this report.]

We have found the eggs of this species only November 10,* April 25, and May 20; but exceedingly small larvæ certainly very recently hatched have been collected by us May 5 to 19, July 15, and September 21. Our experiments have not, however, been conducted in a way to distinguish between eggs and young coming from fully developed females and those from fertile workers.

The larvæ hatching from time to time throughout the summer may be found as pupæ from the latter part of May through June, July, August, and September, to October 30, and even, according to a single observation made at Urbana, to November 20.

Haunts, Actions, and Habits.—The nests or burrows of this ant, in which these breeding operations are carried forward, are widely distributed in corn fields and grass lands,—especially in the latter, along the borders of roads and paths,—and also under stones and boards, in and under decaying logs, and in an indefinite variety of situations. In corn fields they are established almost wholly in the hills of corn, and remain here among the old corn roots throughout the season. As this is the commonest and most generally distributed of all our ants in Illinois, an exhaustive list of its places of habitation would have little present interest. It has never been found by us to form large settlements, or making mounds or conspicuous structures of any kind; but simply scatters its little burrows almost indiscriminately, living in small families rather than in great colonies or city-like aggregations, and piling up only a small temporary heap of pellets around the mouth of its burrow. When its mines are explored they are found to consist of irregularly radiating and connected tunnels, rarely going to a greater depth than six or eight inches, or extending outward over a horizontal area of more than twelve or fifteen inches. Here and there in their course or at their extremities and at various depths are chamber-like enlargements in which their eggs and young and the eggs of the corn root aphis are preserved and cared for. Here also considerable collections of the worker ants are usually found,—especially in winter and in times of summer drouth,—and in these chambers the female resides and lays her eggs.

In April, May, and June the workers seem to be most numerous and active. In July and August their activity declines, particularly in the hottest and driest weather, although if nests be opened at these times the ants will be found in abundance. Again, in September, a period of bustling activity begins which continues until checked by the winter cold.

* These eggs were obtained from a female brought in from the field October 23, 1893. Two females taken at this time were found in earthen cells very much alike, each about three fourths of an inch long by half an inch wide, irregularly oval, with the inside nicely smoothed. No other ants were found in the immediate vicinity. One of these females was placed October 25 in a Lubbock formicary between sheets of glass and fed with sugar. November 5 she had made an oval chamber in the earth (exposed above where it came in contact with the glass), and from this chamber had begun to tunnel laterally. November 10 she was seen with several white eggs in her jaws, and November 12 with a still larger number. These eggs were kept in a mass, and hastily removed from the oval chamber to the tunnel on the slightest disturbance. The carelessness of some workmen broke up this formicary on the 16th of the month, and the eggs were not seen again. The eggs collected April 25 hatched May 5. Those obtained May 20 were from a nest in an oat field on old corn ground, which contained also a queen, or fertile female, great numbers of worker ants, and larvæ of various sizes—from those just hatched to others apparently full grown.

In ordinary winter weather of the milder sort, these ants are not absolutely motionless, but if disturbed crawl slowly and stupidly about, sometimes even painfully attempting to perform their usual duties of restoration and repair. We have not explored their nests in the coldest weather, when the ground is frozen to a considerable depth.

During the first warm days of spring the thoroughly awakened ants begin to open up their burrows to the surface, and carry their own eggs and young and the eggs of the plant lice in their possession upwards and downwards according to the varying warmth of different layers of the soil. When the sun is shining brightly in the middle of the day they bring their charges to the more superficial chambers of their nests, or even expose them on the surface, but keep them farther downward at night and in cold and cloudy weather. The effect of this care upon the plant-louse eggs is shown by the earlier hatching of those cared for by the ants, and by the diminished number of those which fail to hatch at all.

Although this ant is evidently chiefly dependent for food upon the corn root aphis and other plant lice fostered by it, it is not strictly limited to this resource but, early in spring especially, has been found by us with freshly killed insects in its possession—caterpillars, carabid larvæ, and the like. Sometimes in midsummer also it resorts to animal food. July 16, 1884, in digging into a hill of corn infested by the root aphis and this ant, I unearthed a carabid larva. This was suddenly attacked by one of the ants, which pounced upon it just behind the head. The larva struggled vigorously, but the ant soon fastened its jaws on the under side of the neck, just behind the head, and a little to one side of the middle line. After this the struggle lasted only a few seconds, when the larva became completely quiet, and allowed this ant and another to drag it away without the least resistance. I watched this operation for a few minutes with a glass, and then put both ants and larva into alcohol. Although the larva did not visibly bleed when bitten, it was apparently dead, and did not struggle at all when put into alcohol.

June 2, 1891, an ant of the above species *(Lasius niger)* was found with a dead chinch bug in a wheat field, and three others were seen dragging live chinch bugs over the ground, one of which barely showed signs of life, a second of which moved its legs more vigorously, while a third, which an ant was dragging along by the beak, seemed scarcely at all disabled.

Description (Plate X., Fig. 5 and 6; and Plate XI., Fig. 1).—*Lasius niger* and its variety *alienus* belong to a group of small ants, the workers of which are about one sixth of an inch long, varying from yellowish brown to dark brown in color, and covered with a fine dense pubescence intermixed with scattered erect hairs, the surface therefore appearing dull or but feebly shining. The frontal area is faintly impressed, and the ocelli are indistinct. Their antennæ are 12-jointed, the third antennal joint shortest, the succeeding joints gradually longer. The maxillary palpi are long and slender, six-jointed. Between the base of the abdomen and the thorax is a short segment compressed above into a flattened vertical brownish scale, not distinctly notched above. The anal opening is circular.

These two forms are very closely related, and the differences exhibited do not seem to warrant more than varietal separation, although some authors treat them as distinct species. In typical *niger* the average size is larger, the color of the female and worker is usually darker, and the antennal scape and the tibiæ bear, among the usual pubescence, scattered, nearly erect, hairs, which are not usually apparent in *alienus*.

The Grass Root Louse.

(*Schizoneura panicola,* Thos.)

(Plate VIII., Fig. 6; and Plate IX., Fig. 1.)

This species was discovered on the roots of *Panicum glabrum* and other grasses by Mr. H. Pergande, at St. Louis, Mo., in November, 1877, and first described by Dr. Thomas, in 1879, in the Eighth Report of the State Entomologist of Illinois. The first observations of its occurrence in this State on corn were made in 1883, and it has been seen by us more or less abundant on the roots of various plants every year during the past eleven years. Its economic importance is but small, owing to the usually trivial numbers in which it occurs on corn, and the evanescent character of its attack. It is often important, however, that the corn farmer should be able to distinguish it from the far more dangerous corn root aphis—a matter of no difficulty to a fairly good observer. It may be told at once from that species by its white or yellowish color, and by the absence of the projecting cornicles or honey-tubes characteristic of Aphis, these being replaced in the present species by a pair of minute circular openings on the hinder part of the back, each delicately rimmed with brown, and surrounded by a small dark patch.

This root louse has been identified by Prof. Osborn as an alternate form with a species of the same genus, *S. corni,* Fabr., from the leaves of the dogwood (U. S. Department of Agriculture, Division of Entomology, Bulletin No. 22, p. 40); but from all available evidence I am not yet satisfied that the species here described as *S. panicola* ever leaves the ground except to fly from the roots of one food plant to those of another. It has been found by us in various underground situations from the early part of April until the latter part of November, as is shown by the following table, which gives also the plants on which it occurred.

Date.	Young.	Adult wingless females.	Pupæ.	Winged females.
Apr. 5		In log, with ants.		
Apr. 10-25		In breeding cage; on grass roots with ants.		
Apr. 12	Born in breeding cage.			

Date.	Young.	Adult wingless females.	Pupæ.	Winged females.
May 16	Setaria in oat field.	Setaria in oat field.		
May 17-20	Born in breeding cage.			
May 23	Corn.			
May 24	Young grass.			
May 26			Grass in oat field.	
May 28	Young grass in corn field.			
June 1	Setaria in corn field.	Setaria in corn field.	Setaria in corn field.	Setaria in corn field.
June 10		Grass in corn field.		Grass in corn field.
June 13		Corn (1883) and Setaria.		Corn (1884).
June 16	Setaria.			
June 17		Corn.		Corn.
June 23		Corn and Panicum.		Corn.
June 25	Setaria.	Setaria, grass.		Corn, blue-grass, &c.
June 26	Smartweed in corn field.	Smartweed in corn field.		
June 29		Panicum.		
June 30	Timothy in corn field.	Timothy in corn field.		
July 3		Timothy.		
July 13		Setaria, Panicum, and corn.	Setaria, Panicum, and corn.	Setaria, Panicum, and corn.
July 15	Setaria in corn field.	Setaria in corn field.	Setaria in corn field.	Setaria in corn field.
July 25		Sorghum.		
July 28	Corn roots.	Corn roots.		

Date.	Young.	Adult wingless females.	Pupæ.	Winged females.
July 31	Sorghum and Panicum.	Sorghum and Panicum.		
Aug. 4	Panicum and corn.	Panicum in sorghum field.	Panicum in sorghum field.	
Aug. 11	Grass.	Grass and sorghum.		
Oct. 2		Sorghum.		
Oct. 10		Grass.		
Oct. 12		On sorghum roots.		
Oct. 20		Corn in breeding cage.		
Nov. 25		Lasius burrows in corn field.		

From the above table we learn that this grass root louse has been found by us on corn ten times, as follows: May 23, June 13 (twice), 17, 23, 25, July 13, 28, August 4, and October 20 (in breeding cage). Other plants from the roots of which it has been taken are as follows: sorghum (five times) July 25, 31, August 11, and October 2 and 12; timothy (twice) June 30 and July 3; blue-grass (once) June 25; grass (seven times) May 24, 26, 28, June 10, 25, August 11, October 10; Panicum (five times) June 23, 29, July 13, 31, and August 4; Setaria (seven times) May 16, June 1, 13, 16, 25, July 13 and 15; smartweed (Polygonum) (once) June 26.

Thus we see that it has occurred fifteen times on cultivated plants, twenty-two times on the grasses, and once on a dicotyledonous species. It will further be seen that it does not appear to show a decided preference for any single food plant at any certain time of the year. A general preference for grass roots is shown, however, by the fact that in several cases where the roots of corn and grass were closely intertwined, the Schizoneura was found upon the latter only. It occasionally occurs on the roots of grass in fields planted with wheat, oats, etc., and wherever it is found in cultivated fields it is usually much the most abundant in those which were in sod the previous year. We have found it very common in the viviparous wingless form on the roots of various perennial grasses—blue-grass, timothy, and several native species—as the sod was broken up; and there is little doubt that plants of this class furnish its principal sustenance.

LIFE HISTORY.

The life history of this species is still incomplete, all our observations applying only to viviparous females, winged and wingless. Th-

winter is passed in the latter stage, at least in part, as is proven by the occurrence of adult wingless viviparous females as early as April 5, in a log, on grass, attended by *Lasius interjectus*, and as late as November 25, in the burrows of *L. alienus*, in a corn field. The accompanying table shows that the young have been found as early as April 12 and as late as August 11. In the former case they were born in a breeding cage from stem-mothers introduced April 5, and in the latter they were taken from the roots of "grass" in a sorghum field. Between these dates they have been found frequently in May, June, and July upon the roots of various food plants, such as corn, grass, Setaria, smartweed (Polygonum), timothy, Panicum, and sorghum.

The "pupæ" (showing wing-pads) have been collected five times, as follows: May 26, June 1, July 13 and 15, and August 4.

The winged viviparous female (winged pseudogyne) has been found by us eight times, as follows: June 1 on Setaria roots in corn field; June 10 on grass roots in corn field; June 13, 17, and 23 on roots of corn; June 25 on grass roots, on corn, and on blue-grass; July 13 on roots of Setaria, Panicum, and corn; and July 15 on Setaria roots in corn. Almost every year during the past ten years we have taken the winged pseudogyne during the month of June, and but twice (July 13 and 15) in any other month. Pupæ of this form have occurred, however, August 4. June 25, 1889, winged forms were observed migrating from a corn field to a pasture—mostly blue-grass. They came from the roots of corn and grasses, in the corn fields, to the upper leaves of smartweed, corn, and other plants, and, after resting there a few minutes, rose vertically into the air and flew very rapidly, with the wind, to an adjoining field of blue-grass, where they were taken in great numbers by sweeping.

The early spring history of this species is best indicated by notes made April 5, 1884, by my assistant, Prof. H. Garman, now of the State College of Kentucky. Root lice whose identification as *Schizoneura panicola* has lately been verified by us, were obtained by him April 5 from a nest of ants of the species *Lasius interjectus*, which had established themselves in a rotten log at the edge of a corn field near Bloomington, Ill. This nest contained likewise a number of eggs of aphides probably not of this species. The collection made was exposed to a colony of ants of the species above mentioned, which had been kept in a Lubbock formicary during the winter, with the result that the ants from the field were driven away and the Schizoneura and aphis eggs were seized upon and carried away into the burrows of the colony. Here all were cared for during about three weeks, when the observations terminated. A tuft of blue-grass was placed within reach of the ants, and upon this the root lice were colonized and began to breed April 12, the young there born being alive and in good condition April 25.

According to another experiment, begun by Mr. C. M. Weed May 16, 1887, a wingless female of this species obtained from the roots of Setaria in an oat field was placed on that plant in a breeding cage. The next day she had moulted and given birth to young, additions to her brood being made at intervals to May 21, when the observation terminated.

On the 26th of May the winged pupæ found in an oat field preponderated greatly over all the other forms and stages; a fact possibly to be accounted for by the relatively scanty food supply in that situation, and the consequent necessity for migration elsewhere. June 10, on the other hand, in a corn field where winged specimens were present in large numbers, the great majority of those observed were wingless females in various stages.

The closely related *Schizoneura corni* lives from September until June on the dogwood (Cornus), and from June until September on the roots of certain grasses. Our collections contain species of *S. corni* from the dogwood, but the most careful investigation of our large collection of root lice fails to reveal any evidence of its ever having been taken here on the roots of corn.

RELATIONS TO ANTS.

The accompanying table shows that our first and last collections for the year were not from the roots of plants, but from the winter nests of ants; and here the grass louse evidently hibernates. When these nests are broken up, the ants evince no choice between the root lice and their own young in their eager and heroic efforts to carry them to places of safety.

In the spring the ants dig new burrows around the roots of certain plants, and convey their charges to these new habitations; and during the summer they change them from one food plant to another, as the varying condition of the plants and the requirements of the root lice may demand. In return for these favors, this Schizoneura permits the ants to feed not only upon the "honey-dew" coming from the cornicles, but also on a waxy substance excreted from pores in the sides of the abdomen. We have several times seen the ants gathered about a detached mass of this wax, and apparently eating it.

The ants collected in attendance on this root louse all belonged to the following forms: *Formica schaufussi*, Mayr (Plate XI., Fig. 2), once in attendance; *L. interjectus*, Mayr; *L. niger*, Linn., and its variety *alienus*, Forst; and *L. flavus*, De Geer. The ant last mentioned is perhaps most commonly found in charge of it, the other species of Lasius mentioned differing but little with respect to the frequency of their occurrence in this relation.

So far as now known, this insect is little likely to call for remedial measures, as corn is liable to injury by it only after grass, and the damage is, at most, slight and evanescent.

DESCRIPTION.*

Wingless Viviparous Female (Plate IX., Fig. 1).—Body ovate, more or less elongate, dirty white with a yellowish tinge, with a variably developed pattern of yellowish fuscous markings in the adult, dotted with white at the origin of the minute hairs which are scattered over the smooth surface of the body.

Head rather small, but longer than the succeeding segments, uniformly yellowish dusky, with a darker spot each side of the median line, a little in advance of the eye. Antennæ attaining middle of side of metathorax, not very thick, somewhat hairy, especially on outer joints,

* By Mr. C. A. Hart.

colored like the head; apical joints dark brownish, spur nearly black, third joint pale except near apex; six-jointed, IV and V nearly equal, V a little the longer; IV about twice as long as thick; III nearly or quite as long as IV and V combined, and equally thick; II about three fourths as thick as I, and III half as thick as I; I and II together two thirds the length of III alone; and VI half longer than V, the spur constituting one fourth of its length. V bears the usual round sensorium, placed upon a slight prolongation of the apex beneath. On VI, at the base of the spur, is a round sensorium, posterior to which are three or more smaller sensoria. The eyes are quite variable in the extent of the black pigment, but usually of good size. The posterior tubercle is distinct, and bears three equidistant oval lenses radiating from the apex of the tubercle. Rudimentary ocelli sometimes visible.

The prothorax bears above an irregular oblique spot, with dark outline, on each side of the disk. Dark lines, in line with these spots, lie on each side in the transverse thoracic sutures, becoming double posteriorly, and from these a double row of small spots continues to the tip of the abdomen, sometimes obscured by the discal markings of the segments. The four segments behind the head are almost entirely fuscous, except on the suture and at the sides of the first abdominal segment. The three or four segments preceding the cauda are yellowish fuscous except near the lateral margin. The other abdominal segments show faint mottled fuscous bands. The cornicles are very distinctly indicated by fine dark rings nearly level with the surface, surrounded by a dark blotch. Cauda very short, subtriangular, not projecting, it and the anal plate yellowish fuscous, hairy.

Beneath slightly paler than above, with markings of similar color; legs and beak brownish yellow. The beak attains the base of the abdomen, last two joints dark brownish yellow, tip black. The basal two joints are together about twice as long as the third and fourth combined. The third joint is slightly broader than the others, about as long as broad; the fourth joint is half longer, pale-ringed just before the tip. Legs nearly smooth, femora darker apically, tibiæ paler except at base and apex, claws dark, large. The abdomen has a marginal row of dark blotches, in which are situated the spiracles, and above these, a large subcircular excretory pore on segments 1-4 and 7. A similar large oval pore lies just below the lateral margin of the prothorax. These are homologous with the tubercles of the corn root louse, and perhaps with the cornicles also. Below the spiracles is a row of dark spots in the sutures. The seventh segment bears the usual transverse oblong brownish yellow plate.

Length 1.5 mm., breadth .9 mm., antenna .5 mm.

Described from numerous specimens from roots of grass and corn.

The young show the usual differences of size and color, and proportionate greater length of appendages. The antennæ have but five joints, the third proportionally shorter.

Pupa.—Oval, more elongate, yellowish white, head and thorax dusky, no distinct markings except the double row of spots. Antennæ about attaining base of posterior wing-pads, with suture between III and IV imperfect. Wing-pads attaining middle of second segment be-

neath, posterior pair pale, turned downward more than the anterior, which are brownish dusky. Plate of seventh segment beneath indistinctly marked. Tip of abdomen hairy.

Length 1.13 mm., breadth .6 mm., antenna .38 mm.

Described from five specimens found on grass roots.

Winged Viviparous Female (Plate VIII., Fig. 6).—Elongate, smooth, with sparse inconspicuous hairs, dirty whitish, varied with fuscous and dark brownish, dotted with white at origin of hairs. Head above and mesothorax above and below dark brownish, edges of meso- and meta-thoracic plates with blackish outlines. Remaining surface markings fuscous brown, sutures whitish.

Antennæ fuscous brown, apex darker, base of third joint paler, basal two joints one half thicker than the others; IV a little more than twice as long as thick, V a little longer, VI nearly half longer than IV, the spur three eighths of its length; III about equal to V and VI combined; I and II combined about equal to VI. Sensoria distinct, one at tip (beneath) of joints III, IV, and V, and at base of spur on VI, last two quite large, that on VI accompanied by the usual group of smaller sensoria. Often one at middle also of III, and sometimes a third near by it. Eyes brownish black, ocelli distinct. A pale notch on hinder margin of head just within each eye.

Prothorax with a dusky band anteriorly, behind this a pair of large transverse spots, sometimes a small pair behind these. Mesothorax with pale spots at sides. Metathorax with a narrow transverse mark of dusky brown. Wings with a granulated surface, veins and stigma light brownish, stigma half as wide as long on costal margin; cubital obsolete two thirds of distance from base to the fork; stigmal vein but feebly curved. Running parallel to the posterior margin of the postcostal vein and stigma, and separated from them by a narrow paler interval, is a distinct and narrow thickening and darkening of the wing.

Abdominal segments with a row of marginal blotches, one on each segment. The double row of small spots in the sutures is present, but confused with the discal markings. First and second abdominal segments each with a short transverse discal band; bands of next three segments more or less confluent, forming a fuscous brown patch; sixth segment with a long discal band; those on seventh and eighth extending to margin. Cornicles distinctly indicated by a fine dark ring in the marginal patch of the sixth segment. Cauda short, not projecting, it and anal plate fuscous brown, hairy.

Beak as in viviparous female, attaining hind coxæ. Prothorax mostly pale beneath; mesothorax pale only around the coxæ; metathorax with blackish transverse line, ends of latter partly surrounding coxæ. Legs darker fuscous brown, first tarsal joint prominent. In the suture back of the prothorax is an elongate spiracle in a small transverse dusky brownish spot; just below the margin of the prothorax is a large oval excretory pore. The abdomen beneath is pale, first and second segments, and sometimes the sixth, each with a short discal transverse line. Seventh with usual oblong dark plate, which is hairy like the anal

plate. An indistinct row of short transverse lines in the sutures extends back from the hind coxæ on each side. Exterior to these is a row of light brownish spots including the pale spiracles. The spot on the first segment combines with the marginal blotch. In the blotches, on the first and seventh segments, and just below those on the second, third, and fourth segments, are large circular excretory pores similar to those on the thorax, outlined by a fine darker line.

Length 1.8 mm., breadth .8 mm., antenna .63 mm., fore wing 1.8 mm.

Described from five specimens, three taken on grass roots, one on corn root, and one resting on corn leaf.

Schizoneura panicola, Thomas, is nearly related in habit and structure to the European *S. venusta*, of Passerini, but differs from that species, according to Passerini's very brief description, in the color of the head and abdominal fasciæ, which are light dusky instead of black. *S. panicola* differs also from *S. venusta* in the absence of the discoidal patch on the abdomen, and in the longer beak—reaching the hind coxæ, while that of *venusta* is said to extend only to the middle coxæ. The latter species is given by Passerini as occurring in Europe in autumn on the roots of *Setaria viridis*, *S. glauca*, *S. italica*, *Panicum glabrum*, *Eragrostis megastachya*, and *Ceratochloa australis*; also in the month of June on the roots of wheat ("Aphididæ Italicæ," p. 69).

Trama erigeronensis, Thos.

(Plate IX., Fig. 2.)

This root louse is included here because it has been found a few times in corn fields under circumstances to indicate its probable occurrence on the roots of corn itself. It is not strictly a corn insect, however, so far as we now know.

We have at hand specimens of the wingless viviparous female that have been taken as follows: March 19, (situation not given); April 1, from an ant hill (*Lasius mixtus*), on grass and a dicotyledonous weed; April 5, under a log at edge of corn field attended by *Lasius niger*; April 8, at roots of old corn; April 9, from an ants' nest; April 11, from roots of blue-grass, attended by *Lasius interjectus*; April 23, from nests of Lasius; April 26, in Lasius nest in old log; May 7, taken in corn field; November 25, from roots of Panicum, in corn field, with ants. Thus we see that this species has been collected here once in March, seven times in April, once in May, and once in November.

Specific determinations have been made of the following species of ants attending this root louse; *Lasius niger*, *L. mixtus*, and *L. interjectus*. It is attended by about the same species of ants as the other root lice treated in this publication, and the range of food plants as shown above is also about the same as those given for several other species.

DESCRIPTION.*

Having a large series of this perplexing species, which is quite evidently the same as that described by Dr. Thomas in the Eighth Report

* By C. A. Hart.

of this office (p. 168) as a Tychea, and again by Mr. O. W. Oestlund, in his "List of the Aphididæ of Minnesota" (p. 56) as *Tychea radicola*, a full description is here submitted, from which it may be seen that an imperfect knowledge of the species has caused conflicting statements. The number of antennal joints, as well as other characters, throw it out of Tychea, and place it in Trama, as defined by Koch.

Wingless Viviparous Female.—Body broad-ovate, very convex, abdomen often subglobose, surface smooth, dirty whitish, a few sparse hairs on antennæ and legs.

Head rounded on front and sides, base broad, about twice the length, an oblong dusky spot extending from the base of the beak over the vertex, between the antennæ, nearly to the posterior margin of the head, wider behind, divided by a whitish median line. Fully developed antennæ with six distinct joints, dusky whitish, darker apically, the spur or sometimes the entire apical half of VI dark brown or blackish, tip reaching posterior margin of mesothorax. Joint I very short, transverse; II nearly as thick as I at apex, but narrowed strongly towards base, about one half longer than I; III still longer, but not as long as I and II combined, about twice as long as thick; IV as long as II; V as long as III, or a little shorter, wider apically; VI broad fusiform when seen from above, thickest near middle, tapering to base and to apex of spur; basal part of VI as long as V, spur about one fourth of total length of joint. Even in some good-sized examples the suture between joints III and IV is imperfect, and these two joints are shorter, especially IV, which becomes distinctly shorter than II. In other specimens of the same lot, for example one 1.8 mm. long, III and IV are much shortened and completely united into one joint, which is very little longer than VI. V is also shorter, being about as long as II. Sensoria moderate in size, round, one, as usual, at apex of V and one at base of spur on VI, with one or two very indistinct minute sensoria adjoining it on the posterior side. Eyes small, ocular tubercle feebly elevated, with three lenses as usual.

Thorax and abdomen unicolorous, prothorax separated from mesothorax by a lateral constriction, in front of which the side margin is subangulate. The dorsum is provided with numerous glands for the secretion of a waxy substance, which rises in short columnar tufts from each gland, giving an appearance of rows of tubercles. Alcohol soon dissolves most of the excretion, and even obliterates all traces of many of the glands. These glands are arranged in regular series, appearing in fresh specimens in alcohol as clear smooth spots encircled by a fine dark line. There are six longitudinal rows, each with one gland on each segment, equidistant on the abdomen, the outer row being at the lateral margin. The two middle rows approach at the base of the abdomen, and are close together on the thorax and head, the head having four unequal glands in each row, placed within the dusky patch. The other four rows do not appear on the head, and are very indistinct on the thorax, excepting the prothoracic spot of the outer row, which is small but distinct, and below the side margin, those on the other thoracic segments being dorsal. On the abdomen, the outer row consists of large lateral spots; the seventh segment has but four spots, two lateral

and two dorsal, the latter small and inconspicuous. Cornicles wanting. The anal plate, cauda, and a short and narrow transverse band on the eighth segment above, are light yellowish brown, a whitish line on the anal plate just behind the cauda. Anal plate strongly prominent, subglobose, very convex below and more flattened above, minutely scabrous, clothed with rather long incurved hairs; cauda represented by a shorter subtriangular elevated plate on its upper surface.

Beak brownish dusky, tip black, attaining or slightly surpassing hind coxæ, apical joint about as long as last antennal joint, penultimate joint about half as long, and somewhat thicker, being about as long as thick; lunate marks at its base distinct; apparent basal joint slender, about two and a half times as long as the apical two combined. Legs rather short, light brownish dusky, coxæ paler, sutural lines brown about coxæ, two distinct claws and two tarsal joints on all the legs, tarsi and claws dark; fore legs very close to head. Prothoracic spiracle light brown, distinct, below the lateral gland. Abdominal spiracles each in the posterior margin of a small brownish spot, anterior margin of spiracles finely outlined in black; sometimes an inner row of light brown spots, one beneath each abdominal spiracle. Seventh ventral segment with a thickened and slightly darker plate at middle, which has at each end a group of sparse hairs. A few hairs on the ventral segments preceding the seventh.

Length of body 2.2 mm., greatest width (across abdomen at middle) 1.1 mm., antenna .55 mm.

The young are more slender, with long beak and five-jointed antennæ, or four-jointed in the youngest.

Described from ten lots of specimens.

The cauda and anal plate and antennal structure will distinguish this species, in case the glands are not evident, from the others infesting corn.

Forda occidentalis, n. sp.

(Plate IX., Fig. 3.)

Another root louse which has been found on corn in unimportant numbers is a species of Forda, here described as new. It seems to be mainly a grass root louse, and has been taken by us eight times, as follows: April 4, (no situation given); April 10, on *Capsella bursa-pastoris*, attended by *Formica fusca gagates:* April 11, on roots of blue-grass in edge of corn field, with *Lasius interjectus:* April 23, from a nest of Lasius; April 28, in blue-grass sod, attended by *Lasius niger:* April 30, in a pasture, with *Lasius niger:* May 7, in a corn field; May 31, on roots of corn, on sod ground, attended by Lasius.

It will be seen that these collections have all been made in early spring, and with but two exceptions in the month of April. The life history of this species is thus unknown.

DESCRIPTION.*

Wingless Viviparous Female.—Body oval or ovate, smooth, uniform light glaucous green, sutures not conspicuous, body and appendages sparsely covered with fine and rather short hair.

* By C. A. Hart.

Head rather broad and subtruncate in front, width at base about twice its length. Antennæ distant, each in a short broad groove or impression, five-jointed in the mature individual, moderately long and slender, attaining the sides of the metathorax, slightly darker than the body, fifth joint and apex of fourth pale brownish; joint I about twice as thick as III, its posterior side about equaling its basal diameter; II a little longer and more slender, about twice as long as thick; III the most slender and much the longest joint, being nearly twice as long as I and II combined; IV and V about equal, each longer than II, and combined about three fourths as long as III, spur of V tapering, short, extending beyond the sensorium about as far as the diameter of V at base. On the lower side of the apex of IV is a large round sensorium, and at the base of the spur of V is an extremely large one, semicircular or sublunate, fully as wide as the diameter of III, strongly convex, glassy and apparently transparent when looked through in profile. Two or three minute sensoria adjoin it on the distal side, next the spur. On one antenna there is an additional sensorium on IV towards the base. Eyes moderately large, placed near the posterior angle of the head, ocular tubercle broad and rather high, showing in alcoholic specimens three oval lenses, their long axes radiating from the apex of the tubercle.

Prothorax set off from remainder of body by a slight constriction or deepening of the suture, and usually showing an oblique impression on each side above. Remaining body segments without distinct markings or structures above, gradually shorter to posterior extremity. Eighth segment, cauda, and anal plate pale brownish, the former small and short, the cauda reduced to a subtriangular plate on the upper surface of the anal plate, the latter one half longer than the cauda and as long as the seventh segment, semiglobular, minutely scabrous, clothed with fine short hair, a white line adjoining the apical margin of the cauda.

Beneath, colored as above; beak long and slender, reaching middle of abdomen in adult, base and apical joint pale brown, the latter tipped with black, as thick as joint II of the antennæ, and as long as antennal joints I and II combined; penultimate joint half as long, and one half wider than its length; apparent basal joint about twice as long as the apical two combined, pale and slender. Legs moderately long, each with two distinct claws and two tarsal joints; coxæ slightly darker. Seventh ventral segment often dark, eighth concealed at middle, anal plate beneath with color and surface as above. Spiracles pale brownish, very inconspicuous. No glands or tubercles seen.

Length of body 2.1 mm., greatest width 1 mm., antennæ .75 mm.

The young are similar to the adult, antennæ five-jointed, III a little shorter than in the adult.

Described from six lots of specimens.

The clear pale green color, greatly elongated third antennal joint, very large sensoria, and absence of cornicles, easily distinguish this species from other root lice.

Tychea brevicornis, n. sp.
(Plate IX., Fig. 4.)

This species of root louse is not important, and has not been known to occur in destructive numbers, but from its occasional presence on corn roots, it deserves mention along with others of its group and habits.

A colony of this Tychea was found on corn roots at Normal, Ill., on the 28th of July. The specimens in this collection all appear to be young pseudogynes, or wingless viviparous females, from about one third to two thirds grown. A large adult wingless viviparous female was taken on the 25th of October from an ants' nest in a pasture field near Champaign.

Description.*

Wingless Viviparous Female.—Body broad-oval, pale dirty whitish in alcoholic specimens, smooth, sutures not distinct.

Head short, rather narrow between antennæ, but very broad at base, which is more than three times as long as the frontal margin, the union between head and prothorax being very close; lateral margins concave, a pale dusky brown patch occupying the anterior surface between the antennæ, terminating behind with a semicircular irregular margin, not extending towards the acute lateral angles nor attaining the hind margin. It is divided by a median whitish line, on each side of which is a white glandular dot. An angular brownish patch also surrounds each eye. Antennæ short, but rather slender, hardly surpassing the posterior margin of the prothorax, five-jointed, uniform light brownish, with pale sutures; I short, twice as thick as III, and not as long as thick; II one half longer than I and nearly twice as long as thick; III nearly as long as I and II combined; IV very short, about as long as thick; V as long as III, with a short cylindrical spur about one half the diameter of the segment, and scarcely as long as the diameter of this joint at the base. Sensoria rather small and inconspicuous, round, one as usual at the apex of IV beneath, and one at the base of the spur of V. Eyes distinct, contiguous to the prothoracic margin, ocular tubercles feebly elevated, with the usual three lenses. Prothorax very indistinctly separated from head, but distinctly marked off posteriorly by the deepening of the suture on each side and the more rapid widening of the body just behind it. Upon the abdominal segments appear traces of four large excretory glands on the dorsal surface of each segment. No cornicles. Cauda and anal plate light yellowish brown, very short and broad, the former at the apex of the abdomen, the latter on the ventral surface, not visible from above.

Beneath yellowish, a faint yellowish brown tint between the posterior legs. Beak short, seldom attaining the middle coxæ, and about as long as the antennæ, base and apical half light brownish yellow, extreme tip blackish; apical joint about equal in diameter and length to the second antennal joint; penultimate joint a little shorter and about equal in length and breadth, the lunate marks at its base distinct; apparent basal (second) joint considerably longer than the apical two combined, and rather slender. Legs light yellowish brown, moderately long,

* By C. A. Hart.

the anterior coxæ closely embracing the base of the head, the others widely separated from each other by the broad flattened meso- and metasternum, the middle legs being nearly as far apart as the posterior pair, the anterior about half as far. Two distinct claws and two tarsal joints on all the legs. Exterior to each leg is an irregular longitudinal spot of pale dusky brown, the spots near the anterior legs uniting with those on the head which surround the eyes. Spiracles brownish, distinct. Seventh segment with a transverse thickened plate at middle beneath, light yellowish brown posteriorly.

Length of body 1.8 mm., breadth 1.1 mm., antenna .42 mm.

Described from two lots of specimens.

The European analogue of this species is *Tychea phaseoli.*

Geoica squamosa, n. gen. et sp.

(Plate IX., Fig. 5 and 6; and Plate X., Fig. 1, 2, and 3.)

Among the minor aphid insects of the corn plant is a small whitish or yellowish mealy species, occurring with ants and in their nests in corn fields and elsewhere often enough to attract the attention of any close observer of the corn root insects, but never yet numerous enough in our observations to do any perceptible harm.

The following chronological list shows its dates of occurrence in our collections, its forms, its food plants, and attendant ants:

Jan. 20, timothy roots; Lasius; viviparous female.
Feb. 13, in grass roots; in Lasius colony; oviparous female.
Mar. 9, sod, by fence, near corn field; *Lasius niger.*
" 21, in last year's corn hill; burrows of Lasius.
" 23, in last year's corn hill; burrows of Lasius.
" 26, sod; several nests of *Lasius niger.*
" 29, sod, along fence between corn field and pasture; *L. niger;* eggs.
Apr. 1, grass roots and a dicotyledonous weed; large nest *Lasius mixtus.*
" 4, roots of shepherd's purse; *Lasius niger.*
" 5, breeding cage; young, from eggs of Mar. 29.
" 6, on roots of old corn and under boards.
" 10, roots of shepherd's purse; *Formica fusca gagates.*
" 19, grass roots, in meadow; *Lasius niger.*
" 26, in blue-grass sod; frequent in nests of *Lasius niger.*
May 7, grass; Lasius nest.
" 8, timothy roots.
" 9, roots of young oats in corn ground.
" 19, sod; *Lasius niger.*
" 19, on corn roots in old sod ground, one with beak in root; *Lasius niger.*
" 21, on corn roots in grass ground; *Lasius niger.*
" 21, on corn roots in grass ground.
" 21, on corn roots, meadow last year; one killed by mite; *Lasius niger.*
" 24, on corn roots, grass ground; *Lasius niger.*
" 25, on young grass roots.
" 28, on corn roots; *Lasius niger.*
" 29, on corn roots; *Lasius niger.*
" 31, in Lasius nest.

May 31, corn roots, sod ground; Lasius; pupa, showing wing-pads.
" 31, in sod; *Lasius niger*.
" 31, on blue-grass roots; in Lasius nest; pupæ.
June 1, young corn roots and base of stalk, sod ground, one fourth the corn infested.
" 1, corn roots, sod ground.
" 5, breeding cage; winged female from pupæ of Mar. 31.
" 6, corn roots, abundant, sod ground; *Solenopsis debilis*.
" 13, corn roots, sod ground.
July 14, clover roots.
" 15, on roots of corn.
" 28, on roots of corn.
Aug. 11, on roots of clover (twice).
Sept. 25, on roots of *Panicum crus-galli;* Lasius.
Oct. 15, timothy roots; oviparous female.
" 20, corn roots.
" 28, timothy roots; male and viviparous female.
" 29, in meadow; *Lasius niger;* oviparous female.
Nov. 19, blue-grass and timothy in corn field; oviparous and viviparous females and young.
" 24, corn field; burrows of Lasius.
" 24, about roots of corn; oviparous female.

We see from the above list that this species has been found on the roots of the following plants:

Corn (seventeen times), Apr. 6, May 19, 21 (three times), 24, 28, 29, 31, June 1 (twice), 6, 13, July 15, 28, Oct. 20, Nov. 24. Also in corn hill of previous year (twice), Mar. 21 and 23.

Oats, May 9.

Timothy (five times), Jan. 20, May 8, Oct. 15, 28, Nov. 19.

Blue-grass (three times), Apr. 26, May 31, Nov. 19.

Panic-grass (*Panicum crus-galli*), Sept. 25.

Grass (five times), Feb. 13, April 1, 19, May 7, 25.

"Sod" (six times), Mar. 9, 26, 29, May 19, 31, Oct. 29.

Clover (three times), July 14, and Aug. 11 (twice).

Shepherd's purse (twice), Apr. 4 and 10.

A dicotyledonous weed, Apr. 1.

Thus it is shown that of the forty-seven sets of specimens of this species in the collections of the State Laboratory of Natural History eighteen were taken from the roots of cultivated plants, twenty-one from roots of grasses, three from clover, three from weeds, and two or three from ants' burrows but not on plants.

The fact that it has been found on corn much oftener than on other plants does not necessarily mean that it affects this plant to a greater extent than others, as in our investigations corn has been examined more frequently than the others mentioned.

It must be noted that this species has been seen but once in a field that was not in grass the previous year; viz., May 9, on roots of oats in old corn ground.

It often occurs in the formicaries of ants with other species of root lice, mealy bugs (Dactylopius), and coccinellid larvæ. Collections were not always made of the ants in attendance, but a careful study of the

eighteen lots of ants taken in company with this root louse shows that *Lasius niger* has been so taken fifteen times, and the following species once each: *Lasius mixtus*, *Formica fusca gagates*, and *Solenopsis debilis*. During the winter and early spring these lice have been found wandering in the burrows of *Lasius niger*, still guarded and cared for by the ants.

The five known forms of this insect are as follows: the egg, wingless pseudogyne or viviparous female, pupa, winged pseudogyne, and the wingless sexed form, consisting of true oviparous females and of males. The eggs have been found in spring, from which the young root lice have hatched in the first part of April. These are viviparous, and give birth to another generation of the same kind, and successive generations follow during the entire summer. Young have been taken in nearly every collection here during the summer months.

In the fall, usually in October and November, the viviparous form gives birth to true sexed individuals, males and oviparous females. These copulate and the females lay their eggs in the loose earth around the roots of plants in the ant burrows in which they are kept. The ants keep these eggs during the winter and spring, and from them in due time the young viviparous root lice hatch. Thus the circle of life continues. It is shown, however, by our collections that some of the lice also live during the winter on the roots of plants, in the formicaries of ants, most of these being viviparous and young; but the oviparous form sometimes occurs there during the winter or very early part of the spring.

DESCRIPTION.*

This plant louse is closely allied to certain species commonly placed in Tychea, a genus of the Rhizobiinæ, which is a subfamily whose members have not hitherto been known to acquire wings. A careful study of the winged individual bred from a pupa shows that it is a new generic type most nearly related to Hormaphis, of the Pemphiginæ; and as Tychea seems to contain at least two dissimilar groups of species, whose only bond of union is a resemblance in the number and length of the antennal joints, it will be well to divide the genus, retaining the old name for the typical species, such as *phaseoli* and *brevicornis*, and placing *setariæ* and its allies together with the present species at the foot of the Pemphiginæ, as a new genus, for which the name Geoica is now proposed. Here also belongs the species described by Buckton as *Endeis carnosa*, which surely is not an Endeis at all. *Tychea panici*, Thos., is apparently a young Rhizobius.

GEOCIA† n. gen.

Antennæ 5-jointed, not annulated, first and second joints short, third longest, fourth and fifth shorter, subequal, often connate, the fifth with a short thick spur at tip. Sensoria present on the third antennal joint of the winged individual, and in all of the forms at the apex of the fourth joint and base of spur on fifth, the latter sensorium lunate in the wingless individuals. None present on the tibiæ of the oviparous

* By C. A. Hart.
† *Ge*, earth; *oikos*, house.

female. Eyes distinct. Beak rather short and thick, last two joints longer than basal portion. Fore wings with the stigma large, the cubital simple, obsolete basally, the two discoidals united at base. Hind wings without discoidal vein. Two distinct tarsal joints and two claws on all the legs. Anal plate flattened, drawn forward dorsally and compressing middle of posterior segments, cauda short, transverse, inconspicuous. Cornicles and excretory glands wanting.

G. squamosa, n. sp.

Wingless Viviparous Female (Plate IX., Fig. 5 and 6).—Body broadly ovate, more or less distinctly and widely margined, sutures distinct, surface alutaceous. General color whitish to pale straw-color, covered with a mealy excretion. Entire surface, including antennæ and legs, with light brown points from which arise short thick scale-like hairs, the basal half of each erect, but near middle strongly and often almost rectangularly bent backwards, the apical half of those on the vertex apparently flattened and expanded; a large brush of hairs at tip of abdomen. In alcoholic specimens, a varying pattern of dark brown longitudinal lines radiating from the cauda, above and below, usually four each side of middle, which unite on each side at the base of the abdomen, and often extend upon the thorax as a single stripe; lines usually dilated at the sutures. At the base of the abdomen the inner pair diverge; the outer pair are more isolated. A similar marking is sometimes seen in other species; it relates perhaps to internal structure.

Head short, a small brown spot each side of middle, and an indistinct pale median line. Antennæ robust, attaining the side of the mesothorax, usually five-jointed in the adult, but joints III and IV often coalesced more or less, the point of union marked by a distinct constriction. The apex is faintly fuscous. I and II are subequal, about as long as thick, rounded, I very slightly thicker than II, remaining joints nearly as thick as II; III longest, nearly or quite as long as I and II combined; IV about as long as II; V longer, but not as long as III, apical spur short and thick, its diameter nearly half that of the joint, and slightly longer than thick, its length being about one fifth the entire length of the joint. At the apex of IV is a round sensorium, and at the base of the spur of V, and partly encircling it, is a rather large lunate-reniform one, with a minute one between it and the spur, the latter group especially surrounded by dense minute pubescence. Other joints without sensoria. Eyes very small, black.

Prothorax broad, not constricted, with a brown impressed pit at the middle of each half dorsally; remaining body segments with brown spots and transverse lines in the sutures, two longitudinal series usually distinct, one at the inner limit of the impressed margin, the other about one third of the width of the body from each side. No trace of cornicles. Anal plate large, longitudinally oblong, subtruncate at tip, flattened above, fuscous, strongly retracted among the dorsal segments just preceding, and but slightly projecting behind, the cauda represented only by a small transverse plate at base; preceding two or three segments strongly arcuate, brown at middle.

Beneath, color same as above. Rostrum very robust, yellowish fuscous at base, distal segment fuscous, tip blackish, reaching posterior margin of mesothorax. Basal portion less than twice as long as thick, last joint a little longer, penultimate half as long as last and about twice as thick. Legs, including coxæ, yellowish fuscous, with blackish sutures, sparsely hairy, moderately long. Thoracic spiracles in dark spots behind and exterior to the anterior and middle coxæ, abdominal spiracles in a row of similar spots on each segment. Below the spiracles is a row of dark spots in the sutures, and dark points often occur midway between adjacent spiracles. The seventh segment has a transversely oblong brown spot at middle as usual. Genital valves brown, often concealed.

Length 1.9 mm., greatest width 1.4 mm., antenna .4 mm.

The young are paler, more elongate, with longer beaks, and clearly four-jointed antennæ.

Described from a large series of examples usually taken in ants' nests upon the roots of various grasses and other plants, or wandering in the galleries.

Pupæ (Plate X., Fig. 1).—This is very similar in general color-markings and vestiture to the viviparous female, but is more elongate. The antennæ are as in the viviparous female, and are five-jointed; the eyes are large and well developed, occupying the entire side of the head back of the antennæ, the posterior tubercle distinct. The head and thorax are darker than the abdomen, metathorax darker than mesothorax, wing-pads also darker towards tips, attaining side of second abdominal segment. Prothorax slightly longer than in the viviparous female; abdomen exactly as in that form. Head and first two segments of thorax beneath darker than the remaining body segments.

Length 1.95 mm., breadth 1 mm.

Described from two specimens, taken May 31 of different years.

Winged Viviparous Female (Plate X., Fig. 2 and 3).—The single specimen in our possession is not in good condition, and cannot be fully described. The head and thorax are blackish, the abdomen pale, with dark spots at the sides of the segments above, and transverse discal bands. The antennæ are more slender than in the wingless female; joints I and II are very short and subequal, III twice as long as I and II combined, IV and V equal, the two combined about equal to III, spur of V about half as thick as the basal portion, and a little longer than thick, subcylindrical. On the lower side of III are eight or nine large sensoria arranged in a single row; and two can be seen on V. The wings are not large, subcostal vein broad, stigma large, radial vein strong, outer two thirds straight, directed a little above the tip of the wing, cubital obsolete at base, beginning below middle of stigma. Discoidal veins united for a short distance at base. Hind wings with but a single vein, the discoidals entirely absent.

Described from one individual, bred about June 5 from a pupa taken May 31 from blue-grass roots in a Lasius nest.

Among material taken in the fall and winter I find two additional forms presenting constant differences, and from what I know of the

forms of related species, I believe them to be the sexed individuals, and therefore describe them here.

Wingless Oviparous Female?—somewhat smaller than the viviparous female, easily recognized by the absence of the peculiar thick, angular bent, scale-like hairs which constitute the vestiture of the viviparous female at all ages, these being replaced by fine short erect hairs, straight or nearly so, a little longer and more distinct in younger specimens. Antennæ clearly 4-jointed in all specimens seen. Spots about and near spiracles usually well marked. Genital valves distinct in adult. No trace of sensoria other than the usual ones on the last two antennal joints. Otherwise as in the viviparous female.

Length 1.85 mm., breadth 1.25 mm.

Male?—Small, more oval, abdomen less expanded, color as in the viviparous female, surface clothed with long erect hairs, less fine and more conspicuous than in the supposed oviparous female. Antennæ distinctly 4-jointed, I and II combined about equal to IV; III a little longer. Beak somewhat longer than in the preceding forms. Rows of abdominal spots more approximate on each side, hairs of back arranged in rows more distinctly than in the young of the form just described. Anal plate more projecting, eighth segment more prominent. Otherwise not different from the forms already described. Sensoria of last two antennal joints as usual.

Length .8 mm., breadth .41 mm., antenna .28 mm.

As in related species, a careful search fails to reveal any other sensoria, such as those which appear in the sexed individuals of *Aphis maidiradicis*.

The Woolly Grass Root Louse.

(*Rhizobius spicatus*, n. sp.)

(Plate X., Fig. 4.)

Another grass root louse, belonging to the genus Rhizobius, and here described as *R. spicatus*, has been encountered occasionally on corn in our studies of the insect enemies of that plant. It is represented in our collections by six lots of specimens, of which one was obtained from a corn field at Urbana April 1, a second from grass roots July 20, a third from corn roots at Tamaroa, Perry county, October 5, another from roots of crab-grass (*Panicum proliferum*) at the same time, another from grass roots October 10, and the last from a corn field December 5.

The April and October specimens were adults, except that with those taken October 5 were sometimes a few young,—full grown females placed singly in small cavities under ground, each being accompanied by a small group of young. These cavities were at various depths, from just below the surface to six inches under ground, and were lined with a bluish waxy excretion, doubtless derived from the woolly coating of the root lice.

The July specimens and those brought in December 5 were young, the latter about half grown.

DESCRIPTION.*

Wingless Viviparous Female.—Body white or cream color in alcoholic specimens, oval or elliptical, covered when alive by a bluish white cottony excretion; a few sparse short hairs.

Head short, subtriangular, narrowly rounded in front. Antennæ very short, scarcely surpassing the posterior angles of the head, spike-like in form, brown or dusky, sutures white. I short and thick; II equally thick and a little longer, being about as long as thick; diameter of remaining joints nearly equal, about two thirds that of II; III nearly one half longer than thick; IV a little shorter than thick; V somewhat more slender, about as long as III, subconic, with a few very short hairs, spur minute, dark brown. No distinct sensoria visible. Eyes black, minute, near posterior angles of head.

Thoracic segments not very short, sides of body sinuate inwardly at posterior angles of prothorax. A row of dark brown spots lies near the margin on each side of the body, one in each suture. There are also four longitudinal rows of dark spots on the dorsum, at about equal distances across it, one spot on each segment, usually indistinct. They appear as small pale brown spots, consisting of a central brown dot surrounded by a fine brown ring. There also sometimes appears a pattern of longitudinal lines similar to that noted in *Geoica squamosa*, consisting of six lines, grouped in three pairs, the lines of each pair rather near together on the abdomen, and diverging on the first abdominal segment, those of each side uniting on the thorax into a single band, often absent. No trace can be seen of cornicles or tubercles.

Beneath whitish, beak and legs brownish. Beak short, rather slender, reaching about half way between fore and middle coxæ; last two joints about as long as basal portion. Last joint about twice as long as thick, tip black. Penultimate joint one half shorter and somewhat wider being about as long as broad. Legs short, middle and hind coxæ equidistant, anterior coxæ about half as far apart. First tarsal joint minute, but present; claws two, minute on posterior legs. Venter of abdomen marked with a row of indistinct transverse brown spots in the sutures, and often with longitudinal darker lines, a pair each side of the median line, and another line exterior to these. Spiracles distinct, in minute blackish rings. Anterior spiracle slightly elevated. Anal plate ventral, not elevated, eighth dorsal segment visible behind it from below; anal and genital apertures transverse, brownish.

Length 1.8 mm., breadth .7 mm., antenna .12 mm. The young are broader, with proportionally longer legs.

Described from six lots of specimens.

The Chermesinæ are doubtless the lowest plant lice and most nearly related to the Coccidæ. The affinities of Rhizobius seem to be in this direction, and it is also closely related to the other Rhizobiinæ, most of which would probably prove to be Pemphiginæ if the winged forms were known. It would therefore seem a more natural arrangement to place the Rhizobiinæ above instead of below the Chermesinæ, as it now stands, bringing it next to the Pemphiginæ.

* By C. A. Hart.

Although the species are generally credited with only one tarsal joint and one posterior claw, I am inclined to think that a minute first tarsal joint of the usual form is really present; and the claws of the posterior tarsus, although smaller than the others, seem to be both distinctly present in the species here described.

No winged forms of Rhizobius have ever been reported, yet there is in our collections a singular pupa, evidently of this genus but of a different species, having well-developed wing-pads.

Rhizobius panici, Thos. *(Tychea panici)* is closely related to this species, but differs distinctly in the antennæ and beak. *Rhizobius poæ,* Thos., appears to be a Dactylopius.

The Sorghum Mealy Bug.

(*Dactylopius sorghiellus,* Forbes.)*

(Plate X., Fig. 7 and 8.)

This mealy bug is an oval, distinctly segmented, reddish or flesh-colored insect, covered with a bluish waxy bloom, and commonly bears a thicker mass of waxy substance imbedding the bases of a tuft of hairs at the tip of the abdomen. It is about .07 inch long, and about as thick as wide, its width between a third and a half of its length. It has a pair of short, eight-jointed antennæ, and a black simple eye on each side of the head.

It is of common occurrence on corn, generally infesting the roots, and usually found only where the corn has been planted on sod. It is doubtless normally a grass insect. It was first reported by me in 1885 as a sorghum insect, and described under the name of *Coccus sorghiellus* in my Fourteenth Report as State Entomologist of Illinois (p. 71). It has since been found by us on corn (roots, leaf sheath, and leaf), on sorghum (August 4), and on the roots of June grass, timothy, and probably other meadow and pasture grasses, clover, and cocklebur (*Xanthium strumarium*). It is commonly attended by ants, especially the species most frequently acting as host to the corn root aphis, *Lasius niger* and its variety *alienus.* It sometimes passes the winter in their nests, where we have seen ants feeding on the waxy surface-covering of the mealy bugs.

Its methods of multiplication are similar to those of the plant lice, viviparous females producing young in spring, and a sexual oviparous generation appearing in fall. We have found adults in the earth on the roots of grass (timothy) March 24, and have collected them from earth, among the roots of clover, May 14. May 15 we have taken them from the roots of young corn with the small brown ant *Lasius niger alienus* in attendance, and May 17 have seen adults and half-grown young together in the same situation. The young thus seem to make their first appearance for the year in the early part of May. May 18 and 19 many specimens were obtained on corn roots at Champaign, and at Polo in northern Illinois, those at the former place rapidly producing young by viviparous generation. These were at this time scattering over the corn plant, and were most abundant in the youngest folded leaves. This

* *Coccus sorghiellus,* Forbes, Fourteenth Rep. State Ent. Ill. p. 71.

mealy bug has also been collected by us May 20 at Mendota, and May 21, 24, 28, 30, and 31 at Champaign, adults and young occurring on both corn and grass (pasture sod), usually with the above-mentioned ant in charge. June 5 it was found on June grass, behind the ensheathing part of the leaf, and the 6th and 16th on corn roots again, and the 13th on the roots of young cocklebur in a corn field—here, also, in charge of *Lasius alienus*. Our remaining collections—one in July, three in August, and two in October—all contained adults, those for October either eggs or young also. October 20 a single reddish brown female, with legs of a similar color, was found on the outer surface of a corn-leaf sheath about four inches from the ground, surrounded by a little speck of flocculent material containing many eggs. October 25 adults and young—whether oviparous or viviparous does not appear from our notes—were taken together in old pasture ground near Champaign, attended by the two common ants mentioned above. No males of this species have yet been recognized.

DESCRIPTION.

The body is oval, distinctly segmented, .07 of an inch long by .027 inch wide, and .021 inch deep. The surface is covered by a bluish bloom, and a waxy mass imbedding the bases of a cluster of long hairs commonly adheres to the anal extremity. The antennæ are short, reaching to the coxæ of the first pair of legs, and distinctly eight-jointed, the first two joints thick (the first much the thicker) and about equal in length, the third as long as the second but narrower, the fourth the shortest of all, and about as wide as long. Each of the following joints is slightly larger and longer than the preceding, and the eighth is enlarged to a kind of club, as wide as the second joint and very nearly as long as the sixth and seventh together. The rostrum is very short, two-jointed, conical, projecting from between the bases of the first pair of legs. It is not as long as the femur, and its width is about half its length. The maxillary filaments are four in number, and when extended reach the abdomen. The eyes are placed upon the sides of the head at a distance behind the bases of the antennæ about equal to the first joint of the latter. They are black and simple, each consisting of a single ocellus. The tarsi are all 1-jointed, two thirds as long as the tibiæ, and tapering regularly to the claw. This is strongly curved, with a pair of slender capitate hairs, longer than the claw itself, springing from its base. The tibiæ and the femora are of about equal length; the antennæ and legs are slightly hairy, and the body nearly smooth, only a few minute hairs being scattered over the surface. There are also a few long hairs at the tip of the abdomen. The latter is two-lobed and emarginate, with a small cauda at the base of the emargination, slightly blackish distally. This emargination becomes a cup-shaped depression when seen from behind.

Egg.—Oval-oblong, subcylindrical, about twice as long as thick, brownish, surface smooth and shining.

Length .30 mm., width .16 mm.

2. *Roots evidently injured or destroyed by perforations, gnawing, burrowing, decay, or other loss of substance.*
   a. Roots eaten away, not burrowed or perforated, and without rotten or withered tips. Tap-root commonly gone or decayed. White grubs in soil among or beneath the roots.

THE WHITE GRUBS.

Genera Lachnosterna and Cyclocephala.

(Plate XII., Fig. 1-8; and Plate XIII., Fig. 1 and 2.)

White grubs or "grub worms" are among the immemorial enemies of agriculture on both sides of the Atlantic, and in both Europe and America the problem presented by their injuries on the farm and in the fruit and vegetable garden still calls for throughgoing investigation and scientific treatment. In fact, the steady increase of their numbers in this State—probably connected with the gradual enlargement of the area laid down in grass—has made such an investigation of their life histories, habits, and economic relations simply imperative and indispensable.

They infest a great variety of plants, nearly all of which have an agricultural value, many of them being the great staple crops of the farm and garden. Grasses of every kind, all the small grains, Indian corn, potatoes, beets, and the root crops generally are liable to destruction by them, as well as strawberries and young fruit trees, young evergreens, larches, and young forest trees of various kinds.

Like most other injurious insects of the first class, they are liable to great variation and fluctuation of numbers in different localities and in successive years, sometimes getting the temporary mastery of a considerable tract, appropriating nearly its whole growth of vegetation to their own use, and then, within a year or two, disappearing from view for a time as an injurious agency. Apart from these seemingly spontaneous fluctuations of numbers, they are most likely to cause great loss when the crop on ground infested by them is changed by rotation from one affording them an abundance of food to one yielding a relatively scanty growth—as when grass lands are planted to corn. A number of grubs which would produce no visible effect in a dense sward, may be sufficient to devour completely a field of young corn.

They hatch most commonly in grass lands (although frequently also in corn), from eggs laid there by various kinds of beetles, all commonly confused under the general name of "June beetles" or "May beetles" or "dor-bugs." These large, thick, short, snuff-brown beetles, a half inch to more than three fourths of an inch in length, nearly as thick from above downwards as they are wide, and about half as wide as long, are universally known because of their great abundance in May and June, during which months they fly at night, filling the air at dusk

with their hoarse buzzing, and often invading lighted rooms in our houses, where they bump and bumble about, as awkward as frolicking cart horses. In this stage the insects are but short-lived, the males dying soon after the sexes pair, and the females living but a few days after they have laid their eggs in the ground.

The young grubs hatching among the roots of grass or grass-like plants commence to feed at once, and live in the earth in the larval stage for at least two years (so far as known), most of them changing to the dormant pupa from the middle of June to September of the second or third year after hatching, and becoming fully developed "June beetles" again, still in the earth, in August or in September of this same year. These beetles do not, as a rule, emerge from their earthen cells until the following spring, but spend the winter at rest, each in the underground cavity made originally by the grub while preparing to pupate. In May and June they come out and pair and lay their eggs as already related. A single species (*Cyclocephala immaculata*) has a slightly different life history, the grub not pupating until spring.

Our common and destructive white grubs all belong to the genera Lachnosterna and Cyclocephala, by far the greater number of species and individuals to the former genus; of which there are thirty-two species known to occur in Illinois. The genus Cyclocephala, on the other hand, contains but one species in this State. The life histories of these various kinds are not sufficiently different to make discrimination of species a matter of practical importance, and for economic purposes, consequently, the white grubs may usually be classed as one.

No wholly, or even fairly, satisfactory defence against them has yet been discovered, but in the contest with so abundant, so widespread, and so destructive an insect even imperfectly protective measures, or merely palliative ones, are worthy of the most careful attention. The practice of the farmers of the Old World, where a contest against closely related insects of like habit has been waged from time immemorial, is not usually applicable to American agriculture, but may nevertheless become so as conditions gradually change with the denser settlement of this country and a corresponding increase in the value of our agricultural products. I have consequently summarized the economic procedure of England, France, and Germany for the "cockchafer grub," the "*ver blanc*," and the "*engerling*,"—the names by which the European "white grubs" are known in those countries respectively.

INJURIES TO CORN AND OTHER VEGETATION.

The injuries of the American white grubs to corn may begin as soon as the roots of the young plant become large enough to attract the attention of a hungry insect, and may range—according to the age of the plant, the kind of weather, and the age and abundance of the grubs—all the way from a slight and temporary retardation of growth to an immediate and complete destruction of all the corn. An early loss of the tap root exposes the plant to severe suffering by early drouth, and it is often so reduced in vigor from root injury that it fails to form brace roots at the proper time, and hence has so slight a hold upon the earth

that it cannot keep itself erect or recover itself after prostration by a windy summer storm.

In any case where the plant is yellowed, or dwarfed, or killed outright,—especially if these appearances be most marked on the higher, lighter parts of the field,—the presence of white grubs may be suspected.

As the roots of an infested plant are evidently eaten away, injury by the white grub is not easily mistaken for any other, and the presence of the conspicuous insects themselves, in the earth among or beneath the roots, will commonly confirm the diagnosis. If they are not thus found where other evidence points to them as the cause of the injury, they may frequently be discovered by digging down a foot or two in the worst-injured tracts.

As a fair illustration of the extent and general effect of a severe attack on corn, our observations of their work in a twenty-acre field near Champaign, Illinois, are worthy of detailed report. This field of rich, black land had been heavily fertilized with straw-pile manure and seeded to timothy in 1884. It was pastured continuously until 1888, when it was left for hay, yielding a good crop of clean timothy that year. The sod was broken in the spring of 1889, and planted to corn May 10, immediately after breaking. This first planting was taken by web worms and cutworms, but the second grew well, and promised an excellent crop until about tasseling time, when the owner noticed that much of the corn had a yellowish and unhealthy appearance, and that it blew down readily when the ground was wet. These fallen hills pulled up easily, and the roots had a stubbed appearance, as if cut off near their origin. A search in the earth where the corn had stood commonly yielded six to twelve white grubs to a hill. The crop on two or three acres of the highest land was a total failure, and the yield was light on the lower ground.

The following year (1890) the field was plowed April 28 and planted again to corn, although an abundance of grubs were noticed when the plowing was done. Several hundred were, in fact, collected by us April 28 for breeding-cage experiments, nearly all belonging to the species *L. rugosa*. An estimate based at this time on a count of the grubs found within the length of a rod in a fourteen-inch furrow, gave between six and seven hundred to the square rod, or at the rate of two hundred and eighty-eight pounds per acre. By the time the young corn was six inches high about two thirds of it had been destroyed by the grubs. The field was not replanted, but about the 10th of June it was twice harrowed and sown to hemp. On account of the lateness of the season and a midsummer drouth the hemp did not grow well, and about a hundred bushels of corn were finally taken from this twenty-acre field. July 26, in the part of the field which had been worst infested, but three grubs and a single pupa were found in digging with a spade twenty holes, ranging in depth from a foot to twenty-six inches. On the 1st of September a trench four feet long, three feet wide, and two feet deep was dug in this same part with the result that only one adult June beetle and two long-dead larvæ were found. In another space eight feet long by three

feet wide two adults and a single living larva were dug out, all the foregoing being within a foot of the surface. In two large areas turned over at the margin of the worst-infested spot, two living larvæ and one adult were taken, the former among the corn roots and the latter about ten inches down.

From these field observations, and parallel extensive breeding operations in the insectary, we have reason to infer the transformation to the imago stage during the season of 1890 of the greater part of the white grubs in the ground.

In 1891 the entire field was sown to hemp; but in 1892, three years after breaking, it was planted again to corn, and again heavily injured by grubs. August 25, a general survey of the field showed that no part was free from them, and that probably every acre had been injured more or less. The damage was most serious now on the lower ground, where a tract of about two acres bore only a few scattered stalks with ears. Most of the corn here had failed to tassel, and much of it had died when from eight or ten inches to about three feet high. Patches of a rod to two or three rods across on which the corn was dead or worthless were to be found in all parts of the field. Nearly all the foxtail-grass (Setaria) had also been killed, the roots being cut off just below the surface, and even the common purslane (Portulaca) was similarly destroyed. Most of the grubs were at this time within three inches of the surface, and were well scattered through the ground, being by no means confined to the hills of corn. In one selected area of four feet square, which included only two corn hills, eighty-one grubs were dug up, some scarcely beneath the surface, and none deeper than three inches. In another area of equal size, containing three corn hills, one hundred and thirty-six grubs were found, twenty-one of them in a single hill. Here, however, a few had burrowed to a depth of six inches. The grubs were at this time apparently from two-thirds to three-fourths grown, the most abundant species being *L. rugosa*—the same as that of the previous years.

In addition to affording an excellent illustration of the destructive capacity of the common white grubs, this record is of special interest as evidence that *L. rugosa* at least will lay its eggs and breed abundantly in fields of corn. On no other supposition can we explain the appearance of such vast numbers of partly grown larvæ three years after the ground was broken from grass in the spring; three years, that is, subsequent to the latest time at which the eggs could possibly have been laid in the grass. It seems very likely that this second lot of grubs was hatched from eggs laid in the corn in the summer of 1890 by the beetles which came out of the ground in this same field. If this inference be correct, it follows that planting to hemp for a year will not clear the ground of grubs.

A somewhat similar inference of a readiness to breed in corn is to be drawn from our observations on another plot of about four acres on the University farm near Urbana. This field, broken up in the spring of 1890 and put into corn, was planted in 1891 partly to corn, and partly to oats; in 1892 to oats and corn again, but with the areas re-

versed; and in 1893 to corn. On this the third year from sod, more than half the corn fell flat on the ground by the middle of September, most of the roots being eaten off by white grubs, of which three or four were commonly to be found in a hill. Owing to the consequent weakening of the plant the brace roots failed to form, the ears which set were small and very often imperfect, and a large percentage of the stalks were barren, the total height of the plant varying from six or eight feet to less than a foot. Even the tallest stalks were slender and unhealthy in appearance, the lower leaves, and sometimes practically the entire foliage of the plant, being as dry and brittle as in midwinter. Those stalks which had been killed early were usually so decayed as to be readily pulled apart at the nodes.

From these data we must conclude that the species concerned—which was either *inversa* or *fusca*—may live as a larva through four full years, making the entire life history cover a five-year period, or else that the eggs were laid later than 1889 in either corn or oats.

The white grubs taken by us in corn fields under circumstances to satisfy us that they either were or had been feeding on the roots of corn belong to eight species, as follows: *Lachnosterna fusca, tristis, inversa, hirticula, rugosa, gibbosa,* and *ilicis,* and *Cyclocephala immaculata.* Of these *L. fusca, inversa,* and *rugosa* are much more common in such situations; and to them by far the greater part of the damage done to corn by the white grubs in central Illinois must be attributed.

Next to Indian corn, the crop most generally and seriously injured in Illinois by grubs is grass; and here the loss is the more serious because continuous and usually unnoticed. A very large number of these insects may live their long lives in the sod, feeding steadily at the roots, and thus diminishing the yield without actually deadening any continuous area. It is only when through uninterrupted multiplication they become excessively abundant, or when severe drouth checks the growth of vegetation, that brown patches may appear in midsummer, sometimes merging in areas of an acre or more over which the turf, loosened by a destruction of its roots, may be rolled up like a carpet.

That they were original inhabitants of the wild prairie sod is shown by the common testimony of old settlers, and by Walsh in the "Practical Entomologist" (Vol. I., p. 60), where he reports that in 1845 he found white grubs eating off young corn when it was a foot in height, in a field broken from prairie land the preceding year.

Patches of wheat, barley, and other small grains may be similarly killed, all underground parts of the plant being completely eaten up; but clover is scarcely ever damaged to any considerable degree, and grubs are relatively rare in clover sod mixed with grass. Their injuries to potatoes have often been reported, and are generally well known, and they are among the worst insect enemies of the strawberry grower. In regions where the sugar beet is an important crop, they are among the chief injurious insects to be taken into account. Young larches and evergreens are sometimes killed by them in the nursery rows, and probably every kind of delicately rooted shrub and of young fruit and forest tree is liable to destruction by them.

No general list of their food plants has ever been prepared and nothing whatever is known of preferences with respect to food among the different species of grubs. That they may live for a considerable period on earth alone is shown by Dr. Riley, who says that he has known the larvæ of the common May beetle to feed for three months upon nothing but pure soil;* and Professor Perkins, of Vermont, has kept individuals of all ages alive for weeks, and sometimes for months, in sand more free from organic matter than the soil of any field fit for growing crops.† The remarkable fact that the grubs may eat locust eggs in the ground has been mentioned in the First Report of the U. S. Entomological Commission (p. 305).

The beetles of the white grub feed most frequently on the leaves of various species of trees. Oak, hickory, ash, box-elder, elm, chestnut, butternut, black walnut, basswood, hackberry, hazel, willow, black locust, mountain ash, tame and wild cherry, and pear are the species positively known by us, by personal observation, to be eaten by the adult beetles of various species; and apple, plum, Lombardy poplar, sweet gum (Liquidambar), maple, and birch may be added to the list on other authority. When a tree is much infested, the leaves are eaten entire except perhaps a stub of the petiole, or the petiole and a part of the midrib. Even the bark of the younger twigs may be gnawed away. Two species, *hirticula* and *fusca*, have been charged with an almost wanton injury to the foliage of trees (oak and chestnut) done by gnawing through the leaf petioles without eating the leaves (Proc. Ent. Soc., Washington, Vol. II., p. 59), and we have noted the same habit as occasionally exhibited to some small extent in the "artificial forest" on the University premises at Champaign. The imagos sometimes eat the leaves of blue-grass also, and we have once found them feeding on heads of clover and once on corn. Several species have been known to eat the leaves of raspberries ("Insect Life," Vol. I., p. 366).

Concerning the food of the separate species, we have only notes on the preferences of *L. inversa, L. hirticula,* and *L. fusca.* In our breeding cages we learned that adults of *L. inversa* would feed upon the blades of blue-grass, at least when nothing else was available, and that, supplied with leaves from a variety of trees, they ate freely of oak, elm, and chestnut, and slightly of hazel, but neglected ash. *L. hirticula* also ate blue-grass in our breeding cages under similar circumstances, and devoured chestnut very freely, but at first did not touch ash or oak. Later it ate elm, oak, and chestnut greedily, hazel and hickory sparingly, and birch not at all. Oak and chestnut leaves seem, on the whole, to be the favorite food of this species. *L. fusca,* similarly fed, also ate oak and chestnut greedily, and ash and elm less freely. A single species *(L. rubiginosa)* has been reported to eat "New Jersey tea" *(Ceanothus americanus)* in Kansas.‡

These notes on the food of the beetles are of interest because of the damage sometimes done by these insects, especially to trees on lawns, during the brief period of their excessive abundance in May and June, but still more because it is in the adult stage that the white grubs are most

* St. Louis "Globe-Democrat," March 25, 1876.
† Fifth Ann. Rep. Vermont Agr. Exper. Station (1891), p. 151.
‡ Proc. Ent. Soc. of Washington, Vol. II., p. 244.

susceptible to organized attack. If they are ever thoroughly mastered by the farmers of America, it will apparently be by concerted measures, possibly supplemented by legal requirement, for the destruction of June beetles before they have laid their eggs.

The food of the larva of Cyclocephala does not differ from that of the common species of Lachnosterna so far as our observations go, the Cyclocephala grub having been taken by us from grass and from corn. The food of the imago of *C. immaculata* is not known to me. Specimens of this insect enclosed June 23 in a breeding cage with branches of basswood, ash, birch, oak, elm, hard maple, and soft maple, began to die on the 25th, and had all died by July 2 without eating anything.

LIFE HISTORY AND HABITS.

Lachnosterna. Imago (Plate XII., Fig. 1, 4, and 6).—The adult beetles of the genus Lachnosterna, hibernating in the earth in the cells where they originated, emerge in spring and early summer at periods varying according to the species of beetle, the general advancement of the season, and the character of the weather at the time. Warm and genial days in spring often bring them suddenly out in myriads where previously only scattered individuals have been seen, and their flight at night is of course more free when the weather is warm than when their energies are chilled by cold and storms.

In Central Illinois *L. fusca* is usually the earliest to appear, commencing to emerge as early as April 12, and continuing alive to June 4. *Inversa* and *hirticula* are likely to follow a few days thereafter*, and *tristis*, usually a woodland species, at about the same time (May 7 with us to June 7). *L. gibbosa* is relatively late, our earliest specimens having been taken May 11, and our latest June 25; and *L. rugosa* later still—the latest, in fact, of all our very abundant species, ranging from May 18 in our collections to July 28, at which latter date specimens were taken flying at night in Northern Illinois. July 16, an imago of this species was observed in Champaign county feeding on a leaf of corn in the field. *L. crenulata* appears in Illinois in July and August, and, according to Dr. Riley, *L. ephilida* is also a late species, occurring in the same months. (Proc. Ent. Soc. Washington, Vol. II., p. 133.)

As a rule, the males are not only the first to appear but surpass the females in number, taking the season through. They also come to lights much more freely than the females, as is shown by a comparison of our collections made at lights with those made the same night from trees on which the beetles were feeding. The 7th of May, 1891, for example, a collection of *L. inversa* made with a lantern trap contained 1,210 males and twenty-four females,—a ratio of fifty to one,—while we took from trees the same night one hundred and twenty-two males and seventy-three females—less than two to one. Taking all our collections of this species for the summer of 1891, we find that in those from lights (1,418 specimens) the males are to the females as fifty-one to one, while in those from trees (271 specimens) the ratio was one and one half to one. This is, however, much greater than the usual difference in other Lachnosternas, the species evidently varying with reference

* April 29 is our earliest date for each, and June 24 is our latest for *hirticula* and June 28 for *inversa*.

to their sensibility to light. *L. fusca* gave us on the date first mentioned, May 7, less than two males to one female (1.6 to 1) at the lantern trap, while for *tristis* the ratio was 1.4 to 1 (79 and 56). *L. hirticula* seems to be an intermediate species in this respect. Of 537 specimens discriminated as to sex, 152 males and 33 females were taken at lights (nearly 5 to 1) and 194 males and 158 females on trees (about 1.3 to 1).

However taken and at whatever part of the season, it is rarely that the females exceed or even equal the males in the same collection. Throwing together 2,600 specimens of several species, taken at frequent intervals throughout the season of 1891, the sexes of which we have separated, it appears that the ratio of males to females at lights was 16.5 to 1, and from trees and various surface shelters (839 specimens) 1.3 to 1. My data on this subject may be conveniently exhibited in the following tabular form:

Species.	Dates.	At Light.		On Trees, etc.	
		No. of Specimens.	Ratio of male to female.	No. of Specimens.	Ratio of male to female.
fusca	Apr. 18—June 4	94	2.2	193	1.3
hirticula	Apr. 29—June 24	185	4.6	352	1.3
inversa	Apr. 29—June 28	1,418	51.0	271	1.5
tristis	May 7	135	1.4		
gibbosa	May 15—June 24	42	13.0	20	2.3

The adult beetles emerging from the ground, flying about at night* in search of food, pair in the trees, to which they resort in myriads, and retreat again to the earth by day. Their first flight is made in the early evening, beginning at dusk, as they pass from the ground where they have lain hidden by day to the trees on which they feed. With the advent of day they fly from the trees to the earth, and hide themselves an inch or less under ground, or sometimes merely creep under fallen grass and other similar shelter.

Particulars concerning this retreat to their hiding places at the dawn of day are given in notes made by Mr. John Marten and Mr. Philip Hucke, detailed for night-work on June beetles May 19, 1891.

3:45 a. m. Mr. Hucke reports the occasional dropping of a beetle from trees in the artificial forest (chiefly butternuts and hickories) where these observations were made. At 4:05, an occasional beetle still dropping to the ground without making any effort to fly. At 4:10 the air suddenly became full of flying beetles. One and then another began to make a buzzing noise with its wings, when, as if at a general signal, they deserted the trees in thousands, and by 4:25 everything was still again and nearly every one was gone.

Within the woods the beetles flew to a distance from the trees about equal to the height from which they started, the lower ones on the trees making a somewhat longer flight proportionally. Striking against the weeds and undergrowth, they folded their wings, and by 4:30 o'clock reached the ground within a hundred feet of the trees from which they

* A single species has been observed to fly by day in Utah. (Proc. Ent. Soc. Wash., Vol. II., p. 241.)

took their flight. Probably in a clearer place they would make longer flights.

The Egg.—Some of the species begin to lay their eggs in the earth early in June, and this operation is in progress for about a month. The eggs are placed from an inch to three inches beneath the surface, each enclosed separately in a cavity just large enough to hold it, several, however, being frequently placed near each other, but never, according to our observations, in a common cell. There appears in no case any special preparation of the soil or chamber containing the egg, the statement commonly made to the effect that the eggs are laid in a ball of earth being clearly erroneous. The eggs are oblong-oval when first deposited, but soon swell by absorption to a nearly spherical form. The males begin to die not long after pairing, and the females also perish as their ovaries are spent. The eggs hatch in from ten to eighteen days, according to our experiments. As the data upon which these statements are based are few, they may profitably be given in some detail.

Our earliest observations on this subject were made June 28, 1889, when some transparent white eggs were found among the roots of corn on the University premises, about an inch and a half below the surface. The ground was quite free from weeds and grass. These eggs, kept in earth in a breeding cage, hatched July 11 as unmistakable white grubs, but whether of the genus Lachnosterna or Cyclocephala it is not now possible to say. In 1890, thirty-seven specimens of *L. inversa* obtained from the earth by following the plow in corn fields and grass lands at various dates from April 2 to 29 were confined in a breeding cage with an abundance of sod. On the 8th of May three of these beetles had emerged from the earth in the breeding cage, and they were thereafter fed with leaves of oak, elm, and chestnut, all of which they freely ate. By the 17th of the month the abdomens of the female were much swollen and full of well-developed eggs, as determined by dissection, but no eggs were to be found as yet in the earth. May 26 and 31 and June 4 a thorough search of the cage showed that oviposition had not yet begun, but on the 5th of June half a dozen eggs were deposited, and next day many were found, each in its separate cavity, as above described. Males began to die June 6, in this breeding cage, and the first female died on the 14th of June, her ovaries being spent, as shown by dissection. No eggs had hatched June 21, although those isolated for observation were advanced in development, showing the outlines of the larva within. On the 23d the first one hatched, and recently extruded eggs were also found; and on the 28th the breeding cage still contained, besides young grubs, well-developed eggs apparently about to disclose the young. The beetles had in fact not yet all perished, although those alive were sluggish and apparently about to die.

The next year (1891) beetles (*L. inversa*) collected May 18 and 19 at lights and from the earth were placed in a barrel of earth, itself sunk into the ground, and eggs were obtained June 1, deposited singly as before.

A similar experiment with adults of *L. hirticula* was started April 8, 1890, and here also the first two beetles emerged the 8th of May. On the 25th of June no eggs were to be found, but on the 28th eggs were first discovered—of a shape to indicate their recent extrusion.

Nine of these were isolated, and from them larvæ hatched on the 7th of July.

May 8, 1891, both sexes of this species were confined in a barrel of earth sunk in the ground and planted to corn, the beetles being supplied with elm leaves as food. They deposited eggs June 5 from two to three inches below the surface, but the enclosure being invaded by a parasitic fungus (Sporotrichum), the experiment came to an end before the eggs had hatched.

Observations on *Lachnosterna fusca* are closely parallel to the foregoing. Beetles to the number of twenty-eight, collected from the earth in corn fields and in sod from April 8 to 28, were placed in the insectary, where they commenced to emerge May 1, but began almost at once to die. They were fed, as above, on oak, ash, chestnut, and elm, preferring the oak and the elm. On the 4th of June two beetles were found in cavities in the earth below the sod, one of them with a freshly laid egg just under the abdomen. Fungous disease appearing in this lot of beetles interrupted the experiment. May 8, 1891, a large number of beetles of *L. fusca* caught at a lamp or dug from the earth were used for a similar experiment. June 1 oviposition began, the eggs being deposited about two inches below the surface, among the corn roots in the breeding cage, singly, as before, without special preparation of the cavity for their reception.

A similar trial with *L. rugosa*, taken from earth and weeds at Urbana June 1, 1891, gave us the eggs June 11, disposed singly about an inch below the surface; and in another, with *L. gibbosa* collected May 20, the eggs were found June 5 about three inches below the surface in the loose earth of the breeding cage, placed separately, but clustered somewhat, three to six in a group.

The eggs of all these species agreed in color, shape, and general appearance with those obtained from *L. inversa*, as described above.

Larval Period.—Our knowledge of the length of life of the white grubs in the larval stage is based solely upon inferences mostly drawn from the varying sizes of the grubs that appear in collections made at any given time. Since the eggs are all deposited practically within a month, and since the larva grows but slowly, differences in size due to variations in time of hatching must be but small. It is easily seen, however, from almost any large collection made in spring or early summer at one time and place that grubs of the same species or group can be readily assorted into two lots differing notably in size, and never, so far as my observation goes, into more than two.* This is readily to be explained on the supposition that the larger specimens are two years old that season and that the smaller have hatched from eggs laid the preceding summer. Upon this supposition the Lachnosterna larva lives as a grub a trifle over two full years, changes to the pupa and imago at the beginning of the third year of its life, and emerges from the earth an adult, prepared to lay its eggs, at the end of this three-year period.

The growing grubs feed, of course, only during the season of growing vegetation, usually retiring from the middle to the last of No-

* To verify this statement it is necessary that the observer should learn to distinguish species, or at least groups of species, of these insects in the grub and larval stage, characters for which are given further on in this treatise. Adult grubs of some of the smaller species might otherwise be mistaken for young of the larger ones.

vember to a depth beneath the surface varying according to the severity of the winter weather, and coming up again within reach of food commonly some time in March or early April.

The time and place of hibernation have their especial economic interest, since while in their usual winter quarters the white grubs are far beyond the reach of any agricultural operations. The distance to which they retreat in this latitude is about a foot and a half, if I may judge from a single observation made November 29, 1886, in a badly infested field of wheat in Sangamon county, Illinois. Here, around the margins of denuded patches,—the ground being frozen some four inches deep,—the white grubs were found repeatedly in numbers averaging four or five to the square foot at a depth varying from a foot and a half to two feet. In 1890 they had already come up, in the pastures, from their winter quarters by the 24th of March; were still at the surface in their usual number during the latter part of October; and had not wholly withdrawn by November 25—although at this late date most had gone beyond the reach of the plow. Notwithstanding this well-marked habit of retreat at the approach of winter, they occasionally linger at the surface and hibernate at a depth scarcely greater than that at which they are to be found during the summer season.

Pupation and Formation of the Beetle.—The full-grown white grubs, presumed to be two years old according to the preceding section, will live an active life in the earth, feeding freely from March to June or July, during which months they change to the pupa a few inches under ground, in oval cells made by the grub by turning about in the earth. In this smooth-walled chamber the cuticular remnant of the last moult will be found enclosed with the pupa—that is, the crust of the head of the grub and shriveled fragments of its last skin. Our first date for this pupal transformation of *L. inversa* is June 13, 1889, but Professor Perkins notes* the pupation of two larvæ out of several hundred early in May.† In this chamber they lie until August or September, when they change to the June beetle, *fusca* and *gibbosa* as early as August 11, and others—at least individuals of *implicita*, for example—not before September 17. A small percentage of the adults thus formed late in the summer and in early fall, may escape from the earth before the winter opens, but this is relatively a rare occurrence, the great mass of the generation continuing through the winter in the pupal cells within which they originated. They are to be found in winter from no more than two or three inches to about ten inches beneath the surface. Hence they escape in spring, as already described, pairing and laying their eggs for the generation following.

From the foregoing it will be seen that the white grubs of the genus Lachnosterna hibernate in two stages only, those of larva and imago, the grubs themselves representing at least two generations.‡

* Fifth Ann. Rep. Vt. Agr. Exper. Station (1891), p. 148.

† From the fact that the grub of Cyclocephala pupates in May in Illinois, I surmise that the above-mentioned larvæ belong to this genus, and were not distinguished from the Lachnosterna larvæ among which they occurred.

‡ For the full particulars upon which the foregoing statement is based, see Seventeenth Rep. State Ent. Ill., pp. 31-38. To the data there tabulated, I may add the following items noted in 1891: Grubs of *L. fusca* collected in corn fields near Champaign, April 16 and 17 and May 2, had begun to pupate July 18; and those of *L. rugosa*, taken at the same times and places, had formed two pupæ at this last date just mentioned.

Cyclocephala (Plate XII., Fig. 8; Plate XIII., Fig. 1 and 2).—The white grubs of the genus Cyclocephala differ from those of the various species of Lachnosterna in so far, at least, as to hibernate in the larval stage only, to pupate in May and June, and to emerge as beetles in June and July—later on an average than the species of the other genus. Pupation is consequently earlier than in Lachnosterna, and the emergence of the imago occurs later in the season, the essential difference being that adults of Cyclocephala escape from the earth one or two months after the completion of their larval life, while those of Lachnosterna continue in the earthen cells as pupæ and imagos about ten months. The difference in the economic application of these biographies is not, however, very great, since the period of active larval life of Cyclocephala seems to terminate on an average only three or four weeks before that of Lachnosterna. My detailed notes on the transformation of white grubs belonging to this genus are but few in number, but as they accord with those already given by entomologists, they serve to support the common statements concerning the life history of these beetles.

Our only species in Illinois is *C. immaculata*, and its larvæ occur in grass with the other white grubs, and have been found infesting corn on sod. Grubs of this species collected in grass lands at Urbana, Ill., April, 1887, had all emerged as adults July 19. Others collected from corn fields April 25, 1888, had pupated, at least in part, June 20, and afterwards gave the imago—at what date is not now known. In April, 1890, grubs were collected from the 6th to the 29th from roots of corn from sod plowed in fall, and from a field of young oats. All but one of these had pupated by June 4 (some of them quite recently), and this one presently died. The first beetle appeared June 16, and all had emerged as adults (five males and eight females) June 19.

A dozen of the beetles bred from this collection were placed in a breeding cage and furnished regularly with fresh sods. By July 2 they had laid numerous eggs among the grass roots, and five days later one of these had hatched. July 26 several young larvæ were living and doing well, but by August 10, through some misadventure or mismanagement, all had died. Again, twenty-one larvæ of Cyclocephala turned out by the plow in an old corn field near Urbana May 2, 1891, were placed in a breeding cage. No notes were made on this collection until July 10, at which date imagos had emerged, and numerous eggs of this species were found in the earth, deposited singly like those of Lachnosterna.

In electric light collections made April 11 and 12 (thirteen days in May, fifteen days in June, and thirteen days in July, 1887, this species first appeared June 10, became abundant by the 17th and 18th, continued so until the 1st of July, and disappeared July 14—both beginning and continuing decidedly later than any of the six species of Lachnosterna collected at the same time.

NATURAL ENEMIES.

In the struggle for existence the white grubs and the June beetles enjoy many pronounced advantages, and are subject to relatively few and feeble checks on their multiplication. The large size and the sub-

terranean habit of the grubs protect them in great measure against two of the three principal classes of natural enemies of insect larvæ; namely, birds and insect parasites. They are more liable to fungus parasitism, it is true, but many kinds of much less abundant insects suffer far more heavily therefrom, and authentic reports of the notable destruction of our American white grubs by fungus parasites are rare. The beetles are especially protected by their large size and heavy armor, by their nocturnal habit and their skill in hiding themselves by day, by the enormous numbers in which they appear, and by the relatively short term of their adult life. Cold and heat, drouth and wet weather have little noticeable effect upon these insects in any stage, and even starvation does not kill the grubs, for in the absence of other food they can live for months on earth alone.

Great as the number doubtless is of individuals of the several species which fall victims during the year to various enemies and other hostile agencies, the evidence now before us does not warrant us in placing any considerable reliance on these natural checks to the multiplication of the white grubs, but we are rather led to conclude that American agriculture must look to its own resources for a remedy. If, however, we take into account the fact that our common white grubs are native insects, most of them living originally in the prairie sod, which formed a denser, more uniform, and more continuous covering to the surface of the country than the crops now raised by the farmer, and further recall the fact that under these primitive conditions these insects rarely produced any conspicuous effect upon our native vegetation, we may infer with some confidence that they are not likely to increase indefinitely and inordinately, but that the natural checks which held them primitively within a certain well-defined limit will reassert themselves under the not very different conditions of a developed agriculture. Such data as we have concerning the enemies of these insects, animal and vegetable, are presented here more as an indication of the incompleteness of our knowledge, than because of their present practical value.

Birds.—White grubs and June beetles are eaten to some extent by a considerable variety of birds, doubtless by many more than my cullings of the scanty literature of this subject have brought to light.

In my own studies*, I have found June beetles eaten by the robin, catbird, brown thrush, wood thrush, hermit thrush, bluebird, and meadow lark; Mr. E. V. Wilcox† has found both June beetles and white grubs in the stomachs of robins‡; and Glover long ago recorded the occurrence of June beetles in the stomach of a woodpecker (Rep. U. S. Comm. Agr. 1865, p. 38). Dr. A. K. Fisher§ reports the occurrence of these beetles in the food of the red-tailed hawk, the red-shouldered hawk, the broad-winged hawk, the sparrow hawk, the screech owl, and the great horned owl; and white grubs in that of the red-shouldered hawk, the sparrow hawk, and the barred owl. Dr. C. V Riley's assistants** recognized fragments of the beetles in the stomachs of six English

* Bull. Ill. State Lab. Nat. Hist., Vol. I, No. 3, pp. 93, 94, 101, 105, 109, 120; Trans. Ill. Hort. Soc. 1880, p. 236.

† Bull. Ohio Agr. Exper. Station, No. 43 (1892), p. 127.

‡ See also Lintner's 9th Rep. St. Ent. N. Y. (1893), p. 356.

§ Bull. 3, Div. Economic Ornith. and Mammalogy, U. S. Dept. Agr.

** Bull. 1, Div. Economic Ornith. and Mammalogy, U. S. Dept. Agr., p. 111.

sparrows, and four large white grubs in one of this species, out of five hundred and twenty-two specimens examined.

To this list I can add only the crow* and the blue jay, on the authority of Dr. B. H. Warren, author of the "Birds of Pennsylvania," the chuck-will's widow ("Insect Life," Vol. II., p. 189), the king bird (Lintner) and the crow blackbird, whose habit of picking up white grubs after the plow is a matter of common observation.

Of these twenty species, taking into account their numbers and their feeding habits, I judge that the robin, the catbird, the brown thrush, and the crow blackbird devour much the largest numbers of these insects,† although it is possible that if the smaller insectivorous hawks—the sparrow hawk especially—were permitted to increase freely they would equal or surpass any of these, because of the greater number of insects which they take at a meal. Chickens, ducks, and turkeys are fond of white grubs, and may often be seen scattered over freshly plowed ground in search of them and other subterranean insects.

Mammals.—The only native mammals known to feed on these insects in any considerable numbers are moles, ground squirrels, and skunks—none of them very likely to be tolerated by the farmer, whatever may be their insectivorous habits.‡

Among the domestic animals, pigs are well known as eager hunters for white grubs, in search of which they diligently root up an infested turf; a fact which may sometimes be advantageously applied for the protection of corn to follow upon grass.

Insects.—The special insect enemies of the white grubs now on record belong to three or, possibly, four species, two of them hymenopterous and one dipterous, a second dipterous insect bred by us from dead white grubs being doubtfully parasitic. To this number I am able to add another hymenopterous parasite, *Pelecinus polyturator*, a remarkable insect whose larval history has heretofore been wholly unknown. From a collection of white grubs obtained from an orchard at Champaign, Illinois, May 9, 1892, and kept in a breeding cage at my office insectary, a specimen of *Pelecinus polyturator* emerged August 26, 1892. As the parasite was seen in the act of emerging from its pupal envelope, there can be no doubt of either the fact or the date.§ An examination of the remains of the grub containing the pupa skin of the parasite showed that the former belonged to the species *L. gibbosa*. My office specimens of the adult of this parasite are recorded under nine collection numbers, all bearing dates in late summer and early fall—July 21, 26, August 1, 2, 11, 16, 28, and September 1 and 16. It is hence probably single brooded, maturing in July and August.

Perhaps the most destructive insect enemy of the white grub is *Tiphia inornata*, Say, a hymenopterous species which we have never bred, but which has been reported by Dr. Riley** to occur occasionally

* Townend Glover also records the destruction, by crows, of great numbers of both grubs and beetles.

† Nine out of forty-four robins shot by me in April, May, and June had eaten June beetles; six catbirds out of forty-one; and twelve brown thrushes out of forty-three.

‡ Raccoons and bears, both of which are said to be fond of these insects ("Insect Life," Vol. II., p. 373) are still less likely to be permitted to indulge their liking. Badgers and weasels are said by Riley to devour the grub (Sixth Mo. Rep.).

§ The adult Pelecinus, its pupa skin, and the remains of the parasitized grub are all in my laboratory collection. (Nos. 18843, 18844, and 18845.)

** Sixth Ann. Rep. State Ent. Mo., p. 122.

in very large numbers in ground infested by Lachnosterna larvæ. He says: "One can scarcely dig for half an hour in any soil in this part of the country, without meeting with a curious egg-shaped cocoon, of a pale golden brown or buff color, and with a soft exterior surface, in touch as well as in color reminding one of the punk used by dentists. Upon cutting this cocoon open, it will be found to consist of about a dozen delicate layers, the outer ones soft and loosely spun, the inner ones more and more compact and paler in color. Within this cocoon, if fresh, there will be found a whitish grub which, though lacking legs, has the joints of the body, at the sides, swollen so as to look like the fleshy pseudopods possessed by many larvæ. * * * From having repeatedly found the head parts of some Lamellicorn larva attached to these cocoons, I had long suspected that such larvæ formed the food of this Tiphia, and on carefully examining these head-parts I recognized them as belonging to the common white grub. But all doubt as to this fly being parasitic on said white grub ceased when, in 1872, Mr. A. W. Smith, of St. Louis, brought me a number of the cocoons which he had taken from a low part of his farm on the Illinois bottom, where the white grub was very thick, and the yellow cocoons so numerous as to attract attention."*

Ophion bifoveolatum is likewise reported by Riley as a white grub parasite (Proc. Ent. Soc. Washington, Vol. II., p. 134), and this was quite probably the species of Ophion bred at my office in 1886. From white grubs brought to the insectary April 27 the specimen emerged May 11, but was lost from my collections before being determined specifically.

A tachinid fly has also been found parasitic on the grubs (Proc. Ent. Soc. Washington, Vol. II., p. 131), and a second fly, *Microphthalma nigra*, Macq., has been repeatedly bred by us from the dead bodies of white grubs. The habits of the family Dexidæ, to which this last-mentioned insect belongs, make it doubtful, however, if these flies may not have developed from eggs laid on the bodies of grubs already dead.

Tiphia inornata, mentioned above, ought probably to be called a predaceous rather than a parasitic insect, as it attacks the grub from without, and devours it bodily. Ants destroy white grubs in breeding cages,† and very possibly attack them sometimes in the field. It is quite likely that various other predaceous insect species, ground beetles espe-

* "*Tiphia inornata*. *Larva*.—Length 0.25-0.50 inch when full grown; greatest diameter 1/3 the length; largest in middle; 12 joints and a subjoint, exclusive of head. Head bent over on the breast. Color translucent-white, with a broad, transverse, opaque wrinkle around each joint; on all the stigmata-bearing joints except 1, this wrinkle is constricted into two ellipsoidal pieces dorsally, strongly bulging laterally into semi-oval tubercles, like pseudopods, and subobsolete ventrally. Labrum edged with brown. Stigmata small, circular, brown, and placed on posterior part of joint 1, and on anterior part of joints 4-11. Anal slit transverse.

"Described from 13 specimens. The color becomes more yellowish in alcohol.

"*Imago*.—This insect is very variable in size, 2 male, 7 female specimens which I have bred from the cocoon ranging from 0.35 inch to 0.68 inch in length of body. The wings are either very faintly or more deeply smoky-yellow. The color is jet black, but on my largest female a faint bluish or purplish hue is noticeable. In studying by the light of the specimens before me, Say's three descriptions which follow, I am forced to the conclusion that they all refer to but one species. Certain features common to all the specimens are curiously omitted in one or other of the descriptions, and inserted in one or both the others, while every feature mentioned belongs to the one species taken in its variations. It beomes a question, in such a case, which name to use, but I employ the first because it is appropriate, and seems to have been the only one used by subsequent authors."—C. V. Riley.

† Fifth Ann. Rep. Vt. Agr. Exper. Station (1891), p. 153.

cially, may devour white grubs occasionally, as has indeed been suggested by Riley (Sixth Ent. Rep. Mo.), but I have no record of precise observations to that effect. The fact that the beetles may sometimes fall a prey to carnivorous insects, is shown by two specimens brought to my office by a student of the University, May 21, 1891. One of these was an example of *L. hirticula*, which he had found with the tip of its abdomen torn open, crawling up a stem of grass. The other was a *Chlaenius tomentosus*, found clinging to the Lachnosterna and feeding upon its viscera partly drawn out of the wound. The frequency with which mites are found clustered upon white grubs in their earthen cells,* especially upon those recently dead or in a weakened condition, has given rise to the supposition, hitherto not experimentally verified, that these mites may be parasitic on the grubs.

On the whole, the general tenor of our own observations, as well as those published by other entomologists, must lead us to attach comparatively little economic importance to the insect enemies of white grubs, whether predaceous or parasitic.

Reptiles and Amphibians.—The fact that the toad occasionally eats June beetles has been reported (Proc. Ent. Soc. Washington, Vol. I., p. 69,) and could no doubt be verified extensively by dissections of toads made at times when the June beetle is abroad. Frogs must likewise be placed on the list of the natural enemies of these beetles.† Prof. Perkins, of the University of Vermont, has found as many as ten in the stomach of a single frog of medium size.‡ It is altogether likely that insectivorous reptiles, serpents especially, would be found to destroy a still greater number of these insects, but no studies have been made, to my knowledge, on this point.

Fungi.—But one contagious disease of the American white grub occurring in nature has been positively and definitely connected with a fungus parasite. This parasite (*Cordyceps melolonthæ*) has been several times referred to in economic literature, first in the "American Journal of Science and Arts" (August, 1824). It was treated at length in an illustrated article published by Riley in the "American Entomologist" for June, 1880. According to a correspondent of Walsh's in 1869, it has sometimes been very common in Virginia;§ and Mrs. Treat reported the occurrence of thousands of infested specimens in Benton county, Iowa, in 1865.** Perkins mentions it as infesting grubs of Lachnosterna in Vermont.†† This species is, so far as known, incapable of artificial cultivation, and could consequently be used for insecticide purposes only by distributing as carriers of infection white grubs which had been in contact with others infested with it. Indications have not been wanting of the occurrence of a bacterial disease native to our Lachnosterna larvæ, but no precise studies have been made sufficient to warrant the assertion that such bacterial diseases really occur. The common insect parasite, *Sporotrichum globuliferum*, the so-called white fungus of the

* Fifth Ann. Rep. Vt. Agr. Exper. Station (1891), p. 147; Rep. U. S. Dept. Agr. 1892, p. 165.

† "Insect Life," Vol II., p. 195, and Trans. Wis. State Agr. Soc., Vol. XIX. (1881), p. 297.

‡ Fifth Ann. Rep. Vt. Agr. Exper. Station (1891), p. 153.

§ Am. Ent. Vol. I., p. 91.

** Am. Ent., Vol. II., p. 53.

†† Fifth Ann. Rep. Vt. Agr. Station (1891), p. 148.

chinch bug, has never been found by us infesting Lachnosterna larvæ in a state of nature, although these larvæ have been proven quite susceptible to it in the course of our experimental work. June beetles have been frequently found, however, with this fungus growing upon their dead bodies, but, for all that is clearly known to the contrary, it may have taken its start upon them after the death of the beetles.

In Europe, according to Giard and Krassilstschik, three diseases of the European white grubs have been detected: one of them due to a fungus infection by the species most commonly known as *Isaria densa,* Link (=*Botrytis tenella,* Saccardo); and the other two, bacterial diseases studied by the last-named author.

These fungous diseases will be more fully treated in the following section, where numerous experiments for the infection of the white grubs will be described in some detail.

PREVENTIVE AND REMEDIAL MEASURES.

If we use the word remedy for measures intended to arrest an injury already begun, and prevention for measures applied in advance of such injury, we must say that efficient remedies for the injuries of white grubs are but little applicable to their work in corn, and that we are confined consequently, for the main purposes of this article, to a discussion of preventive measures only. Such measures of prevention may be either local or general: applied, in the first case, to the field in which corn is to be planted, and intended to forestall injury in that field only; or, in the second case, applied elsewhere or more comprehensively, with a view to a more general effect in reducing the number of white grubs over a larger area.

Local preventive measures can take effect only on the white grubs themselves, while the most valuable general measures are those directed to the destruction of the June beetles before their eggs are laid.

Local Prevention.—It is now well settled, as has been shown in the preceding pages, that at least some species of the white grubs may be freely and abundantly bred in fields of corn; but it still remains true that by far the greater number of those in the country at any time have arisen from eggs laid by the beetles in ground bearing a crop of grass; and that corn is consequently much more likely to be damaged if planted on sod than if it follows clover, some small grain, or corn itself. The first effort of the corn farmer threatened by these insects should consequently be directed to clearing the grubs out of the grass land which he wishes to plant to corn. For this purpose it is very desirable that hogs should be pastured for a considerable time on meadows or pastures before plowing for corn, and that they should also be given the run of the field while it is being plowed. This measure will be practically useless, however, under ordinary circumstances, if resorted to later than October or earlier than April, as in the interval between these months the grubs will be beyond the reach of pigs, buried in their winter quarters.

Further, I do not, myself, in the least doubt the great profit to the average farmer of providing for the collection of white grubs after the plow, by hand, in soil where they are particularly abundant, especially where any kind of cheap labor may be had. In estimating the value of

this method, we should bear in mind the fact that a small number of grubs may do a great amount of harm to young corn on comparatively clean ground, because of the small amount of vegetation offered to them as food while the corn is young.

Next, we should take into account the relatively small damage done to clover by the grubs, and the further fact that we have no present evidence that the eggs of the June beetle are ever laid in clover land. It is consequently a good practice, so far as grub injury is concerned, to insert clover (sown perhaps with oats) between grass and corn in the rotation; and this is especially to be advised on light soils not perfectly adapted to corn. Here it will have the effect not only to eliminate the grubs in part, but also to diminish the damage to the following crops of corn by increasing the strength of the land, thus helping the corn plant to withstand such loss of roots as it may nevertheless be subjected to. In this connection it need hardly be said that a generous treatment of the soil, by heavy fertilization, thorough cultivation, and the like, will diminish loss to corn by enabling plants attacked to throw out new roots more vigorously to take the place of those eaten by the grubs. Indeed, by some most intelligent and successful farmers, high fertilizing with frequent rotation is regarded as the essential and sufficient defense against these insects.

The management of corn on lands containing grubs should also be directed especially to the protection of the plant from drouth, as, in the presence of these insects, dry weather takes a double effect by retarding root growth under circumstances which require it to be vigorously stimulated instead.

To prevent the laying of the eggs of the June beetle in the *corn field* in May or June, it is desirable that the ground should be kept practically free from weeds at that time, as it is well known that a surface growth of vegetation is a strong attraction to these insects searching for places suitable for the support of the young. Some of our more recent observations show that the beetles are likely to deposit their eggs in the field from which they themselves have emerged, provided that it offers them suitable conditions—a fact which makes it clearly inadvisable that a field which is badly infested one year, should be planted to corn the next.

General Prevention.—The principal and most effective preventive measures of general promise are those for the collection and destruction of the June beetles before they have laid their eggs. They are practically confined to the following four methods, mentioned in the order of their importance: (a) shaking and jarring down the beetles at night from the trees in which they feed, and their collection on sheets or cloth-covered frames similar to those in use for the peach and plum curculio; (b) exposing light traps early in the evening in places frequented by the beetles; (c) the spraying of trees to which they resort, with Paris green or other suitable insecticide; and (d) the turning of pigs into woodlands, forest plantations, and the like, where the June beetles conceal themselves by day.

These are all measures calling for coöperative action by all or at least the greater part, of the farmers of a neighborhood, since it is use-

less to expect any pronounced effect from isolated and individual action. They can only be carried out by previous agreement of those interested, by the offer of premiums for the beetles, or by the passage and enforcement of laws bearing equally upon all. In estimating the value of these methods it should be remembered that each female beetle is the average equivalent of a large number of grubs.

In illustration of the effectiveness of the first mentioned of these methods, I quote from notes of Assistants Marten and Hucke, made in 1891.

May 19, 2:40 a. m. Shaking the trees in the university forest plantation made the beetles fall very easily, the second shake generally getting all, or nearly all, there were in a tree. Those shaken from the trees made no effort to fly up again, and only one such came to the lantern trap near by.

3:45 a. m. The beetles apparently as abundant as ever on butternut and hickory. The lightest shake of either of these trees brings down the beetles by dozens. Butternut trees six to eight inches in diameter drop them in considerable numbers when shaken by the hands—so easily are they detached.

From other notes it is apparent that the June beetles cling more closely to the trees early in the evening,—from eight to ten o'clock,—a fact doubtless to be connected with the gradual stupefying effect of the night dews and the cooler air towards morning.

This is the standard method in both France and Germany for the control of injuries by the European white grubs. The results attained in the former country are shown by an article, "La Chasse aux Hannetons," published in the *Revue des deux Mondes* for 1878. In consequence of an offer of premiums for beetles in the department of *Seine-Inférieure*, 1,149,000,000 of these cockchafers were collected and paid for in that year, at an expenditure of $16,000. It was estimated that these beetles would have given origin the following year to 23,000,000,000 white grubs. The proprietor of an establishment for the manufacture of sugar from beets, whose crop was seriously affected by the ravages of the grubs, offered a prize of $4 for each one hundred kilogrammes (about two hundred and twenty pounds avoirdupois) of the beetles, and obtained as a consequence 28,000,000 cockchafers,—equivalent to 560,000,000 grubs the following year.*

Details of the common procedure in France are given by A. Wallés in "Bulletin de la Société Centrale d'Apiculture et d'Insectologie" for June, 1890. "It would be a mistake," he says, "to wait until the cockchafers [English name for the European equivalent of our June beetles] have emerged, since the whole benefit of the capture of the beetles will be lost if the females are given time to lay their eggs. Measures for the destruction of these insects must be taken, consequently, from the time that a few begin to appear. Further, if in certain parts of the territory involved the capture of the beetles is neglected, the good effect of the procedure will be considerably diminished. These two points are essential and imperative.

* Similar statements concerning enormous collections and their cost in Germany are given in Taschenberg's Practical Entomology (*Praktische Insektenkunde*) Vol. I., Pt. II., p. 37.

"The cockchafer catchers should be provided with hooked poles, with an awning cloth, or the like, and with bags for their catch. It will be well for them to go in little groups, and to make their rounds from the time of the first appearance of the insect. This last observation is most important. On the 12th of May, for example [in France], no more than twenty per cent. of the cockchafers captured in the trees will be females. A little later, on the contrary, the males will have disappeared, and scarcely any but females will be found. These, however, will have laid their eggs.

"The beetles may be most easily shaken down from the trees in which they are concealed, at the dawn of day, when they are still stupid with the coolness of the night, and this is, consequently, the time at which these collections should be made. Two persons will do well to work together when tall trees are to be visited. One strikes the branches and shakes them by means of the hook fastened into the end of his pole, while the other picks up the beetles. They can, of course, change places occasionally. When there is grass under the trees a cloth must be spread to catch the beetles, which would otherwise often be lost. It will be very easy to clear the trees of smaller size by shaking them energetically, but not violently enough to break them.

"It is perhaps in the canton of Mayenne that the cockchafer hunt is pursued by the inhabitants with the greatest method, energy, and perseverance. There those engaged in the chase of the beetles are divided into squads of four (men, women, or children), each of which is furnished with the following instruments: (1) A sheet of burlap three yards by two, in the ends of which two flexible sticks are fastened. Strings intended to support the apparatus are attached to these sticks. (2) A long pole armed with an iron hook. (3) A sack of coarse cloth. The squad being thus equipped, two hold the sheet extended under the branches. Owing to the flexibility of the rods at the end, the surface of the sheet easily takes the concave form of a common hammock. The branches are then shaken with the hand or with the hooked stick, and the cockchafers fall upon the cloth and accumulate in the center."

Between 2 and 5 o'clock a. m. is the best time for capturing our American June beetles. If they are thus collected in very great numbers, they may be most conveniently killed by throwing them into tubs or barrels of water with kerosene on the surface. If the number is so great as to be likely to be offensive if left to decay, they may be scattered upon the fields as a fertilizer.

The foregoing method is but little likely to be brought into use on the scale required to make it effective unless the white grubs become, at least locally, more destructive than they are at present in any part of the State of Illinois. It is quite within the bounds of possibility, however, that this or some similar method will be ultimately forced upon the American farmer.

Our June beetles are strongly attracted by lights; a disposition which may be used for their destruction in fields. An apparatus consisting of a lantern suspended over a tub of water, placed in or near trees or groves resorted to by the beetles, will often collect large numbers of the adult insects, which, flying against the lantern, drop into the water, where they are readily killed if a little kerosene has been

poured over the surface. This method is, however, of little value as compared with that above described, since it attracts males in very much greater proportion than females—sometimes fifty of the former to one of the latter. It is also ineffective on moonlight nights, and when the weather is cool or windy; is much more expensive; and, under the most favorable circumstances, less thoroughgoing. Its effect is shown by office notes made in 1888 and 1891. June 9 of the former year one hundred and twenty-seven beetles were caught in a pan fifteen inches across partly filled with water and kerosene, above which an ordinary lantern was suspended, the apparatus being placed on a bench under trees, in Urbana, Ill. A similar experiment, made May 7, 1891, with a tub of water and oil and a common kerosene lamp yielded 1,290 beetles, of which all but forty-one were males. In this case the trap was placed in a small forest plantation on the University farm at Urbana. These beetles were all taken between 7:45 and 9:15 p. m., after which only now and then one would come to the light. Later in the season no doubt the proportion of females to males would have been greater; but statements made in another part of this article, under the head "Life History and Habits," show that the disproportion continues throughout the season.

The spraying of trees most resorted to for food is a possible measure, since the beetles are killed by arsenical poisons—a fact demonstrated by laboratory experiments made by us in 1888 with oak leaves dipped in Paris green mixture, one ounce to twenty gallons of water. The expense of a general application of such an insecticide will, however, prevent its common use.

When pigs can be turned, in May and June, into groves, orchards, or forests infested by the beetles, they cannot fail to destroy immense numbers of them, since they eat them eagerly, and can easily find them, hidden as they commonly are by day barely under the surface of the ground. This is a measure only occasionally applicable.

Remedial Measures.—Direct remedies for the attacks of white grubs are either inapplicable to the corn field, are of doubtful economic value, or are too little understood, as yet, to make them worthy of recommendation. For example, kerosene emulsion may properly be applied to infested lawns, and, if followed by a copious watering, may kill large numbers of the grubs, but the cost of this material and treatment will preclude its use against grubs in corn; and kainit and other potash fertilizers (the sulphate especially) will destroy grubs in the earth, but for this purpose must be used at a rate inadmissible in farm practice—more than a ton per acre according to Prof. Perkins (Fifth Ann. Rep. Vt. Agr. Exper. Station, p. 152).

Among remedial measures of uncertain value may be mentioned the cultivation and dissemination of the fungus parasites of the white grub—uncertain because not yet thoroughly tested, and because such tests as have been made do not demonstrate the practical utility of the method.

These parasitic fungi do, however, sometimes spontaneously destroy immense numbers of white grubs in the field, and some of them can be easily cultivated in quantity outside the body of the insect—almost as easily as mushrooms may be grown for the market. The subject of the fungous diseases of these insects is therefore a very suitable

one for investigation, and should undoubtedly be most thoroughly studied from every point of view.

THE CONTAGIOUS DISEASES OF THE WHITE GRUBS.

The *native* contagious diseases of the American white grubs are not, so far as known, encouraging subjects for practical use in the destruction of these insects; but certain other insect diseases, due to parasitic fungi capable of artificial cultivation, offer a more promising resource. Numerous experiments have been made in recent years in France with a native fungus parasite* of the European larva of *Melolontha vulgaris* (already frequently referred to as the agricultural equivalent of our species) which have been carried so far by Prof. A. Giard as to lead to the artificial cultivation of this fungus on a large scale, and its sale to farmers as a specific for that insect.

Experiments with this fungus for the destruction of larvæ of Lachnosterna and allied American genera were made in my laboratory in 1892, and similar and still more extensive experiments were made with two other species (*Isaria leprosa* and *Sporotrichum globuliferum*) occurring spontaneously in America. This work was done under my own immediate supervision by an assistant, Mr. John Marten, from whose report I take the following statement of methods and results:

Two culture tubes of *Botrytis tenella* were obtained in 1892 from a Parisian firm of chemists, who offered the spores of this fungus in glass tubes for sale; and another was received directly from Professor A. Giard. March 31, 1892, fifty grubs taken from a rotten oak log—most of them *Polymœchus brevipes* and the remainder *Serica vespertina*—were thoroughly dusted with a portion of the contents of one of these tubes, and were then placed in an earthen dish with a quantity of the rotten wood. A check lot was established under similar conditions, but not dusted with the spores. The first effect of this treatment was observed April 6, when a single larva each of Serica and Polymœchus was found dead, the latter with flabby thorax and the abdomen somewhat hard. This lot of larvæ was examined at intervals of two days, and April 8 one more was found dead, April 10 sixteen, on the 12th seventeen, on the 14th one, on the 16th three, on the 18th four, and, finally, May 2, sixteen more—making forty-nine in all.

Infection by this fungus is unmistakably indicated by a pale pink tint of the dead larvæ, deepening to a definite rosy color, which disappears, however, with the development of spores upon the surface of the grub. This characteristic color was shown by twenty of the above larvæ, the first exhibiting it April 8. It was noticed that the Serica larvæ, although seemingly affected like the others, did not change color in this way. An external mycelium was first shown April 16, on a grub which had died on the 8th and had then been transferred to damp sand and covered with a bell jar. Others showed this external growth on the 18th and 20th, while spores first appeared April 26. From such spores successful cultures were made in test tubes of agar-agar, the culture medium assuming the deep red color to which this fungus gives rise. Proof was consequently complete of the destruction of at least a considerable number of these grubs by a thorough infection with spores of

* *Botrytis tenella* or *Isaria densa*, as it is variously called by different authors.

Botrytis tenella. In the check lot, in the mean time, three larvæ had died; one on the 14th and two on the 18th of April—all of them, however, without any appearance of fungous affection.

A single experiment was begun May 9, 1892, intended to test the possibility of the transfer of the disease characterized by the fungus *Botrytis tenella* from one white grub to another in the earth. For this purpose thirty Lachnosterna larvæ were placed in a breeding cage and covered with earth, and with these were buried separately five dead grubs covered with a dense growth of the spore-bearing mycelium of Botrytis from one of the experiments just described. Wheat was sown in the cage to furnish natural conditions and to afford food, and a check lot was established, similarly provided for. Seven days thereafter no effect was visible, and one grub was dead in the check. At the end of a fortnight two larvæ had died in the experimental lot, but with no appearance of a fungus mycelium. One month later (June 23) sixteen living larvæ were found in this cage, one had died from hymenopterous parasitism, and the eleven remaining were dead, but with no appearance of a fungus growth. Matters remained in substantially this condition until July 5, when one additional dead larva was found, together with two living pupæ. August 26, when the experiment was abandoned, the cage contained eleven adult June beetles (Lachnosterna), one remaining pupa, and a second larva killed by a hymenopterous parasite (*Pelecinus polyturator*). The dead white grubs whose remains were detected in the earth showed no trace of fungous infection, and the check cage was reported, by the assistant who performed the experiment, in practically parallel condition.

From the foregoing it appears that no clearly distinguishable effect was produced by this attempt at artificial infection.

Similar experiments with this same fungus species were made in 1892 by Prof. Herbert Osborn, of Ames, Iowa, and by Mr. F. W. Mally, at Washington, both under direction of Dr. Riley, Entomologist to the U. S. Department of Agriculture.*

By Prof. Osborn, forty-three Lachnosterna larvæ were used in two experiments and a number not given in a third, with the effect to convey the fungus only to a single grub; and here, as no culture experiments are given, it seems possible that some other fungus may have appeared.

In Mr. Mally's experiment nine grubs were used in two experiments, and eighty-eight others were kept as checks. Here also the treatment was without result.

The material used by Osborn and Mally was apparently derived from a commercial source (Fribourg & Hesse, 26 rue des Écoles, Paris), and may have been in a condition inferior to that from Prof. Giard, with which my own experiments were made.

May 25, 1892, a third experiment was begun with this fungus. Fifty grubs, chiefly Cyclocephala, with a few Lachnosternas, were thoroughly dusted with spores of *Botrytis tenella* and placed in a cage with blue-grass sod, a check lot being established at the same time. June 29, this cage was overhauled, and ten live grubs, three dead ones, two pupæ and eleven adult Cyclocephalas were found. One of the dead lar-

* Rep. U. S. Dept. Agr., 1892, p. 163.

vae had developed white mycelium; another was characteristically pink in color; while the third showed no signs of disease. The dead larvæ were placed on damp sand, and by July 8 one had formed spores of Botrytis from which successful cultures of *tenella* were afterwards obtained. The check lot developed fewer imagos, and contained a dead larva and pupa on June 29. These failed to develop parasitic fungi when placed on damp sand, and this experiment was not carried farther.

Perhaps the most successful attempt to kill our common white grubs with this Botrytis in our breeding cages began August 26, 1892, when nineteen grubs from a corn field were thoroughly covered with spores from a culture made in agar-agar in July. The dusted grubs were placed in a breeding cage, without food, and moistened from time to time with water. September 24 ten of them were dead, and spores had formed on four. Within the bodies of the others a mycelial growth was discernible, but none appeared on the outer surface. The cage was not again disturbed until March 28, 1893, when eight more dead grubs were found, only two of them showing fungus spores. The six others contained no mycelium, and probably died from other causes.

Experiments with *Isaria leprosa*, Fr., were begun April 19, 1892, in accordance with a suggestion made by Dr. Roland Thaxter, from whom a culture tube of this fungus was received March 21. This culture was repeated on agar by Professor Burrill of the University of Illinois, and April 19 twenty grubs were dusted with spores from this second growth, and placed in an earthen vessel which was filled with leaf mould and sunken in the earth. Grubs died in this lot April 23, 25, and 27, most of them becoming firm to the touch and of a dusky brownish hue. The record shows the death of thirteen, in all, of this experimental lot up to May 20, at which time ants invaded the cage, and the experiment was discontinued. Five dead specimens transferred to damp sand May 30, simply decayed without visible fungus growth. Only two of the lot, in fact, formed a mycelium, and none matured spores.

The second lot of larvæ, thirty in number, Cyclocephala and Lachnosterna mixed, was dusted May 25, 1892, with spores of *Isaria leprosa*, from the above-mentioned culture on agar. They were placed in a breeding cage and left undisturbed until June 29, when five dead larvæ, fifteen living ones, two pupæ, and one adult Cyclocephala were found, the remaining seven having died and disappeared. Two of those taken dead from the cage were placed on damp sand June 29, and grew the fungus rapidly in the form of stalk-like bundles which bore spores abundantly by July 1. Agar cultures made from these spores on the 8th of July were indistinguishable from the original culture or from the fungus growing on the grubs. There was no appearance of a fungus growth on any of the grubs in the check lot corresponding.

The common parasitic fungus *Sporotrichum globuliferum*, characteristic of the so-called white muscardine of the chinch bug, was also used by us at this time in these white grub experiments, and seemed on the whole more efficient than either *Botrytis tenella* or *Isaria leprosa*. April 19, 1892, thirty grubs taken from an old corn field were thoroughly covered with spores of Sporotrichum from a culture made on corn meal wet with beef broth. This culture was derived directly from

dead insects which had been collected at Urbana February 23. The specimens were moistened and then rolled about in the fungus spores until they were almost completely covered, looking as if they had been rolled in flour. They were buried in leaf mould in a crock, which was sunk in the earth in the insectary, and kept covered with a board and a wet cloth. The first result appeared April 25, when one grub was dead and two more were scarcely alive. Others were found dead the 27th and 30th, May 2, 7, and 15, and June 1 and 15—twenty-nine in all. An external mycelium appeared first April 30, and by May 15 it was present on twenty-two of the grubs, and by June 15 on all but four of the lot. Spores were first formed (on two specimens) May 3, and by June 1 on several others also.

A second lot of thirty grubs was dusted with spores of *Sporotrichum globuliferum* May 9, 1892, from the same culture as that used in the above experiment. May 16 nine grubs were dead, and by June 23 only seven remained alive. Later, three of these died and four became adults. Dead examples transferred to damp sand May 16, had developed spores of Sporotrichum by May 23. From two of them an external growth of fertile hyphæ took the form of long flattened sheets, or bundles, of threads, which spread over the sand three fourths of an inch in every direction. Spores were formed in immense numbers on the margins and upon the surfaces of this growth. These were ripe by July 8, and successful cultures of *Sporotrichum globuliferum* in its usual form were made upon agar by their use. The bodies of those grubs that died in the earth after infection, and were left under ground, did not grow an external mycelium if the earth was kept wet, but rapidly decayed instead, leaving only the thicker chitinous portions of their skeleton to indicate their fate. It would seem from this and previous experiments that excessive moisture in the earth may possibly prevent the *post mortem* fruiting of *Sporotrichum globuliferum* by causing a too rapid bacterial decomposition of its host.

Three grubs had died in the check lot during the period of the preceding experiment, but none showed any trace of fungus parasitism.

Two other lots of white grubs, nineteen in each, were treated with Sporotrichum spores obtained from cultures August 26, 1892. By September 24 eleven were dead in one lot and eight in the other. In this experiment, as in the preceding one, the dead grubs decayed rapidly when left in the earth, and only those lying on the surface, or buried in comparatively dry earth near it, ever developed spores.

So far as we may judge from laboratory experiments only, it would seem possible that artificial cultures of *Sporotrichum globuliferum* may be found useful for the destruction of white grubs in the field. Much practical experiment will be needed, however, to test this supposition thoroughly.

The most abundant native fungus parasite of the grub, *Cordyceps melolonthæ*, is not, so far as known, capable of artificial cultivation, and if used at all, according to our present knowledge of its life history it can be conveyed to healthy insects in the field only by infection methods in which grubs parasitized by this fungus are used as the starting point of the infection. I am not aware, however, that any successful experiments to this effect have yet been made.

DESCRIPTION OF GRUBS.

Until the publication of the Seventeenth Report from this office no distinguishing larval characters had been recognized for the larvæ of Lachnosterna, and even Cyclocephala had not been separated in the larval state from the other genera. It has not yet proven possible to find strict specific characters for the Lachnosterna larvæ, the distinguishing features recognizable being rather those of groups than of species. Three such groups have thus far been recognized among larvæ subsequently bred, first represented by *hirticula* and *rugosa,* the second by *fusca* and *inversa,* and the third by *gibbosa.*

Genus Cyclocephala.—The tip of the abdomen and the summits of the folds on the backs of segments four to nine are crowned with short brown hairs, not thickly set. Segments one to nine are short, ten and eleven are equal and twice as long as nine, twelve is more than three times as long, and segment thirteen is very short and followed by a large round anal plate which attains the tip of the abdomen. The anal slit is transverse. The hairs on the ventral surface of the last segment are uniform and irregularly scattered. The front and clypeus are a little roughened, the labrum somewhat more so; the mandibles slightly sulcate.

C. immaculata (Plate XII., Fig. 8; and Plate XIII., Fig. 1 and 2).—The body of this species is cream-colored, and is covered with scattered soft brown hairs; the spiracles are orange; the head is ferruginous, with a short longitudinal brown line behind the usual frontal V, and a black dot at the base of each mandible. The first joint of the antennæ is globose, the second is cylindrical, three times as long as the first, swollen near the distal end, the third is longest of all, the fourth shorter and prolonged into a short tooth anteriorly on the under side, the fifth as long as the second and tapering to a point.

Genus Lachnosterna.—Body covered with soft brown hairs, the tip of the abdomen and the summits of the folds on the backs of segments four to nine covered with short stiff hairs, thickly set. The spiracles are ferruginous. Segments one to nine are short, ten and eleven are equal in length, twelve is one half longer than eleven, thirteen still longer than twelve, and the anal plate is small, triangular, anterior margin rounded, not attaining the tip, the anal slit consequently angular. On the ventral side of segment thirteen is a triangular patch of conspicuous brown hairs, the outer of which are simple and pointed, the inner flattened and hooked at the tip, with a median double row of mucronate hairs, inclined inwardly, extending lengthwise through the middle of the patch. The mandibles are sulcate above, the antennal joints variable.

L. fusca and *inversa* (Plate XII., Fig. 5).—In these larvæ the subanal spines or hairs are relatively short and weak, the greater part of the hairs being hooked, these hooked hairs forming a large triangular patch on each side of the middle line, extending outward as far as the ends of the anal slit. The spinules of the double median row are scarcely thicker or more conspicuous than the hooked hairs adjacent. The two rows are parallel, extend about two thirds the length of the ventral surface of the segment from the anal slit forward, and are sep-

arated from each other a distance about equal to the length of a spinule, the distance between the spinules in a row being approximately half as great. The number of spinules is from twenty-one to twenty-five in each row.

L. hirticula and *rugosa* (Plate XII., Fig. 2 and 3).—In this group the median rows of mucronate spinules are much more prominent than in the preceding, the bases of the spinules being decidedly thicker than the hairs adjacent, and the spinules placed much more closely in a row (almost in contact), the rows being decidedly shorter—about half the length of the ventral surface of the segment—and stopping short of the anal slit. The rows are also further apart—a distance about twice the length of a spinule. The hooked hairs are fewer and more sparsely placed. Spinules about twenty-nine in a row.

L. gibbosa (Plate XII., Fig. 7).—A much smaller larva than the preceding, characterized by a still greater shortening of the median avenue through an approximation of the hairs and a lateral thickening of their bases, these now becoming at least twice the diameter of the hairs adjacent. Tips of the spinules strongly inclined, nearly meeting in the middle, spinules of each row contiguous. The rows approximate at the ends, and extend about one third the length of the ventral surface of the segment. Patch of hooked hairs much reduced in size, not reaching ends of anal slit, but extending farther forward than the ends of the rows of spinules.

LIST OF ILLINOIS SPECIES OF LACHNOSTERNA.

There are thirty-two species of white grubs belonging to the genus Lachnosterna credited to Illinois by the collection of the adults, twenty-six of which (marked with a star) are in my office collections. The habits of the larvæ of these species are so far as known practically identical, but the greater part of them have of course never as yet been bred separately to the imago.

L. lanceolata, Say.* Rare, Central and Southern Illinois.
L. prætermissa, Horn.* Rare, Southern Illinois.
L. glaberrima, Blanch. Rare, Illinois.
L. ephilida, Say.* Frequent, Southern Illinois.
L. longitarsus, Say.* Infrequent, Illinois.
L. gibbosa, Burm.* Abundant throughout State.
L. hirtiventris, Horn.* Rare, Central Illinois.
L. congrua, Lec.* Infrequent, Illinois.
L. prunina, Lec.* Rare, Northern Illinois.
L. crassissima, Blanch.* Infrequent, Central and Southern Illinois.
L. inversa, Horn.* Abundant throughout State.
L. bipartita, Horn.* Infrequent, Southern Illinois.
L. micans, Knoch.* Infrequent, Central and Southern Illinois.
L. arcuata, Smith.* Rare, Southern Illinois.
L. dubia, Smith.* Not common, Central and Northern Illinois.
L. insperata, Smith.* Rare, Northern Illinois.
L. fusca, Fröhl.* Abundant throughout State.
L. grandis, Smith. Rare, Illinois.
L. marginalis, Lec.* Rare, Illinois.

L. fraterna, Harr.* Frequent, Central and Southern Illinois.
L. nova, Smith.* Rare, Central Illinois.
L. corrosa, Lec. Rare, Illinois.
L. rugosa, Mels.* Common, Central Illinois.
L. implicita, Horn.* Frequent, Central and Northern Illinois.
L. balia, Say.* Infrequent, Central and Northern Illinois.
L. villifrons, Lec.* Infrequent, Central and Northern Illinois.
L. limula, Horn. Rare, Illinois.
L. hirticula, Knoch.* Abundant throughout State.
L. ilicis, Knoch.* Common throughout State.
L. crenulata, Fröhl.* Infrequent throughout State.
L. inepta, Horn.* Rare, Southern Illinois.
L. tristis, Fabr.* Abundant throughout State.

The following species will probably be found to occur in Illinois: *L. gracilis,* Burm. (Can. to N. C. and Tex.); *L. affinis,* Lec. (D. C., Kan., Col., Ind. Ter., and Tex.); and *L. knochii,* Gyll. (Mass. to Ga., Kan., and Tex.).

*Key to the Illinois Species of Lachnosterna.**

The classification of the June beetles presents unusual difficulty because of their general uniformity of appearance and the large number of species, and extensive use must be made of the sexual characters, external and internal. This difficulty reaches a climax in the group of species allied to *fusca,* which are almost absolutely indistinguishable by any other means. One would naturally doubt the validity of such species, but on a careful study of these characters, I find them easily recognizable and subject to but little variation, and have no doubt of the distinctness of the species based upon them.

A very useful character is the sculpture of the last two ventral segments of the male, each species presenting its own characteristic pattern. The internal sexual structures of both sexes seem to be a reliable means of identifying species. The claspers of the male rest just within the opening at the tip of the abdomen, and may be easily drawn out and examined. It is desirable that specimens should be mounted with the claspers protruded. In the females and some of the males the two spurs at the end of the hind tibia are distinctly articulated and freely movable when fresh; but in the majority of the species the males have one spur firmly soldered to the tibia, appearing like an acute prolongation of the apical margin. The notch or sinuation at the base of this spur is very strong and distinct in *congrua* and *hirtiventris,* and least developed in *gibbosa,* which may be immediately recognized, however, by its remarkable angulate spur. The antennal club of the male is usually much larger than that of the female.

The antennæ are usually ten-jointed, three joints in the club and seven in the stem, but several species have normally only six joints in the stem, making the antennæ 9-jointed. Besides this, there is a tendency to lose one joint of the stem in one or even both antennæ of individuals of either group, so that we may find 9-jointed antennæ in species normally 10-jointed, and 8-jointed antennæ in those normally 9-jointed.

Other distinguishing characters are found in the vestiture, color, and punctuation; the clypeus; the outline, margin, and basal channel of the thorax; the distinctness of the elytral costæ; the length of the antennal club; the teeth of the tarsal claws, etc.

The following key makes extensive use of the characters of the male, without which the species could scarcely be identified with any certainty. The females may be determined by comparison with the males. The classification is based on the excellent monograph of Dr. Horn, "Review of the Species of Lachnosterna of America North of Mexico," in Trans. Am. Ent.

* Prepared by Mr. C. A. Hart.

Soc., v. 14, p. 209; and free use is made of Mr. J. B. Smith's studies of the sexual structures, "Notes on the Species of Lachnosterna of temperate North America, with Descriptions of New Species," in Proc. U. S. Nat. Mus., v. 11, p. 481.

1 Surface clothed with scales, subopaque; male with ventral segments carinate at middle, hind tibiæ with both spurs free, and hind tarsi long and slender; female apterous; antennæ 10-jointed. 13–17 mm.... *lanceolata*, Say

Surface above glabrous.... 2

Surface above pubescent or hairy.... 30

2 Antennæ 10-jointed.... 3

Antennæ 9-jointed.... 4

3 Fixed spur of hind tibia short; metasternum hairy, penultimate segment with an elevated slightly roughened transverse ridge, narrowly separated from the posterior margin. 15-16 mm... *prætermissa*, Horn.

Fixed spur of male wanting; metasternum nearly naked; slender, rufotestaceous, shining; penultimate ventral segment of male rugulose, last ventral concave with two feeble cusps in the concavity. 13–15 mm.... *glaberrima*, Blanch.

Fixed spur short; similar to preceding, clypeus less distinctly emarginate; abdomen of male channeled, penultimate ventral with a depressed roughened space at middle, near hind margin, depression open behind, its floor with sharp blackish posterior edge, occupying a deep emargination of edge of segment, and separated by a small notch at each end from the sides of the impression, which terminate posteriorly in thick projecting angles. 14–19 mm.... *ephilida*, Say.

Fixed spur long or moderately long.... 6

4 Inner spur of hind tibia of male anchylosed.... 5

Inner spur of male free.... 33

5 Fixed spur of male short; clypeus deeply emarginate; elongate cylindrical, pale yellowish testaceous, head darker; abdomen of male flattened at middle, last ventral irregularly concave. 10.5–13 mm. *longitarsus*, Say.

Fixed spur at least moderately long.... 25

6 A marked sinuation at end of male hind tibiæ, at base of fixed spur, in line with under surface of tibia.... 7

No distinct sinuation at apex of hind tibiæ as described.... 11

7 Subcylindrical, slender, yellowish testaceous, thorax and head darker; claw tooth small; penultimate ventral of male abruptly declivous at middle. 10.5–13 mm.... *gracilis*, Burm.

Oblong oval, darker; claw teeth strong.... 8

8 Fixed spur boot-shaped; clypeus feebly emarginate; thorax rather coarsely and sparsely punctate; penultimate ventral of male obliquely plicate each side of the middle, last segment with a deep concavity limited behind by a sharp elevated margin overhanging posteriorly. 12–17 mm.... *gibbosa*, Burm.

Fixed spur of usual form.... 9

9 Abdomen of male at middle hairy and rather deeply channeled, last ventral with a rather smooth triangular impression, hind margin with a broad emargination, prolonged at middle in an acuminate point up the middle of the triangle, and closed by paler membrane; thoracic punctures coarse and close, denser anteriorly, a smoother median space. 17-18 mm.... *hirtiventris*, Horn.

Abdomen glabrous at middle.... 10

10 Abdomen of male deeply and sharply impressed along middle, penultimate ventral strongly and acutely emarginate, slightly transversely plicate each side of median channel, last ventral with broader deep longitudinal impression, widening posteriorly and ending behind in two black projecting lobes separated by an acute notch; thorax evenly, moderately punctate; color rufocastaneous to piceous. 15–19 mm.... *congrua*, Lec.

Abdomen of male flattened at middle, penultimate ventral with a straight transverse carina, last ventral irregularly concave, anterior margin elevated; last ventral of female deeply and broadly emarginate, impressed or eroded at middle; thorax coarsely, deeply, and irregularly punctate; elytral punctures distinct, costæ feeble; color brownish to castaneous. 16.5–20 mm.....*affinis*, Lec.

Sexual characters as in preceding; thorax very coarsely and closely punctate; elytral punctures feeble, costæ usually well marked; color castaneous to piceous, pruinose. 17–18.5 mm.....*prunina*, Lec.

11 Clypeus concave, moderately reflexed, feebly emarginate.....12

Clypeus flat, narrowly reflexed, deeply emarginate.....21

12 Penultimate ventral of male without distinct elevated transverse ridge.....13

Penultimate ventral with distinct elevated transverse ridge, straight or curved.....14

13 Penultimate ventral of male with curved rugose impressed channel along posterior margin at middle, in front of which is a broadly triangular, not elevated, rugose space, last ventral with smooth cupuliform depression; body large and broadly ovate, subpruinose; thorax closely, rather coarsely, punctate. 15–21 mm.....*crassissima*, Blanch.

Penultimate ventral with subcircular rugose impression, border widely interrupted behind by hind margin of segment, sometimes slightly elevated, last ventral with broad smooth impression; fixed spur rather short and broad; clypeus more distinctly emarginate; thoracic punctures rather coarse and sparse. 15–18 mm.....*inversa*, Horn.

14 Transverse ridge deeply divided by the longitudinal median impression; thorax coarsely and rather closely punctate, with smoother median line. 15–19 mm.....*bipartita*, Horn.

Transverse ridge entire.....15

15 Surface opaque, conspicuously pruinose; thoracic punctures distinct, sparse, and irregularly placed, median line smoother; penultimate ventral of male with short arcuate ridge; fixed spur not long. 15–17 mm.....*micans*, Knoch

Surface shining, not pruinose; thorax not very coarsely or closely punctured.....16

16 Transverse ridge short, strongly arcuate; female with last segment emarginate.....17

Transverse ridge longer, straight or but slightly curved.....20

17 Ridge overhanging throughout.....18

Ridge not overhanging.....19

18 Ends of ridge at extreme hind margin of segment and overhanging the next; clypeus feebly emarginate; oblong-oval, rufocastaneous to piceous. 19 mm.....*arcuata*, Smith.

Ends of ridge distant from hind margin of segment; otherwise not superficially distinguishable from the preceding. 18–20 mm....*dubia*, Smith.

19 Ridge small, distinct, the ends as well as the rest of the ridge near the middle of the segment; claspers of male symmetrical; not noticeably different from the preceding species.....*insperata*, Smith.

20 Ridge slightly curved, ends overhanging, declivous at middle; female with last ventral not emarginate; closely resembling the preceding. 18–22 mm.....*fusca*, Fröhl.

Ridge nearly straight, not overhanging posteriorly, last ventral granulate-punctate; female with last ventral emarginate; larger and more robust; thorax subangulate before the middle.....*grandis*, Smith.

21 Thoracic punctuation moderate; club of male antenna much shorter than stem.....22

Thoracic punctuation very coarse; club of male antenna about as long as stem.....23

22 Penultimate ventral of male granulate and feebly impressed posteriorly, feebly elevated in front, elevation continued by plications extending obliquely backward on each side; claspers large, expanded, with

rounded posterior outline; thoracic punctures more or less sparse. 15–18 mm.....*fraterna*, Harr.

Penultimate ventral of male similarly sculptured, but the elevation stronger and shorter, forming with the lateral oblique extensions an approach to an acute ridge; claspers small, deeply emarginate behind; thoracic punctures sparse, leaving irregular smooth spaces on the disk. 15–17 mm.....*nova*, Smith.

23 Penultimate ventral of male with a semicircular elevation in front of a deep smooth fovea; thorax broadest at base with a smooth space each side of middle. 16.5–21.5 mm.....*marginalis*, Lec.

Penultimate ventral of male with the posterior border vertical at middle, horizontal portion obliquely plicate each side; thorax widest at middle, obtusely angulate, punctures moderately close, sparser at sides of middle. 17–20 mm.....*corrosa*, Lec.

Penultimate ventral broadly impressed and granulate at middle, forming an oblique declivity, at each end of which is an obtuse elevation; thorax widest at middle, subangulate.....24

24 Thorax with punctures irregularly confluent, a distinctly elevated smooth median line; last ventral of male with apex acutely emarginate. 21.5–23.5 mm.....*knochii*, Gyll.

Thorax with punctures dense, but not confluent, median line sometimes smoother; last ventral of male with a broad triangular emargination, closed by membrane, at apex. 18–23 mm.....*rugosa*, Mels.

25 Sutural stria deeply impressed, sutural costa normal.....26

Sutural stria feeble or wanting, sutural costa scarcely elevated.....29

26 Form more or less ovate, head and thorax darker than elytra.....27

Form elongate, parallel, color uniform.....28

27 Last ventral of male convex, penultimate with a subcircular rugose depression, limited in front by a small narrow arcuate elevation, feeble at middle, on each side more distinctly and sharply elevated, extending obliquely outwards; clypeus deeply and acutely emarginate, front glabrous; thoracic punctures moderately coarse, rather sparse. 14–17.5 mm.....*implicita*, Horn.

Last ventral of male with smooth cupuliform depression, penultimate with elongate concavity at middle along hind margin, in front of which is a short obtuse punctate arcuate elevation; front with erect hairs, clypeus broadly not deeply emarginate; thoracic punctures rather coarse and sparse, irregularly placed. 15–16 mm....*balia*, Say.

28 Last ventral of male broadly concave, penultimate with a feeble arcuate elevation; front with short erect hairs, clypeus deeply emarginate; thoracic punctures coarse and deep, sparsely and irregularly placed, often leaving large smooth spaces. 14.5–16 mm..*villifrons*, Lec.

29 Last ventral of male concave, penultimate with an obtuse transverse ridge divided by a depression at middle; rufotestaceous; clypeus emarginate; thorax moderately coarsely punctate, not closely, but somewhat irregularly. 14–18 mm.....*limula*, Horn.

30 Hind tibia of male with one spur fixed.....31

Hind tibia with both spurs free.....32

31 Surface with erect hairs, those of elytra in rows (sometimes indistinct from rubbing); base of thorax channeled each side; penultimate ventral of male with a broad and long transverse impression, limited at each end by a smooth oblique plica, space in front slightly elevated, last ventral broadly concave; clypeus emarginate; thorax variolately and irregularly punctate. 16.5–19 mm.....*hirticula*, Knoch.

Surface covered with short grayish pubescence; base of thorax not channeled; penultimate ventral of male with a broad transverse impression, a slightly oblique tuberosity at each end in front, last ventral feebly concave, broadly emarginate at apex; clypeus deeply emarginate; thorax very densely granulate-punctate, median line smoother, slightly elevated. 19–23.5 mm. (*ciliata*, Lec.)..*ilicis*, Knoch.

32 Clypeus emarginate; surface with short yellowish recumbent hair; penultimate ventral of male vaguely concave at middle; thorax with margin coarsely serrate, coarsely and densely punctate. 17–20 mm. *crenulata*, Fröhl.

Clypeus entire.....34

33 Subcylindrical, rufotestaceous; clypeus emarginate; thorax moderately punctate, with smooth median line; last ventral of male longitudinally subcarinate at middle, anterior margin elevated each side, penultimate with sharply limited cupuliform concavity, its margin rising into an acute rugose tuberosity on each side, hind tibial spurs slender. 15 16 mm.....*inepta*, Fabr.

34 Surface with yellowish hair long on head, thorax, and about scutellum, short on remainder of elytra; thorax coarsely, closely punctured, last two ventrals of male broadly transversely impressed, anterior margin of last ventral elevated, penultimate with a short acute transverse carina near the front margin. 11.5–15 mm.....*tristis*, Fabr.

THE GREEN JUNE BEETLE.

(Allorhina nitida, L.)

(Plate XIII., Fig. 7.)

The larva of the green June beetle, *Allorhina nitida,* commonly known as a white grub where it occurs, is distinguishable from the species of Lachnosterna and Cyclocephala by its somewhat larger size when full grown; by the thick covering of short stiff hairs easily visible to the naked eye; but especially by the difference in its method of locomotion upon a hard surface. The common white grubs (Lachnosterna) creep only by means of their legs, dragging the heavy abdomen clumsily along; but the larva of the green June beetle, when thrown upon a hard surface, turns immediately upon its back, and moves somewhat easily in this position by alternate contraction and expansion of the segments of the body, using the stiff hairs upon the back as an aid.

This is a southern species, and in the Southern States largely replaces Lachnosterna, its larva being there known as *the* white grub. In Central Illinois it occurs but rarely, but becomes noticeably abundant in the southern part of the State, where it has been occasionally reported as injurious in a small way. Although it has not been found in corn fields, its food and habits are such as to make it altogether likely that under favoring circumstances it might injure corn in the same manner as the Lachnosterna larva—or rather as the larva of the Cyclocephala, which it more closely resembles in its life history. The grub is normally a grass insect, but infests likewise strawberry fields, and has been found by Dr. Riley to feed in confinement upon the roots of wheat. It seems to be less dependent upon living vegetation than even the white grubs, apparently living much more generally upon a rich soil. Indeed, the beetles seem to be attracted to manured land when about to lay their eggs, or to that which has been heavily mulched or contains an unusual amount of decomposing vegetation.* Townsend has found them living in clean earth under circumstances to indicate a carnivorous habit.†

The life history of this insect is, as already intimated, different from that of Lachnosterna, especially in the fact that pupation of the

* Bull. 23 Md. Agr. Exper. Station, 1893, p. 79.
† "Insect Life," Vol. IV., p. 25.

larva takes place in May, the beetles issuing in June. Its length of larval life is not known, nor the precise time or place of oviposition.

The following description of the larva is taken from Dr. Riley.*

"*Full grown larva.*—Length 40 millimetres, somewhat largest posteriorly, subcylindrical, broader at thorax and eighth and ninth abdominal segments, which are materially swollen. More flattened ventrally, with a distinct swollen lateral ridge just below the stigmata, which rather increases the flattened aspect of the venter. General color, glassy yellowish white, inclining to green or blue towards the extremity. Head, rather small, flattened, well inserted into the prothoracic segment, chestnut-brown in color. Dorsal surface of the body strongly transversely corrugate or wrinkled, each of the chief segments having three distinct ridges, the whole body studded with short, thick, yellowish bristles, which are most dense on the dorsal ridges and more sparse, but longer, on the ventral and anal segments. Dorsally these stiff hairs are directed posteriorly and materially assist in the dorsal locomotion. The legs are honey-yellow, covered with similar stiff bristles, without definite tarsal claw. They are short, compared with the larvæ of Lachnosterna generally. Prothoracic segment with a honey-yellow horny plate in front of the spiracle, which, as usual, is rather larger than the abdominal spiracles. Mandibles short, stout, dark brown, with the left (looking from the dorsum) 4-dentate, and the right 3-dentate. Antennæ short, 4-jointed, joints subequal in length, diminishing in width from 1 to 4, maxillary palpi 3-jointed, joints subequal in length, terminal narrowest at tip. Labial palpi 2-jointed, joint 1 longest, somewhat swollen at tip, and bearing a short pointed joint 2 on the inner side of its tip. Labium covered with short stout bristles. Maxillæ with long, stiff bristles on the inner surface, and with two long, sharp, black teeth near the tip.

"The half-grown larva does not differ in structure or coloration."

PRIONUS.

(Plate XIII., Fig. 3-6.)

The occasional occurrence in corn of large thick-bodied grubs belonging to a different family from the common white grubs of this article, calls merely for general mention. The larvæ in question are those of two species of large brown, flattish, long-horned beetles (*Cerambycidæ*), and belong to the genus Prionus (*P. imbricornis* and *P. laticollis*). They are sometimes common in prairie or pasture sod, where they feed upon the roots of grass, and have also been a few times reported in corn fields in Illinois and Missouri, doing an injury apparently identical with that of the white grubs. These larvæ are at once distinguishable from the latter insects by their greater size (3 mm. in length and nearly half as thick when full grown), by the form of the body (tapering from the head backwards), and by the fact that it is little, if at all, curved. They are, further, at once distinguishable by the rudimentary and inconspicuous character of their legs. They are much more generally known to economic entomology for their injuries to the roots of the vine and apple and some forest trees than for their agricultural relations.

* Bull. 23 Md. Agr. Exper. Station, 1893, p. 80.

b. *Roots penetrated, perforated, irregularly burrowed, and more or less eaten off and eaten up. Underground parts of stalk usually also similarly injured.*

Wireworms in soil among the roots.

(For a discussion of the wireworm injury to corn, see this report, p. 24.)

Small, slender, soft-bodied, white or yellowish-white grubs in the roots and earth.

THE SOUTHERN CORN ROOT WORM.

(*Diabrotica 12-punctata*, Oliv.)

(Plate XIV., Fig. 1-5.)

Injuries to corn by the southern corn root worm have not been seen by us in Northern Illinois and but rarely in the central part of the State, but they are more likely to occur southward. Outside this State they have been recognized by entomologists in Ohio, Indiana, Kentucky, Arkansas, Mississippi, Louisiana, Alabama, South Carolina, Virginia, and Maryland. As the beetle occurs from Canada southward through the Atlantic region, and thence to Minnesota, Kansas, Louisiana, and Mexico, it will probably be found much more generally present in corn fields than the above report would indicate.

Its injuries are very similar in general character and effect to those of the much more abundant and better known northern corn root worm (*Diabrotica longicornis*), with which they have doubtless frequently been confounded. They are distinguishable with some difficulty from those due to the various species of wireworms, and it will often require the recognition of the larva itself to determine positively to which of these two classes of insects a given root injury is due. The presence of this root worm in the field gives origin to the usual general effects of the loss of roots by the plant, varying according to the age of the corn, the gravity of the injury, and the kind of soil and weather. A conspicuous damage, noticeable on a casual inspection, may vary from the death of the plant to a slight retardation of its growth or to a general spindling, yellowish, and unhealthy look.

In the young plant, about six inches high, the characteristic perforations of the stalk under ground may result in the sudden withering of the whole plant, or, more commonly, in the killing of the central leaf or tuft of growing leaves—an appearance which has given to this insect the common name of the "bud worm" in some of the Southern States. In certain instances the plant has been killed, as in Maryland, almost as soon as it has sprouted.

As the season advances, the corn in affected fields is likely to be uneven in size, and later, as the plant becomes top-heavy with growth, it may fall to the earth when the soil is softened by rains, and especially during windy storms. Having once so fallen, it will, if badly injured, fail to rise again; and it may further be seen that the plant has but little hold upon the ground, a whole hill, perhaps, being readily pulled up with one hand. As a consequence of the loss of roots and the general weakening of the plant, many stalks fail to set the ear, or

form only a nubbin. The injured plant also matures slowly, remaining green longer than the average, and being thus especially subject to injury by frost.

A closer examination of the young plant will commonly show a perforation of the underground part of the stem either at or near the upper circle of roots. Later, as the corn plant increases in size, the roots themselves are seen to be gnawed irregularly, great holes or notches being eaten out, first in one direction and then in another, until the roots are severed or consumed. In the larger roots the larva may perhaps completely bury itself, but it is much more likely to eat in and out irregularly than is the smaller northern corn root worm presently to be described. It differs from this last species likewise in the fact that it commonly devours everything as it goes, leaving little or no refuse in its burrows; and in the further fact that it works all along to some extent in the base of the stalk, which it penetrates, but not deeply, finally causing the stalk to blacken and rot where water gets admission to its injuries. Its attack on corn is also earlier, briefer, and much more vigorous and destructive, owing to the larger size of the larva and its more rapid growth and earlier maturity. Even in well-grown corn it very commonly bores into the stalk beneath the upper circle of brace roots, or behind the sheath of the lower leaf—habits in which it differs from the northern corn root worm.

Search for this root worm should be made in or about the injured parts—from the middle of May to the middle of August in the latitude of the southern half of Illinois. It is a soft, slender-bodied, worm-like insect, a little over half an inch in length when full grown, and nearly ten times as long as thick. The surface is slightly wrinkled or warty, white when young, and yellowish when old. The head is dark brown, sometimes nearly black, and there is a pale brown leathery patch on the top of the segment next behind the head, and a nearly circular similar patch on the top of the last segment of the body. The legs are very short and small, and the skin bears only a few long scattered hairs.

It seems most likely to attack early planted corn, and hence in the Northern States has been found most frequently in sweet corn. An injury of fifty per cent. is a not unusual effect of its presence in Southern Illinois, and elsewhere it has been reported as sometimes destroying almost every hill when the corn was young.

This corn root worm has not been taken in the act of injury to the roots of any other plant than corn, but has once been seen eating off a stem of young wheat in fall.* Lugger found the pupæ among the roots of a common prairie plant, the cone flower (Rudbeckia), but says nothing of injury to that plant; and my assistant, Mr. Marten, reports the occurrence of young larvæ among the roots of *Cyperus strigosus* and *Scirpus fluviatilis*—two sedges common in moist low lands, the roots of which presented the same appearance of injury as those of infested corn.

The food of the adult *Diabrotica 12-punctata* is widely varied, apparently much more so than that of the northern Diabrotica. It has been for a long time commonly known as a squash beetle, eating both

* Webster, in Bull. 45 (1892), Ohio Agr. Exper. Station, p. 203.

leaves and green fruit of squashes, melons, and cucumbers. We have seen it eating into pumpkins, sometimes to the depth of half an inch, and feeding upon clover blossoms and upon the leaves of tame and wild sunflowers (Helianthus). We have found it in May eating away the edges of the leaves of young corn in the field, and in July and August making small round holes in corn leaves in our breeding cages. In September and October it has occasionally been taken from the tip of the ear of corn, feeding on the silk, and once in August we saw it gathering up fallen corn pollen. It has also fed upon ragweed leaves in our breeding cages in August. By other observers it has been reported to feed on the petals of various flowers, including roses, dahlias, Cosmos, and the cotton plant; upon young volunteer oats (December), on certain moulds, on the horse nettle *(Solanum canadense)*, on cabbage, cauliflower, and beans; and on the leaves of plums, cherries, apricots, and raspberries. Webster has also seen it eating unripe kernels of wheat and corn.

LIFE HISTORY.

As is very commonly the case with American injurious insects, the life history of this beetle is incomplete. Our studies of it are deficient not only in continuity of experimental work, but even in a number and distribution of observations and collections sufficient to give us a fair ground of probable inference. We are especially uncertain as to the number of broods and the stage or stages of hibernation. In the latitudes of Central and Southern Illinois it seems most likely that this is a two-brooded insect, but if so, data published from Alabama and Mississippi would make it extremely probable that it is three-brooded there. Webster's observations in Indiana would lead us to suppose that it hibernates as an adult, he having found it feeding upon volunteer oats as late as December 14, and abroad in spring as early as April 17, at which time the sexes appeared *in copula*.

Our own voluminous collection records of the adult do not clearly bear out the suppositions made above concerning the hibernation and the number of annual generations of this species. Without ever having made any special search for it, I find that we have actually obtained it in eighty-two collections,—mostly of a miscellaneous character,—ranging from April 20 to November 15. We have thus taken the imago once in April, six times in May, eight times in June, sixteen times in July, twenty-eight in August, eighteen in September, four in October, and once in November—a gradual rise in frequency from April to August, and a similar gradual decline thence to the end of the season. In our special collections of hibernating insects this species has not appeared; and in our large electric-light collections, made from May to September in 1886 and 1887, it occurred infrequently, and in no case until July.

As we now understand the subject we may say that in the latitude of the southern half of the State the eggs are laid in May and June, that the root worms do the greater part of their mischief also in these months, pupating from the middle of June to the last of July, and yielding the beetle in July and August. The new generation commence to pair by the beginning of the month last mentioned, and young larvæ of the generation following may be found early in September.

The larva has first been observed in spring in the latitude of Illinois (namely in Maryland) on May 31, and in Virginia June 18. By the 19th of July this brood of larvæ was largely full grown in 1889, larvæ, pupæ, and freshly emerged imagos occurring at that time at Jacksonville, in Morgan county, in this State. We have in fact once seen a freshly developed beetle of this species July 5, and Webster reports it as pairing in Central Indiana in July. Dr. Riley seems to have found eggs of beetles in his breeding cages July 7, from individuals which emerged the day preceding, the larvæ having originally come from Virginia June 18. Garman finds the ovarian eggs of this (?) generation mature in Kentucky July 29, these two being as yet the only observations on record concerning the egg.

The pupation of this brood of larvæ is not, however, altogether completed in Illinois before the end of July. Indeed, larvæ taken the 20th of August at Champaign, Illinois, in 1889, were possibly of this same brood. The beetles have begun to pair again, however, as early as August 8 with us, and young root worms, doubtless of a second generation, have been collected at Champaign September 6. Garman's observations in Kentucky are not especially different from these, but the dates given for Alabama ("Insect Life," Vol. IV., p. 104) show a much earlier start of the species. The active larva is reported as occurring there from March to the middle of May, these earlier larvæ beginning to pupate certainly by April 30, and to yield the imago May 21. The occurrence in Minnesota of pupæ September 3, which gave the imago three days afterwards, is a fact which has no special bearing upon this life history.

I need only add that the eggs are placed, either singly or in groups of two to twelve or more, according to Riley's observations, below the surface of the soil near the plants, in cracks or immediately about the base of the plants.

NATURAL ENEMIES.

So far as now known, the most effective natural check on the multiplication of this insect is a bacterial parasite (*Bacillus rufans*) observed by me to infest the larva, killing about three fourths of a considerable collection of these corn root worms brought from Jacksonville July 19, 1889. We do not yet know what part of the larva is first attacked by this *Bacillus*, but by the time the resulting disease has reached a fatal stage, it swarms in all the fluids of the root worm, which have become practically a pure culture of this bacterial species. Infested larvæ lose their characteristic yellowish tinge, becoming gray and somewhat swollen, and after death they change color through pinkish to dull dark red, the internal organs breaking up to a fluid pulp, held for a considerable time in the tough cuticle of the dead larva. The fluids of such specimens have a milky appearance in the pale worms and a reddish tint in the others. This last color is due, not to the color of the bacilli themselves but to an excreted coloring matter diffused through the fluids in which they grow. In artificial cultures, consequently,—a number of which I made in 1889,—a similar color is imparted to the culture medium, whether this be solid or fluid.

The readiness with which this *Bacillus* is cultivated artificially and the apparent deadliness of its attack make it a very promising subject for experimental investigation, and it is consequently much to be desired that if it be again encountered in this or any other insect species, it may be thoroughly investigated from the practical point of view.

The following description of the *Bacillus* itself and of its mode of growth on agar and in culture fluids will serve for its identification wherever found.

Bacillus rufans, n. sp.*

Oval or short-cylindrical to rod-like, very variable in shape and size, often 1 to 5 microns long and .5 to 1.5 microns wide, free ends rounded; occurring singly, in pairs or in rods of three or four segments; sometimes slowly motile, usually not flagellate; aërobic; non-liquefying, chromogenic; pathogenic in insects.

The various liquid and solid media, as well as the tissues of affected insects, are diffusely tinged with red. The color spreads uniformly throughout the substances, which at first become yellowish, then, during two or three days, gradually deepen to orange and finally to dark blood-red. The growth on agar and on gelatine is smooth, shining, slightly elevated, more abundant upon the moister portions near the bottom of the tube, brownish white with scattered specks or dots of deep orange, usually aggregated in small blotches, the whole growth finally becoming a dirty cream color. Bouillon becomes tinged first near the surface, and the color gradually extends to the bottom, with a rather distinct line of separation from the still uncolored deeper material. A fragile white or slightly stained pellicle forms, but this readily breaks up and settles to the bottom as a loose precipitate. The organisms themselves are white. They readily stain with ordinary aniline dyes. The staining is sometimes solid throughout, but often, especially in the insect fluids, there is a broad central band of white. In a slide from an old fluid culture many spore-like forms occur. These appear like the ones with only the ends of the cells stained, except that the differentiation is more marked, and they are somewhat swollen in the central portions, becoming broadly, instead of rather narrowly, oval, as in other cases. Sometimes the rod-like forms have irregular dots of white (vacuoles).

Growth takes place at the ordinary temperature of the room, but not rapidly. Other temperatures were not tried.

I have discovered no insect enemy of this species, but Dr. Riley reports the rearing of two dipterous parasites of it; one from the larva and pupa, and one (a tachinid) from the beetle. Professor H. Garman† notes the occurrence of small numbers of predaceous beetles and larvæ in summer and fall with young root worms in the earth. He also mentions some internal parasites of the imago—Gregarinæ and nematode worms.

Notwithstanding the abundance of the adult Diabrotica and its general distribution upon a great variety of plants, it seems but little noticed by birds. It has occurred but once in my own studies of the

* Prepared by Prof. T. J. Burrill, from my office notes and slides.
† "Psyche," Vol. VI. (1891), p. 47.

food of birds (in July, eaten by a catbird), and was not once recognized by Dr. Riley's assistants in their studies of the contents of the stomachs of one hundred and two English sparrows which had eaten insects.

REMEDIAL MEASURES.

Until the life history of this species is better known, measures of prevention or of remedy can scarcely be intelligently discussed. The fact that its injuries to corn occur without apparent reference to the crop of the previous year makes it unlikely that the favorite method of rotation will serve for the protection of corn against this species. According to the scattered observations hitherto reported sweet corn seems to be much more liable to injury than the field varieties, from which fact we may surmise that the time of planting has something to do with the intensity of the attack. The vicinity of cucumbers, squashes, and other of the commoner food plants of the beetle may, however, account for this seeming preference.

DESCRIPTION.

The following description of the stages of this insect is copied from Professor H. Garman's article in "Psyche" (Vol. VI. pp. 48, 49).

Egg.—"Matured ova from ovaries of females are much like those of *D. longicornis*. They are white, oval, with the surface reticulated and sculptured so as to produce numerous hexagonal, pitted areas. Prof. Forbes gives the dimensions of the egg of *D. longicornis* as .025 inch by .015 inch. Ova of the spotted species measures a trifle larger, being .027 inch in length by .016 inch in diameter."

Larva (Plate XIV., Fig. 4 and 5).—"Body cylindrical, tapering a trifle towards the extremities, composed of twelve segments behind the head. Skin wrinkled, papillose along the sides, white, sometimes becoming yellowish just before pupation. Head dark brown, nearly black in some examples, with a few rather strong hairs arising from the surface; a narrow median longitudinal line of black above, and two pale lines which converge from the bases of the antennæ, following sutures, to meet at the middle line on the posterior part of the head; ventral side of head pale medially. No eyes. Antennæ of three segments, white. Labrum dark brown. Mandibles dark brown, black at tips, with four or more blunt denticles. Maxillæ pale, armed with numerous strong spines within. Labium pale. Cervical shield pale brown, with a narrow median longitudinal white line, broadly triangular in shape. Jointed legs pale, each with a dark brown chitinous supporting framework at base; each segment of legs provided with a number of strong hairs; a single brown tarsal claw, beside which arises a white, elliptical, striated plate slightly longer than the claw. Dorsal shield of posterior body segment nearly circular in outline, brown, with numerous minute black specks, slightly rimmed at posterior margin, and in young examples obscurely bituberculate; furnished with several strong marginal hairs, and with four minute, striate, centrally placed, spatulate appendages. Spiracles round, the two anterior pairs sometimes with brown rims, the rest pale. Posterior segment with a single fleshy proleg.

"Length about .56 inch, diameter about .06 inch. Examples ready for pupation about .37 inch long."

Pupa (Plate XIV., Fig. 2 and 3).—"Translucent white, with scattered brown hairs on dorsal side of body arranged as follows: One within, and a pair posterior to, the base of each antenna; a transverse, arched row near the anterior edge, a pair near the middle, one at the middle of each side, and one at each side, near the posterior margin, of the prothorax; four each on the meso- and meta-thorax; three at the extremity of each femur; a pair at the middle and one at each side of each abdominal segment, except the posterior three; antepenultimate and penultimate segments of abdomen each with six, the four inner being in pairs and posterior to the others; two within, and three without each of the large spines borne on the posterior segment. Caudal spines straight or curved, black-tipped. Wing-pads covering the posterior femora below. Antennæ curving around the femora of the two anterior pairs of legs and then extending inwards towards the ventral middle line.

"Length .22–.25 inch."

Imago (Plate XIV., Fig. 1).—"Pale green, or greenish yellow, marked with black. Head and mouth-parts black, the former showing a brownish cast medially on ventral side. Three basal articles of each antenna pale, sometimes with dusky dots on posterior side; remainder of antennæ black. Prothorax uniformly green or yellow. Elytra green or yellow, with twelve large black spots, six on each, arranged in three cross series; the first series at the base, the second at about the middle, and the third midway between the second and the tips of the elytra. Scutellum brown or black. Mesothorax beneath the coxæ, the basal third to half of femora, and the abdomen, yellow or green. Metathorax beneath, the distal portion of the femora, and the whole of the tibiæ and tarsi, black.

"Head with a basal pit behind antennæ. Prothorax above smooth and shining, obsoletely punctulate, with a pair of pits, one on each side of the middle line. Margin of prothorax sinuate at sides, no prominent angles. Elytra minutely, regularly punctulate, each elytron with a humeral prominence. Antennæ, metathorax beneath, abdomen, and legs, clothed with a fine silken pubescence.

Length .25–.28 inch; antennæ about .19 inch."

c. *Roots visibly penetrated and perforated scarcely at all: sometimes decayed at tips, but not eaten away. Principal injury interior, in form of minute burrows which are commonly longitudinal.*

THE NORTHERN CORN ROOT WORM.

(Diabrotica longicornis, Say.)

(Plate XIV., Fig. 6-8; and Plate XV.)

The northern or common corn root worm *(Diabrotica longicornis)* is by far the most destructive corn root insect dependent on that plant alone. Indeed, it now seems likely that if it were not for the fact that it is highly susceptible to a measure of prevention which farmers have very generally taken unconsciously, as a part of a sound agricultural routine,

it would long ago have seriously threatened the profitable continuance of corn culture in the very part of the country best adapted to that great crop. Even as it is, its injuries are undoubtedly to be reckoned by millions of dollars annually*, although the essential facts concerning its ravages and their ready and complete prevention were officially and widely published nine years ago†.

INJURIES TO CORN.

The presence of this insect first betrays itself in badly infested fields when the plant is a foot or so high. If at this time patches of corn are observed which seem to be standing still, so that the plants adjacent leave them behind, giving the field an uneven appearance, it is possible—especially if the field has been in corn two years or more preceding—that this retardation of growth is due to the presence of this corn root worm. In this case, if the corn be pulled up, many of the larger roots will be seen to be short and stubbed and rotten at the ends. On others a deadened brown line will be found, running irregularly lengthwise, while still other roots may be dead their whole length. Possibly when the earth is shaken off a slender white grub will be discovered, two fifths of an inch long and about as thick as a pin; but more frequently the observer must carefully split or peel some of the affected roots, when a slender sinuous brown burrow filled with excrement wil be exposed, running from one end of the root to the other, usually with the root worm just mentioned somewhere in its course. This grub is white, except the head, the top of the first segment of the body, and a little patch on the last segment, which are yellowish brown. The body is smooth and cylindrical, the head is short, deep, and rounded, and the tip of the body is also bluntly rounded off, somewhat like that of a common grub. These last characters will serve to distinguish it from small wireworms which are often found in such situations, but which are usually flattened from above, especially at the head, while in them the end of the body is commonly more or less toothed or notched or pointed. The grubs or larvæ of several small flies will often be found about the roots of corn, and careless or unskilled observers have occasionally mistaken these for the corn root worm, but this latter insect has six short legs on the three segments just behind the head, while the grubs of flies are footless. We have seen as many as fifteen or twenty to a hill, and I do not doubt that in fields heavily attacked they are much more numerous. As the root dies, however, it is forsaken and another is attacked, until, not infrequently, almost every root will become infested as fast as it puts forth. This damage may thus extend to the practical destruction of the entire root growth, and the consequent death of the plant; or it may remain miserably dwarfed, six inches, perhaps, when other plants measure four or five feet. If the stem is perforated above the roots, the injury is probably due to the southern root worm or to some of the species of wireworms, which one can only be told by finding the insect itself.

* Webster estimates the damage to corn in twenty-four counties of Indiana in 1885 at two million dollars, basing this judgment on a loss of $16,000 by one large farmer, and on his personal knowledge of its distribution and abundance in that State.

† Twelfth Rep. State Ent. Ill., pp. 29, 30.

Attention may perhaps be first attracted when the corn is putting forth the silk, by the extraordinary number of barren stalks upon which no ear is forming, or stalks may be seen which have scarcely life enough to tassel. It may also be observed that the corn is unaccountably late, looking evidently greener and younger than other fields which had no advantage at the start. Or injury may be first suspected during a period of drouth, patches here and there, or the entire field, suffering unduly from this cause. The most conspicuous evidence of this injury, however, at this stage of growth, is the prostration of the corn after a soaking rain with wind, and the evident inability of the plant to right itself. If one of the worst affected stalks be pulled up, the observer will notice that the roots are few in number, that many of them are withered and brown, and that others are rotted away to stubs. In these discolored roots the minute brown burrow of the insect may usually be detected, and the corn root worm itself may often be exposed. A minor attack frequently has the effect so to retard the ripening of the corn that it is not ready for the earliest frosts, and the ear consequently remains soft and unfit for use; or the loss of roots may have diminished the size of the stalk and ear, leaving a small nubbin where a full ear might have been expected.

The injury continues from about the first or the middle of June to the last of August. As some of the larvæ mature and cease their work in the latter half of June, and others not for two months later, plants once infested may be freed of the attack, at least in part, by the pupation of the root worms, and others, spared at the beginning of the season, may become infested later. It has sometimes been observed that large, rank stalks which did not ear out had evidently been injured after the corn had begun to tassel: while others, which leaned over at the root and then grew erect, had been infested earlier in the season but had thrown out new roots after the root worms had matured.

It is a matter of common observation that injuries by this insect are most noticeable during dry years and upon the higher parts of the field. We have no evidence, however, that the corn root worms themselves are more numerous at such times or in such situations, and the greater injury may be due simply to the diminished ability of the plant to withstand attack. I have, in fact, seen vigorous and flourishing hills of corn badly infested during wet seasons with no visible effect upon their growth, even the larger, burrowed roots remaining fresh and efficient, notwithstanding the injury.

In case no retardation of growth or damage to the crop has been observed, less conspicuous mischief may often be indicated by the great abundance in the field, late in July and in August, of a small grass-green beetle about a fifth of an inch in length, resembling in shape and general aspect the common small striped squash beetle to which, indeed, it is closely allied. These beetles are most likely to be seen clustered at the tip of the ear and feeding upon the young silk, or lurking at the base of the leaf where it joins the stalk, feeding there upon the fallen pollen of the plant. They should also be looked for upon the blossoms of ragweed, smartweed, and other plants in bloom among the corn. This is the adult insect to which the corn root worm, so-called, has given origin, and its presence in extraordinary numbers in any field of

corn is presumptive evidence that the plant has suffered earlier considerable root injury of the character above described.

It is very rarely that these phenomena are to be observed on ground not previously in corn, although sorghum and broom corn have been found somewhat favorable to the development of this insect. It is only where through neglect it has become enormously abundant in a field that we may anticipate its escape from the corn in very large numbers before it has laid its eggs, in which event, corn not succeeding corn may possibly suffer the following year.* The general damage to a field is in the worst cases sufficient to destroy the crop so far that the disgusted farmer turns his pigs into his corn to get what they can, and makes no attempt to harvest his crop. A badly infested field was described to me by Dr. Boardman in 1882, which is worthy of mention as illustrating one of the common effects of root injury by this beetle. "I should say," he writes, "that one fourth of the corn in this field was rotting or beginning to rot. I found, on cutting an ear open, that I could slice the cob as easily as if it were a turnip. The infested corn [in Stark county] is yielding from ten to fifteen bushels per acre."

Although the corn root worm beetle is distributed throughout the Mississippi Valley, and south even to Central America, it clearly becomes comparatively rare southward, and has never been taken by us in Southern Illinois in any numbers, nor found injurious in the larval stage except in the northern two thirds of the State.†

This root worm has not heretofore been certainly found infesting any other plant than corn.‡ and the amount of skilled attention which has been given to this point by entomologists and other accurate observers, makes it practically sure that it is so closely limited to corn at the present time in Illinois that we may base our economic methods upon the supposition that it infests no other plant.

FOOD OF THE BEETLE.

The beetles, beginning to appear in June and continuing until November, feed entirely during this whole period upon the softer and more delicate parts of the vegetation present at the time. They collect the pollen from the tassels of the corn, or gather that which has sifted down among the leaves and collected at their bases, where these join the stalk. They also gnaw away the fresh silk from the tip of the ear (where they may often be found congregated in numbers of a dozen to twenty, or more), probably thus doing a considerable amount of mis-

* As an example of this tendency to spread from the infested field, I may note the not uncommon occurrence at Rankin, Ill., July 1, 1887, of this corn root worm in a field of corn following oats, but only on that part of it which bordered an infested field in corn the previous year. It is possible that other instances of this kind reported previous to 1891 may have related to the southern corn root worm, *Diabrotica 12-punctata.*

† I now believe that the statement made by me in 1886 (see "Entomologica Americana," Vol. II., p. 174) to the effect that I found it injurious to corn in a field near Cairo, in Southern Illinois, which had been under water for nearly three weeks in the spring, really referred to the southern corn root worm *(Diabrotica 12-punctata)*, of whose habit as a corn root insect nothing was at that time known.

‡ A statement from a correspondent, published in my Twelfth Report (p. 19) that it is sometimes very abundant in the roots of purslane (Portulaca), I believe to have been based on the frequent occurrence in the main root of that plant of the burrows of a coleopterous larva resembling the corn root worm, but certainly different; although never having bred it, I am unable to identify it precisely. It is shorter than Diabrotica, and has the mouth parts black instead of brown.

chief by destroying the silk before it has served for the fertilization of the grain, and causing thus a partial blasting of the ear. They often eat the pollen of smartweed and ragweed among the corn, and outside the fields are very abundant upon thistle blossoms, and likewise upon heads of red clover, the pollen and petals of which they feed upon. By Professor French, of Carbondale, Ill., they are said sometimes to infest the bean plant; Dr. Boardman, of Stark county, reported them as abundant on cucumber and squash vines, and we have repeatedly seen them late in the year (October 11 to December 16) gnawing into ripe pumpkins in the field, eating through the outer hard coat, and burying themselves in the pulp to a depth of nearly half an inch. We have found them feeding on flowers of Helianthus, goldenrod, and other Compositæ, and on the pollen of sorghum and of squash; and Professor Webster has seen them on the blossoms of the cotton plant. A farmer in De Kalb county asserts that they eat the pulp of apples where the skin has been broken from some other cause, enlarging such injuries so as seriously to damage the fruit. This same fact was reported to me some years ago from Grundy county, by Mr. O. B. Galusha, then Secretary of the State Horticultural Society, thin-skinned apples apparently suffering worst and, according to the judgment of my informant, being thus injured without the assistance of other insects. They have been repeatedly detected by us beneath the husks of ears of corn, where the tips had been exposed or injured by birds or grasshoppers, feeding here on the broken grains. In one instance the beetle had apparently made its way through the husk itself, and was feeding upon the soft grains beneath. By Professor Burrill, of the University of Illinois, it was found in 1889 (September 30) feeding upon a fungus belonging to the genus Phallus; and I demonstrated by dissections in 1882 the fact that it sometimes feeds largely on the smaller fungi—blights, rusts, etc.*

LIFE HISTORY.

This species is single-brooded, as far as known. Although a few beetles may occasionally linger late in open winters,—to December 16 of the present year (1892) for example—and as a rare exception may even pass the winter alive, the species hibernates almost invariably as an egg in the earth.† As a rule, which is, so far as known, practically without exception, these eggs are deposited in fields of corn and hatch there the following spring—at just what date has not been precisely ascertained. The larvæ have first been detected in Central Illinois June 10. They were found by me less than half grown near Polo, in Northern Illinois, June 14, 1883. As the beetle was reported by an excellent observer (Dr. E. R. Boardman) to have occurred one season in southeastern Iowa as early as June 25, some larvæ must hatch by the beginning of that month. Pupation can scarcely begin later than June 20 if Dr. Boardman's date for the beetle is correct, and the same observer

* Twelfth Rep. State Ent. Ill., p. 23.

† I have in my office collection two specimens (one male and one female) obtained March 14, 1883, at Normal, Illinois, with a quantity of miscellaneous insects collected from their hibernating quarters. On the other hand, beetles collected from pumpkins at Urbana, November 2, 1892, and placed in breeding cages with pieces of pumpkin as food, had died in large numbers by November 20; a very few were still alive December 4; two remained December 17; but December 28 all were dead.

reports the finding of the pupa itself in the earth June 29. On the other hand, larvæ ready for pupation have occurred in our collections as late as August 26—giving a period of something over two months for the pupation of an entire generation.

The extreme dates definitely fixed for the next transformation—the emergence of the beetle—are June 25 for the earliest* and not earlier than August 31 for the last—again a period of something more than two months. We have seen the beetles copulating at various dates from July 19 to September 25,—an interval of two months and six days,—observations which probably fix approximately the beginning and the end of oviposition. The eggs, however, were not all laid by October 1, 1882, as I determined by dissecting females at the time. For the present we may assign August 1 and October 5 as the average dates for the first and last deposit of eggs.

The recognition of this eight or nine weeks' period for the passage of the whole of a brood from one stage to another, enables us to say with some assurance that the eggs laid during this long interval in one year will hatch through a corresponding interval the year following—approximately from May 15 to July 15, or a little later. While these dates are, some of them, inferred, there is no doubt of the extension of each stage of the development over as long a period as that here given; namely, two months to nine weeks. We have no precise observations concerning the length of life of any individual in any one stage; neither do we know the number of eggs laid by each female, except as an inference from dissections. I have counted as many as fifty well-formed eggs of nearly full size in the ovaries of a single female beetle.

HABITS OF BEETLE AND LARVA.

The growing larvæ remain concealed from view within the roots, burrowing, not through the middle but nearer the surface, in a slightly sinuous longitudinal direction, sometimes from the stalk outwards, but more frequently mining inwards from the outer end of the root. They have considerable power of locomotion when removed from their burrows, and seem capable of going from one root to another. Indeed, the fact that they must concentrate in hills of corn after hatching, demonstrates their power of locomotion when still very young.† It is altogether likely, consequently, that if a hill of corn is killed by them before they have reached maturity, they will be entirely able to search out another.

When full grown they leave the root preliminary to pupation, shortening up and changing to the pupa stage in the dirt close by. At this time they may often be found in considerable numbers by pulling up infested corn and shaking out the dirt from the roots. The beetles emerge from the pupa under ground, and, coming to the surface, most commonly crawl up the stalk of corn adjacent. When recently transformed they are of a pale yellowish color, with scarcely a tinge of green. Their first food consists, as already mentioned, of the softer tissues of the corn plant itself, especially of the silk at the tip of the ear, or the

* On Dr. Boardman's authority.

† Although their thoracic legs are very short, they are nevertheless functional, and the hinder end of the body is provided with a kind of anal proleg, which serves as an aid to locomotion.

pollen from the tassel, or sometimes of the soft kernels, especially if these have been exposed by any injury to the husks. They also spread to various blossoming weeds in the field, and after a time begin to desert the corn field, scattering elsewhere for food. It is commonly towards the last of August that they are first noticeably frequent on thistle blossoms, heads of clover, and other outside blooming plants. They do not, however, leave the corn fields generally for some time thereafter, but may be found there in greatly diminished numbers at least as late as the middle of October.*

How soon after pairing their eggs are laid we do not now know; neither has the process of oviposition ever been directly witnessed. The frequent occurrence of dead female beetles (in October and November) in the earth in corn fields in the midst of the eggs, and the distribution of the eggs themselves is, however, sufficient evidence that the beetle enters the earth to lay her eggs, and that she may perish there after her ovaries are spent. Although the eggs of this beetle have never been found outside of corn fields, notwithstanding extensive search in many other situations, it is certain that the eggs are not necessarily all laid before the female leaves the field in which she emerged. I have, on the contrary, frequently proven by dissection of beetles taken from flowers by roadsides, in meadows, and the like, that females thus dispersed may still contain eggs in large numbers. A considerable part of the beetles, and apparently the greater part, do, however, lay their eggs under ordinary circumstances before they leave the field of corn; and it is also highly probable on general grounds that those which go elsewhere in search of food return to corn fields for oviposition. Since the larva is not known to infest any other plant than corn, or, indeed, to be capable of living upon any other, it is altogether likely that the female instinctively searches out the corn plant when seeking a place of deposit for her eggs.

As this is a surmise or inference, however, and not a matter of observation, it remains possible that if the corn root worm is neglected it may in time accumulate in such numbers as no longer to confine its chief injuries to fields previously in corn, but that the beetles, forced to scatter early, in search of food, from the fields in which they emerge will deposit their eggs freely everywhere in the ground, instead of being confined as now chiefly to corn fields. It is probably in fields of clover that this is most likely to occur, since the beetles sometimes become abundant there, feeding upon the pollen of the second growth.

The depth at which the eggs are laid varies from an inch to five or six inches, the greater part of them being near the surface of the ground. They are usually deposited in bunches of three or four to eight or ten, within a space of half an inch across, not in contact with each other, nor in any cell or cavity, but always simply scattered in the earth. Most

* The following is a list of dates, precisely recorded in my office collection records, for the occurrence of this beetle:

In corn fields. July 19 (pairing), 21, 27, 28; August 1, 3, 5, 6, 7, 12, 13, 17 (pairing), 18, 19, 21, 22, 25 (pairing), 27; September 4, 7, 9, 11, 12, 16. 17. 25 (pairing), October 1, 7, 13, 14, 18; November 1, 7.

Outside corn fields. March 14, (1883); August 19, 20, 21, 22, 25, 26, 27, 29; September 4, 7, 13, 15, 16, 22; October 1, 3, 10, 13, 16, 18; November 2, 24; December 1, 16.

careful examinations made in 1882, and many times repeated, of the earth between the rows, and of the roots of all the weeds growing in the field, have failed to discover so much as a single egg outside a space a few inches across, around each hill. A similar careful search of the roots of thistles, ragweeds, and goldenrod outside the fields, upon the flowers of which the beetles were feeding in great numbers, had a similar result; and we have found no evidence in the roots of these plants, either in the corn fields or elsewhere, that they have ever been infested by the larvæ. In short, not the slightest direct proof has thus far been found that the beetle breeds anywhere except in fields of corn. It is very probable that a few develop in other situations; but the number seems to be so small as to defy discovery, except by accident.

NATURAL ENEMIES.

Of natural enemies of this insect, practically nothing is known. While in the corn root, the larva is scarcely liable to harm. When outside the roots, it has possibly been destroyed now and then by predaceous insects, which are often numerous in and about hills of corn, but dissections of insects of this class (reported in my Twelfth Report), do not confirm this supposition. The soft-bodied pupæ scattered in the earth without special protection of any kind would certainly seem to be exposed to insect enemies of this class, but of this fact we have no definite evidence. The beetles are not eaten by birds, so far as known, and our breeding experiments have yielded no insect parasites.* The spent adult, female or male, may become infested before death with intestinal parasites (Gregarinæ), and we have occasionally found the dead bodies yielding a growth of *Sporotrichum globuliferum*—a fungus parasite of living insects generally distributed everywhere.

PREVENTION AND REMEDY.

A judicious rotation of crops is so simple and complete a preventive measure, that *remedies* for injury to corn by the northern corn root worm are practically unnecessary. The eggs being laid in corn ground in the fall and the larvæ hatching the following spring, feeding so far as known upon nothing else but corn, the planting of such infested land to any other grain must inevitably lead to the starvation of the young when they hatch in spring. This is not an inference from the life history of the insect merely but even before the time and place of oviposition were known, it had been commonly noticed that corn was rarely if ever liable to injury by this insect if planted on ground which had borne any other kind of crop the preceding year. I have, however, some reason to suppose that sorghum and broom corn are not good crops to follow with corn when this root worm is present.

The frequency of the rotation must depend upon circumstances, and especially upon the general abundance of the insect at the time. I know of no part of Illinois in which corn is not safe for at least two years, and in many situations another year may be added to this period. No field on which the crop has already suffered to any noticeable ex-

* An assistant, Mr. C. W. Woodworth, reported September, 1885, the finding of two small locustids—specimens of which were not brought in—eating the adult Diabrotica. One of these was taken with a half eaten beetle in its jaws.

tent should be planted to corn the following year; and it will likewise be prudent to avoid continuing in corn any field in which the grass-green beetle of this species is seen to be abundant in September and October.

The only other preventive measure worthy of mention is one equally to be commended as a general agricultural practice; namely, the maintenance of the fertility of the soil by the use of manures, etc. This will not, so far as known, diminish in any way the amount of insect attack, but it will enable the plant to stand a minor injury with relatively little loss. It is possible that experiments with various kinds of fertilizers will show that some of them, the potash salts for instance, may have an immediate deleterious effect upon the larvæ in the earth, but we have at present only a speculative basis for this supposition.

Description.

Larva (Plate XIV., Fig. 7; and Plate XV., Fig. 2-8).—The corn root worm, when fully grown, just previous to its last moult, is .4 of an inch in length by one tenth that width, white and smooth when under a low power, but when more highly magnified, the skin is seen to be minutely roughened with very small tubercles. The body is cylindrical, narrowing a little anteriorly, the first segment being the shortest and narrowest of all. There are a few scattered stiff hairs to each segment, most numerous anteriorly, and especially upon the head. The latter is narrower than the first segment, convex but flattened above, about two thirds as wide as long, and smooth except for the hairs already mentioned. It is yellowish brown, a little darker in front and at the sides beneath. A narrow dark line extends along the middle of the head, widest posteriorly, where it is divided by the very narrow white suture, which forks at the middle, sending two narrow straight branches to the anterior angles of the head.

Here the short, white, three-jointed antennæ are situated, the first joint about twice as wide as the last, and the second joint very short. The eyes are wanting. The mandibles are dark, with black tips, and the other mouth appendages are white. The thoracic segments all bear short two-jointed legs, each about as long as the segment to which it is attached. They are pale brown, armed with short, stout spines and terminating in a single claw and a flattened, membranous, oval appendage, which extends some distance beyond the tip of the claw. The top of the first segment is coriaceous and yellowish brown while all the others are soft except the last, upon which is a circular brownish patch of leathery consistence. Beneath this segment is a prominent retractile wart or tubercle, serving as a false leg. The segment is entire and rounded posteriorly, where it is set with a few long hairs or slender spines.

Just before pupating, the larva becomes very much shortened and thickened, assuming more the form of a common grub. The abdominal segments now become much more distinctly marked, and the head takes a vertical position. The length in this, which may be called the semi-pupa stage, is only about one fifth of an inch, and the greatest breadth .045 of an inch. The body now tapers more posteriorly than before.

the last two segments being conspicuously narrower than the preceding. In other respects the larva remains unchanged.

The only objects which I have noticed in the ground about the roots of corn, which are likely to be mistaken for the corn root worm, are very young earthworms, the larvæ or grubs of small gnats and other flies, and young wireworms. On a careful examination the first two of these may be readily distinguished by the fact that they are entirely destitute of legs, while, as already remarked, the root worm has three pairs of jointed legs just back of the head. In this respect it agrees with the young wireworms, which are (also like the root worm) destitute of appendages to the other segments of the body. Their crust is, however, firmer than that of the latter species, the head is longer, flatter, and thinner, the body also usually somewhat flattened and the last segment commonly either notched or variously toothed.

Pupa (Plate XIV. Fig. 8).—The characters of the newly formed pupa are well shown by the figure, but as some changes occur previous to the escape of the beetle, a description of the latest stage is given. The length is .18 of an inch, and the greatest width about .1 of an inch. The color is pure white throughout, with the exception of the brownish red eyes, which now show through the skin, and a pair of brown, horny, curved hooks, attached to the tip of the abdomen about equaling in length the preceding segment. The arrangement of the wings, wing covers, legs, and antennæ, and the position of the head, are well shown in the cut. Two white erect hairs are seen between the antennæ, and another pair above and between the eyes.

Several scattered slender spines appear upon the back of the prothorax, as well as an irregular transverse row upon each of the other segments of the thorax and abdomen. These hairs are especially long and strong at the tip of the abdomen, and a few likewise appear upon the tibio-femoral joints. The hairs, as well as the forceps-like claws at the tip of the body, already mentioned, doubtless serve to fix the pupa skin in the earth when the beetle emerges. The spiracles are distinctly visible as small brown rings upon the back of each of the first eight abdominal segments, but upon the three remaining segments posterior to these they are not apparent.

Imago (Plate XIV., Fig. 6).—The adult beetle is about one fifth of an inch in length by about half that in breadth, and a little widest posteriorly. Its head is nearly as wide as the thorax, smooth, or nearly so, with a large circular depression between the eyes, from which a narrow groove leads forward, dividing between the antennæ and enclosing between the branches of the fork an elevated ridge, which extends downward to the labrum. On either side of this, and in front of each antenna, the surface is minutely rugulose. There is also an angular depressed line just within each eye. The antennæ are rather long, extending backwards beyond the middle of the elytra. The second and third joints are short and equal, and together about as long as the fourth. The remaining joints of the antennæ are of nearly equal length. The first and second joints are nearly smooth, the remainder pubescent. The eyes are black, the head and first joint of the antennæ are pale brown or green or brownish green, and the rest of the antennæ, the labrum, and mouth parts brown.

The thorax is not as wide as the elytra, and is strongly narrowed behind the middle, making the margin sinuate. The anterior angles are rounded and the posterior obtuse. The sides of the thorax are narrowly expanded and recurved, leaving a gutter-like margin along the whole length. It is not margined behind. The disk is very slightly pubescent, and sparsely and faintly punctured, most distinctly posteriorly. A little behind the middle, upon each side of the median line, is a large conical fovea, but there is no median ridge or groove. A strong, erect hair occurs in front of the posterior angle, and another behind the anterior, and two or three short hairs follow the latter.

The elytra are coarsely and irregularly punctured, and sparingly pubescent, with short stiff hairs. The surface is diversified by four or five obscure and irregular ribs, of which the outermost is largest, and forms a well-marked longitudinal angle. This and the one next it unite anteriorly in a prominent humerus. The edge of the elytron is recurved like that of the thorax, forming a still deeper gutter just within the margin.

The thorax and elytra are commonly brownish green or grassy green throughout, but the humeral angles are occasionally touched with brown, as is likewise the smooth scutellum. The sutural line is also sometimes brown. The epipleuræ are green, and do not attain the tips of the elytra. The legs and under surface of the body are pubescent except the prosternum, which is smooth, or nearly so. The abdomen is sparsely punctured. The thighs are usually green, but the tibiæ, the tarsi, and the sides of the metasternum are more or less deeply tinged with brown.

Egg (Plate XV., Fig. 1).—The egg is of a dirty white color and very minute, .025 of an inch in length and .015 of an inch wide; narrower at one end than at the other, having in fact almost precisely the shape of a hen's egg. Under the microscope the surface is seen to be thickly dotted with minute hexagonal pits, about twenty in its entire length, and under a higher power the bottom of each of these pits exhibits still more minute depressions, seven or eight to each reticulation.

EXPLANATION OF PLATES.

PLATE I.

Fig. 1. *Myrmica scabrinodis lobicornis*, female; enlarged ten diameters.
Fig. 2. Male of same species; enlarged nine and one fourth diameters.

PLATE II.

Fig. 1. *Myrmica scabrinodis lobicornis*, worker; enlarged eight and one half diameters.
Fig. 2. *Solenopsis debilis*, worker; enlarged eighteen diameters.
Fig. 3. *Agonoderus pallipes*, imago; enlarged four and one fourth diameters; its work in seed corn.
Fig. 4. *Aphodius granarius*, imago; enlarged six and one half diameters.
Fig. 5. *Clivina impressifrons*, imago; enlarged eight and one half diameters.
Fig. 6. The Seed-corn Maggot, *Phorbia fusciceps*, larva, enlarged eleven diameters.
Fig. 7. Puparium of same, enlarged ten and one half diameters.

PLATE III.

Fig. 1. The Seed-corn Maggot, *Phorbia fusciceps*, imago; enlarged eight and two thirds diameters.
Fig. 2. Seed-corn injured by larva of the same.
Fig. 3. The Black-headed Grass Maggot, Sciara sp., enlarged five diameters.
Fig. 4. Labrum of same, upper surface.
Fig. 5. Labrum, lower surface.
Fig. 6. Mandible.
Fig. 7. Maxilla.
Fig. 8. The Pale-striped Flea-beetle, *Systena, taeniata*, imago; enlarged ten diameters.

PLATE IV.

Fig. 1. The Pale-striped Flea-beetle, *Systena taeniata*, larva; enlarged nineteen diameters.
Fig. 2. Side view of same.
Fig. 3. The Banded Ips, *Ips fasciatus*, larva; enlarged eight and one third diameters.
Fig. 4. Pupa of same; enlarged nine diameters.
Fig. 5. Imago of same; enlarged eight diameters.
Fig. 6. Cardiophorus sp., larva, dorsal view; enlarged four diameters.

PLATE V.

Fig. 1. *Drasterius elegans*, imago; enlarged seven and one half diameters.
Fig. 2. Larva of same; enlarged seven diameters.
Fig. 3. Caudal segment of larva, more enlarged.
Fig. 4. The Wheat Wireworm, *Agriotes mancus*, imago; enlarged seven diameters.

Fig. 5. Larva of same, enlarged five diameters.
Fig. 6. Side view of same.

PLATE VI.

Fig. 1. *Agriotes pubescens*, imago; enlarged six diameters.
Fig. 2. *Melanotus fissilis*, imago; enlarged three and four fifths diameters.
Fig. 3. *Melanotus communis*, imago; enlarged four diameters.
Fig. 4. Side view of a middle segment of larva of same species, showing muscular impression, spiracle, etc.
Fig. 5. Caudal segment of same, dorsal view; greatly enlarged.
Fig. 6. The Corn Wireworm, *Melanotus cribulosus*, larva; enlarged four diameters.
Fig. 7. Side view of a middle segment of same.
Fig. 8. Caudal segment, dorsal view; greatly enlarged.

PLATE VII.

Fig. 1. The Corn Wireworm, *Melanotus cribulosus*, imago; enlarged four and a half diameters.
Fig. 2. *Asaphes decoloratus*, imago; enlarged four and one fifth diameters.
Fig. 3. Larva of same, dorsal view; enlarged three and three fourths diameters.
Fig. 4. Caudal segment of same; more enlarged.
Fig. 5. The Corn Root Aphis, *Aphis maidiradicis*, oviparous female; enlarged fourteen diameters; *a*, hind tibia, showing sensoria.
Fig. 6. Male of same species; enlarged twenty-five diameters; *a*, antenna.

PLATE VIII.

Fig. 1. The Corn Root Aphis, *Aphis maidiradicis*, wingless viviparous female; enlarged fourteen diameters; *a*, apex of abdomen showing cornicles, tubercles, and cauda.
Fig. 2. Antenna of same.
Fig. 3. Pupa of same species; enlarged twenty-one diameters.
Fig. 4. Winged viviparous female of same species; enlarged sixteen diameters.
Fig. 5. Antenna of same.
Fig. 6. The Grass Root Louse, *Schizoneura panicola*, winged viviparous female; enlarged eighteen diameters; *a*, antenna.

PLATE IX.

Fig. 1. The Grass Root Louse, *Schizoneura panicola*, wingless viviparous female; enlarged twenty-nine diameters.
Fig. 2. *Trama erigeronensis;* enlarged twenty diameters; *a*, antenna; *b*, beak; *c*, cauda.
Fig. 3. *Forda occidentalis;* enlarged twenty-one diameters; *a*, antenna, *b*, beak; *c*, cauda.
Fig. 4. *Tychea brevicornis;* enlarged twenty-two diameters; *a*, antenna, *b*, beak.
Fig. 5. *Geoica squamosa*, wingless viviparous female; enlarged twenty-three diameters.
Fig. 6. Structures of same; *a*, beak; *b*, antenna; *c*, tarsus.

PLATE X.

Fig. 1. *Geoica squamosa*, pupa; enlarged twenty-four diameters.
Fig. 2. Winged viviparous female of same species, antenna.

Fig. 3. Wing of same.

Fig. 4. The Woolly Grass Root Louse, *Rhizobius spicatus;* enlarged twenty-six diameters; *a*, antenna; *b*, beak.

Fig. 5. The Small Brown Ant, *Lasius niger alienus*, female; enlarged four and one half diameters.

Fig. 6. The same, worker, enlarged eight and one fourth diameters.

Fig. 7. The Corn Mealy Bug, *Dactylopius sorghiellus*, adult female, dorsal view; enlarged twenty-nine diameters.

Fig. 8. The same, ventral view.

PLATE XI.

Fig. 1. The Small Brown Ant, *Lasius niger alienus*, male; enlarged eight and one fourth diameters.

Fig. 2. *Formica schaufussi*, worker; enlarged eleven and one half diameters; *a*, portion of upper surface of abdomen greatly enlarged.

PLATE XII.

Fig. 1. *Lachnosterna rugosa*, male imago; enlarged two and one fifth diameters; *a*, last two ventral segments.

Fig. 2. Larva of same; enlarged two and one half diameters.

Fig. 3. *Lachnosterna rugosa* or *hirticula*, last abdominal segment of larva, seen from beneath; enlarged six diameters.

Fig. 4. *Lachnosterna fusca*, male imago; enlarged two diameters; *a*, last two ventral segments.

Fig. 5. *Lachnosterna inversa* or *fusca*, last abdominal segment of larva, seen from beneath; enlarged six diameters.

Fig. 6. *Lachnosterna gibbosa*, male imago; enlarged two diameters; *a*, last two ventral segments; *b*. spurs at tip of hind tibia.

Fig. 7. Larva of same, last abdominal segment; seen from beneath; enlarged six diameters.

Fig. 8. *Cyclocephala immaculata*, last abdominal segment of larva, seen from beneath; enlarged six diameters.

PLATE XIII.

Fig. 1. *Cyclocephala immaculata*, larva; enlarged three and one third diameters.

Fig. 2. Imago of same; enlarged three diameters.

Fig. 3. *Prionus imbricornis*, imago; natural size.

Fig. 4. *Prionus laticollis*, imago; natural size.

Fig. 5. Prionus, larva; natural size.

Fig. 6. Prionus, pupa; natural size.

Fig. 7. The Green June Beetle, *Allorhina nitida; a*, larva; *b*, pupa; *c*, male imago; all enlarged one and a half diameters; *d*, *e*, *f*, *g*, mandible, antenna, leg, and maxilla of larva; more enlarged.

PLATE XIV.

Fig. 1. The Southern Corn Root Worm, *Diabrotica 12-punctata*, imago; enlarged five and two thirds diameters.

Fig. 2. Pupa of same, dorsal view; enlarged ten diameters.

Fig. 3. Ventral view of pupa.

Fig. 4. Larva of same, dorsal view; enlarged five diameters.

Fig. 5. Side view of larva.

Fig. 6. The Northern Corn Root Worm, *Diabrotica longicornis*, imago; enlarged ten diameters.

Fig. 7. Corn root broken across to show larva of same within.

Fig. 8. Pupa of same; enlarged eight and a half diameters.

PLATE XV.

Fig. 1. The Northern Corn Root Worm, *Diabrotica longicornis*, egg; enlarged eighty diameters.
Fig. 2. Larva of same; enlarged six diameters.
Fig. 3. Head of larva, dorsal view; greatly enlarged.
Fig. 4. Labrum and leg of larva.
Fig. 5. Mandible of larva, seen at right angles to cutting edge.
Fig. 6. The same, seen obliquely from side.
Fig. 7. The same, seen directly from side.
Fig. 8. Mouth parts of larva, seen from beneath.

NOTE.

The following figures are from drawings made by Miss Lydia M. Hart: Pl. I; pl. II, fig. 1, 2, 4-7; pl. III, fig. 1, 8; pl. IV, fig. 3-5; pl. V, fig. 3, 4; pl. VI, fig. 1-3; pl. VII, fig. 2, 5, 6; pl. VIII, and IX; pl. X, fig. 1-4, 6-8; pl. XI, fig. 2; pl. XII, fig. 1, 3-8; pl. XIV, fig. 1. The drawings for pl. IV, fig. 1, 2, 6; pl. V, fig. 1, 2, 5, 6; pl. VI, fig. 4-8; pl. VII, fig. 3, 4; pl. X, fig. 5; pl. XI, fig. 1; pl. XII, fig. 2; pl. XIII, fig. 1, 2; and pl. XIV, fig. 2-5, were by Mr. M. Westergren; and those for pl. XV, fig. 3-8, by Mr. H. Garman. Pl. II, fig. 3; pl. III, fig. 2; and pl. XIII, fig. 3, are from Dr. C. V. Riley; and pl. III, fig. 3-7; pl. XIII, fig. 4-7; pl. XIV, fig. 6-8; and pl. XV, fig. 1, 2, are reprinted from previous reports of this office.

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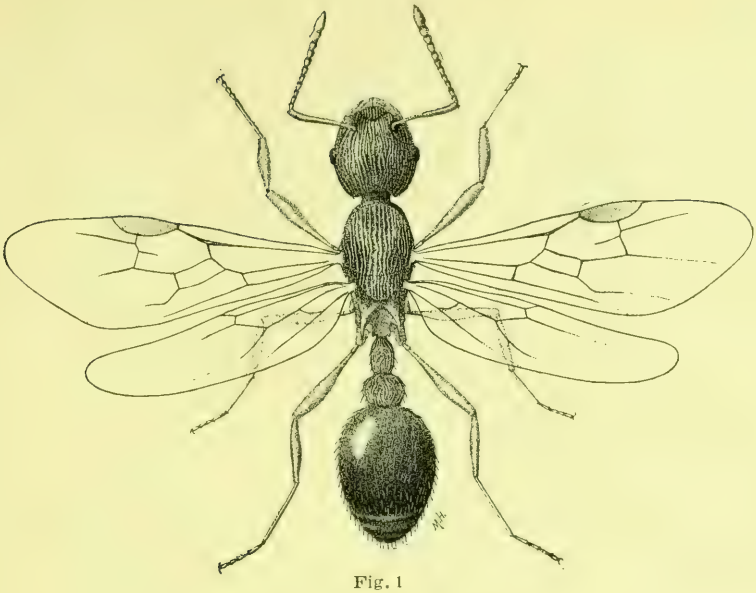
PLATE I.



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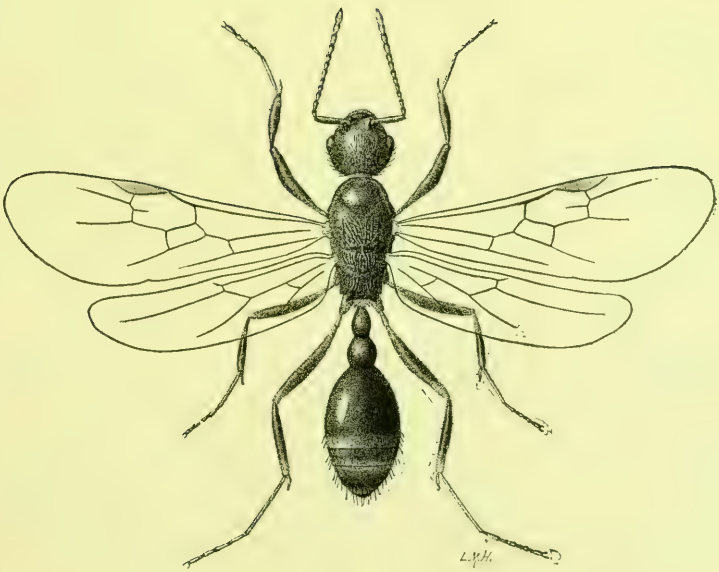

Fig. 2.

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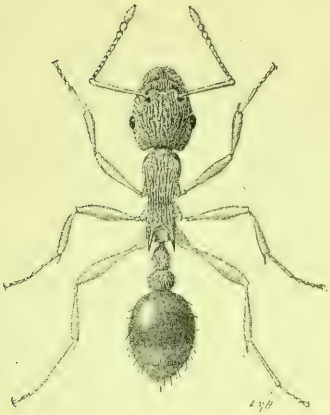

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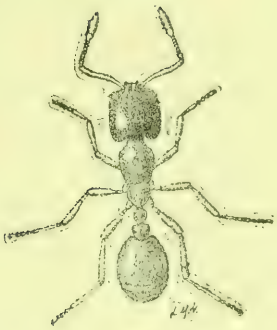

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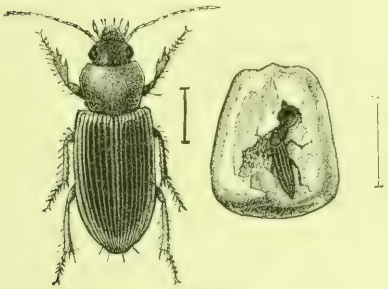

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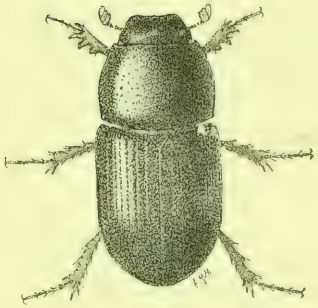

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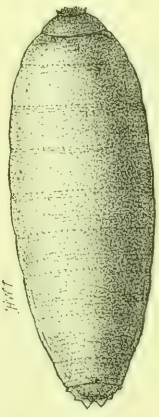
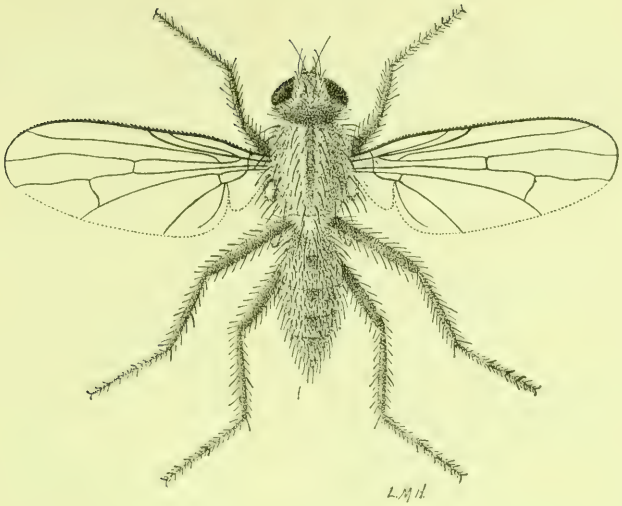


Fig. 7.

Plate III.



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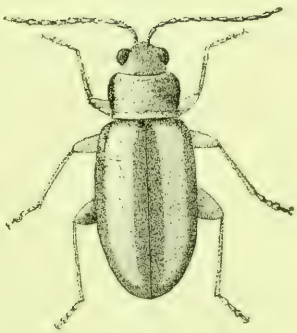

Fig. 8.

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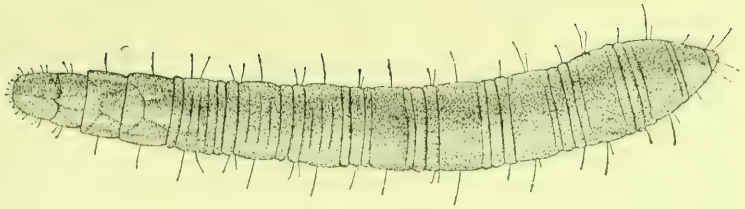

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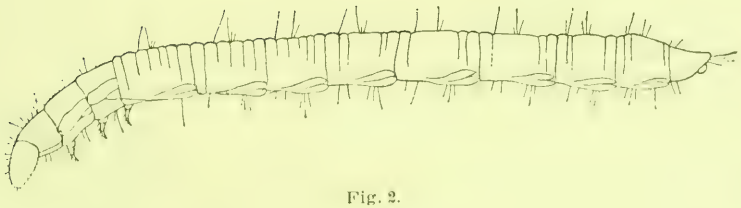

Fig. 2.

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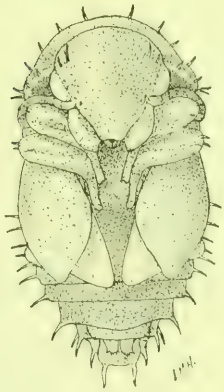

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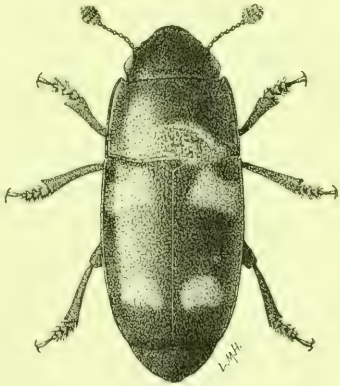

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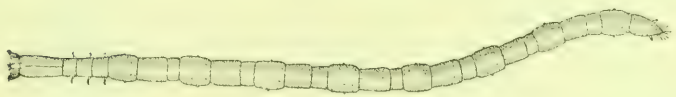

Fig. 6.

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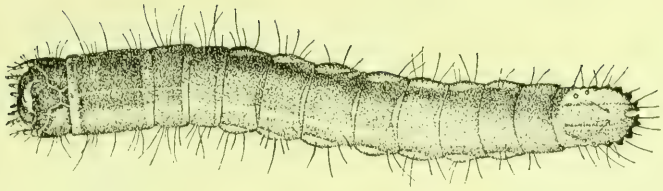

Fig. 2.

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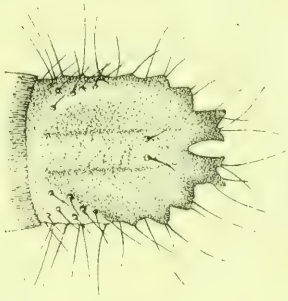

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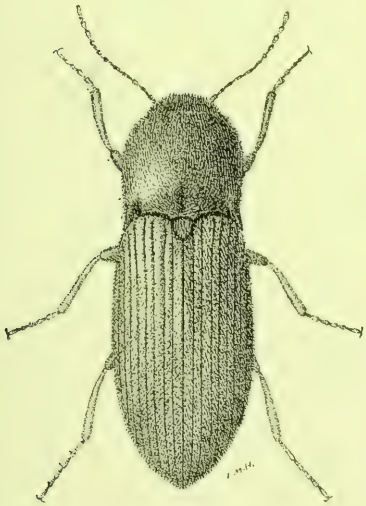

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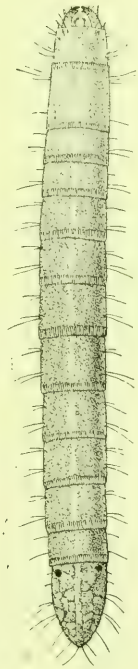

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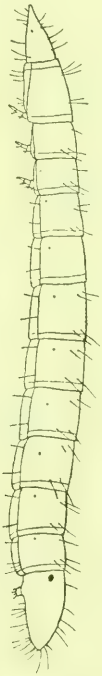
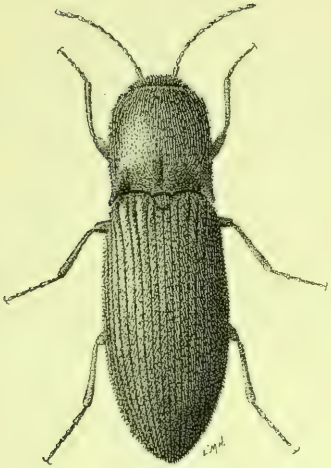


Fig. 6.

Plate VI.



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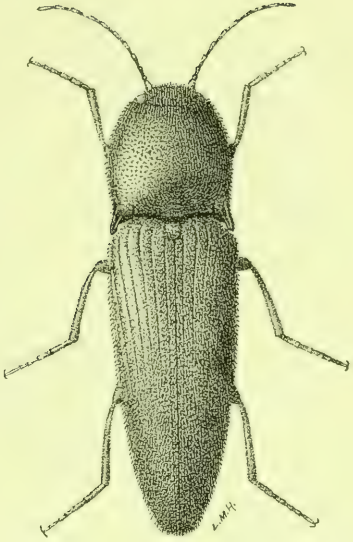
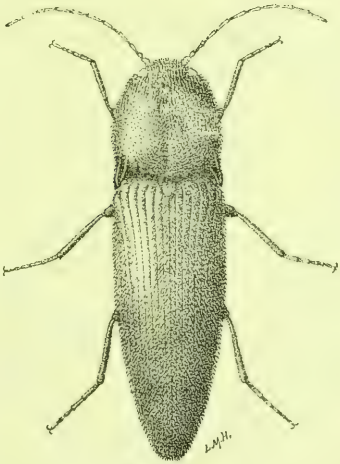


Fig. 2.

Fig. 4.



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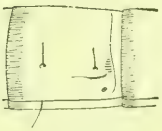

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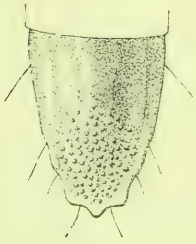

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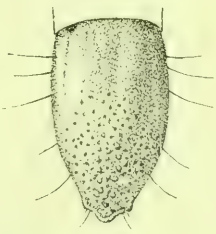

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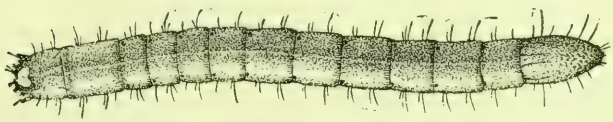

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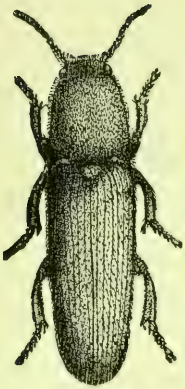

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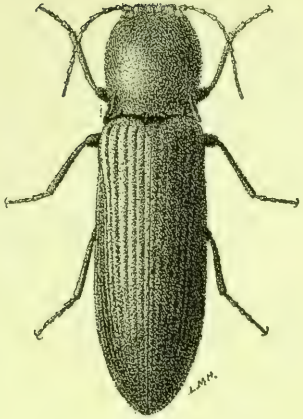

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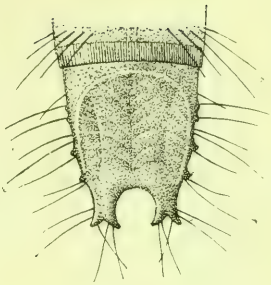

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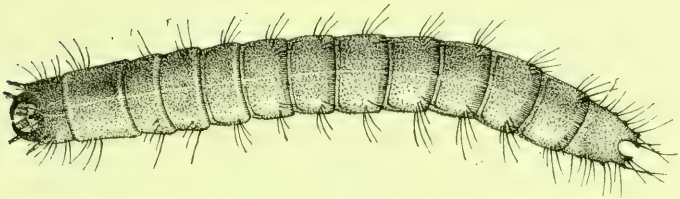

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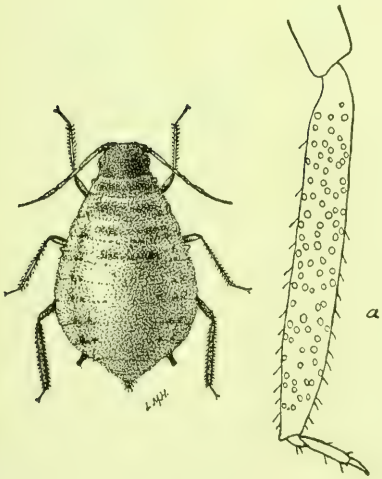

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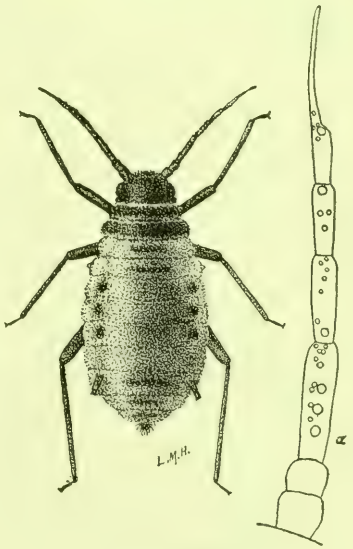

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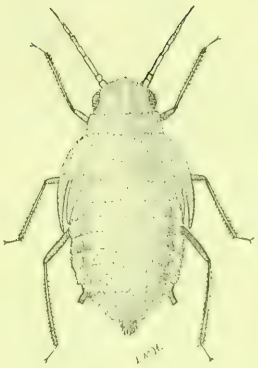

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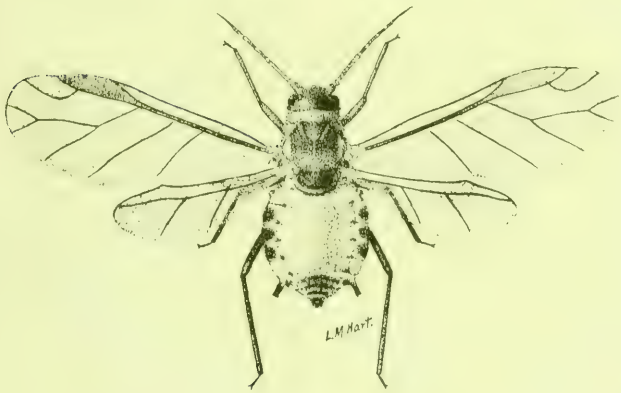

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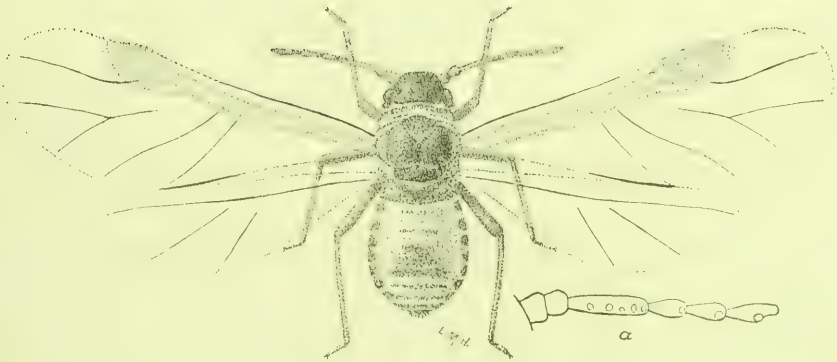

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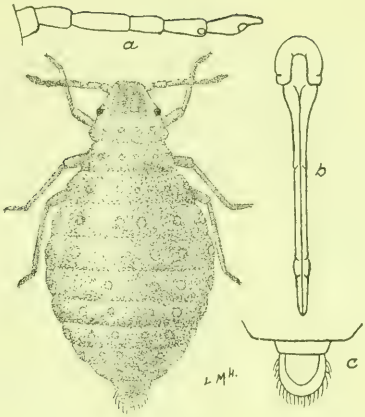

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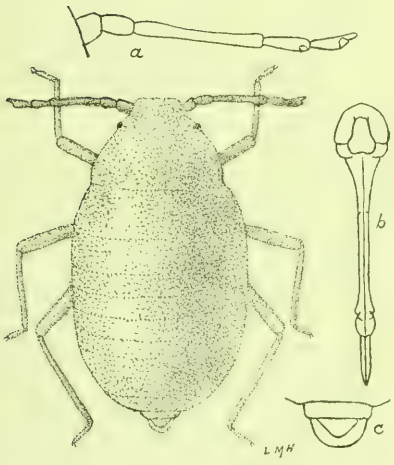

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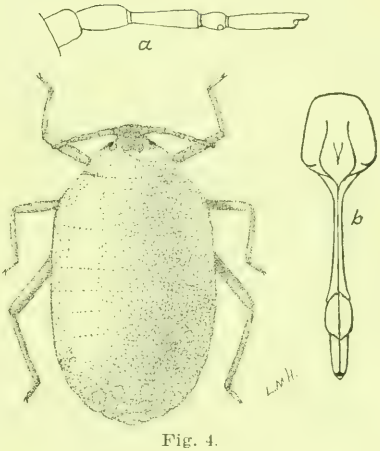

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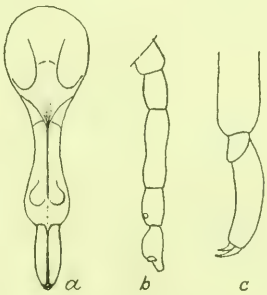

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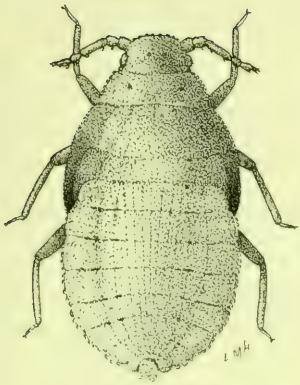

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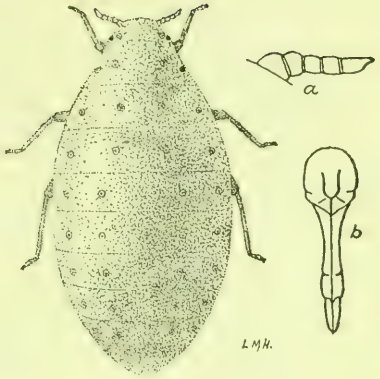

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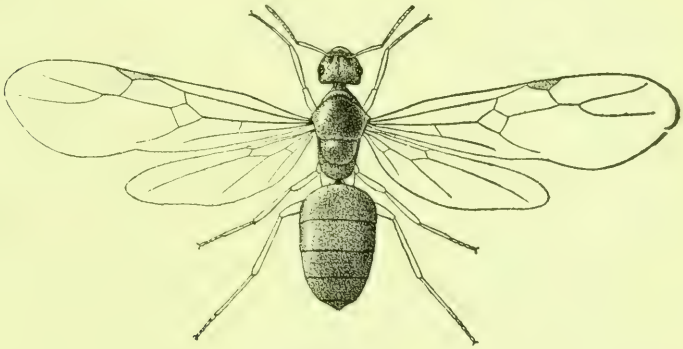

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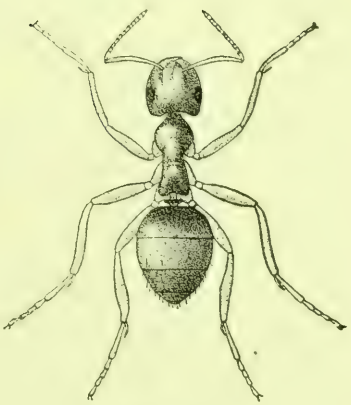

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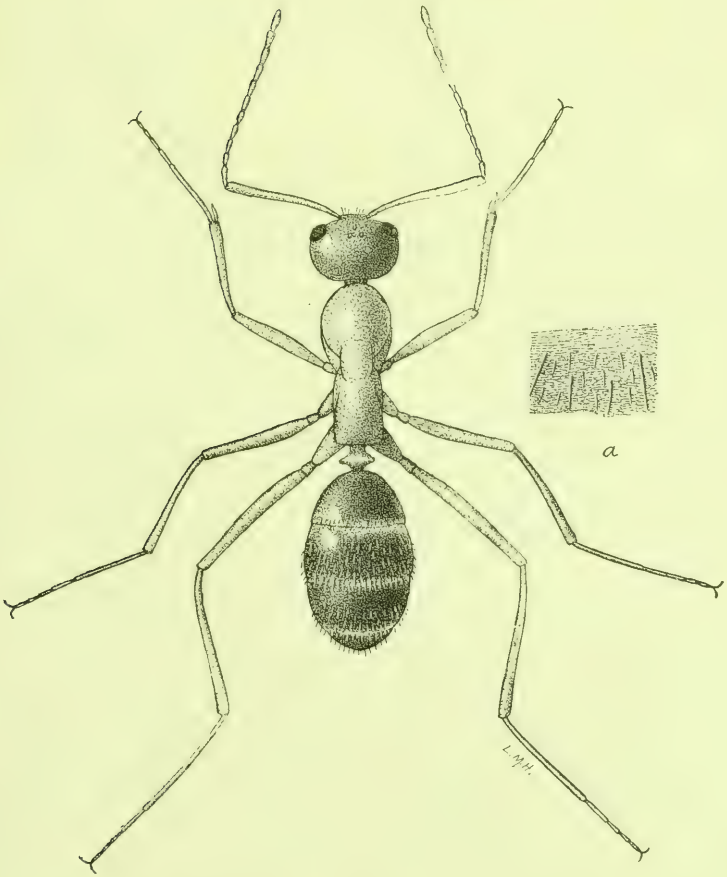

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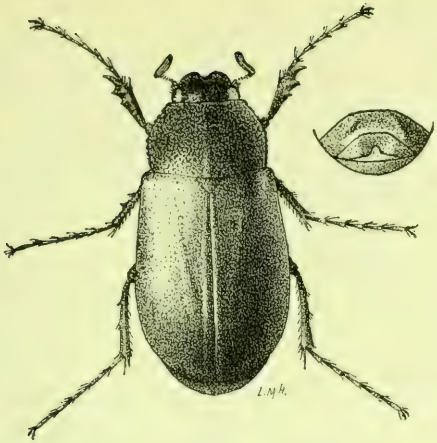

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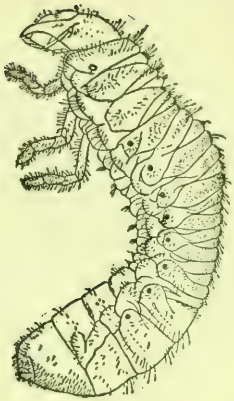

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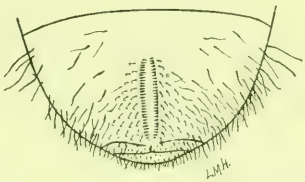

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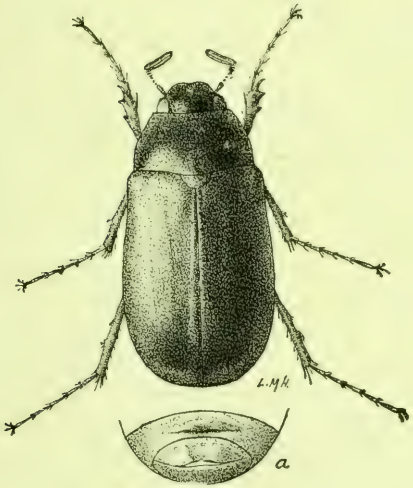

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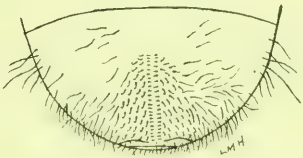

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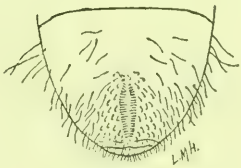

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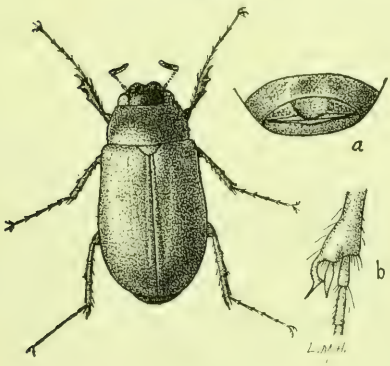

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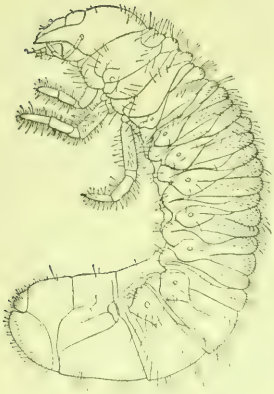

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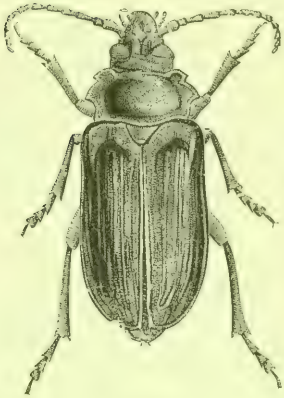

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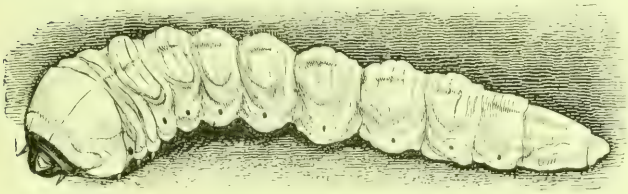

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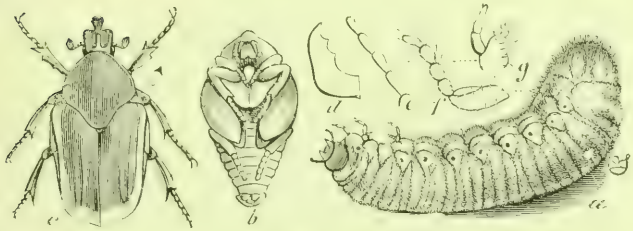

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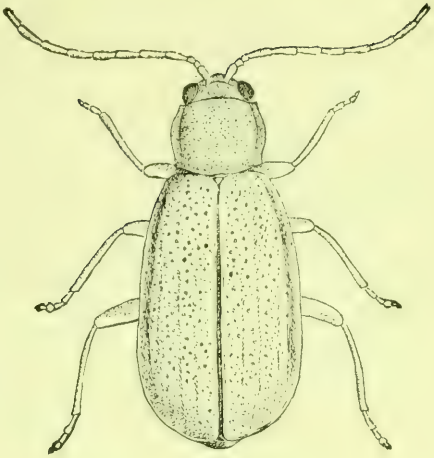

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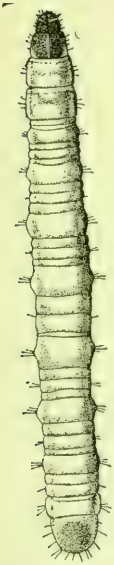

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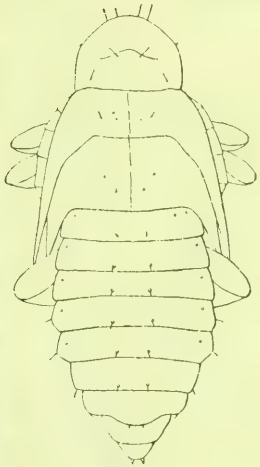

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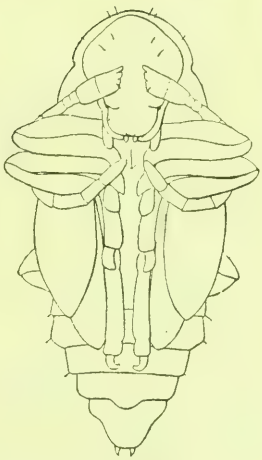

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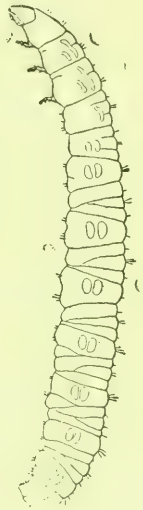

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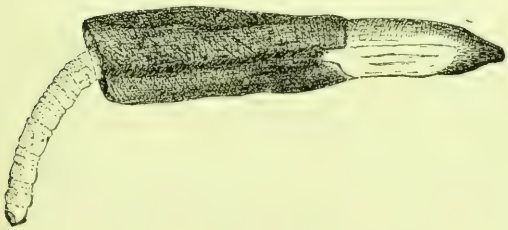

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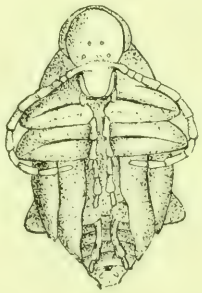

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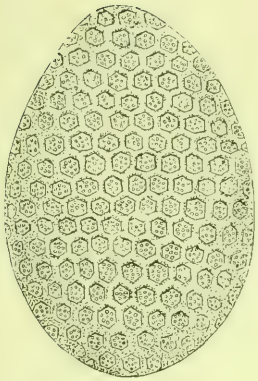

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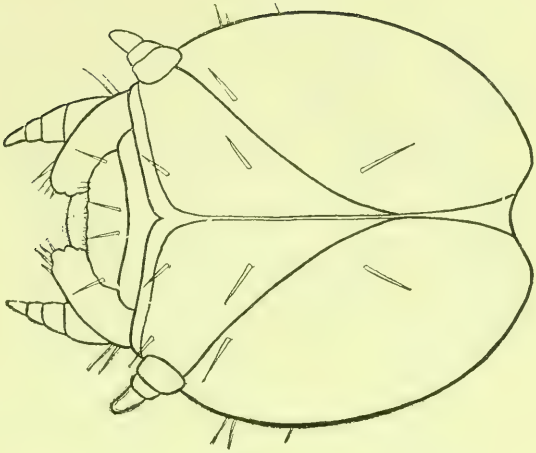

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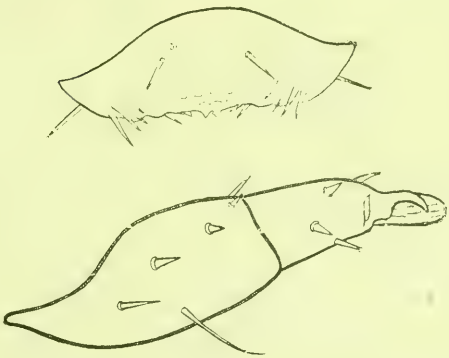

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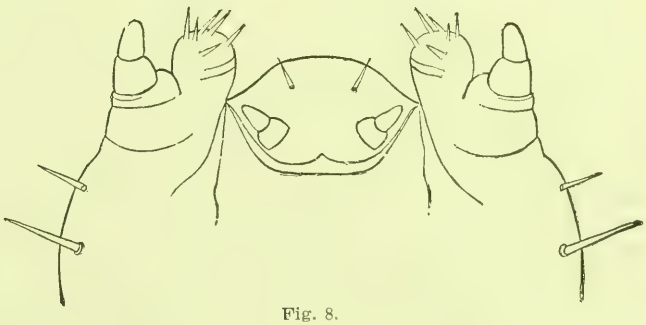

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