





University of Illinois  
Library at  
Urbana-Champaign  
ACES

## UNIVERSITY LIBRARY

### UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

The person charging this material is responsible for its renewal or return to the library on or before the due date. The minimum fee for a lost item is **\$125.00**, **\$300.00** for bound journals.

Theft, mutilation, and underlining of books are reasons for disciplinary action and may result in dismissal from the University. *Please note: self-stick notes may result in torn pages and lift some inks.*

Renew via the Telephone Center at 217-333-8400, 846-262-1510 (toll-free) or [circlib@uiuc.edu](mailto:circlib@uiuc.edu).

Renew online by choosing the **My Account** option at: <http://www.library.uiuc.edu/catalog/>

---

---







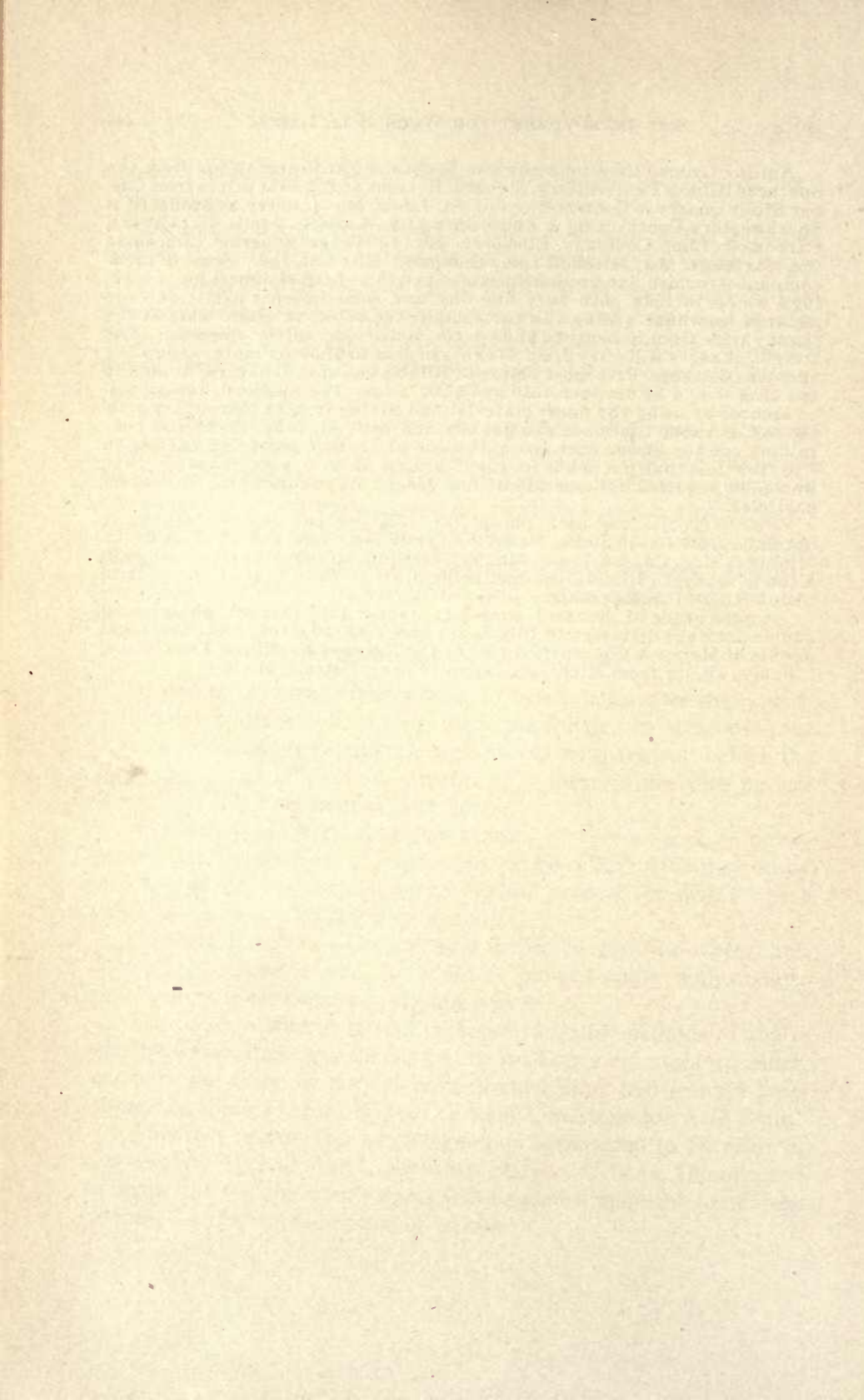












UNIVERSITY OF ILLINOIS  
Agricultural Experiment Station

---

BULLETIN NO. 116

---

ON THE LIFE HISTORY, HABITS,  
AND ECONOMIC RELATIONS OF THE WHITE-  
GRUBS AND MAY-BEETLES

---

By S. A. FORBES  
STATE ENTOMOLOGIST



URBANA, ILLINOIS, AUGUST, 1907

## CONTENTS OF BULLETIN NO. 116.

Introduction: Subject a difficult and complicated one .....	447
The economic species.....	448
Life histories of the injurious species.....	449
<i>Lachnosterna</i> at lights and on trees in comparison.....	451
Variation of numbers in different localities and years .....	452
Food and feeding habits of the species .....	454
Results of feeding experiments with May-beetles ( <i>Lach-</i> <i>nosterna</i> ) .....	455
Comparative collections of <i>Lachnosterna</i> from food plants, Urbana, 1906.....	456
Movements of migration and dispersal .....	457
Habits of reproduction .....	462
Captures of <i>Lachnosterna</i> at light-traps, open fields, Urbana, 1906 .....	463
Collections of <i>Lachnosterna</i> from trees, Urbana 1906.....	464
Extract from breeding cage report.....	465
Relations to weather.....	466
Modes and places of hibernation.....	467
Principal enemies .....	468
Swine .....	468
Crows and blackbirds .....	468
The common grub wasp ( <i>Tiphia</i> ).....	469
Miscellaneous insect enemies.....	472
Relation to soil and subsoil.....	476
Relation to agricultural management.....	477
Injuries to crops.....	477
Prevention and remedy.....	478

## ON THE LIFE HISTORY, HABITS, AND ECONOMIC RELATIONS OF THE WHITE-GRUBS AND MAY-BEETLES (*LACHNOSTERNA*).

The insects generally known as white-grubs are the young, or larvæ, of the large brown beetles commonly called "June-bugs" or May-beetles. For a practical knowledge of these destructive insects it is necessary that we should know the various species of them which do serious injury to agricultural and to horticultural crops; the life histories of all these species; their relative numbers in different parts of the state in different years and in different periods of years; their food, both as grubs and as adult beetles, including their common preferences where several kinds of food are available to them; their significant habits, especially those of reproduction; their relations to variety of weather and to seasonal change; their modes, times, and places of hibernation; the range of their daily movements and of their movements of migration and dispersal; their enemies, their diseases—especially those of a contagious character, and the other natural checks on their multiplication; their relation to varieties of soil, to its physical condition, its moisture, and its exposure to the sun; their relation to varieties of the subsoil also; the effects on their continuance and increase, of various agricultural operations and kinds of farm management; and their own effects, under varying conditions, on the several kinds of crops subject to injury by them. Finally, the whole field of preventive and remedial measures of a more or less artificial character must be thoroughly explored, including the results of practical experiments on the scale of actual farm management.

The subject is made especially difficult and complicated by several facts and circumstances. There are many species of these insects recognizable in the beetle stage but seemingly not distinguishable as larvæ; hence one frequently can not tell what kind of grub he is dealing with until he has reared specimens to the adult. The life history of these insects has a prolonged cycle, probably of three years, but just how many is not definitely known, and life histories can be completed only by keeping specimens alive, under more or less artificial conditions, for this entire time. The various species differ sufficiently in certain parts of their life histories to make it necessary to follow each out separately; and it is not impossible that important differences may be found due to differences in lati-

tude and climate, between northern and southern Illinois; hence each species must be studied in different parts of the state. The most important species—that is the most abundant ones—are not the same in all parts of Illinois, and the relative importance of the various species must be made out for each region separately. The unexplained sudden disappearance, several times noticed by us, of nearly the whole grub population of badly infested fields before their transformation to the pupa, suggests the occurrence among these insects of contagious diseases—a supposition borne out by several field and insectary observations; and the whole subject of their bacterial and other fungus parasites consequently invites attention. The enormous effect of the rapid multiplication, under favorable conditions, of certain insect parasites—a hymenopterous enemy, *Tiphia inornata*, especially—requires a critical and complete study of the life history of these parasitic insects also, especially as there is some probability that we shall be able to increase their efficiency by artificial measures.

No one has heretofore undertaken to work out to a finish this difficult but highly important economic problem, and our present knowledge of the white-grubs is a patchwork of fragments, contributed by a considerable number of observers working on various species and in different parts of the country. The nearest approach thus far made to a continuous investigation of the subject was carried on in this office in the years of 1886–1890, and its results were published in 1891 in Volume III. of "Insect Life."\*

They were also incorporated, with some later studies, in the Eighteenth Report of the Illinois State Entomologist, printed in 1894. In the year 1906 I finally began what I now hope may prove to be a steady and comprehensive study of this problem for the state of Illinois; and I have now to report some of the first results of this work, which I have incorporated, however, with other data and conclusions in a way to give us a fairly full synopsis of the present state of our knowledge, and a clear view, consequently, of its deficiencies.

#### THE ECONOMIC SPECIES.

The kinds of white-grubs common enough in Illinois to attract attention because of their injuries, belong, so far as we now know, to nine species, although it is likely that this list would be longer if the injurious grubs of southern Illinois were as well known to us as those of the central part of the state. Besides these nine injurious

\*"On the Life History of the White-grubs." By S. A. Forbes. Insect Life, Vol. III., No. 5, pp. 239-245.

grubs, there are three other very abundant kinds which resemble closely the injurious species, although they are themselves harmless in the grub stage.

Eight of the species known to be injurious belong to the genus *Lachnosterna* and one to the genus *Cyclocephala*. Of the abundant but harmless grubs, one, frequently called the muck-worm because it lives in stable manure, is known to science as *Ligyris relictus*; another, called the carrot-beetle in the adult stage, is *L. gibbosa*; and the third is the larva of the green June-bug of southern Illinois and of the Southern States generally, known in the beetle stage as *Allo-rhina nitida*. All the last three species are injurious as beetles, but only one of them, the larva of the carrot-beetle, is at all injurious as a grub, and then only slightly or occasionally so. The eight species of *Lachnosterna* known to be injurious in Illinois are *L. fusca*, *rugosa*, *inversa*, *implicita*, *gibbosa*, *tristis*, *ilicis*, and *hirticula*; and the injurious *Cyclocephala* is *C. immaculata*.

*Life Histories of the Injurious Species.*—The life histories of the white-grubs of the genus *Lachnosterna* are very imperfectly known, especially as to the length of time required for the growth and development of a complete generation. The literature of the subject records, in fact, but a single case in which a *Lachnosterna* has been reared from the egg to the adult. An egg of *L. arcuata* laid in Washington about June 8, 1893, hatched in approximately eleven days, and changed to the pupa August 8, 1895, and to the beetle twenty-three days later.\* As this beetle would doubtless have hibernated in the earth to emerge the following spring and lay its eggs in June, the entire period from the egg to the egg again was three years. This is the length of the life cycle which has commonly been inferred, from circumstantial evidence, for our species of *Lachnosterna* generally. It is worthy of note, however, that *Melolontha vulgaris*, the European white-grub nearest in classification and habits to our American species, has been found, according to Xavier Raspail, to have, in France, a period of three or four years—the shorter period if the years are moist and the longer one if they are dry.† In Germany, on the other hand, this species has a four-year period at the north and a three-year period at the south, with various occasional exceptions and irregularities of appearance; and a related species, *M. hippocastani*, has a five-year period in north Germany. Our American species of *Lachnosterna* will probably be found to present similar variations of life history.

\*"Biologic Notes on the May-beetle *Lachnosterna arcuata* Sm." By F. H. Chittenden. Bull. 19, N. S., Div. Ent., U. S. Dept. Agr., p. 77.

†Bull. de la Soc. Zool. de France, 1891, p. 271; Mém. de la Soc. Zool. de France, 1893, T. VI., p. 202.

Whatever the length of life in the grub stage, all our most abundant species of *Lachnosterna* begin to pupate in June or July in central Illinois, and begin to change to the beetle in August or September, remaining, with rare or doubtful individual exceptions, under ground in this stage until the following March, April, or May. They then emerge from their winter quarters, feed on the leaves of various trees, and pair and lay their eggs in the earth in June and July. An exception should perhaps be made, provisionally, of *L. tristis*, concerning which my records are unusually imperfect, agreeing, so far as they go, with those of the other species of our list, but stopping short before the middle of June. That is, we have an abundance of the beetles collected from the latter part of March through April and May and into early June, most frequently, however, in May, but have no collections in any stage at any date later than June 5. Four of our lots of *tristis*, collected in March and April, were beetles taken from the earth, which must have transformed the preceding summer or fall.

Pupæ of the above species have been taken by us from their underground cells only in June, July, August, and September, and the adult beetles have been found under ground in the cells where they originated, in August, September, October, and November, and again in April and early May. Adults of various species have been seen pairing in May, and in one case in June, and eggs of seven of these species—*tristis* being omitted—have been secured in June and July, much the greater part of them in the former month. So far as my rather scanty records go, the eggs may be expected to hatch from ten days to four weeks from the time of deposit. My dates for the hatching of eggs of known species are, for *inversa*, June 23 and July 11; for *fusca*, June 27; for *implicita*, July 16, 21, and 24, and August 7; and for *hirticula*, July 7.

From this it will appear that white-grubs found in the earth beyond the middle of September will not change to the beetle that year, but, barring destruction by parasites and other fatal accidents, may be expected to pass the winter as grubs and to continue in that stage at least until the following June. This is a point of special economic interest, since the owner of infested fields needs to know whether the grubs in the ground during the latter part of the season will continue there in dangerous numbers during the following spring, or whether he may expect relief from their injuries by reason of their change to the beetle.

The data of my collections, when taken in the aggregate for several years, give little indication of any fixed order of succession

in the first appearance of the different species of *Lachnosterna* in spring. *Inversa*, *fusca*, *rugosa*, *hirticula*, and *tristis* have all been taken by us in the later days of March, and *gibbosa* on April 6. *Implicita* and *ilicis* have made their first appearances about a month later than the average, but, although *implicita* is sometimes excessively abundant, these two species have been much less frequently taken by us than the others, and the record might have been different if the collections made had been equally numerous. The dates of last occurrence are also nearly the same for these species, and their periods of greatest abundance do not vary greatly.

*Fusca*, however, commonly appears in large numbers at electric lights about a week earlier than the other species, and *gibbosa* is about as much later than the others—a fortnight later than *fusca*. Our records of egg-laying are substantially the same for all the seven species covered by them. So far, consequently, as the mere period of adult activity is concerned, these insects are virtually one species, and we must look to other facts and conditions for any specific distinctions of habit or agricultural relation.

I find that the data of the relative abundance and dates of emergence of the various species derived from electric-light collections disagree widely with the data of collections made from the food plants of the beetles at the same time. Apparently some of the species are more strongly attracted to lights than others. In 1891, and again in 1906, collections were made at Urbana from trees and from lights during the greater part of the active period of the May-beetles, with the results shown in the following table.

LACHNOSTERNA AT LIGHTS AND ON TREES, IN COMPARISON. URBANA.

	1891		1906	
	Lights	Trees	Lights	Trees
No. Specimens .....	1874	836	142	3484
<i>L. gibbosa</i> .....	.02	.02	.00	.03
<i>L. inversa</i> .....	.76	.32	.54	.00
<i>L. dubia</i> .....	.00	.00	.02	.00
<i>L. fusca</i> .....	.05	.23	.00	.01
<i>L. rugosa</i> .....	.00	.00	.24	.06
<i>L. implicita</i> .....	.00	.00	.15	.72
<i>L. hirticula</i> .....	.10	.42	.03	.07
<i>L. ilicis</i> .....	.00	.00	.02	.10
<i>L. tristis</i> .....	.07	.00	.00	.01

In 1891, when 1,874 specimens were taken from lights and 836 from trees, the dominant species at lights was *inversa* (76 per cent.), *hirticula*, *tristis*, and *fusca* following with ratios of 10 per cent., 7 per cent., and 5 per cent. respectively. The dominant species from trees, on the other hand, were *hirticula* (42 per cent.), *inversa* (32 per cent.), and *fusca* (23 per cent.), the only other species being *gibbosa* (2 per cent.). The results for 1906, when 142 specimens were taken at lights and 3,484 at trees, were equally discordant. The leading species at lights this year was *inversa* (54 per cent.), *rugosa* and *implicita* following with 24 per cent. and 15 per cent. respectively; while the leading species in trees was *implicita* (72 per cent.), followed by *ilicis* and *rugosa*, 10 per cent. and 6 per cent. respectively.

*Variation of Numbers in Different Localities and Years.*—The numbers of the several species vary greatly from year to year in the same locality, and in different localities during the same season. It consequently happens that the dominant species in a locality may be different in successive years, and that the dominant species in one locality may be different from that in another, within the same year. Collections have not been made on a large enough scale or in sufficiently continuous series to enable us to exhibit these differences in any detail, but the following may serve as illustrations:—

Collections made at a street-lamp in Maywood, near Chicago, by O. S. Westcott,\* on seventeen nights from May 9 to June 14, 1887, contained 798 specimens of *fusca* and 313 of *gibbosa*—*fusca* predominating in a ratio of more than 2½ to 1; and collections made the following year at the same place by the same person, on seventeen nights between June 2 and July 2, gave 73 specimens of *fusca* and 1,836 of *gibbosa*—*gibbosa* now predominating in a ratio of 25 to 1. The difference in the collection period of the two years was due to the difference in the weather of the spring, which was backward and stormy in 1888. If we compare the collections of the same periods for these two years—June 9 to 14 in 1887, and June 9 to 13 in 1888—we have 96 specimens of *fusca* to 82 of *gibbosa* in 1887, and 29 of *fusca* to 1,020 of *gibbosa* in 1888.

A similar comparison may be made between the contents of frequent collections from trees made at Urbana through the whole period of activity of the May-beetles in 1891 and again in 1906—836 specimens in the former year and 3,484 in the latter. (See table on p. 451.) In the collections of 1891 the dominant species were *hirticula* (42 per cent.), *inversa* (32 per cent.), and *fusca* (23 per

\**Entomologica Americana*, Nov., 1888, Vol. IV., p. 155.

cent.), the only other species represented being *gibbosa* (2 per cent.). In 1906, on the other hand, the dominant species was *implicita* (72 per cent.), the remaining species, mentioned in the order of their abundance, being *ilicis* (10 per cent.), *hirticula* (7 per cent.), *rugosa* (6 per cent.), *gibbosa* (3 per cent.), and *fusca* and *tristis* (each 1 per cent.). This latter comparison is vitiated, however, by the fact that the collections were made from different kinds of trees, those of 1891 mainly from butternuts and hickories, and those of 1906 from poplars, willows, elms, and oaks,—another example of the fragmentary and disjointed character of the data now available for a study of this subject.

It so happens that extensive collections of May-beetles were made in 1888 both in Cook county, Ill., by Westcott, and in the District of Columbia by J. B. Smith,\* and a comparison of the relative numbers of the dominant species in these two widely separate localities would be possible by their means if it were not for the fact that Westcott's specimens were all taken at lights and Smith's were obtained from trees and shrubs. As already shown, collections are not comparable when made in these different ways.

Much more nearly equivalent collections were made in 1906 by two assistants of my office, one working at Urbana, in Champaign county, between May 26 and June 23, and the other at Elliott, in Ford county, between May 23 and June 5, the first collecting at lights scattered through fields of grass a total of 142 specimens in ten nights, and the second obtaining at a single light in a large corn field 389 specimens in six nights. At Urbana the dominant species was *inversa* (54 per cent.); at Elliott it was *gibbosa* (71 per cent.). At Urbana *gibbosa* was not taken in these light-collections, and at Elliott *inversa* made but 20 per cent. of all obtained.

A further profitable comparison may be made of data contributed by Prof. M. V. Slingerland from the product of light-traps kept in continuous operation at Ithaca, N. Y., during the seasons of 1889 and 1892.† Four hundred and thirty-eight specimens of *Lachnosterna* were taken during the first of these years, and 273 during the second. *Fusca* was much the most abundant species in both years, making 76 per cent. of the product of the traps in 1889, and 90 per cent. in 1892. *Dubia* was next to *fusca* in 1889 (15 per cent.); and this species and *ilicis*, each 4 per cent., were likewise next to *fusca* in 1892. The similarity of the records for these two years is possibly due to a three-year period of the dominant species,

\*Proc. U. S. National Museum, 1888, Vol. II., p. 488.

†Canadian Entomologist, March, 1893, Vol. XXV., p. 81.

*fusca*, but, unfortunately, as no comparable collections were made in the intermediate years, the evidence is not complete. Westcott's Maywood collections, already referred to, on the other hand, hint at a two-year period for *L. gibbosa*. This species predominated over *fusca* in 1886, as shown by records made on five nights, from the 26th of May to the 1st of June, in a ratio of 3.6 to 1, and again in 1888, in a ratio, as already stated, of 25 to 1, but was much less abundant than *fusca* in the intermediate year.

#### FOOD AND FEEDING HABITS OF THE SPECIES.

The white-grubs and the May-beetles, larvæ and adults of the same insect species, differ totally in their food and feeding habits, the grubs eating the roots of various kinds of plants and the beetles eating the leaves of trees and shrubs. In the absence of any means of distinguishing the species one from another in the grub stage, no evidence has been obtained of any special choice, by any of the species in this stage, among the various elements of the food of grubs in general. So far as known, all of them may take, with equal relish, all kinds of food which any one of them will eat. If the different species of grubs do indeed make definite and varied choice of food, the fact may be ascertained by breeding to the adult, for determination, pupæ and full-grown grubs obtained in various situations near or among different kinds of food plants; but there is at present too little recorded information on this point to permit us to infer any difference whatever in the choices of our more abundant species.

The species of beetles themselves, on the other hand, differ considerably, although not sharply and completely, as a rule, in their choices of food where several kinds are equally accessible to them. Evidence of these preferences has been obtained by us in three different ways: (1) by experimental feedings with beetles kept in confinement; (2) by parallel collections of beetles made from different kinds of food plants; and (3) by the dissection of specimens of various species, made to determine, by an examination of the contents of their alimentary canals, what kind of vegetation they have been feeding on. The first method shows what the beetles may eat under stress of hunger, or perhaps with starvation as a penalty for refusing what is offered them; the second shows what the different species actually choose when a choice is open to them; and the third enables us to determine with certainty what the beetles have eaten where direct observation is impracticable. The results of our feeding experiments have been so different from those ob-

tained by making collections from the food plants at night that they evidently have comparatively little real value. For example, leaves of Osage orange were offered, without other food, to *fusca*, *inversa*, *implicita*, *ilicis*, *rugosa*, and *tristis*. They were eaten moderately by *implicita* and *rugosa*, and slightly by *fusca*, *inversa*, and *ilicis*, but were constantly refused by *tristis*. On the other hand, extensive observations made in the field have given us no instance of actual feeding on this plant in the open air by any of our species, although it is everywhere in common use as a hedge plant.

The following table shows the different kinds of food offered to *Lachnosterna* beetles in breeding-cages in 1904 and 1905, and data as to the readiness with which each sort of leaf was eaten when but one kind of food was placed in the cage.

RESULTS OF FEEDING EXPERIMENTS WITH  
MAY-BEETLES (*LACHNOSTERNA*).

	Gibbosa	Inversa	Fusca	Rugosa	Implicita	Hirticula	Ilicis	Tristis	Average
Carolina Poplar, ( <i>Populus monilifera</i> )..	1	3	3	3	3	3	3	2	2.62
Willow.....	-	3	3	2	3	-	3	1	2.50
Oak.....	-	2	3	2	2	-	3	3	2.50
Elm.....	3	2	3	2	2	3	3	3	2.62
Apple.....	1	2	3	3	3	3	3	1	2.37
Box-elder.....	1	2	3	1	3	2	2	0	1.75
Plum.....	1	0	3	0	3	3	2	0	1.50
Peach.....	1	0	1	0	1	1	1	0	.71
White Ash.....	1	2	1	1	3	2	1	0	1.57
Tulip tree, ( <i>Liriodendron</i> )..	0	1	1	0	1	1	0	0	.57
Hedge.....	-	1	1	2	2	-	1	0	1.40
Lilac.....	-	1	2	-	1	-	-	-	1.33
Cherry.....	-	1	1	-	1	-	-	-	1.
Corn.....	-	2	2	2	2	-	1	0	1.50
Grass.....	-	2	2	2	1	-	1	0	1.60

1=slightly eaten, 2=moderately eaten, 3= freely eaten, 0 = refused to eat, - = not offered.

An attempt was also made to test the general food preferences of each species by offering several different kinds of food in the cage at once. Under these conditions, *L. fusca*, *inversa*, and *implicita* ate most freely of Carolina poplar and willow; *L. ilicis* and *hirticula* ate most freely of oak, but freely, also, of Carolina poplar and elm; and *L. tristis* ate only oak when that was present. *L. rugosa* selected poplar and elm, and *L. gibbosa*, oak and elm.

In 1906, at Urbana, extensive collections were made with equal care from each of the four different kinds of trees which May-beetles

seemed to prefer as food. The beetles were gathered by shaking them from the trees at night and picking up those which fell to the ground.

The following table gives the results of these collections made at Urbana from Carolina poplar (cottonwood), willow, oak, and elm, on twenty-six different nights between May 14 and June 28, 1906.

COMPARATIVE COLLECTIONS OF *LACHNOSTERNA* FROM FOOD PLANTS. URBANA, 1906.

Species	Poplar		Willow		Oak		Elm	
	No.	Per cent.	No.	Per cent.	No.	Per cent.	No.	Per cent.
<i>L. implicita</i> .....	1456	.58	855	.34	35	.01	171	.07
<i>L. rugosa</i> .....	169	.85					31	.15
<i>L. gibbosa</i> .....	73	.72	7	.07	18	.17	4	.04
<i>L. fusca</i> .....	39	.85	6	.13	1	.02		
<i>L. hirticula</i> .....	10	.04	6	.03	209	.86	17	.07
<i>L. inversa</i> .....	5		4		2			
<i>L. ilicis</i> .....	2		1		317	.93	21	.07
<i>L. tristis</i> .....					25	1.00		
Total .....	1754		879		607		244	
Per cent. on each tree	.50		.25		.18		.07	

From the foregoing table it will be seen that poplar (cottonwood) was the favorite food, 50 per cent. of the specimens being taken from this tree, and that willow follows next with 25 per cent., oak with 18 per cent., and elm with 7 per cent., poplar and willow together yielding 75 per cent. of the insects. Apple leaves were often eaten freely, but no trees were suitably situated for experimental field-collecting, and hence no comparative records were made which included apple. Apple orchards in the southern part of the state have been reported by assistants as sometimes almost stripped of their leaves. This was notably so in Jackson county in 1904. The pecan- and persimmon-trees of southern Illinois often suffer severely by having their foliage eaten by the beetles.

Certain species of the beetles exhibited marked preferences in the choice of food. *L. hirticula*, *ilicis*, and *tristis* had a special liking for oak, the last named being taken from no other tree. *L. implicita*, *gibbosa*, *fusca*, and *rugosa* were most abundant on poplar, *rugosa* seeming to avoid oak and willow. Not enough specimens of *L. inversa* were taken to warrant conclusions concerning its preferences.

All of the May-beetles taken at lights in the open fields at night in 1906 at Elliott, Ford county, and at Urbana, Champaign county, were carefully dissected and the contents of the alimentary canals

were examined microscopically. Nearly 40 per cent. of all the May-beetles taken had eaten nothing. This percentage was much the highest for specimens taken early in the season, 62 per cent., for example, for those caught before June 6. Probably most of these empty beetles had just come from the earth and had not yet begun to feed. Nearly all of those captured in the fields at lights which had taken food had eaten the leaves of trees, as was shown by the presence in their intestines of small pieces of leaves exhibiting the netted vein-structure and other characteristics of the foliage of the common trees of the vicinity. Only six specimens of about six hundred dissected, had eaten the leaves of young corn. Five of these specimens belonged to *L. rugosa* and the sixth to *L. inversa*. Four additional specimens of *L. rugosa* were taken at Urbana directly from corn while feeding on it. As these ten beetles represent only about  $1\frac{3}{4}$  per cent. of the whole number examined, the facts indicated by them are of little economic significance except as going to show that May-beetles, of these two species at least, emerging in corn fields at a distance from trees too great to enable them to find their more ordinary food, may nevertheless subsist on leaves of corn. The same facts have been shown with reference to blue-grass, and it seems probable that, in the absence of other food, beetles may be able to live on the blue-grass of our pastures. With their actual powers of flight and their strong disposition to assemble in trees at night, not merely to feed but likewise to copulate, their ability to feed on grass and corn seems to signify but little. Corn, oats, wheat, clover, and grass fields were repeatedly examined in both Ford and Champaign counties with a view to the detection of any injury which might have been caused by these beetles. Occasionally at Urbana, and more frequently at Elliott, corn plants were found which, though uninjured in the evening, were partially eaten by the next morning, and, as already mentioned, four May-beetles (*L. rugosa*) were taken directly from the plants while feeding on them. Dissection of these specimens showed beyond a doubt that they had eaten the leaves of corn. Two hundred and sixty-two specimens of this species were taken in 1906, 169 of them from poplar, 31 from elm, and 62 from other situations, and only 9 of these had eaten corn, as shown by dissection.

#### MOVEMENTS OF MIGRATION AND DISPERSAL.

As the larvæ known as white-grubs never appear above ground except by accident, and as they are sluggish insects, incapable of rapid locomotion under ground, each is practically confined, so far as

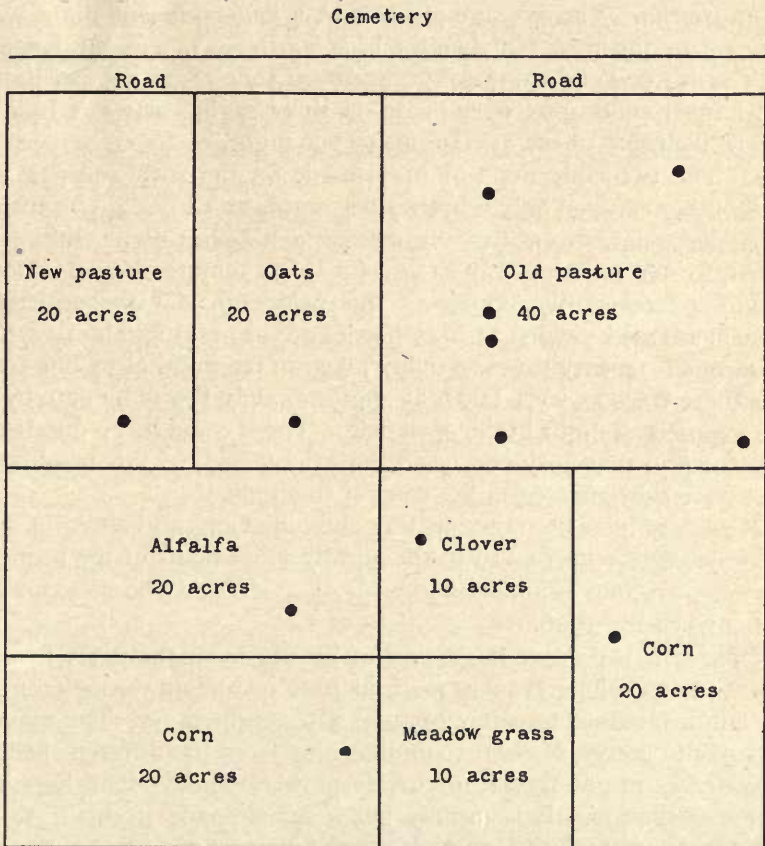
we now know, to the immediate neighborhood of its origin. The grubs change location slowly as their food is exhausted, and injured spots in an infested lawn or grain field will gradually enlarge in all directions, the white-grubs moving outwards into fresh pasturage as the infested vegetation dies from the destruction of its roots. The grubs also sometimes gather in from all directions towards a particularly attractive patch of their food plants; but there is nothing to show that they move from place to place by definite underground migration, or that they cover any considerable distance, such as to take them from one field to another, during the whole period of their active larval life.

The May-beetles also seem local in their distribution. Although very good fliers, they use their wings only to carry them from their place of origin to the trees and shrubs on which they feed and in which they copulate at night, and from these to their daytime hiding places, never moving in swarms, so far as known, or migrating over considerable distances. There is, in short, no evidence of any migration movement of this insect in any stage or under any circumstances, but each locality or considerable neighborhood probably breeds and maintains its own white-grub population year after year. Their most marked movements are the evening flight of the beetles to their food plants, and the morning dispersal from trees to the fields in which the females lay their eggs.

The discovery that certain species, at least, of the May-beetles may feed, and sometimes do feed to a small extent, on corn and grass, and the consequent conclusion that they may not need convenient access to trees for food, raises the important question whether some of these insects, and possibly certain species of them, may not live continuously in the fields, feeding on the crop plants there and laying their eggs in the very places where they themselves originated. If this is the case, collections made in the fields at maximum distances from trees should give us proof of the fact; and I consequently arranged, in the spring of 1906, for the systematic use of lantern traps distributed over an open area of one hundred and sixty acres on the main farm of the University of Illinois, with trees of various sorts in a cemetery along one side of this tract, and no others within less than half a mile from it in any direction. These traps were ordinary kerosene lanterns, with glass globes, placed over large tin trays, each containing kerosene to a depth of about half an inch. These trays were not large enough to secure all the beetles which flew against the lantern globes, but they nevertheless gave satisfactory samples of the beetles flying in the field.

The accompanying plat shows the crops of this tract and the distribution of the lantern traps in each. Forty acres were in corn, seventy acres in grass, thirty acres in clover and alfalfa, and twenty acres in oats. Two of the lanterns were in corn fields, two in clover

Plat showing Distribution of Light-traps.



and alfalfa, one in oats, and seven in meadows and pastures of grass. None were nearer than a quarter of a mile to trees on whose leaves the May-beetles were feeding at the time, nor farther from them than three quarters. To avoid attracting beetles from these trees, each lantern was provided with a tin shade by which its light was hidden on the side towards the trees nearest to it. These lights were

kept burning all night for fourteen nights between May 20 and June 23 inclusive, and were visited at frequent intervals during each of these nights. The weather was so cold during four nights that the May-beetles were not flying, and no account is taken of these nights in this discussion.

The total product of the twelve traps, thus maintained for ten entire nights, was 142 specimens of May-beetles of the genus *Lachnosterna* and 25 specimens of *Cyclocephala*. No account is taken of the latter because their food habits are very different from those of *Lachnosterna*. The average product of a lantern in one night was only 1.2 of the true May-beetles (*Lachnosterna*), and the largest catch of any one night was 40 specimens on June 18, or  $3\frac{1}{3}$  per light. The largest collections were made on three nights between June 9 and 18 inclusive, these averaging 33 per night, or about 3 to each trap. The two collections of May, made on the 26th and 31st of the month, averaged only 6 beetles per night, or 1 to each two traps.

A single light-trap of the same kind, exposed at night without a screen, for ten minutes May 21 and for thirty minutes May 23, close to willow-trees at the border of this field and near the cemetery above mentioned, yielded 11 May-beetles on the first night and 127 on the second—seventy times as many taken in ten minutes by one trap near these trees as were taken at approximately the same date by a trap exposed all night in the open field. There could be no question, consequently, that very nearly all the May-beetles of this neighborhood were concentrated in the trees at this time.

New data have been obtained by our collections and observations of recent years with regard to the nightly movements of the beetles, and these are thus summarized by Mr. J. A. West, who had charge of this work for 1906.

“There is a regular migration of beetles from the fields to the trees in the evening. It takes place in June just about dusk—from a few minutes before to a few minutes after eight p. m. The movement of the beetles is almost simultaneous from the different fields. An observer in one field can scarcely move to another and hope to see the migration. It is usually but a few seconds from the time its beginning is noticed in one place until a companion observer will report its commencement perhaps a quarter of a mile away. Beetles were found rising from the ground in fields of oats, in pasture, old meadow, clover, alfalfa, and in corn. They were most abundant from old pasture and least numerous from alfalfa and corn. They were observed coming from the ground in considerable numbers in oats and clover fields. The following species are mentioned in the order

of their abundance: *L. implicita*, *hirticula*, *ilicis*, and *rugosa*. The evening migration occupies not over fifteen or twenty minutes, and in every instance it seemed completed by 8:20 p. m.

"While the evening migration seemed to result in a complete abandonment of the fields by the beetles, yet the observer may now and then hear a beetle whirr past in the darkness at any hour of the night, and light-traps so placed in the open field as not to attract those from the trees will take specimens in small numbers throughout the night. The beetles distribute themselves regularly over large areas when they leave the feeding grounds in the morning. The following is a record of specimens taken in the fields a quarter of a mile or more from trees, and apparently coming directly from them: *L. implicita*, 11, *L. hirticula*, 5, *L. rugosa*, 31,—total, 47.

All these specimens were taken by hand, the light-traps not seeming to attract them.

"The morning movement is very early. It varies considerably, according to the clearness of the sky. It is so related to the awakening of the birds that it seems as if the first note of the dick-cissel, or other early bird, is the signal for the beetles to fly to their hiding places in the ground. On only two mornings were beetles taken in June after four o'clock. June 18, a dark cloudy morning, a pair of *L. rugosa* were taken at 4:25 a. m. while in copulation on a stem of grass. Ordinarily the movement did not last over fifteen minutes and it very rarely continued for twenty minutes. On the morning of June 7, however, a strong wind was blowing thirteen to fourteen miles an hour from the south. This greatly retarded the flight of the beetles which had been feeding on trees to the north of the fields, and on this morning it began at 3:35 o'clock and continued until 4:10, when the last beetle seen was taken in flight.

"The following notes show the variation in the time of the morning movement of the beetles according to the brightness of the morning and its relation to the awakening of the birds:—

"Morning of June 10, moonlight and very bright. Dick-cissel heard at 3:08; meadow-lark at 3:15; kingbird at 3:20; the following, in order given, from 3:25–3:35,—prairie-chicken, brown thrasher, quail, robin, and horned lark. On this morning the beetle-movement began at 3:18 and lasted until 3:30.

"Morning of June 18, very cloudy and dark. No bird was heard until 3:40, and the movement of the beetles began at 3:45 and was complete in ten minutes. About 3:30 a.m. was the average time for the first bird note, and 3:35–3:45 the regulation time for the morning movement of the beetles."

These data are of special importance as showing the time of night when the beetles are accessible in the trees on which they feed—a subject important to a discussion of measures of prevention and remedy.

#### HABITS OF REPRODUCTION.

With respect to the reproduction of May-beetles, we need to know at what time of day, in what situations, and especially how soon after emerging, the sexes pair, and when, where, how soon, and in what numbers the females deposit their eggs. Our definite information as to the pairing of the beetles is not abundant, but is sufficient to show that they pair at night on their food plants. The males are much more active than the females,—a fact illustrated by their greater abundance at lights in fields at a distance from trees. In the product of the light-traps used in 1906, as described in this paper under "Movements of Migration and Dispersal," pp. 458-460), the males outnumbered the females about 4 to 1, while in collections made at the same time from trees the number of males was only 39 per cent. of the total number taken. Similar data were given in my Seventh Report.\* It will be seen that it does not follow from the greater number of females taken on the food plants that females are actually more numerous than males, but only that the latter are more widely scattered at night, and more generally on the wing.

It has been noticed by some of the office assistants, and particularly by Mr. J. A. West, that May-beetles are sometimes very unequally numerous in neighboring trees of the same kind, one tree containing a buzzing multitude while there are comparatively few on another tree of the same species close by. I have myself once seen a large tree so full of May-beetles in the evening that the noise of their movements was like that of a huge swarm of bees, although the condition of the leaves the following day showed that they had not resorted to this tree for food. Their assemblage in tree-tops is evidently in part for breeding purposes, and not wholly for food.

About fifty pairs of these beetles have been taken by us *in copula*, all but three of them from trees at night. In one case a pair of *L. rugosa* was captured at night by Mr. West from a grass-blade in a pasture, and two pairs of *L. inversa* have been seen copulating in a breeding-cage, also at night. These two pairs had been taken from earthen cells in the ground October 5, 1905, and transferred to the insectary, where they at once went into the earth, first appearing above ground on the 1st of the following May. They began to feed

\*Eighteenth Rep. State Ent. Ill., p. 117.

on elm leaves May 17, and paired at midnight May 25. Our observed dates of copulation all fall within the month of May.

The several species of May-beetles may continue active, in a normal season, from one to two months, reckoning this period from the first appearance of the earliest specimens to emerge to the final disappearance of the beetles for the year. In our work of 1906 the dates of first and last appearance of the more abundant species in collections made regularly near Urbana, at night, from willow, oak, elm, and cottonwood (Carolina poplar), were as follows: *L. implicita*, May 13\* and June 28 (46 days); *L. ilicis*, May 21 and June 23 (33 days); and *L. hirticula*, May 23 and June 18 (26 days). In New York, on the other hand, Professor Slingerland some years ago obtained *L. fusca* in his light-traps from May 6 to July 5, 1889, and from May 26 to June 28, 1892; *L. dubia* from May 8 to July 5, and from May 30 to June 22; and *L. ilicis* from June 1 to July 30.

CAPTURES OF LACHNOSTERNA AT LIGHT-TRAPS, OPEN  
FIELDS, URBANA, 1906.

	Inversa	Implicita	Dubia	Hirticula	Rugosa	Ilicis	Males	Females
May 26.....	4						4	0
May 31.....	6	1	1				5	3
June 2.....	8	3					5	6
June 4.....		6	1	3	4		8	6
June 6.....	2				3		4	1
June 9.....	18	1	1	2	7	2	25	6
June 15.....	22				5		24	3
June 18.....	16	9			15		40	0
June 20.....						1	0	1
June 23.....		1					0	1
Total .....	76	21	3	5	34	3	115	27

Collections made only from the food plants commonly show a more rapid diminution and earlier disappearance of males than of females. We may take as an example 2517 specimens of *L. implicita* collected from trees on twenty-six different nights between May 14 and June 28, 1906. Thirty-nine per cent. of the specimens taken during the first thirteen days were males and only 15 per cent. of those taken during the last thirteen days. On the other hand, in collections made during the same period by means of lantern traps

\*The spring was unusually late this year, and May-beetles did not appear on the wing until May 13.

scattered through the open fields, at a distance from the food plants of the beetles, the ratio of males to females was precisely twice as great during the last half of the period as during the first. Slingerland's data, already referred to, do not support the supposition of a relatively early death of the males. It seems likely, consequently, that females may require repeated fertilization, especially as the eggs are laid gradually, a few at a time.

## COLLECTIONS OF LACHNOSTERNA FROM TREES, URBANA, 1906.

	Implicita		Fusca		Gibbosa		Rugosa		Ilicis		Hirticula		Inversa		Tristis	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
May 14.....	59	90	3	1												
May 15.....	74	95	8	2												
May 16.....	27	52	5	3												
May 17.....	109	200	1													
May 21.....	24	23							1							
May 22.....	19	25			10				2	1						
May 23.....	193	239	7	7	8	2			3		14	5	2	1		
May 24.....	25	26			2				5	1	2	2				
May 25.....	31	35														
May 26.....	104	135	5	4	4	1			13	9	3	1			1	1
May 30.....	4	25							6	5	1			2		
May 31.....	50	108			17	2			28	24	45	21			6	5
June 1.....	24	125							4	3	12	6			3	1
June 2.....	45	129							8	8	12	4				
June 4.....	14	96			3				19	14	5	16			3	1
June 5.....	6	54					1		24	24	12	20			1	3
June 6.....	4	36			15	2	3	8	12	3	6	3				
June 7.....	1	9			20	16	4	17	12	5	7	7				
June 9.....	5	41					14	16	15	8	6	4				
June 15.....	4	27					7	13	21	39	8	12				
June 16.....		17					13	17	4	1	1	2				
June 18.....	12	76					13	37	16		2	3	1			
June 21.....		16					7	22	1							
June 22.....		3					3	4	1							
June 25.....							1									
June 28.....		1							1							
Totals																
Males....	834		29		79		66		196		136		3		14	
Females..		1683		17		23		134		145		106		3		11

Our data show about thirty cases of oviposition by seven of our species in our breeding-cages, ranging in date from the 1st of June to the middle of July.\* As the beetles have begun to emerge more than two months earlier, it is likely that they spend some time in feeding before oviposition begins. In the Eighteenth Report of this office it is said (p. 118) that the statement commonly made to the effect that the eggs are laid in a ball of earth is clearly erroneous. This assertion must be corrected in the light of numerous experiments made in my insectary in 1906 with May-beetles of several species, all of which so deposited their eggs in the ground that each was found inclosed within an earthen ball, a half inch in diameter, probably formed by the extrusion with the egg of an adhesive fluid which, upon hardening, held together the particles of earth which it had penetrated. This method of inclosure was so general that eggs were most easily found by sifting the dirt in breeding-cages and breaking open the spherical pellets of earth thus separated. The eggs were laid at depths varying from not more than an inch to five or six inches below the surface, the number for each female varying from 44 for a specimen of *L. inversa* to 67 for *L. implicita*.

The following extract from the breeding-cage report of Mr. J. J. Davis will give additional particulars of interest.

*L. inversa*. June 12, 1906, 1 female beetle in breeding-cage. June 18, the earth examined and 44 eggs found, each in a ball of earth from 3 to 3½ inches below the surface. Eggs of a pure milky color and of an oval shape, measuring 1¼ × 2 mm. By the end of three days they had swollen to a nearly spherical form, now measuring 2 × 2¼ mm. Hatching first observed July 11.

*L. hirticula*. Beetles collected and placed in breeding-cage June 19, 1906. No eggs were found till July 2, but July 9, 6 were found, each in its ball of earth. The freshest eggs were white with a glossy luster. They measured at first from 1½ × 2 mm. to 2 × 2½ mm. Five days later these eggs had swollen to 2 mm. in diameter, and were 2½ to 2¾ mm. in length.

*L. ephelida*. A single egg obtained August 4, 1905, from beetles collected at Carbondale, Ill., July 26, and placed in breeding-cage in insectary July 29. This egg was comparatively small and definitely oval, measuring at first 1⅓ × 2 mm., and later 1¾ × 2 mm.

*L. ilicis*. From beetles collected June 19, 1906, eggs were found in oval balls of earth July 9, none having been present there on the 2d of that month. The eggs were a dull white, quite different from the glossy luster of those of *L. hirticula*. They measured at first

\*A specimen of *L. ephelida*, taken July 20, 1905, at Carbondale, in southern Illinois, laid eggs until August 4.

$1\frac{1}{2} \times 2\frac{1}{2}$  to  $2\frac{3}{4}$  mm., the shorter diameter later enlarging to 2 mm.

*L. crenulata*. From a single female beetle placed in a breeding-cage July 15, 1905, three eggs were obtained three days later, deposited at a depth of about an inch. These eggs were oval, measuring  $1\frac{1}{2}$  to  $2\frac{1}{2}$  mm. They were white when first laid, but changed afterwards to cream color.

*L. fusca*. Eggs were obtained June 22, 1905, from beetles which had been placed in a breeding-cage April 24. One of these eggs hatched on the 27th of June.

*L. implicita*. Adults collected at Elliott, Ill., from cells in the earth, were placed in a breeding-cage in the insectary October 13, 1905. They were first seen out of their winter quarters April 28, 1906. June 12, 1906, 3 females were alive and 6 eggs were found by sifting the dirt. On the 20th of June only 1 beetle remained alive, and this was a female. No more eggs were found up to June 25, but on the 5th of July 42 eggs were sifted out of the dirt, each in its separate ball of earth. These were from  $.5\frac{1}{2}$  to 6 inches below the surface. Those most recently laid, measured  $1\frac{1}{4} \times 2$  to  $2\frac{1}{4}$  mm., while those which were longest deposited measured  $2 \times 2\frac{1}{2}$  mm.

#### RELATIONS TO WEATHER.

The beetles of *Lachnosterna* transform from the pupa in summer and fall, remaining, as a rule, in their underground cells, from 2 or 3 to 5 or 6 inches below the surface, unaffected, so far as we know, by any degree of cold to which they are likely to be subjected in our climate. Their nocturnal movements after they come out of the earth are, however, easily influenced by the weather. During thirty-one nights, commencing May 14 and ending June 28, 1906, these beetles were studied and collected at Urbana by Mr. West. On five of these nights no beetles were seen or caught, although the fields, the lights, and all the best feeding grounds were visited. The records of minimum temperature for these five barren nights, and the rate and direction of the wind, were as follows:

Date	Minimum Temperature	Rate and Direction of Wind (Anemometer Record)
May 19.....	41° F.	N. E., 6 to 8 miles per hour
May 28.....	42° F.	N. E., 4 to 14 miles per hour
May 29.....	38° F.	S. E., 6 to 12 miles per hour
June 11.....	49° F.	N. E., 12 miles, all night
June 12.....	46° F.	N. E., 14 miles, all night

No beetles were taken on any night when the thermometer registered below  $52^{\circ}$ , except May 21, when the temperature was  $62^{\circ}$  at 9 p. m. but fell to  $46^{\circ}$  before morning. A cold rain or high wind kept them confined at night to their day-time hiding places, and they were never abundant on their food plants, or flying freely, unless the minimum temperature was at least  $60^{\circ}$ . They appeared in greatest numbers on warm quiet nights following bright sunny days. The beetles continue feeding during rain if a storm comes up during a night favorable to their movements; and even their flights are not wholly suppressed by moderate rain if the weather is warm.

#### MODES AND PLACES OF HIBERNATION.

Our common white-grubs hibernate, in the latitude of central Illinois, in the two stages of larva and beetle, and in these stages only. In fifty-seven collections, distributed over several years, obtained by following the plow in fall and in spring, not a single pupa of these species has occurred, although recently transformed beetles, still inclosed in their pupal cells, have been collected by the hundred. The pupa of *Lachnosterna* may possibly go through the winter now and then, transforming the following spring, but this is certainly an extraordinary occurrence in our latitude, quite insignificant as a factor in the life history of the species. It is also a very unusual thing for the beetles to come out of the ground in fall. Indeed, those taken from the earth and placed in breeding-cages in either fall or early spring, commonly bury themselves without delay. Now and then a single specimen may be found active in fall, but we have seen but one such case in the course of our several years' work. The beetles are evidently more resistant to cold than the grubs, and do not attempt, as a rule, to escape by going farther into the ground with the approach of winter.

During the summer most of the grubs are near the surface of the soil. A small percentage may be found to a depth of eight or even ten inches, but the average is about three inches. In late fall they begin to go down as a protection against the approaching winter's cold, and may reach a depth of two to two and a half feet. In October and November, 1905, the downward movement of the grubs infesting a field of corn, part of which had been completely destroyed by them, was followed by digging over, on each of five days, several areas each three and a half feet square, and counting the grubs exposed. The following table gives the dates at which this search was made, the average number of grubs found for each square of three and a half feet, the range in depth of the grubs dug out, and the average depth for each date.

Date	Average Grubs per Square	Range in Depth	Average Depth
Oct. 3, 1905....	29.2	Near surface to 8 in.	3.5
Oct. 10, 1905....	22.6	Near surface to 10 in.	3.1
Oct. 23, 1905....	25.3	Near surface to 10 in.	3.1
Oct. 31, 1905....	22.	Near surface to 16 in.	6.4
Nov. 22, 1905....	24.75	Three in. to 23 in.	10.

November 22, the last of the above dates, most of these grubs were from 7 to 14 inches below the surface; but one was found only 3 inches down, seven had stopped at a depth of about 6 inches, and three had gone to 20 to 23 inches below the surface. The ground did not freeze permanently until several days after this date.

The grubs approach the surface in spring when the frost leaves the ground and the soil becomes fit to plow, and one often sees in the bottom of the furrow the tubular burrows made by them in coming up from their winter quarters.

#### PRINCIPAL ENEMIES.

*Swine.*—Pigs are by far the most destructive enemies of white-grubs and of May-beetles. They are extremely fond of these insects, and of all others within their reach which are large enough to attract their attention, and the diligence with which they will tear in pieces the sod of an infested pasture, and the depth to which they will dig in pursuit of grubs in cultivated ground are matters of common observation. They will also search out and destroy the May-beetles in May and June if allowed to range over pastures and meadows where these insects hide by day and to which they resort to lay their eggs. Pigs are consequently our most useful agents for the destruction of these insects—a point which will be more fully discussed in this paper under “Measures of Prevention and Remedy.”

*Crows and Blackbirds.*—Next to pigs the most efficient destroyers of white-grubs among our common larger animals are crows and crow-blackbirds, both of which eat them greedily where they can find them in sufficient numbers to make them an important article of food. Evidence on this point is less positive with respect to crows than concerning blackbirds. Mr. W. B. Burrows, of the U. S. Department of Agriculture, who has studied the food of the common American crow by examining the contents of more than a thousand stomachs, reports that he has found white-grubs in a comparatively small number of these stomachs; but that May-beetles had been eaten by very nearly all the crows taken at a time when these

insects were abundant in the beetle stage, making, indeed, the greater part of the insect food of all the crows collected at that time.

To these well-known facts I have to add two significant items of observation reported to me by my field assistants. One of these, Mr. E. O. G. Kelly, who was engaged during much of the season of 1906 in a field study of injuries by white-grubs, unusually serious that year in central Illinois, tells me that he often saw considerable numbers of crows following after the plow in fall, evidently picking up white-grubs, and that he has also seen flocks of crows alight in a badly infested pasture and tear the sod in pieces in search of the grubs, fighting with each other for their possession when thus exposed. Another assistant, Mr. A. O. Gross, employed last fall in collecting data for a census of the bird life of Illinois, found, in a trip across the state made on foot in September and October, that next to the horned lark, crows were the most abundant birds on plowed ground, averaging seventy-nine per square mile in all the recently plowed fields crossed on that trip. They could have had no other object there than the search for insect food.\*

In a study of the food of blackbirds, made by Mr. F. E. L. Beal for the U. S. Department of Agriculture in 1894, it was found that these birds ate either beetles or grubs in every month from March to October inclusive. In May these insects made more than a sixth, and in June one ninth, of the entire food. Many stomachs were found to be literally crammed with grubs; and in many more, grubs had formed a large part of the previous meal.

*The Common Grub Wasp (Tiphia).*—Much the most important insect enemy of the white-grubs is a wasplike insect belonging to the hymenopterous genus *Tiphia*. It is a slender, jet-black species, usually about two thirds of an inch long, but sometimes smaller, and with wings either clear or more or less deeply tinged with dusky yellow. It enters the ground in search of the grubs, follows them up in their burrows, and lays on the back of each grub a single egg, which hatches in a little over a week into a footless, maggot-like larva. This larva adheres to the surface of the insect, punctures its skin and sucks its blood for a time, but finally eats it up. The *Tiphia* larva then spins, under ground, an oval brown cocoon within which it goes through its transformations, coming out as a winged insect the following summer. The rate of multiplication of the species is not known, but it is certainly sufficient to enable the *Tiphia* virtually to destroy, under favorable circumstances, the entire grub population of a badly infested field.

\*"An Ornithological Cross-section of Illinois in Autumn." By S. A. Forbes. Bull. Ill. State Lab. Nat. Hist., Vol. VII., Art. IX., p. 318.

The method of the operations of this insect and the main facts of its life history have been worked out in my insectary during the past two years by Mr. J. J. Davis and Mr. J. A. West from cocoons and infested grubs sent in by Mr. Kelly from fields at Elliott, Ill. Thirty-three *Tiphia* cocoons were used in these observations, twenty-one of which were obtained November 25, 1905, and twelve April 27, 1906. From those collected in fall the winged insect emerged at thirteen dates between June 19 and July 28, 1906, and those obtained in spring yielded the adult on eleven dates between June 26 and August 22. These collections consequently do not represent different broods. Only seven of the adults obtained were males, and twenty-five were females, the sex of one being undetermined.

A pair were seen *in copula* in one of the breeding-cages at 9:30 p. m. July 1, and eggs were laid on grubs in the insectary from June 29 to August 21. One lot of young white-grubs brought in September 20, 1906, were already badly infested by very small *Tiphia* larvæ about one eighth of an inch in length. As insectary observations show that the eggs hatch in from seven to ten days, and that the young larva reaches the length of an eighth of an inch in about a week, it appears that the eggs for these larvæ were laid a little later than September 1. The period of oviposition of this grub wasp is thus something more than two months.

In several cases a female *Tiphia* was induced to go through the whole operation of preparing her victim and depositing her egg upon it above ground in a breeding-cage, where she could be continuously watched, and the facts thus learned are unusually interesting. Like others of its family—the digger-wasps, or *Scoliidae*—these insects sting their prey before attaching the egg to it, with the effect to paralyze it more or less completely. Mounting the body of the grub, which struggles violently against the attack, the *Tiphia* seizes with her mandibles the skin of the back just behind the head, curving her body downward around the side of the grub, with the tip of her abdomen beneath and just behind the head, and then, after feeling about with the abdomen for a time, finally stings her victim, with the effect suddenly to quiet its struggles and reduce it to helplessness. Then the *Tiphia* reverses her position and works the tip of her abdomen backward and forward for several minutes in one of the grooves or creases on the back of the larva, usually not far behind the head, apparently smearing the surface there with a viscid fluid, after which she deposits her egg on this sticky surface and goes away.\*

\*The above account is based on insectary observations and experiments. Several white-grubs parasitized by *Tiphia* larvæ have been found in the field since this was written, and in every case the larva was on the under side of the body between the thoracic legs.

The larva, at first almost completely paralyzed by the puncture of the sting and the venom doubtless injected at the same time, slowly revives, recovering presently its full powers of locomotion, so that it is indistinguishable by its behavior from its fellows which have not been stung. The stinging, in this case, is thus a means of quieting the struggles of the grub in a way to permit the *Tiphia* to attach her egg to its back. Commonly, of course, these operations go on under ground. A *Tiphia* introduced into a breeding-cage containing grubs in the earth disappears under ground herself, and does not come out until she has found and infested a grub.

Repeatedly, where grubs were exposed to attack on the surface of the dirt in breeding-cages, the *Tiphia* merely stung them at first, and then proceeded to bury them before depositing her egg. For this purpose, she undermined the grub by digging the earth from beneath it, pulling its body about by means of her jaws until it was in proper position to enter the hole, gradually digging deeper, and finally burying it completely. In one case in which the operation was timed, the grub was buried in ten minutes after it was stung. Sometimes the *Tiphia* abandoned an attempt at burial, and left the grub without placing an egg on it after it was stung.

Apart from that general exhibition of a wonderful adaptation of its actions to the needs of its prospective progeny which this *Tiphia* shares with many other wasps, and especially with those of its own family, there are two points of peculiar interest in this account. It is an unmistakable fact that the effect of the poisoning of the grubs by the *Tiphia* is merely to paralyze the victim temporarily; to overcome its resistance and reduce it to helplessness while the *Tiphia* egg is being placed in position. The sting is used as a mere aid in the struggle of the *Tiphia* with a stronger insect. This fact may point to the explanation of the origin of the remarkable instinct of the solitary wasps to sting and paralyze their prey.

More remarkable still, however, in the light of our present knowledge of the habits of *Tiphia*, is its frequent burial of white-grubs exposed to it on the surface of the ground. Since digger-wasps in general are parasites of underground larvæ only, since the *Tiphia* is not known to infest any insects except white-grubs of the genus *Lachnosterna*, and since in nature it can never find these grubs above ground, its deliberate burial of exposed grubs has all the appearance of a line of action extemporized to meet a previously unknown condition. Either the *Tiphia*, disturbed at finding its prey exposed, buries this as a result of impulse aided by intelligent contrivance, or we shall find, when its habits are known in full, that it

does sometimes normally infest and attack insects exposed above ground by their habits, burying them as a matter of instinct after it has placed its egg. *Tiphia* has not, in fact, been studied as an independent species, but all the data concerning its habits and life history have been gathered in the course of studies of the white-grubs.

The egg of *Tiphia* remains firmly glued to the back of the chosen grub, and hatches in seven to ten days. The young larva breaks its way out from the egg at one end, and, although it begins at once to feed, it does not at first free itself from the shell, but as it grows this finally splits and breaks away. When it first emerges the larva measures slightly more than a millimeter in length. From our scanty data it appears that it takes about two weeks to get its full growth, and that it doubles its size in the last two days of its larval life, during which it is engaged in devouring the body of its host. Previous to this time it has been adherent to the skin of the grub whose fluids it has lived upon. When full grown it is from two thirds to four fifths of an inch in length.

The cocoons are cylindrical ovate, from 17–22 mm. long, clay-colored at first, and wood-brown or cinnamon-brown when older. From our observations thus far made it appears that the larva hibernates within the cocoon, not pupating until the following spring. The adult emerges from a little one side of the larger end, in which it leaves a ragged and irregular opening. In several cases the abundance of these conspicuous brown cocoons in the earth was such as to indicate an enormous destruction of white-grubs, and there is no doubt that this parasite is an important agent in checking destructive uprisings of these insects.

That this wasp, parasitic on white-grubs, is itself parasitized, is shown by the results of observations made on *Tiphia* cocoons collected April 27, 1906, and kept in breeding-cages during the summer. From these emerged, July 7, 16, and 31, adult bee-flies (*Bombyliidae*) of the species *Exoprosopa fascipennis*, each freeing itself from the *Tiphia* cocoon by cutting out a circular piece at the larger end. The eggs from which these flies resulted were probably laid on the *Tiphia* grub in 1905, before the cocoon was spun.

#### MISCELLANEOUS INSECT ENEMIES.

*Macrophthalma disjuncta*.—This little tachinid fly was mentioned in my Seventh Report as bred repeatedly from dead white-grubs, but I was nevertheless uncertain that it was a parasite. Lately its parasitic nature has been proven by repeatedly breeding it from

living grubs kept in breeding-cages in my insectary. Adults have emerged in these experiments March 26, June 8, July 12, and August 8, and others have been taken at electric lights July 9, and in a corn field September 27. Those appearing March 26 lived in confinement until May 14. We have thus seen these insects alive in every month from March to September inclusive. In the breeding-cages, remains of a white-grub were commonly found associated with the cocoon of the parasite.

The adult of this species is a large blackish-gray fly with a general resemblance to the common large blow-fly, but with a grayish white sheen on the basal half of each segment of the abdomen, giving the effect of equal alternating cross-bands of black and gray.

*Ophion bifoveolatum* Brullé.—This well-known parasite of the white-grub has been reared by us several times from these insects. In one case the head and skin of a grub were woven into the wall of the cocoon of the parasite. The species has been bred by us repeatedly from cocoons collected from the latter part of July to the first of September, and kept in breeding-cages through the winter, adults appearing from March 31 to April 27.

The adult is a large, slender-bodied, dark red ichneumon-fly; and the cocoon is quite regularly elliptical, a half inch long by a fourth of an inch thick at the middle, smooth, dull brownish, or more or less blackish—especially towards the end.

*Sparnopolius fulvus* Wied.—This bee-fly, which we have sometimes noticed in corn fields and have collected from miscellaneous sweepings of vegetation in midsummer, also proves to be a parasite of the white-grub, as shown by breeding-cage work done in 1904—1906. It was first detected in this relation by Mr. E. P. Taylor, of my office, who found a white-grub at Elliott, Ill., August 25, 1904, with a dipterous larva attached to its back. This was placed in an insectary cage, which was not examined until April 21, at which time the white-grub had been completely destroyed, and the larva had completed its transformations. It probably had emerged in the fall of 1904. A larva of this same species was next collected July 24, 1906, from among corn roots at Effingham, Ill., and was placed in a breeding-cage to obtain the adult. It pupated August 22, and emerged as a winged insect September 10. All our open-air collections of this fly have been obtained in August.

The adult is about as large as a common house-fly, but is covered with erect yellow fur. The pupa is not inclosed in the last larval skin. Its head bears three large points on each side anteriorly, and a smaller pair beneath at the base of the mouth-parts. The last seg-

ment of the pupa is rather narrowly truncate, with a small slender spine on each side of the truncation, and a shorter one beneath each of these.

Considerable numbers of another species of parasitic larva were taken by Mr. Kelly at Elliott, Ill., August 29 and September 20, 1906. These were evidently white-grub parasites, as the remains of the grubs\* were still clinging to several of them. This species is still in the larval stage at this writing.

Three yellow coarctate meloid larvæ were also found by the same assistant in an infested oats field with the remnants of white-grubs attached to them, and another was taken in a similar condition October 10. These specimens have not yet matured.

*Pyrgota undata* Wied.—One of the most interesting parasitic enemies of the white-grubs is a large, rather unusual-looking fly of the family *Ortalidæ*, noticed by Mr. J. A. West, an assistant of my office, as abundant among the beetles at night. Now and then May-beetles were seen to drop to the earth, trying to rid themselves of the adult flies which were clinging to their backs, each with the last segment of the abdomen thrust in between the wings and wing-covers of the beetle and firmly held in place over the middle of the abdomen. The flies were apparently thus thrusting their eggs into the backs of the beetles through the thin dorsal skin beneath the wing-covers. The tip of the abdomen of the female fly is admirably adapted to this object, being hard and subconical, and directed downwards at a right angle to the axis of the body.

The relations of these insects were experimentally determined by confining, June 9, 1906, adult May-beetles in a breeding-cage with several of the flies. These would light on the backs of the feeding beetles, which would at once drop to the ground with the flies clinging to them. Whenever a beetle spread its wings for flight the insect on its back inserted the tip of its abdomen between the May-beetle's wings, evidently depositing an egg in its back. Beetles so treated lived for some days, and then began to die. On the 27th of June, five of the beetles were dead, and in the bodies of two of these, dipterous maggots were found. July 10, three of the beetles contained each a dipterous puparium, which remained unchanged until May of this year, when all produced adults of *P. undata*. August 29 and September 20, 1906, several puparia were found in the bodies of dead May-beetles, and these, kept in breeding-cages through the winter, produced adults of *P. undata* May 14 and 17, 1907. Like experiments begun during the present year have progressed similarly to the time of writing. Adult flies of this species

were again frequently seen June 12 to 18, 1907, among May-beetles on trees at night, no less than twenty-six specimens being captured. These flies have also been occasionally taken at electric lights, and in various situations by day during different years, from May 20 to June 17.

The puparia of these parasites are dull black, broad ovate, widest at the posterior third. At the tip is a small shallow excavation encircled by a rugose ridge, which is elevated latero-dorsally into a pair of short irregular tubercles, the tips of which are about a millimètre apart. Length 7-8 mm.; greatest diameter, 4.5-4.8 mm.; diameter of anterior end, about 3 mm. The adult flies are yellow-brown, three eighths to half an inch long. The head is subtriangular, the thorax globose, the abdomen slender at base, enlarging apically. The wings are three eighths to half an inch long, conspicuously and characteristically marked. The entire anterior margin of the wings has a broad brown border reaching half way across the wing, and having two broad saw-tooth-like extensions attaining the posterior margin, one at the middle of the apical half and the other at that of the basal half. The first two abdominal segments are about as long as broad, and connate; the next four, in the female, are very short, followed by the genital segment, which is very large, shining, directed downwards and curved slightly forwards.

The male abdomen is similarly shaped: the two basal segments are followed by two more about twice as long as the corresponding ones in the female; the next segment is a little longer than broad, vertically directed, bearing the genital segment, which is directed somewhat anteriorly. The eyes are larger in the female than in the male.

*Other Dipterous Parasites.*—In 1905 a May-beetle of the species *Lachnosterna crenulata* found near Urbana July 15, laid three eggs, and died about the 29th of July. On August 5 an adult tachinid emerged from the body which Mr. Tyler Townsend, of the U. S. National Museum, regards as a new species—*Viviana*. Two dipterous larvæ were found June 27, 1906, in a May-beetle taken alive May 31. July 10 these larvæ had formed puparia, and adult tachinid flies emerged May 17 and 18 of the following year. These are slightly larger than a house-fly, with black subquadrate thorax, the anterior angles each with a triangular red spot. The puparium is very dark red, almost black, subcylindrical, with rounded ends. Length, 7 mm.; width, 3 mm. It is smoothly rounded behind, with a pair of low tubercles placed close together. The species has not been determined.

## RELATION TO SOIL AND SUBSOIL.

It is a matter of common opinion that injuries by white-grubs are more serious on the higher, lighter, and drier parts of our cultivated areas than on the lower and moister parts, but no exact observations have been made to show whether this apparent difference is real under all conditions, and whether, if so, it is due to a greater abundance of the grubs on high lands than on low, or to a lesser average power of recuperation and resistance on the part of plants growing in comparatively light and less fertile soils.

I began in 1904 and 1905 to accumulate data on this and allied points, by having collections of white-grubs made by persons following the plow, who recorded for each field and situation the number of grubs found in each quarter of a mile of furrow. A record was also made, for each field examined, of the succession of crops it had borne for the five years preceding, of the character of the soil, the lay of the land, the conditions as to drainage and to fertilization, and the relation of the field to trees and shrubs on which the parent beetles of the grubs might have found food. Collections were made on this plan from seventy-nine fields in the following twelve counties of central and southern Illinois: Stark, Peoria, Woodford, McLean, Champaign, Macon, Macoupin, St. Clair, Washington, Marion, Jackson, and Union. This work was interrupted by lack of funds and by diversion of assistants to more pressing problems before any sufficient mass of data had been obtained to enable me to draw satisfactory general conclusions on any one of the points of principal interest. So far as they go, they show that the grubs were more abundant on the higher and drier parts of the country than on the lower and moister parts, and that the fewest eggs were laid by the parent beetles in corn fields and the most in grass-lands. Thirty-eight low-land fields gave an average of 21 grubs exposed in a mile of plowed furrow, and 41 of the high-land fields an average of 31 to the mile. The three largest numbers found in any fields were 208, 164, and 140 grubs to the mile, all on high ground. The largest numbers in any of the low-land fields were 112 and 104 in two of them. Again, the average of fields which had been in corn continuously for at least three years preceding was 17 grubs exposed in each mile of furrow, and that of fields which, although in corn at the time, had been in grass for several years preceding, was 37 grubs to the mile. It is evident that useful information may be obtained from data of this description if they are accumulated in sufficient number and are properly classified.

## RELATIONS TO AGRICULTURAL MANAGEMENT.

Injuries by white-grubs are influenced to a considerable extent by the system of farming, and especially by the succession of crops; by the management of pasture-lands, in which, if left wholly to themselves, they are likely to accumulate in increasing numbers year by year; and possibly, also, by the time of the year when infested lands are plowed. While the old idea that white-grubs are essentially insects of pastures and meadows has been exploded by observations of recent years, it still remains true that, other things being equal, they are most abundant in grass-lands, and consequently most injurious to other crops if these follow within one or two years upon an infested pasture or meadow. They seem particularly liable to accumulate in an old turf which has lain unbroken for several years, and are less likely to be destructive where there is a quick rotation of crops, including a short period in grass, to be followed by one or two years in clover. The modern stockman's practice of herding cattle and pigs together is an excellent one from our standpoint, since the pigs, in following the cattle, are likely also to search out the grubs in the turf and to keep the sod practically free from them.

It is a matter of common, though not universal, opinion among farmers who have watched the work of the white-grubs that fall plowing of infested lands is preferable to spring plowing. In the absence of any apparent reason why this should be so, and in the absence also of any experiments upon the subject and of any considerable number of exact observations, this supposition must be regarded as doubtful. Our own field reports give thus far but a single instance, reported by Mr. Kelly in 1905, of a notable difference in white-grub injury corresponding to a difference in the time of plowing of different parts of the same field; and this instance is by no means clear, since there was injury by grubs in both parts of this field—much greater and more extensive, however, on the spring plowing. The white-grubs were also reported as less abundant in the part of the field plowed in fall, averaging there one grub to the hill of corn as compared with seven to the hill found in the part plowed in spring. The data of this observation are incomplete, however, and this difference in number of grubs may have been due to something else than difference in the time of plowing.

## INJURIES TO CROPS.

Injuries to crops by white-grubs and May-beetles are often of the most serious and extensive character. The beetles by their destruc-

tion of leaves of trees and shrubs in spring not infrequently cause the death of those preferred by them for food, and the grubs are particularly destructive in towns to the turf of lawns, in nurseries to young evergreens, in the fruit plantations to strawberry vines, and on the general farm to grass and corn.

The injury by grubs is due, in all cases, to the destruction of the roots of the plants infested and the consequent weakening or actual killing of the plant. The nature and extent of the injury to corn is well illustrated by observations made by one of my assistants, Mr. Kelly, in a field near Ludlow, in Champaign county, about ten acres of which were almost completely destroyed. By digging up to a depth of twenty inches, and searching all the soil belonging to each of sixty hills of corn—an area, that is, three and a half feet square for each hill—it was found that this badly injured area contained an average of 3,460 grubs to the hundred hills, or more than 34 to the hill,—a total of about three hundred pounds of grubs to the acre of corn. The plants varied in height from two inches to six feet, and the total number of ears borne by two thousand hills was 786, all small ears or nubbins.

#### PREVENTION AND REMEDY.

The subject of preventive and remedial measures was somewhat fully treated in my Seventh Report (pp. 127-137), and there is nothing important to add to that discussion at the present time beyond a statement of the results of an experiment with pigs as a means of clearing the grubs out of an infested field. This experiment was made in the field above referred to, near Ludlow, Ill., ten acres of the worst injured part being surrounded with a temporary fence, and one hundred pigs averaging seventy-five pounds each, together with eight large sows, being turned into the inclosure September 23.

By October 13 the pigs had rooted over the whole surface of the ten-acre lot, going, in some places, to a depth of ten or twelve inches. An area equivalent to twenty corn hills was now examined to a depth of twenty inches, with the result that an average of 4.8 grubs per hill were found, as compared with 34.6 per hill at the beginning of the experiment—a benefit of 86 per cent. in twenty days. The grubs found in the field at this time were usually eight inches or more below the surface.

The pigs were in this inclosure until October 20, when they were removed to another badly injured part of the field, and a final examination of the plot was made. In an area equal to ten hills of

corn only two grubs were found—a benefit of over 99 per cent. destroyed by the pigs in twenty-seven days. As the grubs were at this season going down to escape frost, the hogs were burrowing in pursuit of them, sometimes to a depth of two feet.

Although these pigs remained perfectly thrifty, it is proper to say that there is one possibly serious objection to this very common use of swine as a means of keeping in check the white-grubs in grass-land and of clearing them out of fields of corn. It has been shown by Dr. C. W. Stiles, of the U. S. Bureau of Animal Industry,\* that one of the most injurious intestinal parasites of swine, known as the giant thorn-headed worm (*Echinorhynchus gigas*), passes one stage of its life in certain of the white-grubs, and that pigs become infested by it by devouring infested grubs, which themselves obtain it by way of the excrement of the pigs. Where either grubs or pigs become infested by these parasites the situation is more or less dangerous if pigs are allowed to eat the grubs; but pigs which have never been pastured are certain to be free from these parasites, and grubs growing in fields which have not been pastured by pigs are likewise certain to be free from them. The use of such pigs upon such fields would consequently be without danger from this source, and a little attention to these facts will avoid any injurious consequences. That is, if pigs not previously allowed to run out are turned into fields on which pigs have not been pastured within three years, there will be no danger that they will become infested by these thorn-headed worms.

The general measures discussed in my Seventh Report are essentially a destruction of the May-beetles before they have laid their eggs, and the distribution among the grubs of the germs of their contagious diseases. Nothing has thus far been done to test the possibility of the collection and distribution of parasites other than those of contagious diseases, and the latter subject can not by any means be said to have been worked out to final conclusions.

The May-beetles may be destroyed either by spraying repeatedly with arsenical poisons the trees on whose foliage they feed; by shaking or jarring them down in the cooler parts of the night from the trees and shrubs on which they are feeding, and collecting them for destruction; and by trapping and killing them at night by means of lanterns fastened over tubs or traps containing water covered with a film of kerosene. The grubs may possibly be kept in check by the distribution among them of the germs of their contagious diseases obtained by artificial cultivation,—a method which has been

\*"On an American Intermediate Host of *Echinorhynchus gigas*." By C. W. Stiles. Zool. Anz., Feb., 1892, p. 52.

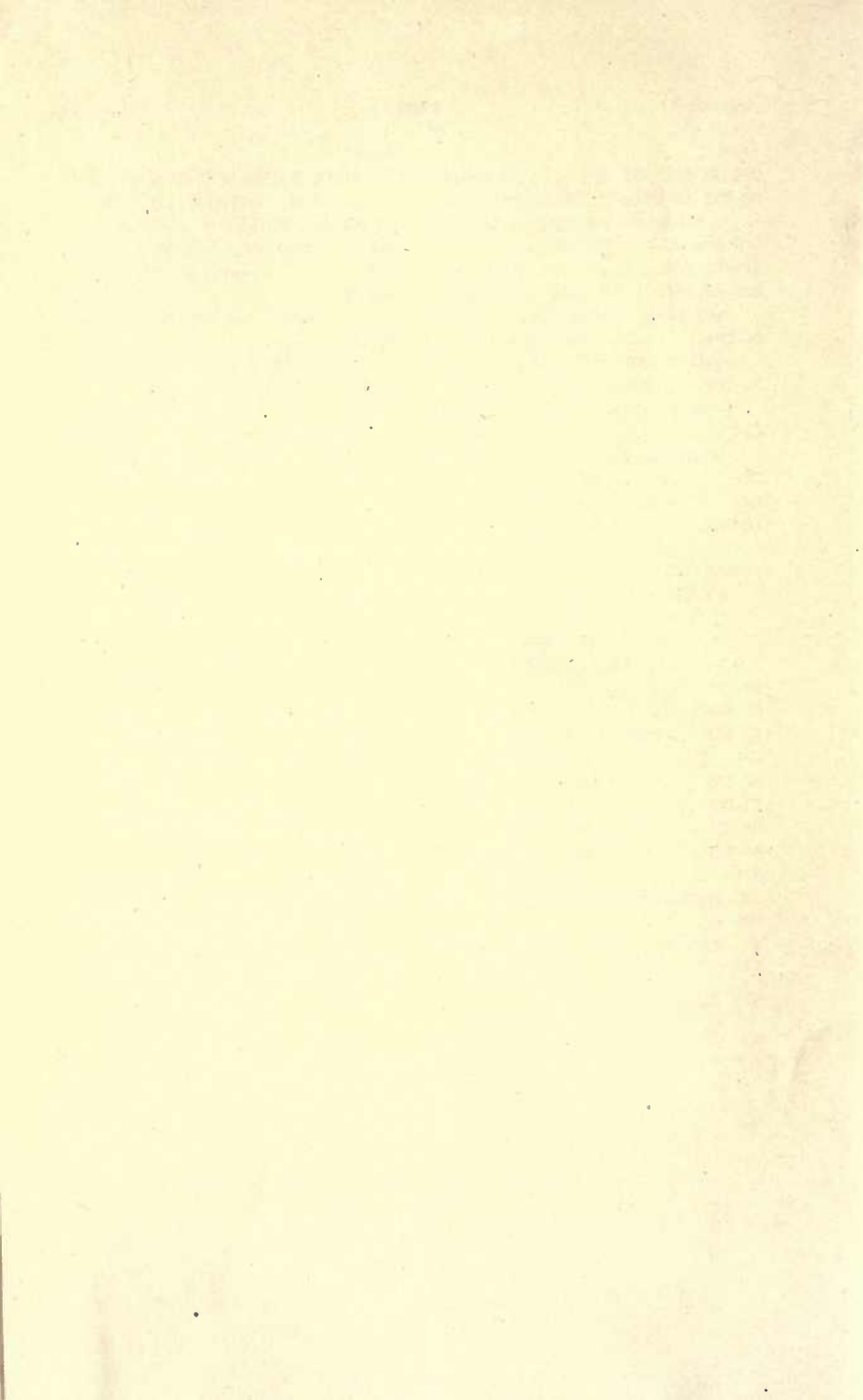
used with some success against the white-grubs of France. The main dependence in the Old World, however, has been a thoroughly organized movement for the collection of the beetles from the trees at night, the usual method of securing general action being to pay a sufficient price for the beetles in quantity to make their collection a profitable enterprise during the time of their presence on the trees. This method can be used to advantage only by owners of very large estates or by communities or combinations of farmers acting together for their common benefit. The same may be said of the destruction of the beetles by poisoning their food. If the ordinary land owner were to proceed by himself, it is probable that his fields would become infested by invasion from without even though he might destroy every May-beetle on his own premises. The least promising of these methods is the simplest and the cheapest of them all—that of collecting the beetles by lantern traps. These take effect much the most strongly upon the males, and collect, under the most favorable circumstances, only a comparatively small percentage of the beetles in their neighborhood. Furthermore, it is available only on dark and relatively quiet nights.

What may be done by way of general concerted action is well illustrated by a campaign of destruction carried on against the white-grubs of the Swedish province of Halland during the ten years from 1885 to 1895, within which time 29,736 bushels of May-beetles and their larvæ were collected at an expense of \$15,554, or about 52 cents a bushel, the state usually paying half of this sum, the Economic Society of the province a fourth, and the communes or counties the remaining fourth. The effect was especially shown in the gradual reduction in the number of beetles collected—from 14,801 bushels in 1887 to 5,611 in 1895, although the number of communes participating in the work had increased in the meantime, and the area covered by the collections was correspondingly greater.\*

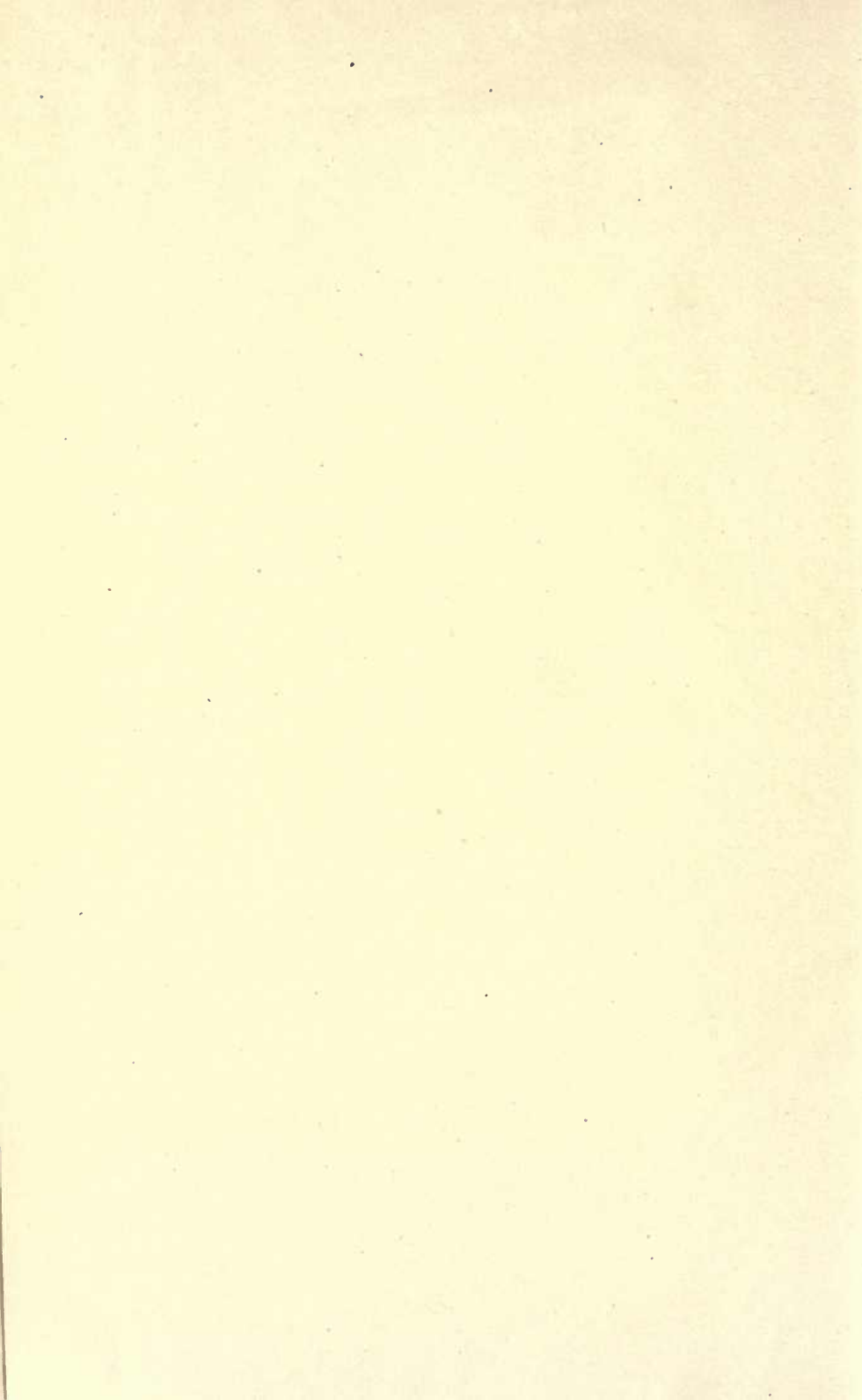
So far as is now to be foreseen, organized work of some such description will finally be necessary to the control of the white-grub pest in Illinois, and throughout America generally.

\*August Lyttkins, in *Entomologisk Tidskrift* for 1897. Stockholm, 1898.









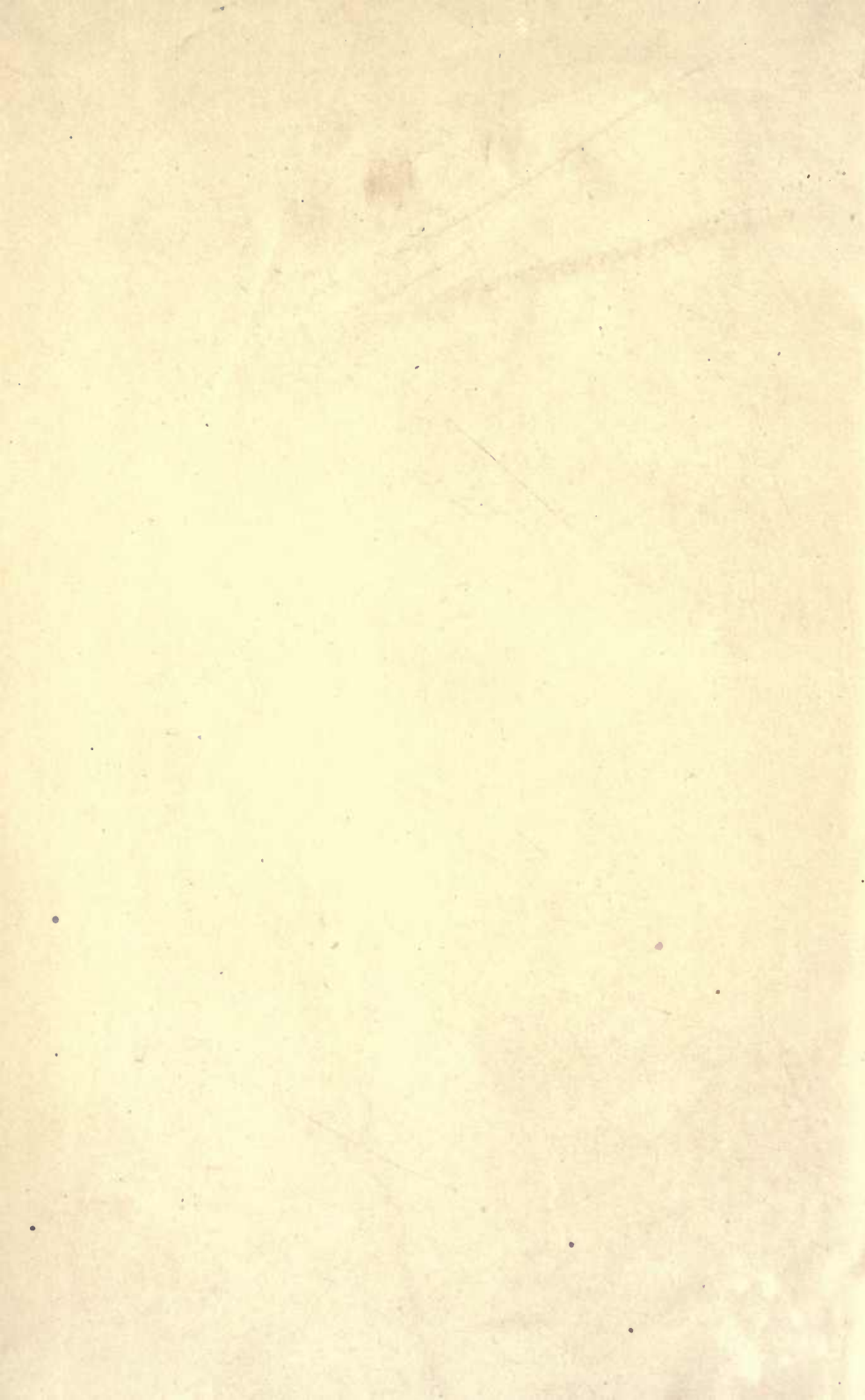


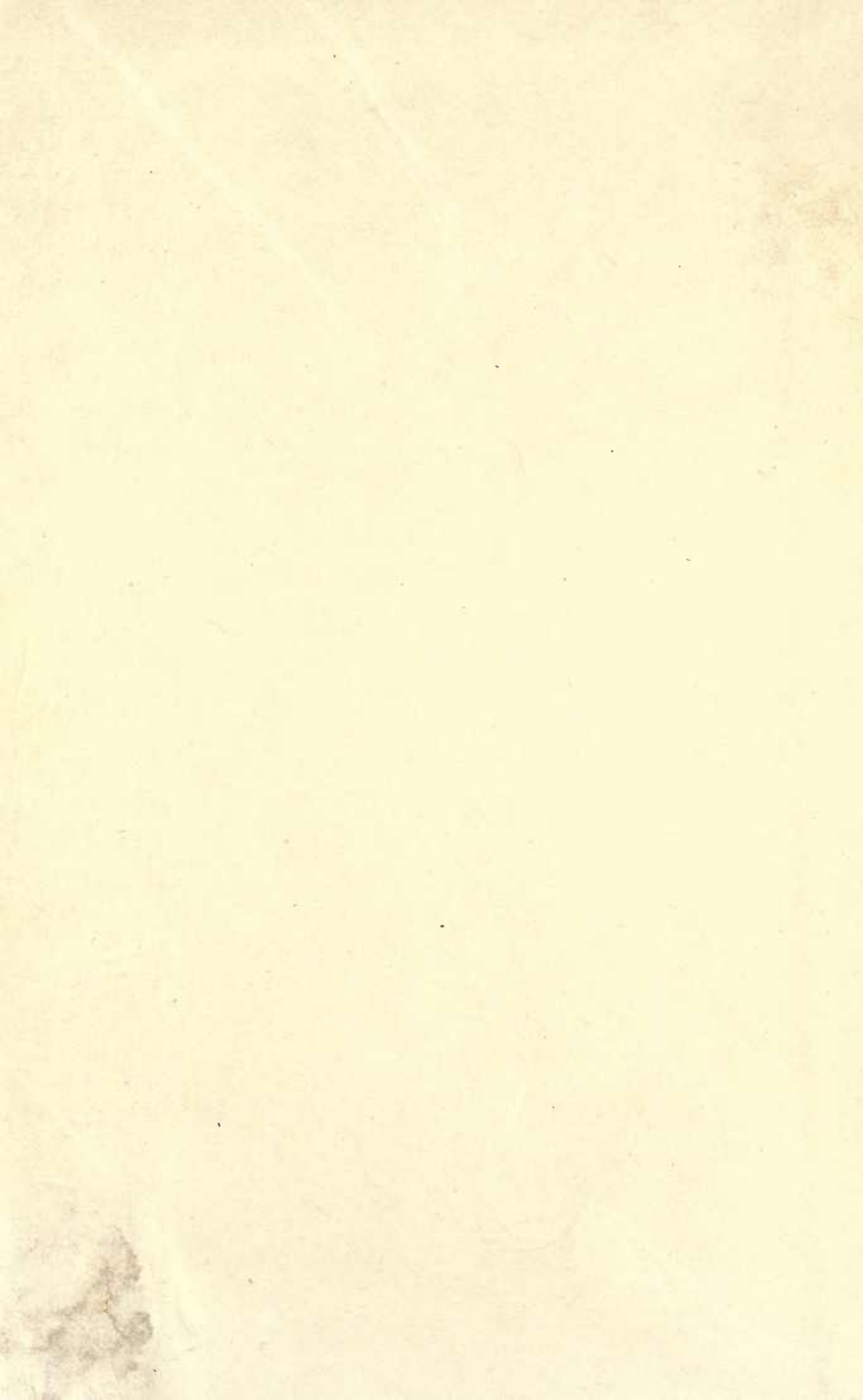
















UNIVERSITY OF ILLINOIS-URBANA



3 0112 078530372