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AN ECOLOGICAL STUDY OF PRAIRIE AND FOREST  
INVERTEBRATES

BY

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## ERRATA AND ADDENDA.

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- Page 50, second column, line 13 from bottom, for *Danais archippus* read *Anosia plexippus*; line 8 from bottom, for *mellifica* read *mellifera*.
- Page 51, line 11 from bottom, for *Danais* read *Anosia*.
- Page 159, at right of diagram, for *Bracon agrilli* read *Bracon agrili*.
- Page 289, second column, last line but one, for *Scalops* read *Scalopus*.
- Page 294, line 3, for *catesbeana* read *catesbiana*.
- Pages 327 and 330, line 12, for *orcus* read *oreas*.
- Page 347, line 4, for *Cecidomyidæ* read *Cecidomyiidae*.
- Page 356, line 7, for *Anthomyidæ* read *Anthomyiidae*.
- Page 368, line 18, dele second word.
- Page 373, after line 10 insert as follows: 53a, *subpruinosa* Casey, 1884, p. 38.
- Page 375, after *submucida* Le Conte, 48, insert *subpruinosa* Casey, 53a.
- Page 377, after line 7, insert as follows:—
1884. Casey, Thomas L.  
Contributions to the Descriptive and Systematic Coleopterology of  
North America. Part I.
- Page 379, line 11 from bottom, for *sensu lata* read *sensu lato*.
- Page 382, line 12, for VII read VIII.
- Page 408, line 2, for *the next article in* read *Article VIII of*.
- Page 410, line 6 from bottom, for =  $\frac{1}{2}$  read '11.
- Page 412, line 7, for 31 read 30.
- Page 421, line 17 from bottom, insert *it* before *grows*.

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### INTRODUCTORY

In four generations a true wilderness has been transformed into the present prosperous State of Illinois. This transformation has been so complete that in many parts of the state nearly all of the plant and animal life of the original prairie and forest has been completely exterminated. Between the degree of change which has taken place in any given area and the suitability of that area for agriculture there has been an almost direct relation. Fortunately, however, for the preservation of prairie and forest animals, the state is not homogeneous, some areas being too hilly, rocky, or sandy for prosperous agriculture.

The character and mode of transformation which has taken place in the past is instructive in several particulars because it serves to guide our anticipations as to the future of our fauna. The forested southern part of the state (see frontispiece) was first invaded by trappers and hunters, who began the extermination of the larger animals. These invaders were in turn followed by others who, with the round of the season, were hunters or farmers, and continued this exterminating process, particularly in the clearings, which began to replace the forest. These pioneers, men of little wealth, possessed a combination of mental and economic habits which was the result of life in a forested country, and naturally they settled in those places most like their former homes—within the forest or near the forest margin. From these settlements they looked out upon the prairies as vast wastes to be dreaded and avoided. As a result of this attitude toward the prairies, it required some time, even a new generation, some economic pressure, and a change of habits before the prairies were settled. Meanwhile the northern part of the state was yet a wilderness; but through the influence of the Great Lakes, as a route of communication with the populous East, a rapid invasion of settlers set in from that direction. Though these settlers also came from a wooded country, they were more wealthy, settled upon a very fertile soil which was favorably located with regard to eastward communication, and they therefore progressed more rapidly than the less favored, more isolated southern invaders on the poorer soil; consequently they spread from the forest

to the prairie more rapidly than did the settlers in the South. There thus developed two active centers of influence, each of which transformed the primeval conditions in the same manner and in the same direction toward an environment suitable for man.

The forests and the upland prairie were first changed. Then the fertile wet prairie was drained, so that today it has largely become either the hilly and rocky areas that survive as forests or the low periodically flooded tracts, and the undesirable sand areas which similarly preserve patches of sand prairie. All the changes are more rapid and complete upon fertile soil than upon the poorer soils in the southern part of the state.

Such considerations as these will aid one in estimating the probable rate of future changes in different parts of the state, and will serve to show in what parts there is urgent need of local studies if ecological records are to be made before extinction of some forms is complete.

A study has been made with the idea of reporting upon representative patches of prairie and forest in a manner which would aid others in making similar local studies, and would at the same time preserve some records of the present condition of the prairie and forest. When this work was planned, we had no general or comprehensive discussion of the conditions of life upon the prairie and in the forest. For this reason a general summary of these conditions and a sketch of the general principles involved are given, so that the reader may gain some conception of the relation of the local problems to those of a broader and more general character.

A section for this report was prepared giving general directions for making such local studies, but later it was decided to publish this separately, in somewhat extended form, as a "Guide to the Study of Animal Ecology."\* This volume should be regarded as intimately related to this paper, and this report should at the same time be considered as a concrete example of the procedure suggested in that "Guide" for ecological surveys. It will be observed that the study of the Charleston area here referred to has been conducted in much the same way as was my cooperative study of Isle Royale, Lake Superior, entitled "An Ecological Survey of Isle Royale, Lake Superior" ('09), although certain aspects have been elaborated here which, for lack of time, were not treated there. The time devoted to the study of the Charleston area was also limited, but in the preparation of the report upon it use has been made of many years' experience and a general knowledge of the prairie and forest. Without such a background

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\*The Macmillan Co. 1913.

much greater caution would have been necessary in discussing many phases of the problem.

#### ACKNOWLEDGMENTS

The study of the Charleston area was carried out with the cooperation of the Illinois State Laboratory of Natural History, through its director, Prof. Stephen A. Forbes, and with the further cooperation of Professors E. N. Transeau and T. L. Hankinson, of the Eastern Illinois State Normal School, located at Charleston. Personally I am indebted to Professor Forbes for the opportunity of taking part in this study as the State Laboratory representative, and for the aid he has given in the illustration of the report. To Professor Transeau I am particularly indebted for the plant determinations, for lists of the plants, and for evaporation data. To Professor Hankinson I am under especial obligation for many specimens, which materially added to my lists, and for a large number of photographs. I am indebted likewise to my associates in this study for their hearty cooperation throughout the progress of the work.

For the determination of entomological specimens I am indebted primarily to Mr. C. A. Hart, Systematic Entomologist of the State Laboratory of Natural History, who named most of the insects collected. For the names of certain flies I am indebted to Mr. J. R. Malloch, of this Laboratory. Others who have determined specimens are as follows: N. Banks (*Phalangida*), J. H. Emerton (spiders), R. V. Chamberlain (myriapods), F. C. Baker (*Mollusca*), Dr. W. T. M. Forbes (lepidopterous larvæ), Dr. M. C. Tanquary (ants), Dr. M. T. Cook (plant galls), J. J. Davis (*Aphididæ*), and Dr. A. E. Ortmann (crawfishes collected by T. L. Hankinson). I am indebted to the U. S. Geological Survey for photographs. Acknowledgments for illustrations are made under text figures and in explanations of plates.

### GENERAL DESCRIPTION OF THE REGION AND LOCATION OF THE ECOLOGICAL STATIONS

#### I. GENERAL DESCRIPTION OF THE REGION

The town of Charleston, Coles county, Illinois, in the vicinity of which these ecologic studies were made, is situated on the Shelbyville moraine which bounds the southern extension of the older Wisconsin ice-sheet. To the south of this moraine lie the poorer soils which characterize so much of southern Illinois; to the north, upon the older Wisconsin drift, are some of the most productive soils found in the upper

Mississippi Valley. The economic, sociologic, political, and historical significance of the difference in the soils of these regions is fundamental to any adequate understanding of man's response to his ecological environment within this area. Some of the results of this difference have long been known, but it is only in recent years that their general bearing has been adequately interpreted in terms of the environment. Hubbard ('04) was the first, I believe, to show the significance of this difference in soils and its influence upon local economic problems. That such an important influence should affect one animal (man) and not others seems very doubtful, and yet in only one other case do we know that the lower animals respond to this ecologic influence. Forbes ('07b) has shown that certain kinds of fish found in streams on the fertile soils are wanting in streams on the poorer soil. To what degree the land fauna and the native vegetation respond to this distinction is not known, as this subject has not been investigated except agriculturally. Here, then, is a factor in the physical surroundings which should be reckoned with in any comprehensive study of the biotic environment. In this portion of the state, on account of the differences in the soil, the physical environment is probably more favorable to certain organisms and less favorable to others, and consequently, to a certain degree, the environment selects, or favors, some organisms. Through their activities and through other agencies of dispersal, the animals along the borders between the two soil types transgress these boundaries, and are therefore forced to respond to the new conditions and to adjust themselves, if possible.

But the soil is not the only environmental influence which has produced an unstable zone or tension line in this area. A second factor is the difference in the vegetation—the difference between the forest and the prairie. In all probability, Coles county was at one time all prairie, but the Kaskaskia and Embarras rivers, as they cut their valleys through the moraine and developed their bottoms, have led forests within the morainic border from farther south. The forests about Charleston have extended from the Wabash River bottoms. On account of the southerly flow of the Embarras through this county, the forest and prairie tension line is about at right angles to that produced by the differences in the soil. The forests have tended to spread east and west from the streams and to encroach upon the prairie, and thus to restrict its area more and more. The fundamental significance of the tension between the forest and the prairie has long been known within the state. It influenced its economic, social, political, and historic development as much as any other single factor during its early settlement. And just as Hubbard ('04) has shown the influence of soil upon man



within the state, so also has Barrows ('10) shown the influence of the forests and prairie upon the state's development. While the influence of the soil upon the animal life of the state is not so well known or established, the influence of prairie and forest upon the animals is universally recognized, even though the subject has been given relatively little study by naturalists.

A third leading agency is the influence of man, who has transformed the prairie and forest to make his own habitat. There are thus recognized in the Charleston region three primary environmental influences: *first*, the relative fertility of the soil (this depending on the geological history); *second*, the kind of vegetable covering, whether prairie or forest (this probably depending largely on climatic conditions); and *third*, the agency of man. The general background of the Charleston region, then, ecologically considered, depends on the combined influence of five primary and secondary agencies, four of which we may call natural and one artificial. All these are different in kind and so independent that they tend toward different equilibria or different systems of unity. Two of these are due to differences in the soil, two others to the character of the vegetation (whether prairie or forest), and the fifth, or artificial one, is due to man. Though the present report does not undertake to include all the problems centered here, as any complete study would, it is desirable to see the relation of our special study to the general problems of the region as a whole.

The undulating plain about Charleston, formed as a terminal moraine, is broken along the small streams by ravines, which have cut a few hundred feet below the general level of the region as they approached the larger drainage lines. The main drainage feature is the Embarras River, which flows southwest about two to three miles east of Charleston, in a narrow valley partly cut in rock. The wooded areas are mainly near the streams; the remainder of the area is under intensive cultivation.

During the preliminary examination of the region, which was made to aid in selecting representative areas for study, it soon became evident that the only samples of prairie which could give any adequate idea of the original conditions were those found along the different railway rights-of-way. Other situations, vastly inferior to these and yet a valuable aid in the determination of the original boundaries of the prairies, were the small patches or strips along the country roads. Most of the patches of prairie along the railway tracks represent the "black soil" type of prairie, which is extensively developed in this part of the state upon the "brown silt loam" soil" (see Hopkins and Pettit, '08: 224-231). Much of the region studied was originally wet prairie

(which has since been drained), but some of the higher ground, formed by the undulation of the surface and surrounded by the black soil, is lighter in color and is well drained. Thus in the black soil areas there are both wet and well-drained tracts, and corresponding differences in the habitats.

The originally wooded and the present wooded areas east of Charleston, in the vicinity of the Embarras River, are in a region quite different from the prairie both in topography and in soil. Here the relief is much more pronounced, on account of both the proximity of the river and the greater development of the drainage lines, which have cut a few hundred feet below the general level of the country. The tributary valleys and ravines are numerous and steep-sided, and in general are wooded, the density varying with the amount of clearing done. Most of the soil of the wooded areas and along the bluffs is distinctly lighter in color than that of the black soil prairie, and is presumably "gray silt loam" (Hopkins and Pettit, '08: 238-242), though along the flood-plain and the river bottom the soils are mixed in character.

## II. THE ECOLOGICAL STATIONS

In the study of an area or an animal association of any considerable size two methods are available. One is to examine as much of the area as is possible and secure data from a very wide range of conditions. This method is useful in obtaining the general or broad features of a region or an association, though to a corresponding degree it must ignore local influences and details, and by it most of the previous studies upon prairie animals have been made. It seemed, therefore, that in the present study a somewhat more intensive method was desirable, particularly in view of the fact that the extinction of prairie and forest is rapidly progressing. The method followed was to examine a large area in order to select a representative sample, and upon the basis of this sample to make as intensive a study as time and circumstances would permit. This method has the advantage of making it possible to preserve at least some record of the *local details*; and at the same time, to the degree that the selected area is a true sample, it also gives the results a much wider application.

The prairie samples examined were all along the rights-of-way, and the forest was a second-growth woods on the bottoms and bluff of the Embarras River, on a farm belonging, at that time, to Mr. J. I. Bates. Practically all of the observations here reported upon were made during August, 1910. The forest is a modified one, but it appears to have been cut over so gradually that its continuity as a forest habitat was not completely interrupted, although the cutting has prob-

ably seriously influenced many animals, particularly those which frequent mature forests, abounding in dead and dying trees and with an abundance of logs upon the ground in all stages of decay. Such conditions are the cumulative product of a fully mature climax forest. Of course the conditions have also been influenced by the extinction, or reduction in the number, of the original vertebrate population of the forest.

The different localities or regions examined are, for brevity and precision, indicated by Roman numerals; the particular minor conditions, situations, or habitats, by italic letters. An effort has been made to indicate the location of the place studied with enough precision to enable students to re-examine the habitats at any future time (Pl. I). The photographs which accompany this report may also aid in locating the places studied. Had similar photographic records been made fifty years ago, they would have been of much value and interest to us in this study, in much the same way as fifty years hence this report will form a part of the very limited record of the conditions found at the present time.

*List of Ecological Stations, Charleston, Illinois, August, 1910*

- Station I. Prairie along the right-of-way of the Toledo, St. Louis and Western, or "Clover Leaf" R. R., between one and two miles north of Charleston: Section 2, Township 12 N., Range 9 E., and S. 35, T. 13 N., R. 9 E. (Pl. I.)
- a. Cord or Slough Grass (*Spartina*) and Wild Rye (*Elymus*) Association. At mile-post marked "Toledo 318 miles and St. Louis 133 miles": S. 2, T. 12 N., R. 9 E.
  - b. Couch Grass (*Agropyron smithii*) Association. The distance of two telegraph poles north of Station I, a, and west of the railway track: S. 2, T. 12 E., R. 9 E.
  - c. Wild Rye (*Elymus*) Association. East and north of the "Yard Limits" sign: S. 2, T. 12 N., R. 9 E. (Pl. II, Fig. 1.)
  - d. Swamp Milkweed (*Asclepias incarnata*) Association. North of first east-and-west cross-road north of Charleston; east of railway track: S. 35, T. 13 N., R. 9 E. A wet area. (Pl. II, Fig. 2; Pl. III, Fig. 1.)
  - e. Cone-flower (*Lepachys pinnata*) and Rosin-weed (*Silphium terebinthinaceum*) Association. Just north of the preceding Station; east of railway track: S. 35, T. 13 N., R. 9 E. (Pl. V.)
  - f. Couch Grass (*Agropyron smithii*) Association. West of railway track: S. 35, T. 13 N., R. 9 E. Moist area.
  - g. Prairie Grass (*Andropogon furcatus* and *A. virginicus* and *Sporobolus cryptandrus*) Association, bordered by Swamp Milkweed (*Asclepias incarnata*) and Mountain Mint (*Pycnanthemum flex-*

*uosum*). This formed the north boundary of the area studied: S. 35, T. 13 N., R. 9 E. (Pl. III, Fig. 2; Pl. IV, Fig. 1 and 2.)

Station II. Prairie area west of Loxa, Illinois. Right-of-way along the Cleveland, Cincinnati, Chicago and St. Louis, or "Big Four," R. R.: Sections 10 and 11, Township 12 N., Range 8 E.

- a. From one half mile west of Loxa west to near Anderson Road, to telegraph pole No. 12330: S. 11, T. 12 N., R. 8 E. (Pl. VI. and VII.)
- b. Prairie at Shea's: S. 17, T. 12 N., R. 8 E.
- c. Cord Grass (*Spartina*) Association. East of Shea's: S. 17, T. 12 N., R. 8 E.

Station III. Prairie east of Charleston. Right of way along the C. C. C. & St. L. R. R.: S. 12, T. 12 N., R. 9 E.; S. 5, 6, and 7, T. 12 N., R. 10 E.

- a. Rosin-weed (*Silphium terebinthinaceum*) Association. Just west of the place where the Ashmore Road crosses the Big Four track; about one mile east of Charleston: S. 12, T. 12 N., R. 9 E.
- b. Blue Stem (*Andropogon*) and Rosin-weed (*Silphium terebinthinaceum*) Association. Three fourths of a mile east of the crossing of the Ashmore Road and the Big Four track: S. 6 and 5, T. 12 N., R. 10 E. An area which grades from prairie into transitional forest conditions. (Pl. VIII and IX.)

Station IV. Bates Woods. On the east bluffs and bottom of the Embarras River, north of where the Cleveland, Cincinnati, Chicago and St. Louis, or Big Four, R. R. crosses the river. On the farm of J. I. Bates: S. 5, T. 12 N., R. 10 E. (Pl. X, Fig. 1; Pl. XI, XII, and XIII.)

- a. Upland Oak-Hickory Association (*Quercus alba* and *Q. velutina*, and *Carya alba*, *C. glabra*, and *C. ovata*.) Second-growth forest. (Pl. XII and XIII.)
- b. Embarras Valley and Ravine Slopes, with Oak-Hickory Association.
- c. Red Oak (*Quercus rubra*), Elm (*Ulmus americana*), and Sugar Maple (*Acer saccharum*) Association. Lowland or "second bottom," Embarras Valley. (Pl. XIV; XV; and XVI, Fig. 1 and 2.)
- d. Small streamlet in South Ravine. This formed the southern border of the area examined. A temporary stream. (Pl. XVII, Fig. 1 and 2.)

## DESCRIPTION OF THE PRAIRIE HABITATS AND ANIMALS

### I. PRAIRIE AREA NORTH OF CHARLESTON, STATION I

This area includes patches or islands of prairie vegetation occurring along the right-of-way of the Toledo, St. Louis and West-

ern, or "Clover Leaf," Railway, north of Charleston. The southern border began just beyond the area of numerous side tracks and extended north of the first east and west cross-road for a distance of about one mile, to the place where the right-of-way is much narrowed and fenced off for cultivation. This is a strip of land through the level black soil area, which was originally composed of dry and wet prairie. The higher portions have a lighter colored soil, and the lower parts have the black and often wet soil which characterized the original swamp or wet prairie. The railway embankment and the side drainage ditches have favored the perpetuation of patches or strips of these wet habitats; the excavations for the road-bed, on the other hand, have accelerated drainage of the higher grounds. The soil taken from these cuts and heaped up on the sides of the tracks reinforces the surface relief noticeably in a region which is so nearly level. Through the depressions fillings have been made in building the railway embankment, and as a result the drainage has been interfered with in some places.

The disturbances brought about by railway construction and maintenance have greatly modified the original conditions, so that the prairie vegetation persists usually only in very irregular areas, sometimes reaching a maximum length equal to the combined distance between three or four consecutive telegraph poles—these poles are generally about 200 feet apart. In breadth the area is usually less than the space between the ditch bordering and parallel to the road-bed or embankment and the adjacent fence which bounds the right-of-way, or about 40 feet. This entire right-of-way is about 100 feet wide. In addition to these changes in the physical conditions, a large number of weeds not native to the prairie have been introduced, opportunities for this introduction being favorable, as railways traverse the entire area. In general, attention was devoted solely to the areas or colonies of prairie vegetation and their associated invertebrate animals, the areas of non-prairie vegetation being ignored, not as unworthy of study, but because the vanishing prairie colonies required all the time available.

#### 1. Colony of Swamp Grasses (*Spartina* and *Elymus*), Station I, a

This colony of slough grass (*Spartina michauxiana*) and wild rye (*Elymus*) is located a short distance north of the "Clover Leaf" switch tracks and just south of the telegraph pole marked "Toledo 318 miles and St. Louis 133 miles." The length of this colony was about 40 paces.

During August, 1910, it was dry, but probably in the spring and early summer, rains make this area a habitat for swamp grasses.

Though it was an almost pure stand of slough grass, with this were mixed a few plants of wild rye (*Elymus virginicus submuticus* and *E. canadensis*). These grasses reach a height of about four feet. The ground was very hard and dry, and there were large cracks in it.

A single collection of animals was made here, No. 179.

Common Names	Scientific Names
Common Garden Spider	<i>Argiope aurantia</i>
Ambush Spider	<i>Misumena alcatoria</i>
Differential Grasshopper, adult and nymphs	<i>Melanoplus differentialis</i>
Red-legged Grasshopper, adult and nymphs	<i>Melanoplus femur-rubrum</i>
Texan Katydid	<i>Scudderia texensis</i>
Meadow Grasshopper	<i>Orchelimum vulgare</i> , adult, and nymphs of <i>vulgare</i> or <i>glaberrimum</i> .
Dorsal-striped Grasshopper	<i>Xiphidium strictum</i>
Black-horned Meadow Cricket	<i>Æcanthus nigricornis</i>
Four-spotted White Cricket	<i>Æcanthus quadripunctatus</i>
Ground-beetle	<i>Leptotrachelus dorsalis</i>
Sciomyzid fly	<i>Tetanocera plumosa</i>

The basic food-supply in such a habitat is of course the grasses, and this fact fully accounts for the presence of large numbers of individuals which feed upon grasses, as do the *Orthoptera* in general. But the *Orthoptera* listed are not exclusively vegetable feeders, for Forbes ('05: 147) has shown that *Xiphidium strictum* feeds mainly upon insects, chiefly plant-lice, as well as upon vegetable tissues, including fungi and pollen; *Orchelimum vulgare* (p. 144), largely upon plant-lice and other insects; and *Æcanthus quadripunctatus* (p. 220), upon plant tissues, pollen, fungi, and plant-lice. These observations were based upon a study of the contents of the digestive tract. The food of the sciomyzid fly is unknown. The garden spider lives exclusively upon animal food; and being abundant, it must exert considerable influence upon other small animals. It not only destroys animals for its food, but many others are ensnared in its web and thus killed. In one of the webs I found a large differential grasshopper. The rank growth of vegetation furnishes the necessary support for the webs of this spider.

Some of the insects, as *Melanoplus differentialis* and *M. femur-rubrum*, oviposit in the soil, but others—*Scudderia texensis*, *Xiphidium strictum*, *Orchelimum vulgare*, and *Æcanthus*—deposit their

eggs in stems of plants or under the leaf-sheaths of grasses (Forbes, '05: 143, 145, 148, 216). The mode of oviposition in these *Orthoptera* raises the question whether or not they are able to pass their complete life cycle within this habitat. Are the species which oviposit in the soil able to endure submergence during the wet season of the year, or must they each year re-invade this habitat from the more favorable adjacent regions? The sciomyzid fly is a regular inhabitant of such situations, for an allied species, *Tetanocera pictipes* Loew, has been found by Needham ('01: 580) to be aquatic, breeding on colonies of bur reed (*Sparganium*), and Shelford ('13a: 188, 284) also finds *plumosa* in wet places.

The flower spider, *Misumena*, captures its prey direct, frequenting flowers where its prey comes to sip nectar,

With more perfect drainage the character of this habitat would change; a more varied growth of vegetation would probably develop; and the relative abundance of the various kinds of animals would also change. The present imperfect drainage is more favorable to the accumulation of vegetable debris than if the habitat was connected with a stream which could float it away. The periodical drying hastens decay, and the deep cracks in the soil become burial places for various kinds of organic debris.

## 2. Colony of Wild Rye, *Elymus virginicus submuticus*, Station I, c\*

Wild rye is a swamp grass. This colony was located about half a mile north of the colony of slough grass (Station I, a) and about 222 feet south of the first east and west cross-road north of Charleston. For a general view of this grassy habitat see Figure 1, Plate II. In length this habitat extends about one third the distance between two consecutive telegraph poles, or about 65 feet. The conditions of the habitat are in general similar to those in the colony of *Spartina*. The black soil was very dry and much cracked when examined, late in August. Though a few plants of *Asclepias sullivantii* grew here among the grass, it was a dense, almost pure stand of wild rye, which reached a height of about three and a half feet.

Only a very few collections were made here, and these were for the sole purpose of determining the general composition of the association.

These collections, Nos. 153, 180, and 181, were as follows:

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\*Animals were not studied at Station I, b, and therefore the location will not be discussed here.

Common Garden Spider	<i>Argiope aurantia</i>	No. 153
Differential Grasshopper	<i>Melanoplus differentialis</i>	_____
Red-legged Grasshopper	<i>Melanoplus femur-rubrum</i>	No. 180
Dorsal-striped Grasshopper	<i>Xiphidium strictum</i>	No. 180
Meadow Grasshopper	<i>Orchelimum vulgare</i> , adult, and nymphs of <i>vulgare</i> or <i>glaberrimum</i>	No. 180
Texan Katydid	<i>Scudderia texensis</i>	No. 181

These are all abundant species. *O. vulgare*, by its persistent fiddling, is noticeable in all such grass spots during hot sunny weather. A live differential grasshopper was found in the web of the garden spider. A comparison of the two colonies of swamp grasses, *Spartina* and *Elymus*, will probably help to give one a general idea of the kind of invertebrates which were abundant in the original swamp-grass area of this vicinity. It will be noticed that grass and grass eaters are the dominant species, and that upon these a smaller number of predaceous animals depend. The characteristic species are the *Orthoptera* and the garden spider. This spider, on account of its predaceous habits, is able to live in a great variety of open situations, but does not normally live in dense woodlands.

### 3. Wet Area of Swamp Milkweed (*Asclepias incarnata*), Station I, d

This colony of swamp milkweed was about one eighth of a mile north of the east and west cross-road. This flat, poorly drained black-soil area, about 80 feet long, was wet throughout August, crawfish holes being abundant (Pl. IIIA, fig. 2; Pl. IIIB, figs. 1, 2). To the east, beyond the boundary fence, in the adjoining corn field, stood a pool of water surrounded by a zone of yellowish weakened corn, visited occasionally by a few shore birds. Along the east side of the newly formed railway embankment (Pl. III, fig. 1) is a shallow trench containing water and a growth of young willows (*Salix*) and cottonwoods (*Populus deltoides*), also blue flags (*Iris versicolor*), bulrush (*Scirpus*), and sedge (*Carex*). The characteristic plants over this area were the abundant swamp milkweed (*Asclepias incarnata*, Pl. IIIA, fig. 1) and *Bidens*. A few plants of water horehound (*Lycopus*) and dogbane (*Apocynum medium*) were present, and many individuals of a low plant with a winged stem (*Lythrum alatum*).

The collections (Nos. 1, 12, 13, 14, 15, 18, 32, 37, 45, 156, and 157) of animals taken here were as follows:



Pond snail	<i>Galba umbilicata</i>	18
Prairie Crawfish	<i>Cambarus gracilis</i>	—
Garden Spider	<i>Argiope aurantia</i>	—
Ambush Spider	<i>Misumena aleatoria</i>	157
Chigger	<i>Trombidium</i> sp.	—
Nine-spot Dragon-fly	<i>Libellula pulchella</i>	—
Stink-bug	<i>Euschistus variolarius</i>	12
Small Milkweed-bug	<i>Lygaeus kalmii</i>	12
Large Milkweed-bug	<i>Oncopeltus fasciatus</i>	1
Ambush Bug	<i>Phymata fasciata</i>	12
Tarnished Plant-bug	<i>Lygus pratensis</i>	12
Soldier-beetle	<i>Chauliognathus pennsylvanicus</i>	156
Black Flower-beetle	<i>Euphoria sepulchralis</i>	156
Four-eyed Milkweed-beetle	<i>Tetraopes tetraophthalmus</i>	12
Milkweed-beetle	<i>Tetraopes femoratus</i> (?)	1
Leaf-beetle	<i>Diabrotica atripennis</i>	1
Dogbane Beetle	<i>Chrysochus auratus</i>	14
Celery Butterfly	<i>Papilio polyxenes</i>	15, 45
Philodice Butterfly	<i>Eurymus philodice</i>	12
Idalia Butterfly	<i>Argynnis idalia</i>	33
Milkweed Butterfly	<i>Anosia plexippus</i>	—
Honeysuckle Sphinx	<i>Hemaris diffinis</i>	32
Giant Mosquito	<i>Psorophora ciliata</i>	13
Giant Fly	<i>Mydas clavatus</i>	12
Honey-bee	<i>Apis mellifera</i>	—
Pennsylvania Bumblebee	<i>Bombus pennsylvanicus</i>	155
Bumblebee	<i>Bombus fraternus</i>	12
Bumblebee	<i>Bombus separatus</i>	12, 157
Carpenter-bee	<i>Xylocopa virginica</i>	1, 156*
Rusty Digger-wasp	<i>Chlorion ichneumonum</i>	12

The soft, wet, black soil contained large numbers of crawfish holes, and from several of them T. L. Hankinson dug specimens of *Cambarus gracilis*. Frogs (*Rana*) were seen but none were secured. A Carolina rail was flushed from the ditch along the track, and on the margins of the water in the adjacent corn field Mr. Hankinson recognized some shore birds. The dragon-fly *Libellula pulchella* was abundant on the wing and resting on the vegetation, and two examples were found in the webs of *Argiope aurantia*. No nymphs were found, but doubtless eggs were laid by some of the numerous adults. It was interesting to observe the fresh burrows of the crawfish which had traversed the fresh firm yellow clay of the recently reinforced railway embank-

ment (shown in Pl. II, fig. 2) and appeared upon its surface. The occurrence here of a small snail, *Galba umbilicata*, is of interest. A very large species of mosquito with conspicuously banded legs, *Psorophora ciliata*, was found here. Though these aquatics and the ground forms did not receive much attention, they are representative of wet places.

The presence of certain plants in this habitat has determined the occurrence of several species of animals. Thus the dogbane *Apocynum medium* accounts for the brilliantly colored leaf-beetle *Chrysochus auratus*, which feeds upon its leaves and roots. But the most conspicuous feature of this habitat in August is the variety of insects which are attracted by the flowers of the swamp milkweed. These flowers may be regarded as so much insect pasture. A few butterflies were observed, *Papilio polyxenes* being found in an *Argiope* web; and on the flowers of the swamp milkweed were *Papilio cresphontes*, *Eurytmus philodice*, *Argynnis idalia*, *Anosia plexippus*, and the honeysuckle sphinx (*Hemaris diffinis*). Among the most abundant *Hymenoptera* were the honey-bee (*Apis mellifera*) and the common rusty digger-wasp (*Chlorion ichneumoncum*). Others were the carpenter-bee (*Xylocopa virginica*) and the bumblebees *Bombus fraternus* and *separatus*. On the flowers of the thistle (*Cirsium*) near this station, *Bombus pennsylvanicus* was also taken. The giant fly (*Mydas clavatus*) was taken on the flowers of the swamp milkweed. Beetles from these flowers were the spotted milkweed-beetles (*Tetraopes tetraophthalmus* and *femoratus*?) the flower-beetle *Euphoria sepulchralis*, and, late in August, great numbers of the soldier-beetle *Chauliognathus pennsylvanicus*. The *Hemiptera* found are equally characteristic, and include both of the common milkweed-bugs (*Oncopeltus fasciatus* and *Lygæus kalmii*) and *Lygus pratensis*. Still other insects were present on the milkweeds, preying not upon the plant, but upon its guests. These were the ambush bug (*Phymata fasciata*) and the ambush spider (*Misumena aleatoria*), the latter being captured with a large bumblebee (*Bombus separatus*) in its grasp. It is thus quite evident that this milkweed has an important controlling influence upon the insects of this habitat at this season. Another abundant animal was the chigger, a larval mite of the genus *Trombidium*, which is brushed from the vegetation by one's arms and legs. These irritating pests were so abundant that to work with comfort in this region it was necessary to powder one's clothes and body with flowers of sulphur. These young six-legged mites are supposed to prey upon insects, as do the adults. According to Chittenden ('06 : 4) chiggers are most abundant in damp places and forest margins, and among shrubs, grass,

and herbage. The adults are known to eat plant-lice, small caterpillars, and grasshoppers' eggs. This mite is thus an important predaceous member of the association. The dragon-flies are well known to feed upon small insects, which they capture on the wing, and on account of their abundance they are influential insects here.

An examination of the list of animals secured at this station shows that there is considerable diversity in the conditions under which their breeding takes place. Indeed the breeding habits and places are almost as diverse as are the feeding relations. Thus the snail *Galba* breeds in the water; and the crawfish, *Cambarus gracilis*, lives as a burrower except for a brief period in spring, when it is found in streams. It is distinctly a subterranean species. The garden spider, in the fall, leaves its eggs in its web. The life history of the ambush spider is not known. It seems probable that the sexes meet upon flowers, and as the flowers fade they migrate to fresh ones—a response which Hancock has observed ('11 : 182-186) in the allied species *Misumena vatia*. The ambush bug, when found on flowers, is in a large number of cases copulating, but where the eggs are laid and the young developed is unknown to me. Though this bug also must migrate with the fading of the flowers, after the habit of *Misumena*, it is winged and does not have to go "on foot" as the spider probably does. When disturbed these bugs do not as a rule seek to escape by flight, and it is not unlikely that they often crawl from one flower to another when the distance is short. The soldier-beetle is similar to the ambush bug in its propensity to copulate on flowers. The milkweed beetles and the dogbane beetle are commonly seen copulating upon the leaves and stems of the plants on which they live. The larva of the milkweed beetles bore into the roots and stems of plants; the dogbane beetle has similar habits. Of the butterflies, *Anosia* was observed copulating on the willows, one sex with the wings spread, the fore ones overlapping in part the hinder pair, the other sex with the wings folded together vertically, the heads of the insects being turned in opposite directions. The eggs of the mosquito are laid near the surface of the water. The honey-bee and bumblebees are social, and the breeding and care of the young are quite different from those of the other animals found in this habitat. *Xylocopa* cuts the nest for its brood in solid wood, and seems rather foreign upon the prairie, although posts and ties are now to be found there. The rusty digger-wasp provisions its nest, which is dug in the ground, with various grasshoppers; upon these the egg is laid and the young larva feeds. This wasp probably did not breed in this moist habitat. The wet substratum here is probably unfavorable for the breeding of those *Orthoptera* which deposit their eggs in the soil.

## 4. Cone-flower and Rosin-weed Colony, Station I, e

This station was continuous with and just north of the swamp milkweed area (Station I, d) just described. The surface of the ground sloped gently upward toward the north, but none of it was free from crawfish holes, and the ground-water level was not far below. The soil is very dark in color.

The general appearance of this habitat is shown in Plate V. The large-leaved plants are *Silphium terebinthinaceum*, and the heads of the numerous cone-flowers (*Lepachys pinnata*) show as black points in the picture. The cone-flower was the dominant plant at this time. There were a few scattered plants of *Silphium integrifolium* and of wild lettuce (*Lactuca canadensis*). At the time the collecting was done in this area *Silphium* was not in blossom, and all the flower-collecting was from *Lepachys*.

The collections of animals taken here (Nos. 8, 40, and 158) are as follows:

Crawfish	<i>Cambarus</i> sp. (Burrows observed)	
Garden Spider	<i>Argiope aurantia</i>	40
Sordid Grasshopper	<i>Encoptolophus sordidus</i>	158
Differential Grasshopper	<i>Melanoplus differentialis</i>	40
Red-legged Grasshopper	<i>Melanoplus femur-rubrum</i>	40
Texan Katydid	<i>Scudderia texensis</i>	40
Dorsal-striped Grasshopper	<i>Xiphidium strictum</i>	40
Black-horned Meadow Cricket	<i>Aecanthus nigricornis</i>	40
Membracid bug	<i>Campylenchia curvata</i>	40
Jassid	<i>Platymetopius frontalis</i>	40
Lygæid	<i>Ligyrocoris sylvestris</i>	40
Ambush Bug	<i>Phymata fasciata</i>	40
Chrysomelid beetle	<i>Nodonota convexa</i>	40
Southern Corn Root-worm Beetle	<i>Diabrotica 12-punctata</i>	40
Robber-fly	<i>Asilidæ</i>	—
Trypetid fly	<i>Euaresta æqualis</i>	40
Eucerid bee	<i>Melissodes bimaculata</i>	8
Eucerid bee	<i>Melissodes obliqua</i>	8
Nomadid bee	<i>Epeolus concolor</i>	8
Social wasp	<i>Polistes</i> sp.	—

Collection No. 40 was made by sweeping the vegetation with an insect net. No. 8 is a collection made from the flowers of *Lepachys pinnata*. The nest of *Polistes* was across the railway track from this station. The abundance of *Melissodes obliqua* and of the pretty

*Epeolus concolor* on the flowers of *Lepachys* indicates the attractive power of this plant. The coarser plants furnish support for the webs of *Argiope*; the flowers serve as drinking cups in which *Phymata* lies in ambush; and the varied vegetation affords food for the numerous *Orthoptera*. The proximity of ground-water accounts for the presence of *Cambarus*, and an adjacent corn field explains the presence of *Diabrotica*. A robber-fly (*Asilidæ*) was seen but not captured. It is interesting to see *Melissodes obliqua* as it hurries round and round the heads of cone-flowers and sweeps up the great masses of yellow pollen. The hind pair of legs, when loaded with pollen, have nearly the bulk of the abdomen. Robertson ('94; 468) says that this is the most abundant visitor to the cone-flower, and more abundant on this flower than on any other.

It is probable that the conditions within this habitat were suitable for the breeding of most of the species listed. *Euaresia æqualis* has been bred from the seed pods of the cocklebur (*Xanthium*) and probably came from the adjacent corn field. It is most likely on flowers that the strepsipterid parasitic insects find many of their hosts (Pierce '09 b: 116). These insects are found on the following prairie insects: *Polistes*, *Odynerus*, *Chlorion ichneumoncum*, *C. pennsylvanicum*, and *C. atratum*. Robertson ('10) records many important observations on the hosts of Illinois *Strepsiptera*.

5. Colony of Blue Stem (*Andropogon*) and Drop-seed (*Sporobolus*), bordered by Swamp Milkweed, Station I, g\*

This colony formed the extreme northern part of the prairie area examined along the "Clover Leaf" track. It extended along the track for a distance of about 200 feet. The area is level black soil prairie. Its general appearance and location are indicated in Figure 2, Plate II, and in Figure 2, Plate III, photographs taken at the time of our study, and in Figure 2, Plate IV, a photograph taken by T. L. Hankinson April 23, 1911. This latter view clearly shows the character of the drainage during the spring wet season. During the late summer, the dry season, the ditch along the railway track concentrates the drainage so that a colony of swamp milkweed (*Asclepias incarnata*) and small willows flourish in it. Upon the well-drained part of this area there is a rather rich growth of *Andropogon furcatus*, *A. virginicus*, and *Sporobolus cryptandrus*, and many plants of the dogbane *Apocynum medium* and a few plants of *Asclepias sullivantii*. This was the largest and best colony of the upland prairie grasses seen along the Clover Leaf tracks; and yet when it is compared with the patches of such

\*No collections were made at Station I, f.

grass east of Charleston (Station III) it is a meager colony. Just south of this grassy colony was a large one of the mountain mint, *Pycnanthemum flexuosum*. This is shown in Figure 1, Plate IV.

The collections of animals (Nos. 1, 2, 3, 4, 6, 7, 19, 28a, 36, 39, 44, 157, and 159) are as follows:

Pond snail	<i>Physa gyrina</i>	19
Crawfish	<i>Cambarus</i> sp.	—
Harvest-man	<i>Liobunum politum?</i>	7
Garden Spider	<i>Argiope aurantia</i>	6, 39
Ambush Spider	<i>Misumena alcatioria</i>	6, 157, 159
Red-tailed Dragon-fly	<i>Sympetrum rubicundulum</i>	7
Nine-spot Dragon-fly	<i>Libellula pulchella</i>	—
Prairie Ant-lion	<i>Brachynemurus abdominalis</i>	36
Lace-wing Fly	<i>Chrysopa oculata</i>	44
Grasshopper	<i>Syrbula admirabilis</i>	3
Sordid Grasshopper	<i>Encoptolophus sordidus</i>	44
Differential Grasshopper	<i>Melanoplus differentialis</i>	39
Red-legged Grasshopper	<i>Melanoplus femur-rubrum</i>	3, 39
Texan Katydid	<i>Scudderia texensis</i>	2, 44
Meadow Grasshopper	<i>Orchelimum vulgare</i>	—, 3
Cone-nosed Katydid	<i>Conocephalus</i> sp.	159
Four-spotted White Cricket	<i>Cecanthus 4-punctatus</i>	3
Stink-bug	<i>Euschistus variolarius</i>	39
Small Milkweed-bug	<i>Lygaeus kalmii</i>	1, 6
Large Milkweed-bug	<i>Oncopeltus fasciatus</i>	1
Rapacious Soldier-bug	<i>Sinca diadema</i>	5
Ambush Bug	<i>Phymata fasciata</i>	1
Four-eyed Milkweed Beetle	<i>Tetraopes tetraophthalmus</i>	1
Rhipiphorid beetle	<i>Rhipiphorus dimidiatus</i>	6
Bill-bug	<i>Sphenophorus venatus</i>	39
Milkweed Butterfly	<i>Danais archippus</i>	—
Giant Mosquito	<i>Psorophora ciliata</i>	44
Mycetophilid fly	<i>Sciara</i> sp.	6
Giant Bee-fly	<i>Exoprosopa fasciata</i>	6
Vertebrate Robber-fly	<i>Promachus vertebratus</i>	39, 44
Honey-bee	<i>Apis mellifica</i>	1
Bumblebee	<i>Bombus fraternus</i>	1
Bumblebee	<i>Bombus separatus</i>	1
Eucerid bee	<i>Melissodes bimaculata</i>	6
Nomadid bee	<i>Epeolus concolor</i>	6
Leaf-cutting bee	<i>Megachile mendica</i>	1
Rusty Digger-wasp	<i>Chlorion ichneumoneum</i>	1
Myzinid wasp	<i>Myzine sexcincta</i>	1, 6

*Physa* and *Cambarus* were found among the milkweeds on account of the wet ground, and the presence of the giant mosquito was probably due to the same condition. The majority of the other animals were attracted to this habitat by the milkweed, particularly by its flowers. Among these were the milkweed bugs and beetles, the milkweed butterfly, the honey-bee, and the rusty digger-wasp. The dense growth of the milkweeds does not appear to be so favorable to the garden spider as is the more open and irregular growth of vegetation elsewhere. The ambush spider frequented the milkweed flowers for prey and also the flower masses of the mountain mint, on which it was in active competition with the ambush bug and the rapacious soldier-bug, which have similar food habits. The mountain mint, whose flowers are frequented by the predaceous animals just mentioned, is also visited by rhipiphorid beetles, the bee-fly (*Exoprosopa fasciata*), the bees *Melissodes bimaculata* and *Epeolus concolor*, and the myzinid wasp *Myzine sexcincta*. The prairie grasses were frequented by a large variety of *Orthoptera*, which showed a decided preference for them, their abundance being evident in the list. The wide-ranging predators and parasites, such as *Liobunum*, *Libellula*, *Sympetrum*, *Chrysopa*, *Brachynemurus*, *Promachus*, *Chlorion*, and *Myzine*, probably forage over extensive areas compared with the relatively sedentary kinds, such as *Misumena*, *Argiope*, *Phymata*, and *Sinea*. *Phymata* was captured on a milkweed flower with a honey-bee; *Promachus vertebratus* was taken on a grass stem with a stink-bug (*Euschistus variolarius*); and *Misumena aleatoria* was taken with a large, nearly mature female nymph of *Conocephalus*.

The conditions which permit an animal to breed in a habitat have an important influence upon the character of its population. It is evident that many of the animals taken do not breed here. Some of the relatively sedentary kinds, such as *Physa*, *Cambarus*, and *Argiope*, and probably *Misumena*, do not cover long distances. Good examples of the wider ranging forms are *Sympetrum*, *Libellula*, *Danais*, *Promachus*, *Apis*, *Bombus*, and *Chlorion*. Several of the animals, as the snails, crawfish, and the dragon-flies, require an aquatic habitat. *Chrysopa* places its eggs among colonies of plant-lice, and *Brachynemurus* probably spends its larval life in dry or sandy places, feeding upon ants and other small insects, as do other ant-lions. Several of the *Orthoptera* deposit their eggs in the soil; and some of the locustids, among grasses and herbaceous stems. Others are found copulating upon the plants on which the young feed, as *Tetraopes*, *Chrysochus*, *Lygæus*, and *Oncopeltus*; and still others copulate in the flowers mainly, as *Phymata*. It is probable that on the flowers some of the para-

sitic species find their hosts, as Pierce ('04) has shown to be the case in the rhipiphorid genus *Myodites*. *Rhipiphorus* is probably parasitic.

### 6. Supplementary Collections from Station I

In addition to the specimens given in the preceding lists for Station I there are others, general collections from this area, which should be listed for this prairie. For details concerning each species of the following consult the annotated list.

Garden Spider	<i>Argiope aurantia</i>	26
Ambush Spider	<i>Misumena alcatoria</i>	31
Chigger	<i>Trombidium</i> sp.	—
Dorsal-striped Grasshopper	<i>Xiphidium strictum</i>	35
Coreid bug	<i>Harmostes reflexulus</i>	27
Ambush Bug	<i>Phymata fasciata</i>	24, 26, 43
Ladybird	<i>Hippodamia parenthesis</i>	Hankinson
Leaf-beetle	<i>Trirhabda tomentosa</i>	Hankinson
Four-eyed Milkweed Beetle	<i>Tetraopes 4-ophthalmus</i>	35
Old-fashioned Potato Beetle	<i>Epicauta vittata</i>	Hankinson
Margined Blister-beetle	<i>Epicauta marginata</i>	Hankinson
Black Blister-beetle	<i>Epicauta pennsylvanica</i>	26, 152
Snout-beetle	<i>Centrinus penicellus</i>	41
Snout-beetle	<i>Centrinus scutellum-album</i>	Hankinson
Giant Bee-fly	<i>Exoprosopa fasciata</i>	24, 31
American Syrphid	<i>Syrphus americanus</i>	11
Tachinid fly	<i>Trichopoda ruficauda</i>	38
Bumblebee	<i>Bombus separatus</i>	22
False Bumblebee	<i>Psithyrus variabilis</i>	22
Eucerid bee	<i>Melissodes obliqua</i>	24, 48
Short Leaf-cutting Bee	<i>Megachile brevis</i>	Hankinson
Halictid bee	<i>Halictus fasciatus</i>	26
Halictid bee	<i>Halictus virescens</i>	23
Stizid wasp	<i>Stizus brevipennis</i>	35, Hankinson
Rusty Digger-wasp	<i>Chlorion ichneumoncum</i>	6
Harris Digger-wasp	<i>Chlorion harrisi</i>	24
Digger-wasp	<i>Ammophila nigricans</i>	24
Solitary wasp	<i>Odynerus vagus</i>	46

## II. PRAIRIE AREA NEAR LOXA, ILLINOIS, STATION II

This station includes patches of prairie along the Cleveland, Cincinnati, Chicago and St. Louis (Big Four) railroad right-of-way between Charleston and Mattoon, Ill., and about one mile west of



the small station of Loxa. Along this track the telegraph-pole numbers were used in locating our substations. This is a rather level black soil area, originally poorly drained and wet, but now considerably modified by the ditching and grading occasioned by railway construction and maintenance. The changes have been similar to those on the prairie north of Charleston, but the ditching has been a few feet deeper and the embankment is higher. The most abundant and characteristic kinds of vegetation are the tall prairie grasses—blue stem (*Andropogon furcatus*), drop-seed (*Sporobolus cryptandrus*), and beard grass (*Andropogon virginicus*)—a rosin-weed (*Silphium laciniatum*), the flowering spurge (*Euphorbia corollata*), wild lettuce (*Lactuca canadensis*), rattlesnake-master (*Eryngium yuccifolium*), and beggar-ticks (*Desmodium*). Many other kinds of plants were also present. The general appearance of this habitat is shown in plates VI and VII.

Our collections from this prairie (Nos. 47–57 and 176–178) are as follows:

Garden Spider	<i>Argiope aurantia</i>	49, 179
Ambush Spider	<i>Misumena aleatoria</i>	47, 178
Sordid Grasshopper	<i>Encoptolophus sordidus</i>	48
Two-lined Grasshopper	<i>Melanoplus bivittatus</i>	55
Differential Grasshopper	<i>Melanoplus differentialis</i>	48
Meadow Grasshopper	<i>Orchelimum vulgare</i>	178
Lance-tailed Grasshopper	<i>Xiphidium attenuatum</i>	48
Dorsal-striped Grasshopper	<i>Xiphidium strictum</i>	48, 50, 57
Stink-bug	<i>Euschistus variolarius</i>	50, 52, 178
Ambush Bug	<i>Phymata fasciata</i>	48, 52, 54, 55, 57, 178
Dusky Leaf-bug	<i>Adelphocoris rapidus</i>	55
Soldier-beetle	<i>Chauliognathus pennsylvanicus</i>	178
Southern Corn Root-worm	<i>Diabrotica 12-punctata</i>	55
Margined Blister-beetle	<i>Epicauta marginata</i>	48
Black Blister-beetle	<i>Epicauta pennsylvanica</i>	48, 178
Rhipiphorid beetle	<i>Rhipiphorus dimidiatus</i>	52
Rhipiphorid beetle	<i>Rhipiphorus limbatus</i>	178
Snout-beetle	<i>Rhynchites œneus</i>	48
Thoe Butterfly	<i>Chrysophanes thoe</i>	55
Dogbane Caterpillar	<i>Annalo cglenensis</i> or <i>tenera</i>	53
Giant Bee-fly	<i>Exoprosopa fasciata</i>	47, 57, 176
Robber-fly	<i>Deromyia</i> sp.	51
Vertebrated Robber-fly	<i>Promachus vertebratus</i>	56
Corn Syrphid	<i>Mesogramma politum</i>	177
Syrphid fly	<i>Allograpta obliqua</i>	177

Tachinid fly	<i>Cistogaster immaculata</i>	55
Pennsylvania Bumblebee	<i>Bombus pennsylvanicus</i>	50, 52, 55, 176
False Bumblebee	<i>Psithyrus variabilis</i>	176
Eucerid bee	<i>Melissodes bimaculata</i>	48
Nomadid bee	<i>Epeolus concolor</i>	48, 52
Halictid bee	<i>Halictus obscurus</i>	55
Halictid bee	<i>Halictus fasciatus</i>	48, 52
Black Digger-wasp	<i>Chlorion atratum</i>	55
Pennsylvania Digger-wasp	<i>Chlorion pennsylvanicum</i>	55
Myzinid wasp	<i>Myzine sexcincta</i>	52, 55
Ant	<i>Formica pallide-fulva schaufussi</i> <i>incerta</i>	52

The general conditions of this prairie appear to have been less disturbed than at Station I; at least the prairie vegetation is more extensive and uniform. The change in the vegetation is apparently greater than the change in the kinds of animals. Their feeding and breeding relations appear to be much like those at the prairie stations previously discussed.

In the flowers of the cup-leaved rosin-weed (*Silphium integrifolium*) was found a giant bee-fly (*Exoprosopa fasciata*) which had been captured by the ambush spider (*Misumecna alcatoria*), and on webs in colonies of this same plant the garden spider (*Argiope aurantia*) was observed, with a grasshopper (*Melanoplus differentialis*) entangled in the web. From the flowers of this *Silphium* the following insects were taken: *Epicauta marginata* and *E. pennsylvanica*, *Rhynchites aeneus*, *Phymata fasciata*, *Encyrtolophus sordidus*, *Melanoplus differentialis* (nymph), *Xiphidium strictum* (adult and nymph), *X. attenuatum*, *Melissodes bimaculata* and *obliqua*, *Epeolus concolor*, and *Halictus fasciatus*. The margined blister-beetle (*Epicauta marginata*) was found both upon the flowers and the leaves of the plant. On the flowers of the purple prairie clover (*Petalostemum purpureum*), *Bombus pennsylvanicus*, *Xiphidium strictum*, and *Euschistus variolarius* were taken. Collection 176 was taken from the flowers of *Liatris scariosa*, and Nos. 55 and 178 from the flowers of *Eryngium yuccifolium*.

Swarms of the small corn syrphid, *Mesogramma politum*, were present, on one day settling by dozens on my hands and clothes, where they were easily grasped by the wing. It had been a warm day, and this swarming was in the sunshine at about 4:30 p. m. The flies came from a large corn field a few feet away.

## III. PRAIRIE AREA EAST OF CHARLESTON, STATION III

This prairie area is about two miles east of Charleston along the "Big Four" railway track. There were two colonies here. One, substation *a*, was on low black-soil prairie just west of the first north and south road crossing the railway track east of Charleston. This was largely a colony of the large-leaved rosin-weed, *Silphium terebinthinaceum*. The second colony, substation *b*, was a mile and a half directly east of substation *a*, and half a mile east of the second north and south road east of Charleston.

Substation or "station" *a* was originally far out upon the black soil prairie; *b*, on the other hand, is of special interest because it was originally wooded, has been cleared and maintained as a railroad right-of-way, and contains today, therefore, a practically unique mixture of forest and prairie plants and animals, with the prairie kinds dominating. The soil, lighter in color than the black soil prairie, is representative of the wooded regions. This colony has every appearance of a cleared forest area invaded by prairie organisms.

The animals at station *a* were not studied, and the only record is that of the black blister-beetle, *Epicauta pennsylvanica* (No. 119), which was abundant on the flowers of *Silphium terebinthinaceum*.

At station *b* excavation was necessary to lower the road-bed, and upon the disturbed soil thus thrown up along the track the prairie vegetation had become established. The general appearance of this region is shown in plates VIII and IX. Here grew large quantities of rosin-weed (*Silphium terebinthinaceum*) and blue stem (*Andropogon*); in places upon high ground, indeed, this prairie grass was dominant. Associated with it was the flowering spurge, *Euphorbia corollata*, as seen in Plate VIII. The forest near by is shown in the background. This same forest and grass area is shown in the background and middle of Plate IX, and in the foreground of the same picture is shown the mixture of prairie and forest plants. Here are hickory sprouts, crab-apple, grape, sumac, and smilax, intermingled with *Silphium*, blue stem, and *Lactuca canadensis*. Not all of these appear in the photograph, but they were present in some parts of the colony.

The collections here (Nos. 58-62 and 175) are as follows:

Leather-colored Grasshopper	<i>Schistocera alutacea</i>	59
Black-horned Meadow Cricket	<i>Ecanthus nigricornis</i>	62
Meadow Grasshopper	<i>Orchelimum vulgare</i>	175
Soldier-beetle	<i>Chauliognathus pennsylvanicus</i>	175
Spotted Grape-beetle	<i>Pelidnota punctata</i>	58
Black Blister-beetle	<i>Epicauta pennsylvanica</i>	

(Sta. III, *a*) 119

Cabbage Butterfly	<i>Pontia rapæ</i>	61
Vertebrated Robber-fly	<i>Promachus vertebratus</i>	62
Pennsylvania Bumblebee	<i>Bombus pennsylvanicus</i>	175
Impatient Bumblebee	<i>Bombus impatiens</i>	175
Bumblebee	<i>Bombus auricomus</i>	175
(Rose-gall)	<i>Rhodites nebulosus</i>	60

No animals were taken here which were dependent upon the sumac, hickory, crab-apple, or smilax. *Pelidnota* lives upon the grape, and grapes are primarily woodland or forest-margin rather than prairie plants. *Schistocerca* is also probably a marginal species. On the flowers of *Silphium terebinthinaceum* were taken *Orchelimum vulgare*, *Chauliognathus pennsylvanicus*, and *Bombus pennsylvanicus*, *auricomus*, and *impatiens*.

The persistence of woodland vegetation in this locality, in spite of the repeated mowings and burnings, shows that it has much vigor, and would, if undisturbed, in a few years shade out the prairie vegetation and restore the dominance of the forest. With such a change in the vegetation there would of course be a corresponding change in the animals.

## DESCRIPTION OF THE FOREST HABITATS AND ANIMALS

### 1. *The Bates Woods, Station IV*

The Bates woodland area is located about three and a half miles northeast of Charleston on the farm that was owned by Mr. J. I. Bates, and consists of about 160 acres. It includes a bottom-land area near the Embarras River, and extends up the valley slope on to the upland. It is isolated from the trees bordering the river (Pl. X, fig. 1) by a narrow clearing, and from those on the northeast, north, and northwest by another clearing (Pl. XI); on the south and southwest it is continuous with partially cleared areas, which extend south to the Big Four railway track.

The river bottom-land is undulating and rises rather gradually toward the base of the bluffs. The bluff line is irregular on account of the ravines which have been etched in it, the largest of which forms the southern boundary of the region examined. The upland is relatively level. The soils on the bottom are darker colored, except in places near the base of the bluff, and at the mouths of the ravines where the upland soil has been washed down. The upland soil is presumably the "light gray silt loam" of the State Soil Survey (Moultrie County Soils, Ill. Exper. Sta. Soil Rep., 1911, No. 2, p. 23). All of

the area examined was well drained, and all was forested. The region is not homogeneous physically or in its vegetation, and for this reason the area is divided into substations in order that the influences of the local conditions within the forest might be preserved, and their individuality recognized.

## 2. The Upland Oak-Hickory Forest, Station IV, a

The general appearance of this forest is shown in plates XII and XIII. This is an open second-growth forest composed of oaks and hickories—such as white oak (*Quercus alba*), black oak (*Q. velutina*), shag-bark hickory (*Carya ovata*), bitternut (*C. cordiformis*), pignut (*C. glabra*), and scattered individual trees of red oak (*Q. rubra*), walnut (*Juglans nigra*), and mulberry (*Morus rubra*). The shrubs are sassafras (*Sassafras variifolium*), sumac (*Rhus glabra*), Virginia creeper (*Pseodera quinquefolia*), poison ivy (*Rhus toxicodendron*), rose (*Rosa*), raspberry (*Rubus*), moonseed (*Menispermum canadense*), and tree seedlings. The average diameter of the largest trees is 8–10 inches. Most of the small growth consists of the sprouts from stumps, and many of these are 2–3 inches in diameter. The forest crown is not complete, and as a consequence there are more or less open patches in which most of the herbaceous growth is found, such as horse mint (*Monarda bradburiana*), pennyroyal (*Hedeoma pulegioides*), everlasting (*Antennaria plantaginifolia*), tick-trefoil (*Desmodium nudiflorum*), and other, less abundant kinds. Even a plant quite characteristic of the prairie, the dogbane *Apocynum*, was found here in one of the open glades.

The forest floor has an unequal covering of dead leaves, largely oak, most of which lie in the low vegetation and in slight depressions. Occasionally there is but little cover and the light-colored soil is exposed. There are few stumps and logs in this part of the forest, and no thick layer of vegetable mold, so that one would not expect to find any animals which normally frequent moist soil and vegetable debris. As this is a second-growth forest it lacks the conditions which abound in an original growth, where are old, dead and decaying trees, and numerous decaying logs and stumps. In this respect the woods is not fully representative of an original upland forest on well-drained bluff land.

The relative evaporating power of the air of this substation was 54 per cent. of that of the standard instrument in the open garden at the Normal School, a fact which indicates a relative evaporation comparable to that of the ordinary black-soil prairie; in producing this condition, the glade-like, open character of this forest is undoubtedly an important factor.

The characteristics of this habitat may be summed up as follows: upland, open, relatively dry second-growth oak-hickory forest, with little undergrowth of shrubs and herbs, and with a small amount of litter and humus; soil dry and firm; and few decaying stumps and tree trunks.

The collections of animals made here (Nos. 64-67, 69, 71, 74-83, 88, 91-93, 102, 103, 107, 109, 118, 120-123, 127, 135, 136, 142, 145, 147, 150, 151, 162, 163, 166, 169, 170, 171, and 183) are as follows:

Land snail	<i>Polygyra albolabris</i>	91
Predaceous snail	<i>Circinaria concava</i>	71
Land snail	<i>Zonitoides arborea</i>	71
Carolina slug	<i>Philomycus carolinensis</i>	71
Land snail	<i>Pyramidula perspectiva</i>	71, 88
Harvest-spider	<i>Liobunum vittatum</i>	82, 123
Harvest-spider	<i>Liobunum ventricosum</i>	123b
Stout Harvest-spider	<i>Liobunum grande</i>	82
Island Spider	<i>Epeira insularis</i>	70
White-triangle Spider	<i>Epeira verrucosa</i>	70
Rugose Spider	<i>Acrosoma rugosa</i>	70, 147
Ground Spider	<i>Lycosa</i> sp.	142, 150
White Ant	<i>Termes flavipes</i>	72, 76, 79
Ant-lion	<i>Myrmecleonidæ</i> (Forest border)	183
Dog-day Harvest-fly	<i>Cicada linnei</i>	162
Periodical Cicada	<i>Tibicen septendecim</i>	—
Forest Walking-stick	<i>Diapheromera femorata</i>	64, 93
Grouse Locust	<i>Tettigidea lateralis</i>	109
Short-winged Grouse Locust	<i>Tettigidea parvipennis</i>	122
Green Short-winged Grasshopper	<i>Dichromorpha viridis</i>	67, 92, 93, 121, 123
Sprinkled Grasshopper	<i>Chlocaltis conspersa</i>	67, 93, 122
Boll's Grasshopper	<i>Spharagemon bolli</i>	67, 150
Lesser Grasshopper	<i>Melanoplus atlantis</i>	67
Acridiid grasshopper	<i>Melanoplus amplexens</i>	67
Acridiid grasshopper	<i>Melanoplus obovatipennis</i>	93
Forked Katydid	<i>Scudderia furcata</i>	109
Angle-winged Katydid	<i>Microcentrum laurifolium</i>	135
Common Katydid	<i>Cyrtophyllus perspicillatus</i>	145
Meadow Grasshopper	<i>Orchelimum cuticularc</i>	67, 93
Meadow Grasshopper	<i>Xiphidium nemorale</i>	93, 103
Striped Cricket	<i>Nemobius fasciatus</i>	67, 93, 122
Spotted Cricket	<i>Nemobius maculatus</i>	122
Woodland Cricket	<i>Apithus agitator</i>	93

Woodland Tiger-beetle	<i>Cicindela unipunctata</i>	136
Caterpillar-hunter	<i>Calosoma scrutator</i>	64
Carabid beetle	<i>Galerita janus</i>	171
Ladybird	<i>Coccinellidæ</i>	81
Splendid Dung-beetle	<i>Geotrupes splendidus</i>	120
Dogbane Beetle	<i>Chrysochus auratus</i>	103
Tenebrionid larva	<i>Meracantha contracta</i>	83
Philenor Butterfly	<i>Papilio philenor</i>	69, 166
Turnus Butterfly	<i>Papilio turnus</i>	—
Troilus Butterfly	<i>Papilio troilus</i>	163
Sphingid larva	<i>Cressonia juglandis</i>	102
Arctiid moth	<i>Halisidota tessellaris</i>	168
Notodontid moth	<i>Datana angusii</i>	65, 162
Notodontid moth	<i>Nadata gibbosa</i>	169
Notodontid moth	<i>Heterocampa guttivitta?</i>	127
Geometrid moth	<i>Eustroma diversilineata</i>	163
Gelechiid moth	<i>Ypsolophus ligulellus?</i>	
	76, 78, Hankinson	
(Cecidomyiid gall)	<i>Cecidomyia holotricha</i>	107, 170
(Cecidomyiid gall)	<i>Cecidomyia tubicola</i>	107
(Cecidomyiid gall)	<i>Cecidomyia caryæcola</i>	107, 170
Syrphid fly	<i>Chrysotoxum ventricosum</i>	163
Corn Syrphid	<i>Mesogramma politum</i>	
	76, 78, Hankinson	
Vespa-like Syrphid	<i>Milesia ornata</i>	103
Pigeon Tremex	<i>Tremex columba</i>	66
(Oak Bullet-gall)	<i>Holcaspis globulus</i>	170
(White Oak Club-gall)	<i>Andricus clavula</i>	170
(Oak Wool-gall)	<i>Andricus lana</i>	170
Formicid ant	<i>Cremastogaster lineolata</i>	118
Formicid ant	<i>Aphænogaster fulva</i>	74-80
Formicid ant	<i>Formica fusca subsericea</i>	163
Mutillid ant	<i>Sphærophthalma</i>	151
Short Caterpillar-wasp	<i>Ammophila abbreviata</i>	127

3. *Embarras Valley and Ravine Slopes, forested by the Oak-Hickory Association, Station IV, b*

This station included the slope of the valley from the river bottom (Station IV, *c*) to the upland forest (Station IV, *a*) and the side of the south ravine, the bottom of which forms Station IV, *d*. This substation is not as homogeneous physically as the upland or lowland forest, because the part along the south ravine is relatively open, is well drained, and has a south exposure, and the southeast slope to the low-

land forest on the other hand, is well wooded and shaded, and much more humid. The substation also has a considerable amount of litter, leaves, and humus. This region may be considered as transitional between the upland and lowland forest, but it represents, not one but two transitional stages, the south slope approaching the upland forest type, and the southeast slope approaching that of the lowland forest. Thus, if one walked from the upland forest down the slope of the south ravine, and eastward to the southeast valley slope to the bottom-land forest, he would traverse all the main degrees of conditions found at Station IV.

The forest cover consists primarily of the following trees: white oak (*Quercus alba*), black oak (*Q. velutina*), walnut (*Juglans nigra*), pignut (*Carya glabra*), and, in smaller numbers, mulberry (*Morus rubra*), red oak (*Quercus rubra*), shag-bark hickory (*Carya ovata*), bitternut (*C. cordiformis*); and of the following shrubs: redbud (*Cercis canadensis*), sassafras (*Sassafras variifolium*), moonseed (*Menispermum canadense*), five-leaved ivy (*Pseodera quinquefolia*), grape (*Vitis cinerea*), prickly ash (*Zanthoxylum americanum*), and sumac (*Rhus glabra*), the latter growing in large colonies on the open south ravine-slope. On the more moist and shaded southeast slope lived the clearweed (*Pilea pumila*), a plant quite characteristic of moist deep-shaded woods. Thus sumac and clearweed may be considered as index plants to the physical conditions in different parts of these two slopes, one shaded and the other rather open.

The atmometer, located on the upper part of the south ravine slope, gave a relative humidity of 31 per cent. of the standard in the garden of the Normal School. It will be recalled that in the upland forest (Station IV, *a*) the atmometer gave 54 per cent., the comparison showing how much less the evaporating power of the air is on the south ravine slope than it is in the upland forest. The relative evaporation was not determined for the southeast slopes, but the presence of *Pilea* clearly indicates that it is less than on the south ravine slope, where the instrument was located. On the lower parts of the valley slope, where this substation grades into the lowland, the layers of dead matted leaves and humus reached to a considerable depth, and looked as if they had been pressed down by drifting snows. Such places were found to contain very few animals.

This habitat is characterized by a sloping surface, by relative openness on the ravine side and dense shade on the valley slope, by relatively humid air, by second-growth forest somewhat transitional between that of the uplands (Station IV, *a*) and the river bottoms (Station IV, *c*), by a relatively large amount of shrubbery, by considerable



humus and litter, by moist soil, and by more logs and stumps than are in the upland forest.

The collections of animals made at this substation (Nos. 68, 84, 85, 87, 89, 90, 94, 100, 104, 105, 106, 108, 110, 111, 124, 125, 131, 132, 133, 140, 149, 161, 164, 165, 166, and 168) are as follows:

Land snail	<i>Polygyra clausa</i>	164
Land snail	<i>Vitrea indentata</i>	140, 164
Land snail	<i>Vitrea rhoadsi</i>	164
Land snail	<i>Zonitoides arborca</i>	84
Carolina Slug	<i>Philomycus carolinensis</i>	89, 125
Land snail	<i>Pyramidula perspectiva</i>	84, 164
Milliped	<i>Cleidogona casioannulata</i>	140
Milliped	<i>Polydesmus</i> sp.	125
Stout Harvest-spider	<i>Liobunum grande</i>	111
White Ant	<i>Termes flavipes</i>	125
Woodland Cockroach	<i>Ischnoptera</i> sp.	140
Green Short-winged Grasshopper	<i>Dichromorpha viridis</i>	110
Boll's Grasshopper	<i>Spharagemon bolli</i>	133
Scudder's Grasshopper	<i>Melanophus scudderi</i>	124
Woodland Cricket	<i>Apithcs agitator</i>	124
Caterpillar-hunter	<i>Calosoma scrutator</i>	100, 149
Wireworm	<i>Melanotus</i> sp.	125
Horned Passalus	<i>Passalus cornutus</i>	85
Tenebrionid larva	<i>Meracantha contracta</i>	140
Troilus Butterfly	<i>Papilio troilus</i>	161
Philenor Butterfly	<i>Papilio philenor</i>	166
Lycænid butterfly	<i>Everes comyntas</i>	161
American Silkworm	<i>Telea polyphemus</i>	163
Hickory Horned-devil	<i>Citheronia regalis</i>	68, 108
Arctiid caterpillar	<i>Halisidota tessellaris</i>	163, 168
Rotten-log Caterpillar	<i>Scolecocampa liburna</i>	125
Notodontid	<i>Datana angusii</i>	104
Notodontid larva	<i>Nadata gibbosa</i>	94
Geometrid	<i>Caberodes confusaria</i>	161
Slug Caterpillar	<i>Cochlidion</i> or <i>Lithacodes</i>	165
Pigeon Tremex	<i>Tremex columba</i>	132
(Acorn Plum-gall)	<i>Amphibolips prunus</i>	131
Old-fashioned Ant	<i>Stigmatomma pallipes</i>	140
Tennessee Ant	<i>Aphænogaster tennesseensis</i>	87
Formicid ant	<i>Myrmica rubra scabrinodis schneckii</i>	140

Carpenter-ant	<i>Camponotus herculeanus penn-</i> <i>sylvanicus</i>	84, 85
Rusty Carpenter-ant	<i>Camponotus herculeanus penn-</i> <i>sylvanicus ferrugineus</i>	90
Short Caterpillar-wasp	<i>Ammophila abbreviata</i>	124

4. Lowland or "Second Bottom," Red Oak-Elm-Sugar Maple Woodland Association, Station IV, c

This station includes the part of the forest located upon the upper or higher part of the river bottom. This area is sometimes called the "second bottom" because it is above the present flood-plain. The general position of the forest is shown in Figure 1, Plate X. The fringe of willows along the river bank is shown at *a*; the flood-plain area is cleared at *b*; the substation forest is at *c*; and part of the forest of the valley slope is seen at *d*. Other views of this station are shown in plates XIV, XV, and XVI (figures 1 and 2). The general slope is toward the river; minor inequalities are due to the action of the temporary streams which are etching into the uplands and depositing their burdens of debris at the mouths of the ravines. Soil, leaves, and other organic debris are washed from the upland, the ravines, and the valley slopes, and are deposited upon the bottoms, forming low alluvial fans, which have been built up in successive layers or sorted again and again as the temporary streams have wandered over the surface of the fan on account of the overloading and deposition which filled up their channels. In this manner the soil in general is not only supplied with moisture, drained from the upland, but the various soils are both mixed as successive layers of organic debris are buried by storms and also mulched by the large amount of this debris which is washed and blown to the lowland. No springs were found upon the southeast valley slope, but in the south ravine pools of water were present during August, 1910, when my observations were made.

The forest, characterized by hard maple (*Acer saccharum*), red oak (*Quercus rubra*), and elm (*Ulmus americana*), forms a dense canopy which shuts out the light and winds, thus conserving the moisture which falls and drains into it, and making conditions very favorable to a rich mesophytic hardwood forest. That the relative humidity is high is shown by the moisture found in the humus of the forest floor, and, further, not only by the presence of clearweed (*Pilea pumila*) and the nettle *Laportea canadensis*, which characterize such moist shady woods, but also by the presence of the scorpion-flies (*Bitacus*). These organisms are permanent residents where such condi-

ditions prevail, and their presence is as clearly indicative of certain physical conditions as that of aquatic animals would be indicative of other physical conditions. In addition to these evidences we have the readings of our atmometer, which showed the evaporating power of the air to be 26 per cent. of the standard in the garden at the Normal School. This shows that the relative evaporation is very low, and that conditions for the preservation of the moisture which falls and drains into this area are very favorable. The general character of this forest is shown in plates XIV, XV, and XVI, Figure 1.

The vegetational cover on the lowland is quite different in its composition from that on the upland. This is shown mainly by the presence of the elm (*Ulmus americana*), hard maple (*Acer saccharum*), and red oak (*Quercus rubra*), and secondarily, by the presence, in smaller numbers, of the black cherry (*Prunus serotina*), slippery elm (*Ulmus fulva*), shingle oak (*Quercus imbricaria*), and the Kentucky coffee-tree (*Gymnocladus dioica*). Other trees present are walnut (*Juglans nigra*), mulberry (*Morus rubra*), and bitternut (*Carya cordiformis*). The shrubs and vines are gooseberry (*Ribes cynosbati*), prickly ash (*Zanthoxylum americanum*), redbud (*Cercis canadensis*), buck-brush (*Symphoricarpos orbiculatus*), green brier (*Smilax*), five-leaved ivy (*Psedera quinquefolia*), moonseed (*Menispermum canadense*), bittersweet (*Celastrus scandens*), and grape (*Vitis cinerea*). The characteristic herbaceous vegetation is nettle (*Laportea canadensis*), clearweed (*Pilea pumila*), bellflower (*Campanula americana*), Indian tobacco (*Lobelia inflata*), tick trefoil (*Desmodium grandiflorum*), *Actinomeris alternifolia*, maiden hair fern (*Adiantum pedatum*), beech fern (*Phegopteris hexagonoptera*), the rattlesnake fern (*Botrychium virginianum*), and *Galium circæans* and *G. trifolium*.

Although the forest is generally dense and therefore deeply shaded, there are some places which are comparatively open. Attention, however was devoted mainly to the denser parts. At one place, near the base of the eastern slope of the valley, a few trees had been cut within a few years, and in this glade the conditions and plants and animals were different from those in the dense forest. (See Pl. XVI, figs. 1 and 2.)

This habitat may be characterized as follows: lowland densely covered by sugar maple-red oak forest (climax mesophytic); very humid air; a moist soil; relatively few shrubs; herbaceous plants—nettles and clearweed—characteristic of damp, shady, rich woods; and considerable litter and humus in places.

The collections of animals made here (Nos. 113, 114, 116, 117, 137-139, 141, 143, 144, 173, 182, and 184) are as follows, the italicized numbers designating collections from the glade:

Predaceous Snail	<i>Circinaria concava</i>	113
Land snail	<i>Vitrea indentata</i>	113
Slug eggs	<i>Philomycus</i> (?) eggs	114
Alternate Snail	<i>Pyramidula alternata</i>	173
Milliped	<i>Callipus lactarius</i>	113
Ambush Spider	<i>Misumena aleatoria</i>	184
Tent Epeirid	<i>Epeira domiciliorum</i>	131, 173
Three-lined Epeirid	<i>Epeira trivittata</i>	138
Spined Spider	<i>Acrosoma spinea</i>	138, 172
Rugose Spider	<i>Acrosoma rugosa</i>	172
Ground Spider	<i>Lycosa scutulata</i>	144
Cherry-leaf Gall-mite	<i>Acarus serotinae</i>	116
Clear-winged Scorpion-fly	<i>Bittacus stigmaternus</i>	141
Leaf-hopper	<i>Aulacizes irrorata</i>	117, 143
Pentatomid	<i>Hymenarcys nervosa</i>	113
Coreid	<i>Acanthocerus galeator</i>	182
Spined Stilt-bug	<i>Jalysus spinosus</i>	117
Short-winged Grasshopper	<i>Dichromorpha viridis</i>	117, 143
Acridiid grasshopper	<i>Melanoplus amplexens</i>	117, 143
Acridiid grasshopper	<i>Melanoplus gracilis</i>	143
Scudder's Grasshopper	<i>Melanoplus scudderi</i>	117
Round-winged Katydid	<i>Amblycorypha rotundifolia</i>	117, 143
Nebraska Conc-nose	<i>Conocephalus nebrascensis</i>	117
Meadow Grasshopper	<i>Orchelimum cuticulare</i>	143
Meadow Grasshopper	<i>Orchelimum glaberrimum</i>	117, 143
Meadow Grasshopper	<i>Xiphidium nemorale</i>	117, 143
Striped Cricket	<i>Nemobius fasciatus</i>	143
Elaterid larva	<i>Corymbites</i> sp.	113
Elaterid	<i>Asaphes memnonius</i>	113
Black-tipped Calopteron	<i>Calopteron terminale</i>	173
Reticulate Calopteron	<i>Calopteron reticulatum</i>	143
Horned Fungus-beetle	<i>Bolctotherus bifurcus</i>	173
Common Skipper	<i>Epargyreus tityrus</i>	173
Imperial Moth (larva)	<i>Basilona imperialis</i>	106
Noctuid moth	<i>Autographa precativis</i>	143
Asilid fly	<i>Deromyia discolor</i>	117
Vespa-like syrphid	<i>Milesia ornata</i>	143, 184
Long-sting	<i>Thalassa lunator</i>	143
Black Longtail	<i>Pelecinus polyturator</i>	117, 143
Cocoon Ant	<i>Tapinoma sessile</i>	139

5. *Supplementary Collections from the Bates Woods, Station IV*

Tent Epeirid	<i>Epeira domiciliorum</i>	167
White-triangle Spider	<i>Epeira verrucosa</i>	126
Spined Spider	<i>Acrosoma spinea</i>	148
Rugose Spider	<i>Acrosoma rugosa</i>	126
Mealy Flata	<i>Ormenis pruinososa</i>	Hankinson
Leaf-hopper	<i>Gypona pectoralis</i>	Hankinson
Pentatomid bug	<i>Euschistus fissilis</i>	124
Pentatomid bug	<i>Mormidea lugens</i>	Hankinson
Tarnished Plant-bug	<i>Lygus pratensis</i>	Hankinson
Coreid bug	<i>Alydus quinquespinosus</i>	Hankinson
Coreid bug	<i>Acanthoceros galcator</i>	Hankinson
Rapacious Soldier-bug	<i>Sinea diadema</i>	Hankinson
Acridiid grasshopper	<i>Melanoplus obovatipectus</i>	124
Pennsylvania Firefly	<i>Photuris pennsylvanica</i>	Hankinson
Margined Soldier-beetle	<i>Chauliognathus marginatus</i>	Hankinson
Soldier-beetle	<i>Telephorus</i> sp.	Hankinson
Chrysomelid beetle	<i>Cryptocephalus mutabilis</i>	Hankinson
Clubbed Tortoise-beetle	<i>Coptocycla clavata</i>	Hankinson
Portlandia Butterfly	<i>Enodia portlandia</i>	63
Eurytus Butterfly	<i>Cissia eurytus</i>	Hankinson
Gelechiid-moth	<i>Ypsolophus ligulellus</i>	Hankinson
(Hairy Midge-gall)	<i>Cecidomyia holotricha</i>	(Near collection No. 96)
Corn Syrphid Fly	<i>Mesogramma politum</i>	Hankinson
(Horned-knot Oak-gall)	<i>Andricus cornigerus</i>	(Near 96)
(Oak Wool-gall)	<i>Andricus lana</i>	(Near 96)
Ichneumon Wasp	<i>Trogus obsidianator</i>	Hankinson
Formicid ant	<i>Aphaenogaster fulva</i>	125
Rusty Carpenter-ant	<i>Camponotus herculeanus pennsylvanicus ferrugineus</i>	97
Spider Wasp	<i>Psammocharis aethiops</i>	Hankinson

6. *Small Temporary Stream in the South Ravine, Station IV, d*

This small temporary stream in a ravine formed the southern boundary of the area examined (Pl. XVII, figs. 1 and 2). At the season of our examination it was a series of small disconnected pools. Very little attention was devoted to the collection and study of its life. Most of the collections were secured by T. L. Hankinson. A few aquatic animals were collected here. In a small pool were taken numerous specimens of the creek chub (*Semotilus atromaculatus*), and one stone-

roller (*Campostoma anomalum*). Frogs, toads, and salamanders were also taken in the vicinity by Mr. Hankinson, who dug from their burrows specimens of *Cambarus diogenes*, and also secured *immunis* and *propinquus*. On the surface of the pools were numerous specimens of a water-strider, *Gerris remigis*. The forest cover is undoubtedly an important factor in the preservation of such pools, as it controls the evaporating power of the air.

Mr. Hankinson tells me that during the summer of 1912 this temporary stream was completely dry, and that no fish have been taken from it since the earlier collection mentioned above. From the mouth of the ravine across the bottom to the river it is only a few hundred feet, and in time of heavy or prolonged rains these pools are in direct communication with the river. Such a stream is an excellent example of an early stage in the development of the stream habitat, and shows its precarious character, and the liability to frequent extermination of these pioneer aquatic animals which invade it in its early stages. This applies particularly to those animals which have no method of tiding over dry periods. On the other hand, those animals which live in the pools, those parts of temporary streams which persist longest between showers, have better chances of survival, particularly burrowing animals, like the crawfish and its associates. It seems probable that crawfish burrows harbor a varied population; not only the crawfish leeches (*Branchiobdellida*) but also the eggs of certain *Corixida* (Forbes, '76: 4-5; '78, p. 820; Abbott, '12) may almost cover the body of some crawfishes. By means of this burrow ground-water is reached, and a subterranean pool is formed. For the elaboration of the stream series see Adams ('01) and Shelford ('11 and 13a).

This temporary stream shows how, by the process of erosion, the upland forest area is changed into ravine slopes, and, later, even into the bed of a temporary stream. Thus progresses the endless transformation of the habitat.

## GENERAL CHARACTERISTICS OF THE GROSS ENVIRONMENT

### 1. *Topography and Soils of the State*

Illinois lies at the bottom of a large basin. This is indicated in part by the fact that so many large rivers flow toward it. The mean elevation of the state is about 600 feet, and about a third of it lies between 600 and 700 feet above sea-level. Except Kentucky, the bordering states are from 200 to 500 feet higher. Iowa and Wisconsin are considerably higher, so that winds from the north and northwest

reach the state coming down grade. Taken as a whole the land surface is a tilted plain sloping from the extreme northern part—where a few elevations exceed a thousand feet—toward the south, bowed in the central part by a broad crescentic undulation caused by a glacial moraine, and then declining gradually to the lowland north of the Ozark Ridge, near the extreme southern part of the state. This east and west ridge occasionally exceeds 1,000 feet, but its average height is between 700 and 800 feet. It is very narrow, only about 10 miles in average width, and rises about 300 feet above the surrounding lowland (Leverett, '96, '99). South of this ridge lie the bottoms of the Ohio River. The largest river within the state is the Illinois.

The soils of the state are largely of glacial origin. Even the unglaciated extreme northwestern part and the Ozark Ridge region have a surface layer of wind-blown loess. In some places considerable sand was assorted by glacial water, forming extensive tracts of sandy soil, and locally dune areas are active. Along the larger streams there are extensive strips of swamp and bottom-land soils. The remaining soils, which characterize most of the state, were either produced mainly by the Iowan or Illinoian ice-sheets, as in the case of the relatively poorer soils, or by the Wisconsin sheet, which formed the foundation for the better soil. The dark-colored prairie soils are due to organic debris. Coffey ('12:42) has said: "Whether this accumulation of humus is due to lime alone or to the lack of leaching, of which its presence is an indication, has not been definitely determined. Neither do we know whether it is due to chemical or bacteriological action; most probably the latter, an alkaline medium being necessary for the growth of those bacteria or other microorganism which cause this form of decomposition."\*

## 2. Climatic Conditions

The climatic features of a region are generally conceded to have a fundamental influence upon its life. The controlling influences upon climate are elevation above sea-level, latitude, relation to large bodies of water—generally the sea—and the prevailing winds. The elevation and relief of Illinois have but a slight influence. In latitude Illinois is practically bisected by the parallel  $39\frac{1}{2}^{\circ}$  in the north temperate zone. This position influences the seasons and the amount of heat received from the sun. The sea is far distant, but the Great Lakes are near by, and proximity to the interior of a large continent

\*Consult Hopkins and Pettit ('08) and the County Soil Reports of the State Soil Survey for a detailed account of the chemical conditions of Illinois soils. The bacterial, algal, and animal population have hardly been noticed by students of Illinois soils.

brings the state within that influence. And, finally, it lies in the zone of the prevailing westerly winds, and directly across the path of one of the main storm tracks, along which travel in rapid alternation the highs and lows which cause rapid changes of temperature, wind, and precipitation, and thus produce the extremely variable weather conditions.

The state is 385 miles long, and as latitude has much influence upon climate, the climate of Illinois differs considerably in the extreme north and south. This is clearly shown in the average annual temperature, which in the northern part is  $48.9^{\circ}$  F., in the central part is  $52.70^{\circ}$ , and in the southern part is  $55.9^{\circ}$  (Mosier, '03). These averages probably closely approximate the soil temperatures for these regions. The average date of the last killing frost in the northern part is April 29; in the central part, April 22; and in the southern part, April 12. The average date of the first killing frost for the northern part is October 9, central part, October 11, and the southern part is October 18 (Henry). The growing season for vegetation in the northern half of the state averages from 150 to 175 days and for the southern half from 175 to 200 days (Whitson and Baker, 12:28). The precipitation shows similar differences, increasing from north to south. The annual average for the northern part is 33.48 inches, increasing to 38.01 in the central and to 42.10 inches in the southern part (Mosier, '03:62). Mosier has shown that the Ozark Ridge, with an average elevation of about 800 feet, condenses the moisture on its south slope so that it has a precipitation of 7.15 inches more than do the counties just north of the ridge. This same humid area appears to extend up the Wabash Valley to Crawford county, and gives the valley counties a rainfall 3 inches in excess of the adjacent counties to the west. The average annual rainfall for the state is 37.39 inches—nearly one third of it during April, May, and June, and if July is included, more than half. The heaviest precipitation, 8.23 inches, is in May and June.

As previously mentioned, the state lies in the zone of prevailing westerly winds and across the path of storms. These have a dominant influence upon the direction of the winds. In the northern part of the state, they are, by a slight advantage, southerly—a tendency which progressively increases toward the south, for in the central part the southerly winds reach 55 per cent., and in the southern part 62 per cent. During the winter the northwest winds predominate throughout the state, to a marked degree in the central part, where they reach 60 per cent., and where also the velocity is greatest, reaching an average of 10.3 miles an hour. The velocity of the wind for the entire



state is highest during spring. During the summer, the southwest winds predominate in the northern and central parts, and in the southern part 82 per cent. of the winds are southerly. The velocity of the wind is least during the summer, and the greatest stagnation occurs in August. During autumn there is a falling off of the southerly winds and an increased velocity as winter conditions develop. The transition in the fall is in marked contrast with the vigor of the spring transition. The cooler seasons are more strongly influenced by northerly winds, and the warmer seasons by southerly winds.

### 3. *Climatic Centers of Influence*

In the preceding section the *average* conditions of temperature, precipitation, and the direction and velocity of the winds have been summarized, but little effort was made to indicate the mode of operation of the determining factors which produce and maintain these average conditions. It is often true that the main factors which explain the conditions seen in some restricted locality can not be found within it because the local sample is only a very small part of a much larger problem. Thus no one attempts to find an explanation of the through-flowing upper Mississippi system within the state of Illinois; a larger unit of study is necessary. The region examined must extend to the headwaters. So, also, with most of the climatic features of Illinois; their approximate sources must be sought elsewhere. Let us therefore consider some of the broader features which influence the climate of North America, particularly that of the eastern part.

The climates of the world have been divided into two main kinds, depending primarily upon the controlling influence of temperature. This is due to the relative specific heat of land and water, that of water being about four times that of land. The sea, which covers three fourths of the earth's surface, is thus an immense reservoir of heat, which is taken up and given off slowly, at a rate one fourth that of the land. It is therefore relatively equable. The northern hemisphere contains the largest amount of land, and is therefore less under the control of the sea than the southern hemisphere; yet the sea's influence is very powerful, particularly near the shore. The large land masses, on the other hand, on account of their lower specific heat, receive and give off heat more rapidly to the air above. For this reason the temperature changes, as between day and night or summer and winter, are much more rapid and much more extreme over land than over the sea. A climate dominated by the equable sea is oceanic; that dominated by the changeable lands is continental. Illinois lies far

from the sea and is therefore strongly influenced by continental conditions. To what degree is the marine influence shown?

Meteorologists (cf. Fassig, '99) have come to look upon the large areas of permanent high and low barometric pressure as among the most important factors in climatic control. There are five of these powerful "centers of action" which influence our North American climate (Fig. 1), and four of these are at sea. A pair of *lows* are in the far north, one in the north Pacific near Alaska, the other in the

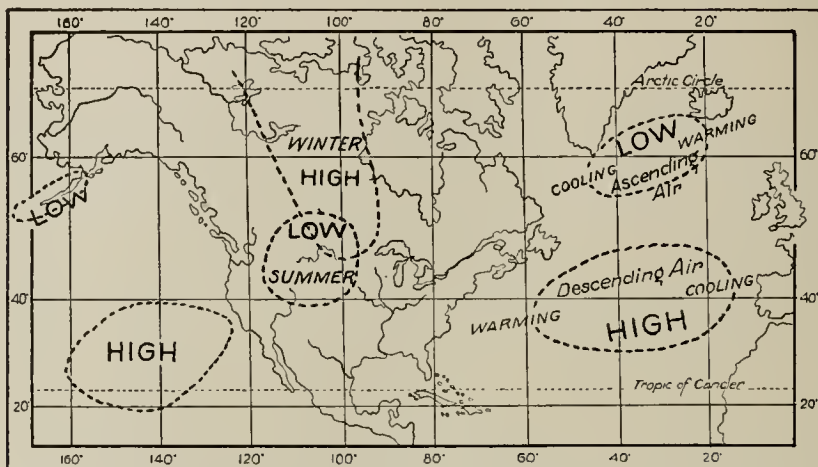


FIG. 1. Diagram showing the positions of the relatively stable areas of high and low barometric pressure, and indicating their influences upon the evaporating power of the air and upon the climate in general.

north Atlantic south of Greenland. A pair of *highs* are farther south, one in the Pacific between California and the Hawaiian Islands, and the other centering in the Atlantic near the Azores. The highs and lows in each ocean seem to be paired and to have some reciprocal relation. The fifth center of action is upon the land. It is a *high* barometric area in the Mackenzie basin of Canada, where it becomes a powerful center of influence through winter and spring, but with the progress of summer conditions weakens, and through the accumulation of continental heat becomes converted into a *low*; thus there is a complete seasonal inversion on the continent.

These large highs and lows, although relatively permanent, are continually changing in intensity and position. The *highs* are regions of descending, diverging, warming, and drying air, producing clearing and clear air on their western side, but the reverse on their eastern side.

The *lows* are regions of ascending, converging, cooling air, with increasing moisture and clouds on their western side, but are the reverse on their eastern side (Moore, '10: 153). These same characteristics apply to the small highs and lows which we are accustomed to see on the daily weather maps.

If, now, we consider these large centers of action, such consideration will do much toward giving us a graphic idea of our climate. During the winter, because of the small amount of heat received in the Mackenzie basin, the temperature becomes very low, and a powerful high barometric area is formed; then the descending air blowing from the *eastern* part of this high, or from small highs originating from the larger one, produce the cold winters and cold waves in winter which characterize the northeastern United States. If, however, the Atlantic high wanders on the eastern coast of the United States in winter, the *western* part of this high, with its descending, diverging, warming, and drying air, produces a mild winter. The climate of the eastern United States is thus, in the cold season, under the alternate invasion of these two powerful centers of action. During the warm season the continental winter high is replaced by a low, due to the accumulating warm continental temperatures which thus have produced an inversion or seasonal overturning. But the Atlantic high is permanent and exerts its influence continuously. If the *western* part of this high encroaches upon the eastern United States during the summer, with its descending, drying, and clear air, it may produce drouth, this depending, of course, on its degree of development. The continental low of summer, with the drying influence of its *eastern* side, has a similar tendency. *Thus the character of the summer is determined, to an important degree, by the interplay and relative balance between these two warming and drying centers.* The activity of these centers has a powerful influence upon the moisture-bearing winds, which influence humidity and evaporation in Illinois, and in the eastern United States.

#### 4. *Relative Humidity and Evaporating Power of the Air*

We are now in a position to examine the facts of relative humidity and the relative evaporating power of the air in the eastern United States. The relative aridity on the plains east of the Rocky Mountains is due primarily to the removal of moisture from the prevailing westerlies in their passage from the Pacific over the various western mountain ranges which extend across their path, combined with the excessive summer heating of the continental mass. Here, then, is the influence of the continental summer low. Farther east the Atlantic high tends to supplement the continental low and to cause the Gulf

winds to bring moisture inland,\* and the Great Lakes region adds its quota.

In the storm-track zone, where stagnation of the air is due largely to the balance existing between the continental low and the oceanic high, the aridity of the plains extends the farthest east, and as an arid peninsula it crosses Illinois, giving during August a relative humidity to the prairie area of 60-70 per cent. of saturation (Johnson, '07). The reality of the arid peninsula across Illinois is further shown by the rainfall-evaporation ratios computed and mapped by Transeau ('05). These ratios were determined by dividing the mean annual rainfall at each place by the total mean annual evaporation. These mapped percentages show that the prairie region is closely bounded by the region with an evaporation ratio of between 60 and 70 per cent. of the rainfall received. These conditions furnish a general background or perspective for a profitable consideration of the local and more detailed studies which have been made of the relative evaporating power of the air in different plant and animal habitats.

For our purpose it is not necessary to consider the history of methods of measuring relative evaporation. This measurement may be made by evaporating water in open pans or by the porous porcelain-cup method. Such cups have been devised by several students, but a modified form of the Livingston atmometer has been mainly used by plant ecologists, and this was the kind we used at Charleston. Transeau ('08) was the first to use such an instrument and to show its value in studying the relation of intensity of evaporation to plant societies. His work on Long Island, N. Y., showed very clearly that evaporation in open places was much greater than in dense forests. These observations were enough to show that evaporation is a factor related to the physical conditions of life upon the prairie and in the forest, and therefore in our cooperative study of the Charleston area in 1910 relative evaporation was made a special feature in the study of representative environments, in order to determine its relation to both the plants and the animals. So far as is known this is the only study yet made in which these determinations have been recorded from the same places where the animals have been studied. Since our data were secured, several papers have been published on relative evaporation in different sorts of habitats in this state and in northern Indiana by plant ecologists Fuller ('11, '12a, '12b), McNutt and Fuller ('12), Fuller, Locke,

\*Zon ('13) has recently asserted that the moisture from the sea does not make a single overland flight inland, but rather is largely precipitated near the sea, is evaporated and carried farther inland, is precipitated again, and this process repeated again and again, so that its inland flight is a vertical revolving cycle of precipitation and evaporation. If this contention is valid, evaporation from the land is a much more important climatic factor than it is usually thought to be.

and McNutt ('14), Sherff ('12, '13a, '13b), and Gleason and Gates ('12). Shelford ('12, '13a, '13b, '14a), utilizing the evaporation data of the plant ecologists, has applied the same to animal associations also, and he has further tested some of these ideas experimentally in the laboratory. In Ohio, Dachnowski ('11) and Dickey ('09) have made records of data obtained by the use of the porous cup, and in Iowa Shimek ('10, '11) has used the open-pan method. Mention should also be made of Yapp's observations ('09) on a marsh in England. A very important summary of evaporation records, in the open and in forests, is given by Harrington ('93). The effect of wind-breaks upon evaporation has been studied by Bates ('11) and Card ('97). Finally, mention should be made of Hesselman's studies of relative humidity in forest glades in Sweden ('04).

Our records from the Charleston region will be given first, and then their significance will be discussed. The unglazed porcelain cups, with a water reservoir, were placed so that the tops of the cups were about six inches above the soil in the habitats examined, and at weekly intervals the water loss was measured. The instruments were in operation simultaneously, so that the results are comparable. The standard instrument was located in the open exposed garden of the Eastern Illinois Normal School at Charleston, which was considered as unity, or 100 per cent. For further details as to the conditions where the atmometers were located consult the description of the stations and the photographs.

An examination of the diagram (Fig. 2) will show that although based upon a limited amount of data (for less than a month, from

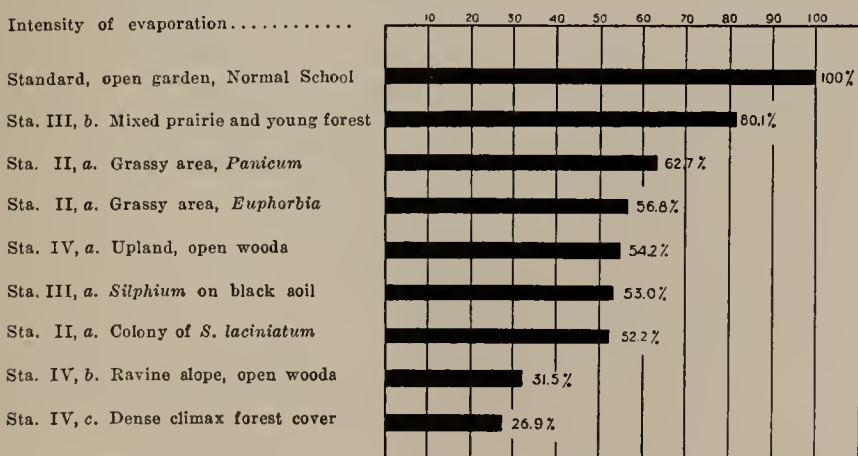


FIG. 2. Diagram of the relative evaporation in different prairie and forest habitats, showing the great reduction in evaporation with the development of a closed forest canopy of a climax forest; Charleston, Illinois.

August 19 to September 22) the facts are in harmony with similar studies elsewhere covering a much longer period, so that there is valid reason for confidence in them. The standard instrument was located, as already mentioned, in an open, exposed cultivated garden, where the intensity of evaporation was very high. The black soil prairie areas, Stations II and III, *a*, have an average of 56.1 per cent.—a condition much like that in the grassy-Euphorbia prairie at Loxa (Station II, *a*)—or a little more than half that of the standard instrument. The dry upland area of mixed prairie and young forest, on gray silt loam (Station III, *b*), has an intensity of 80 per cent. This is in the region of the most extensive grassy prairie about Charleston; the general appearance of the region is shown in Plate XIII. A surprising feature of the table is the evaporation in the open-crowned upland oak-hickory woods (Station IV, *a*). In this forest perhaps two thirds to three fourths of the ground was shaded, and it was very well drained. The evaporation here reached 54.2 per cent., being very near that of the average of the black soil prairie (56.1 per cent.). I had anticipated much less evaporation than on the prairie, a position more intermediate between the prairie and the lowland forest, or about 42 per cent. (cf. Harvey, '14:95). The ravine slope (Station IV, *b*), although somewhat open, has 31.5 per cent.—a very low rate of evaporation—and is remarkably close to that of the densely crowned lowland forest (Station IV, *c*), at 26.9 per cent. The decline, however, in the intensity of evaporation with the degree of completeness of the for-

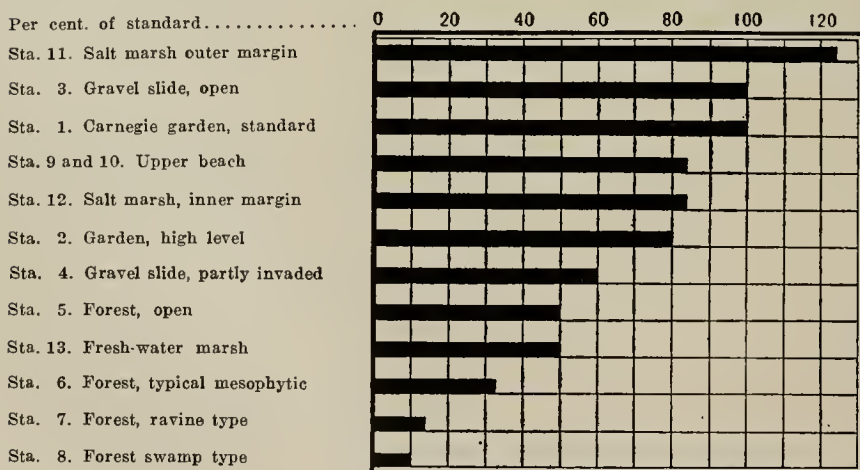


FIG. 3. Diagram of the relative intensity of evaporation in the lowest stratum of different kinds of habitats, Long Island, N. Y. (After Transeau.)

est crown, is strikingly shown in passing from the open upland woods, at 54.2 per cent., to the ravine slope at 31.5 per cent., and on to the lowland forest at 26.9 per cent.

A comparison of these results with those secured by Transeau ('08) on Long Island, is instructive. His standard instrument was also in an open garden (Fig. 3), comparable with the Charleston standard. A gravel slide, partly invaded by plants, had an evaporation of 60 per cent., comparable with the open prairie at Charleston; the open forest, 50 per cent., comparable with the upland open Bates woods at 54.2 per cent.; and the mesophytic forest, 33 per cent., comparable with the ravine and lowland places in the Bates woods at 31.5 and 26.9 per cent. respectively.

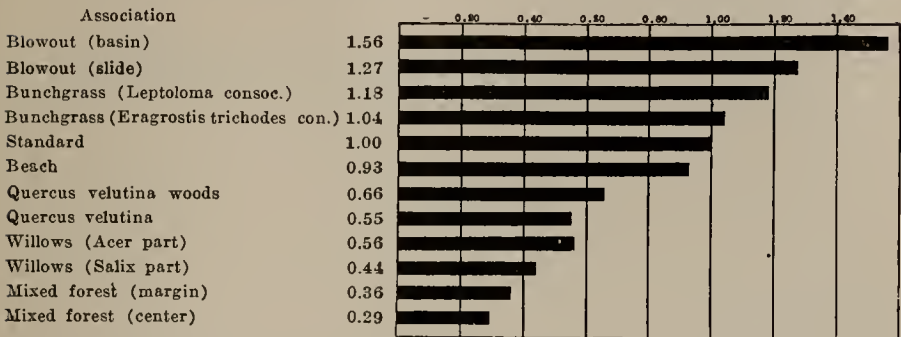


FIG. 4. Relative intensity of evaporation in different kinds of habitats on sandy soil, Havana, Illinois. (After Gleason and Gates.)

Another series of relative evaporation observations was made by Gleason and Gates ('12) on sandy soils at Havana, Illinois. As their methods were similar to those used at Charleston, useful comparisons may again be made. The standard instrument was in an open area comparable to the garden at Charleston. An examination of Figure 4, summarizing the results of their study, shows that upon the grass-covered sand prairie (bunch-grass) the evaporation was about 110 per cent., that in open black oak (*Q. velutina*) woods (on sand) it was about 60 per cent., and that in a denser hickory-black-oak-hackberry mixed forest (somewhat open) it was about 31 per cent. There is thus a close general correspondence between the conditions at Havana and Charleston, although the evaporation upon sand prairie appears to be relatively much greater than upon the black-soil prairie.

Fuller ('11) and McNutt and Fuller ('12) have made comparative studies in different kinds of forest in northern Illinois and in northern

Indiana. Their results are combined and summarized in Figure 5. This diagram shows the relative evaporation near the surface of the soil, the standard of comparison being the evaporation in a maple-beech climax forest, where evaporation is relatively low. The average daily amount, in c.c., shows that there is a progressive increase in evaporation as follows: 8.1 c.c. in a maple-beech forest, 9.35 c.c. in the oak-hickory upland forest, 10.3 c.c. in an oak dune forest, 11.3 c.c. in a pine dune forest, and an increase to 21.1 c.c., on the cottonwood dunes. This expressed on a percentage basis is, in inverse order, respectively 260 per cent. in the cottonwoods, 140 per cent. in the pines, 127 per cent. in the oak dunes, 115 per cent. in the oak-hickory forest, and 100 per cent. in the maple-beech forest.

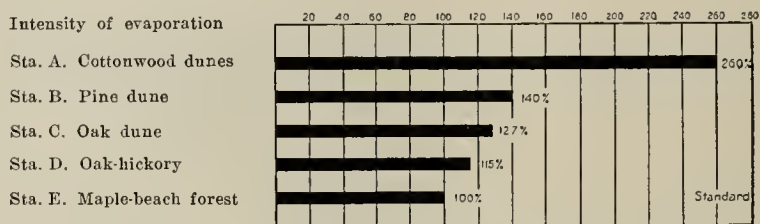


FIG. 5. Diagram showing the relative rate of evaporation in different kinds of forest in northern Illinois and Indiana. [Data from Fuller ('11) and McNutt and Fuller ('12).]

Shimek ('10, '11) has made valuable observations on the relative rate of evaporation on the prairie of western Iowa. He used the open-pan method in four representative habitats. His results show very clearly that the rate of evaporation is much greater in exposed places than where there is shelter from the sun and wind. I have put his data in a form comparable with those which have just been discussed (Fig. 6), and have made the cleared field area, Station 4, the standard of comparison, as it more nearly approaches the standard used at Charleston and by others. Station 3 is on a high bluff, exposed to the

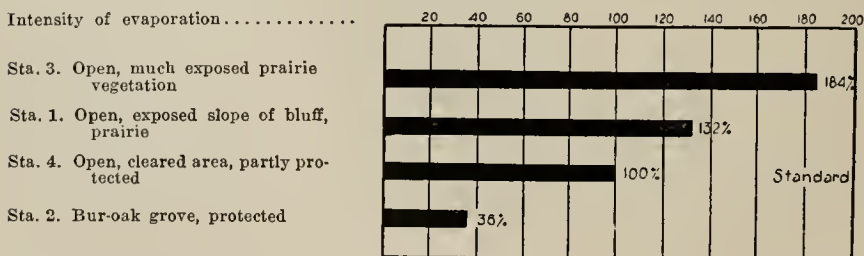


FIG. 6. Diagram of relative evaporation in prairie and forest habitats, in western Iowa. (Data from Shimek.)



west and south winds, and, as might be expected, it has an excessive evaporation—184 per cent. Station 1, also covered by prairie vegetation, and exposed to west and southwest winds but sheltered from winds from the south and southeast, also shows a very high evaporation—132 per cent. Station 4, which was made the standard, had been cleared of forest, and was an open place protected by a ridge. Station 2 was apparently a dense grove composed of bur oak, basswood, elm, and ash, with considerable undergrowth. Here the rate of evaporation dropped considerably—to 36 per cent. The general character of this forest calls to mind the denser oak forests on sand at Havana, Illinois. An important feature of these observations is that they were made far out upon the “prairie”, bordering the plains, most other studies on relative evaporation having been made much farther east.

In Ohio, Dachnowski ('11) and Dickey ('09) have recorded the relative evaporation of the air, using a campus lawn as unity. In the central grass-like area of a cranberry bog the evaporation was 69.2 per cent., and in the marginal maple-alder forest it was 51.2 per cent.

Harrington ('93:96-102), in summarizing European studies on the relative evaporation (with a water-surface as standard) in the open and in German forests shows that the “annual evaporation in the woods is 44 per cent. of that in the fields.” Compared with evaporation in the open, that under deciduous trees is 41 per cent., and that under conifers is 45 per cent.—a difference most marked in the summer. Ebermeyer's Austrian observations (l. c. :99) show that the “evaporation from a bare soil wet is about the same as that from a water surface,” both in the open and in the forest. A saturated soil under forest litter gives an evaporation of only 13 per cent. of that of a free-water surface in the open. Harrington (l. c. : 100) concludes that “About seven-eighths of the evaporation from the forest is cut off by the woods and litter together.” Sherff ('13a, '13b) has shown that in the Skokie Marsh, north of Chicago, the absolute amount of evaporation near the soil was less at the center of a *Phragmites* swamp than at its margin (Fig. 7), that a swamp meadow

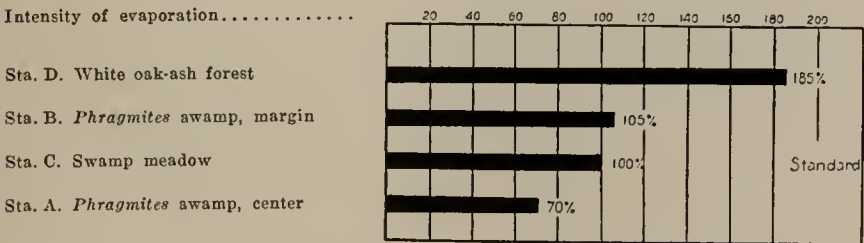


FIG. 7. Diagram of relative evaporation in Skokie Marsh area, near Chicago, at 10 inches (25 cm.) above the soil. Recalculated. (Adapted from Sherff.)

was in an intermediate position, and that in an adjacent white oak-ash forest evaporation was about twice as much as in the swamp meadow. Sherff used as standard the forest (D). This gave him for the center of the swamp (A) 38 per cent., for the swamp meadow (C) 54 per cent., and for the outer swamp margin (B) 105 per cent. In Figure 7, I have used his swamp meadow as 100 per cent., and by recalculation this gives the forest (D) 185 per cent., for the swamp margin (B) 105 per cent., and for the center of the swamp (A) 70 per cent. These figures indicate a concentric arrangement of the conditions of evaporation about the swamp.

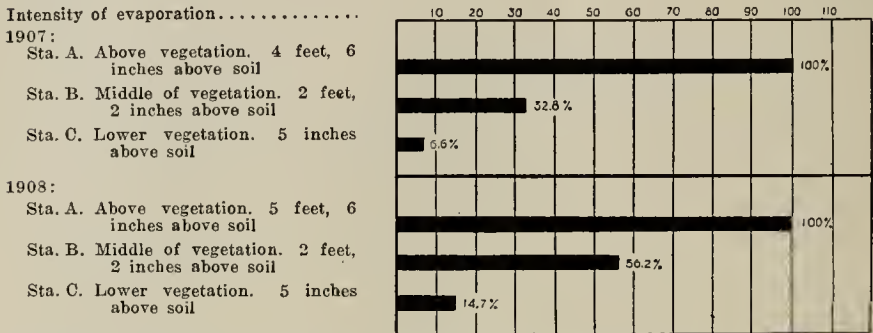


FIG. 8. Diagram showing the relative evaporation at different vertical levels in a marsh in England, the evaporation in the lower layers of the vegetation being much greater than in the upper strata or in the air above it. (Data from Yapp.)

Thus far, attention has been devoted solely to the horizontal differences in evaporation. There are also important vertical ones, varying above the surface of the substratum. Important observations on this subject have been made, by a porous-cup method, in an open grassy marsh in England, by Yapp ('09). The vegetation grew to a height of two to five feet. From his data the accompanying diagrams (Figs. 8, 8a) have been prepared. This shows that when the standard was made the rate of evaporation above the general level of the vegetation, within the grass layer evaporation was reduced from about one half (Sta. B, 1908, 56.2 per cent.) to one third (Sta. B, 1907, 32.8 per cent.) at 2 feet 2 inches above the soil; and that at 5 inches above the soil it was reduced to between one fourteenth (Sta. C, 1907, 6.6) and one seventh (Sta. C, 1908, 14.7) of that above the vegetation. Yapp (l. c.: 298) concludes from his studies that "In general, the results of the evaporation experiments show that the lower strata of the vegetation possess an atmosphere which is continually very much

more humid than that of the upper strata, and farther, that the higher and denser the vegetation the greater these differences are." This is shown in Fig. 8a.

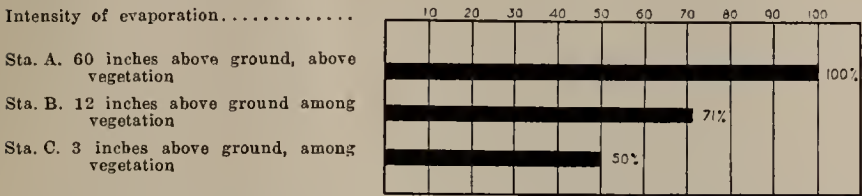


FIG. 8a. Diagram showing the relative evaporation at different vertical levels in a marsh in England, the evaporation in the lower layers of the vegetation being much greater than in the upper strata or in the air above it. (Data from Yapp.)

In America only a few records have been made on vertical gradients in evaporation, two of these in marsh areas, one in Ohio by Dachnowski ('11), and the other near Chicago by Sherff ('13a, '13b). The Ohio observations, made upon a small island in a lake, in a cranberry-sphagnum bog, show that the rate of evaporation above the vegetation is much greater than among it, and that this diminishes as the soil is approached, these results agreeing with those obtained by Yapp. Sherff's observations were made in Skokie Marsh, north of Chicago, and show that the relative evaporation also varies with different kinds of swamp vegetation. From his data a diagram has been made (Fig. 9) in which the rate of evaporation in the upper part of the reeds

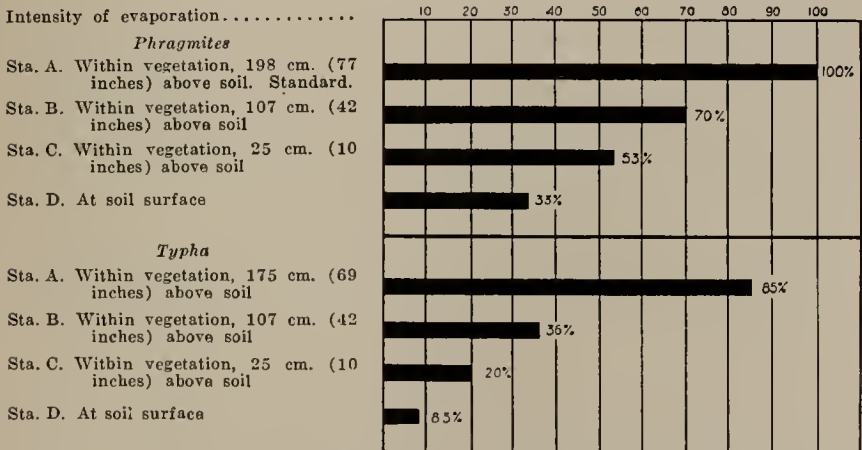


FIG. 9. Diagram of relative evaporation at different vertical levels above the soil within the vegetation of Skokie Marsh. (Adapted from Sherff.)

(*Phragmites*) at 77 inches is taken as 100 per cent. or the standard. Lower down, at 42 inches, the rate is 70 per cent., at 10 inches, 53 per cent., and at the surface, 33 per cent. Among the cattails (*Typha*), in the upper part of the vegetation, at 69 inches evaporation was 85 per cent.; at 42 inches it was 36 per cent.; at 10 inches, 20 per cent.; and at the surface, 8.5 per cent. These results show that at successively lower levels in the vegetation the rate of evaporation is greatly reduced. They tend also to confirm the results of Yapp and Dachnowski. It seems, then, fair to conclude that the rate of evaporation above the swamp vegetation increases rapidly with downward progression, and probably with upward progression also. A vegetable layer, comparable to the mulching of straw used by gardeners, thus acts as a powerful conserver of moisture. There are great differences within a few vertical feet in the open; what is the condition within the forest?

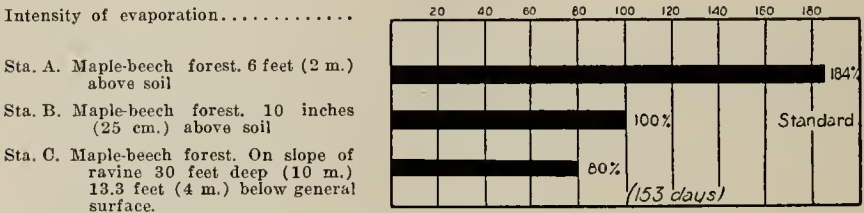


FIG. 10. Diagram showing the relative evaporation in a beech-maple woods, six feet above the soil (A), near the surface of the soil (B), and in a ravine (C). [Adapted from Fuller ('12).]

The character of vertical differences in evaporation within the forest has not been given as much attention as the similar changes in the open; but attention has already been called to the moisture-conserving effect of a forest litter, the evaporating rate in one instance being only 13 per cent. when compared with that from a water surface in the open. McNutt and Fuller ('12) have shown that grazing in an oak-hickory forest changed the average daily rate of evaporation for 189 days from 9.89 c.c., in the ungrazed forest, to 12.74 c.c., in the grazed forest, at Palos Park, Ill. There are thus, within the forest, changes in evaporation with differences both in the ground cover and in the litter on the forest floor which correspond to the change in the vegetation in open places.

Vertical differences in evaporation have been tested in a maple-beech-forest in northern Indiana by Fuller ('12b), who used the porous-cup method. His results have been summarized in Figure 10. This diagram shows that the evaporation at six feet above the surface is nearly twice as much as that at 10 inches above the surface, and

that in a ravine, 13.3 feet (4 m.) below, it was 80 per cent. of that 10 inches above the surface. The relative seasonal activity from May to November is shown in Figure 11. This diagram shows that after the leaves appear the highest evaporation takes place in July. This is probably the critical season for some animals.

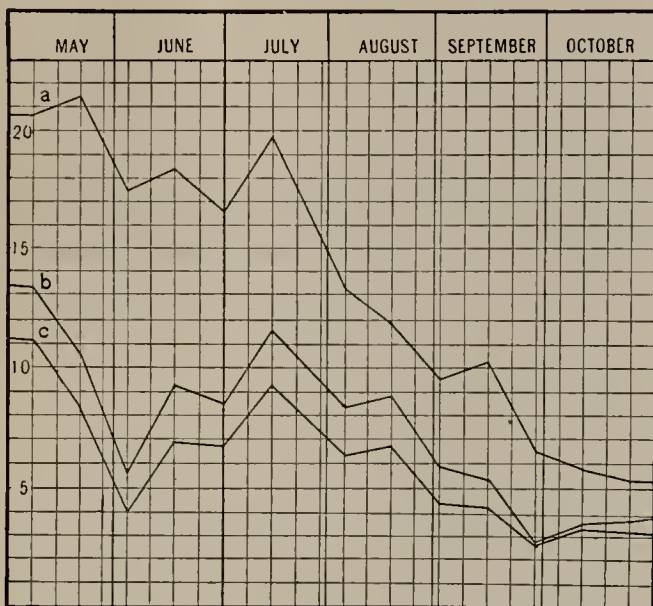


FIG. 11. Diagram showing the average daily rate of evaporation in beech-maple forest, six feet above soil (a), near the surface of soil (b), and in a ravine (c). (From Fuller.)

In the forest, Libernau (Harrington, '93: 34) found that the "relative humidity increases and decreases with the absolute humidity, whereas it is known in general, and also at the Station in the open country, that these two climatic elements are inverse. This is accounted for by the fact that the forest is a source of atmospheric aqueous vapor as well as of cooling." (L. c. : 104: "The absolute humidity decreases in the forest from the soil upwards. The rate of decrease is usually the greatest under the trees and the least at the level of the foliage. The rate above the trees is intermediate between the other two. This rate is least in the late hours of the night, when it may be zero. It increases with the increase of the temperature of the air, becoming greatest in the midday hours, when, under exceptionally favorable circumstances, it may make a difference of 10 per cent.

or even more. Occasionally, in high winds, the absolute humidity is greater over the trees. Over the field station the daily progress of absolute humidity was about the same as in the forest, but the maximum difference was only about half as great. The absolute humidity in and above the forest is greater than that over the open fields, and there is some trace of an increase of this difference to the time of maximum."

A greater relative humidity has been found over evergreen trees than over deciduous trees, which is slight (1. c. : 104), but the psychrometer was close to the evergreens and farther above the deciduous ones.

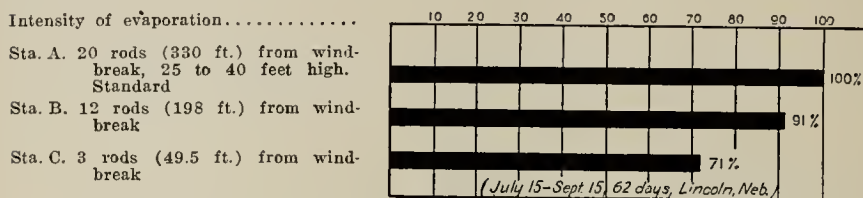


FIG. 12. Diagram showing relative retardation of evaporation by a windbreak, Lincoln, Nebraska. [Adapted from Card ('97).]

The border of the Illinois forest and prairie was characterized by tongues and isolated groves of forest and by glades. The forest had the same kind of influence as windbreaks upon the leeward areas and glades, and therefore the influence of windbreaks upon the evaporating power of the air is of interest. Card ('97) made a valuable study of this series of problems at Lincoln, Nebraska. The influence of windbreaks upon evaporation is summarized in Figure 12. This diagram shows that leeward of a close windbreak ranging from 25 to 40 feet in height, the rate of evaporation in terms of the standard (A), which was 330 feet leeward, was 91 per cent. at a distance of 198 feet (B), and 71 per cent. at 49.5 feet (C), thus showing a marked reduction with proximity to the windbreak. These observations covered 62 days.

Nearer to Illinois, similar though very limited observations were made in central Wisconsin by King ('95) which agree with Card's on the retardation of evaporation by windbreaks. His results are shown graphically in Figure 13.

Recently Bates ('11) has made an elaborate study of the effects of windbreaks upon light, soil, moisture, velocity of wind, evaporation, humidity, and temperature. His results confirm those just given and give additional facts which, however, with one exception, will not be mentioned. The paper itself should be consulted. This investigation by Bates shows that in proportion to the perfection of the windbreak

a quiet, stagnant air strip is formed to the leeward, and that this favors excessive heating during clear days and low temperatures on clear nights. Years ago Harrington ('93: 119) suggested this idea and called attention to the close relation existing between the leeward conditions of windbreaks and forest glades. The glade climate is more rigorous, or extreme, than that upon plains (l. c.: 19, 84-88, 119). Such a climate is thus a bit more "continental" during the spring, sum-

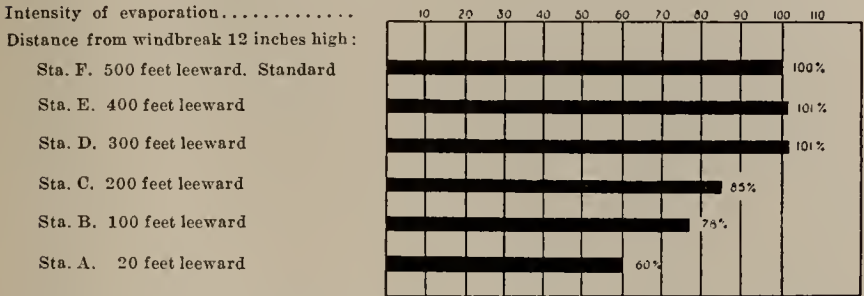


FIG. 13. Diagram showing the relative evaporation, May 31, at different distances leeward of a windbreak, Almond, Wis. [Adapted from King ('95).]

mer, and autumn. These glades are very hot in the early afternoon and cool on clear nights, and the air is relatively stagnant; as Harrington says, it is "lee for winds from all directions." The center of a dense forest may thus possess physical conditions quite different from those of the glade forest margin or in the open. Beginning with the relatively stable conditions within a forest toward its margin, the diurnal temperature variations are much more extreme (Harrington, l. c.: 89) "to a distance of a score or so of rods where it reaches a maximum. The amplitude is greater in glades. Hence the extremes of temperature are exaggerated just outside the forest." The annual soil temperatures of a glade are intermediate between that of the forest and the plain. The forest margin is thus seen to possess many of the characteristics of the glade, for its climate is somewhat more extreme than that in the open, far from the forest.

##### 5. *Temperature Relations in the Open and in Forests*

The temperature relations in open and forested regions are often very different. The density of the vegetable covering in the open and in the forests varies much and may have considerable influence upon animals. Yapp ('09) observed that the marsh vegetation in England

caused marked vertical differences in temperature in the vegetational stratum. He summarizes these results as follows (p. 309): "The temperature results show that the highest layers of the vegetation possess a greater diurnal range of temperature than either the free air above or the lower layers of the vegetation. Regularly, especially in clear weather, both the higher day and the lowest night temperatures were recorded in this position."

Dachnowski ('12: 292-297) studied the temperature conditions in a cranberry bog substratum in central Ohio. He found that at a time when ice formed from 8 to 15 inches thick on the adjacent lake, in the bog it was only 3 to 5 inches thick, and there were small patches where it did not form at all. At a depth of 3 inches in the peat the temperature ranged from 33° to 77° F. (.5°-25.0° C.). In the bordering maple-alder zone, at 3 inches depth it ranged from 33° to 72° F. (.5°-22.0° C.). His observations indicate that the temperature relations within the maple-alder zone are more stable than those in the open central area.

Cox ('10) has also shown that the character of the vegetation in Wisconsin cranberry bogs has much influence upon temperature relations in this habitat.

It seems very probable that similar conditions hold over prairie vegetation, but I do not know of any observations on this point. We are all familiar with the common practice of gardeners of using a mulch of straw to retard temperature changes under it; prairie vegetation must have a similar influence. (Cf. Bouyoucos, '13: 160.)

The relative air temperatures within and without the forest show a distinct tendency to reduce the maxima and minima, and to *lower* the mean annual temperature. Harrington ('93: 53) concludes, therefore, that "*the forest moderates (by reducing the extremes) and cools (by reducing the maxima more than the minima) the temperature of the air within it. The moderating influence is decidedly greater than the cooling effect.*" These effects are not uniform, but are much more marked in the summer, and Harrington further says: "The cooling effect tends to disappear in winter. The moderating effect is the most important one and it is the most characteristic" (p. 56).

The temperature relations within the forest crown show that in general the effects are similar to those found at an elevation of about 5 feet. The maxima are lowered, the minima are elevated, and there is a cooling effect. The differences are most pronounced during the summer, and the temperatures are intermediate in position between those at the five-foot level and those in the open (l. c.: 66). At a height of 24 feet, deciduous trees showed a marked summer cooling



effect, while evergreens showed much less, though they are much more uniform for 9 months of the year. Again, he says: "In summer the average gradient under trees is about  $+2^{\circ}$ ; that is, it grows warmer as we ascend at the rate of two degrees per 100 feet (31 m.). Outside in the general average it grows colder by about a quarter of a degree." This warmer air above the cooler in the forest favors its stability or relative stagnation, although as a whole the forest air is cooler and heavier than the surrounding air and tends to flow outward. The forest thus tends to produce a miniature or incipient barometric high. In conclusion Harrington (p. 72) states that "The surface of the surface of the forest is, meteorologically, much like the surface of the meadow or cornfield. The isothermal surface above it in sunshine is a surface of maximum temperature, as is the surface of a meadow or cornfield. From this surface the temperature decreases in both directions." In the case of a beech forest the warm diurnal layer above the forest crown was only 6.5 feet thick (p. 34).

The conditions above the forest are thus representative of the atmospheric conditions above dense vegetation in general, and are in perfect harmony with Yapp's observations upon the temperature above a marsh ('09: 309), quoted on a previous page, to the effect that temperature changes are extreme here, and greater than in the free air above or in the lower layers among the vegetation. *The forest is thus to be considered as a thick layer of vegetation in its influence upon meteorological conditions.* The conditions above the forest, therefore, exemplify a general law.

In general terms, the temperature of the soil below the zone of seasonal influence is that of the mean annual temperature for a given locality. The surface zone, however, varies with the season. Harrington ('93) has summarized the German observations on the relative soil temperatures in the open and in the forest. In the following quotation the minus sign indicates a forest temperature less than a corresponding observation in the open. These temperatures were taken about 5 feet above the soil. He says (p. 43): "The average of the seventeen stations (representing about two hundred years of observations) should give us good and significant results. It shows for the surface— $2^{\circ}.59$ , for a depth of 6 inches (152 mm.)— $1^{\circ}.87$ , and for a depth of 4 feet (1.22 m.)— $2^{\circ}.02$ . The influence of the forest on the soil, then, is a cooling one, on the average, and for central Europe the cooling amounts to about two and a half degrees for the surface. The cooling is due to several causes: The first is the shade; the foliage, trunks, branches, and twigs cut off much of the sun's heat, absorb and utilize it in vegetative processes, or in evaporation, or reflect it away into space. Thus the surface soil in the forest receives

less heat than the surface of the fields. The same screen acts, however, in the reverse direction by preventing radiation to the sky, thus retaining more of the heat than do the open fields. The balance of these two processes, it seems from observation, is in favor of the first and the average result is a cooling one. . . . The differences of temperature at the depth of 6 inches (152 mm.) are more than half a degree less than at the surface. In this is to be seen the specific effect of the forest litter; it adds a covering to that possessed by the surface, so that while the deeper layer is cooled as much by the protection from the sun's rays as is the surface, it is not cooled so much by radiation of heat to the sky. Its temperature is, consequently, relatively higher, and approximates somewhat more the field temperatures."

"The forest soil is warmer than that of the open fields in winter, but cooler in the other seasons, and the total cooling is much greater than the warming one. . . . The forest, therefore, not only cools the soil, but also moderates the extremes of temperature" (p. 46).

The character of the forest, whether evergreen or deciduous, influences the temperature conditions of the soil, as is seen by a comparison of these conditions in the forest and in the open. The two kinds of forest are much alike in winter; during the spring the soil warms up more rapidly under conifers. Temperature variations are slightly greater under deciduous trees.

#### 6. *Soil Moisture and its Relation to Vegetation*

The moisture in the soil is derived largely from precipitation, but part of it, in some localities, comes directly from the adjacent deeper soils or rocks, and thus only indirectly from precipitation. As Illinois lies at the bottom of a large basin, there must be some subsurface flow from the adjacent higher regions, but to what extent is not known. McGee ('13a: 177) estimates that the general ground-water level—the level at which the soil becomes saturated—has, since settlement, declined 10.6 feet in Illinois. This decline is not limited to drained regions but is a general condition. In addition to these changes of level there are seasonal fluctuations. Sherff ('13a: 583) observed in Skokie Marsh that the water-table was at or above the surface in May, then declined until early September, and then rose rapidly to the surface by the middle of October. The wet prairie at Charleston has undergone just such changes as these; the ground-water level has been lowered and there are marked seasonal changes.

Harvey ('14) has recently shown that the soil of *Eryngium-Silphium* prairie at Chicago contains a large amount of water during

April and until late in May; that the moisture falls and is low during July and August, with a mean of 24 per cent. of saturation for these months; but that in October the soil is again at or near the point of saturation.

The blanket of humid air which accumulates under a cover of vegetation, retards evaporation and conserves soil moisture. The denser the vegetation the more marked is its influence. The litter—the organic debris in an early stage of decomposition—on the forest floor has the same tendency, and has even a greater water capacity than the soil itself. On the other hand, a forest is a powerful desiccator; as Zon ('13:71) has recently put it: "A soil with a living vegetative cover loses moisture, both through direct evaporation and absorption by its vegetation, much faster than bare, moist soil and still more than a free water surface. The more developed the vegetative cover the faster is the moisture extracted from the soil and given off into the air. The forest in this respect is the greatest desiccator of water in the ground." This drying effect is shown particularly near the surface of the soil, where roots are abundant and where drouth is so marked that it may prevent the growth of young plants here (cf. Zon and Graves, '11:17-18).

Warning ('09:45) says: "It may be noted that, according to Ototozky, the level of ground-water invariably sinks in the vicinity of forest, and always lies higher in an adjoining steppe than in a forest; forest consumes water."

McNutt and Fuller ('12) have made a study of the amount of soil moisture at 3 inches (7.5 cm.) and at 10 inches (25 cm.) below the surface in an oak-hickory forest, at Palos Park, Illinois. They found that the percentage of water to the dry weight of the soil at the 3-inch level averaged 18.9 per cent. and at 10 inches was 12.5 per cent. of the dry weight of the soil. The greater moisture near the surface is due to the humus present in this layer. The grazed part of the forest possessed less soil moisture, and shows the conserving effect of vegetation. (Cf. also Fuller '14.)

The artificial control of soil moisture is well shown by the effect of windbreaks. Card ('97) studied the moisture content of the soil to leeward of a windbreak and found that in general there is a "decrease in the per cent. of water as the distance from the windbreak increases." As the physical conditions leeward of windbreaks are similar in many respects to those in forest glades and forest margins, it is very probable that the conditions of soil moisture also will be very similar in these places.

### 7. *Ventilation of Land Habitats*

The preceding account of the temperature, humidity, and evaporating conditions in various habitats forms a necessary basis for an understanding of the processes of ventilation or atmospheric change in land habitats. The differences in pressure due to the different densities of cool and warm air and to the friction and retardation of moving air currents, determine to an important degree the composition of the air in many habitats. In such an unstable medium as air, changes take place very rapidly through diffusion, and through this constant process of adjustment there is a tendency to level off all local differences. These are naturally best preserved where diffusion currents are least developed—in the most stagnant or stable atmospheric conditions; therefore any factor which retards an air current and produces eddies, or slow diffusion, will favor local differentiation of the air.

We have seen that any vegetable cover retards air currents, so that the air within the vegetation becomes different from the faster moving air above it. The accumulation of humidity at different levels above the soil within the vegetation, clearly shows this. The denser the vegetation the more completely are the lower strata shut off and, to a corresponding degree, stagnant and subject to the local conditions. Two factors have an important influence upon these conditions: the character of the cover itself, and the character of the substratum. If both of these are mineral rather than organic, in general comparatively little local influence is to be expected, although in some localities  $\text{CO}_2$  escapes from the earth and on account of its density may linger in depressions and thus kill animals (Mearns '03). Generally, however, the organic materials are of most importance both as a cover and as a substratum, and are often the source of carbon dioxide. Living vegetation may also add oxygen to such stagnant air, but the main source of it is the free air itself. The forest litter, on account of its imperfect stage of decay, consumes oxygen and gives off carbon dioxide; in the humus below it, shut off even more from free access to air, the carbon dioxide is relatively more abundant and the oxygen relatively less so or absent; and in the deeper mineral soil the amount of carbon dioxide is relatively less on account of the absence of organic debris, and a small amount of oxygen is present.

The aeration of the soil is influenced to a large degree by its porosity; the looser it is, the freer the circulation. Buckingham ('04) has shown that "the speed of diffusion of air and carbonic acid through these soils was not greatly dependent upon texture and structure, but was determined in the main by the porosity of the soil. . . . the

rate of diffusion was approximately proportional to the square of the porosity . . . . the escape of carbonic acid from the soil and its replacement by oxygen take place by diffusion, and are determined by the conditions which affect diffusion, and are sensibly independent of the variations of the outside barometric pressure."

In the upper, better ventilated, moist, neutral or alkaline layers of vegetable debris decomposition is brought about mainly by the agency of fungi; but in the deeper, poorly ventilated acid layers, lacking oxygen, bacteria are the active agents (cf. Transeau, '05, '06). The higher the temperature the more rapid the circulation, and on this account ventilation in the open is relatively more rapid than in the cooler woodlands. The black soil prairies are thus favorable to a higher temperature and better ventilation. Dry soil, according to Hilgard ('06:279) contains from 35 to 50 per cent. its volume of air, and in moist or wet soils this space is replaced by water. Thus the conditions which influence the amount of water present have a very important influence upon aeration. As water is drained from the soil, air takes its place; so drainage and the flow of water through the soil facilitate ventilation. The part of the soil containing air is thus above the water-table; and as this level fluctuates with the season and from year to year the lower boundary of this stratum is migratory. Hilgard states that cultivated garden soil contains much more air than uncultivated forest soil. Warming ('09:43) says that the "production of acid humus in the forest leads to an exclusion of the air." If lime is present, such an acid condition can not arise.

While the source of oxygen in the soil is the air, the reverse is the case with carbon dioxide. The surface layers of the soil, among dense vegetation, constitute an area of concentration of carbon dioxide. Because this is more soluble than other gases, it is found in rain water, according to Geikie, in a proportion 30 to 40 times greater than in the air. Rains thus assist in the concentration of carbon dioxide in the soil. This concentration is well shown by the following table by Baussungault and Lewy (Van Hise, '04:474).

Character of soil air	CO <sub>2</sub> in 10,000 parts by weight
1. Sandy subsoil of forest	38
2. Loamy subsoil of forest	124
3. Surface soil of forest	130
4. Surface soil of vineyard	146
5. Pasture soil	270
6. Rich in humus	543

The amount of carbonic acid in the atmosphere is by weight about 4.5 parts in 10,000. The amount in the air is, as Van Hise says, "insignificant in comparison with the amount in soils in regions of luxuriant vegetation. In such regions the carbon dioxide is from thirty to more than one hundred times more abundant than in the atmosphere." This carbonic acid in the presence of bases, sodium, potassium, calcium, and magnesium compounds, forms carbonates and bicarbonates. This is the process of carbonation—one of the most important processes of change in surface soils.

In view of the dominance of  $\text{CO}_2$  in soils we may anticipate that many of the animals living in them possess some of the characteristics of the plants, bacteria, fungi, etc., which are active in such soils. The anaerobic forms live without free oxygen; others live only where oxygen is present. The animals which thrive in the soil are likely to be those which tolerate a large amount of  $\text{CO}_2$  and are able to use a relatively small amount of oxygen, at least for considerable intervals, as when the soil is wet during prolonged rains. This is a subject to which reference will be made later.

The air is the main source of oxygen, and from the air it diffuses into the soil; thus the process of equilibration is constantly in progress. Carbonic acid, also present in the air, is washed down by rain and concentrated in the soil, where it is increased by the decay of organic debris and by respiring animals to such an extent that it exists under pressure and diffuses into the air, thus contributing to the air. In the soil, then, the process of *decarbonization* is of great importance to animal life, and must not be neglected. The optimum soil habitat is therefore determined, to a very important degree, by the proper ratio or balance between the amount of available oxygen and the amount of carbon dioxide which can be endured without injury. The excessive accumulation of carbon dioxide, an animal waste product, is comparable to the accumulation of plant toxins which may increase in the soil to such a degree as to inhibit plant growth. Such substances must be removed from the soil, or changed in it to harmless compounds, or plants and animals can not continue to live in certain places. I have used the term ventilation to cover both the oxygenation and decarbonization of land habitats, and the same principles are applicable to life in fresh-water habitats.

We have just seen how atmospheric ventilation favors the removal of certain injurious waste products from the air and soil. In addition to gaseous waste products there are also liquids and solid kinds which may be equally harmful in a habitat. These are known to exist in confined liquids, as in aquaria (Colton, '08; Woodruff, '12), where they

interfere with the welfare of the animals present, and it is probable that they also exist in soils. The older naturalists elaborated the idea that if organisms were not such active agents in the destruction or transformation of plant and animal bodies such remains would soon encumber the earth. Thus organisms themselves are among the most active agents in influencing directly and indirectly the ventilation of animal habitats.

### 8. *The Tree Trunk as a Habitat*

A living tree trunk is composed of wood, sap (moisture), and bark, all of which are relatively poor conductors of heat. When the trunks are cooled, as in winter, they are slow in warming, not only because of poor conduction but also because of the slow circulation of sap, which is derived from the cool ground-water. As the season progresses, the trunks warm up, this process being retarded in part by the shade and the cool forest conditions; and in the fall, radiation of the heat accumulated also takes place slowly. The tree trunk therefore changes its temperature slowly, as does the soil. The animals which live within wood thus live in a relatively cool and stable environment. In living trees the humidity is relatively high, as it may also be in fallen, decaying logs. Relatively dry logs, before progress of decay, on the other hand, form a relatively dry and uniform habitat. (Cf. on the temperature of trees: Harrington, '93, pp. 72-75; Packard, '90, p. 23; and Jones, Edson, and Morse, '03, pp. 97-100.)

### 9. *Prairie and Forest Vegetation and Animal Life*

The dependence of animals upon plants for food is one of the most fundamental animal relations. It is a world-wide relation, but its mode of operations varies greatly in different environments. For example, many years ago, Brooks gave us a graphic picture of the rôle of marine vegetation in the economy of marine animals. In the sea there are no forests or grasslands, and no corresponding animals associated with these conditions, as on land; but in the sea great numbers of minute plants float, and upon these feed an immense number of small crustaceans and other small animals. These small creatures occur in such large numbers that at times the sea is a sort of gruel which sedentary and stationary kinds may appropriate by simply allowing the sea to flow into their mouths. The food here circulates in their environmental medium, as plant foods do in the soil and air. This condition has made it possible for vast numbers of plant-like animals to grow over the sea floor as plants do over rocks and plains. The living meadows of animals thus furnish pasture for a host of preda-

ceous kinds; and upon these still others prey, so that flesh-eating animals make up the most conspicuous classes of marine animals. Quite otherwise are the conditions on land, where no air current carries food to the hungry mouths of animals. Plants with roots in the soil and stems in the air are able, however, to secure their food from the circulating medium, but being themselves fixed, they are easy prey to animals—both the sedentary kinds, which live in or upon the plant tissues, and the active wandering kinds, which forage over large areas. The predaceous animals, either by active mind or body, must secure their food from the plant-feeding kinds. The great expanses of grassland and forest tend to be devastated by a vast army of animals which far outnumber the predaceous kinds. The conditions of life, therefore, found upon grassland areas, like the prairie, and in the forest, are to the farthest possible extent removed from those found in the sea. This, then, is one of the most fundamental contrasts in the conditions of existence encountered by animals.

These considerations naturally raise the question to what extent and in what particular manner does land vegetation influence animal life? Does a change in the vegetation as great as that between the forest and the prairie have a marked influence upon animals? In the Charleston region we have just such a difference in the vegetation.

Many years ago Bates pointed out repeatedly in his "The Naturalist on the River Amazons" that the animals of that densely forested region were to a marked degree distinctly arboreal and "adapted" to a forest life. In most densely forested regions like conditions probably prevail, and to a corresponding degree open lands harbor animals equally characteristic and as truly terrestrial in habits. The contrast between the conditions of life in the open and in the forest is one of the most fundamental environmental conditions upon land. The significance of this contrast seems to have been realized only in part. The prairies or grasslands are representative of only one kind of open; they are caused by many kinds of factors limiting the extension of forests. Open places are formed by lakes, ponds, and swamps; by the avenues through forests formed by different kinds of streams, as brooks, creeks, and rivers; by the small amount of soil on rock surfaces; and by still other kinds of limiting influences, such as the sea, severe climate, and altitude. Among almost all of the major taxonomic groups of land animals is seen the independent origin and preservation of animals suited for life in the forest; this clearly points to the extensive influence and antiquity of this environment. The same is true of animals living in the open. But to assume that it is solely the kinds of forest trees serving as *food* for animals, or the corresponding kinds of vegetation in the open, which determines whether



an animal lives in the open or in the forest, would be unwarranted in the light of the preceding discussion of the effect of vegetation upon air temperatures, winds, humidity, relative evaporating power of the air, and corresponding changes in the soil. Animal life is most abundant in a narrow vertical layer above the earth's surface, by far the most of it is within a few inches or feet of the surface; and above the level of the forest-crown it diminishes with great rapidity. Below the surface of the soil the same general law holds; most of the ground animals are within the first few inches of soil, only a small number extending a few feet below the surface, and those found at greater depths being indeed very few. The rate of decline is many times more rapid below the surface than it is above it. There is, then, above and below the surface a rapid and progressive attenuation of the favorable conditions for animals and plants, and the animals do not establish thriving communities far from those physical conditions which are also favorable to vegetation. Animals are dependent upon plants for food, but both are dependent upon a certain complex of physical conditions near the surface of the earth.

It is well to recall at this point how the influence of the climate and the vegetation exemplify certain general laws which operate in all habitats. The differentiation of habitats upon the earth is primarily due to temperature and the specific heat relations of the earth, which result in the several media—gases, liquids, and solids. With a higher temperature all would be gas, and with a lower one all would be solidified. The present intermediate conditions, therefore, permit the present differentiation. These media are further differentiated by temperature about as follows: Since the source of solar energy, heat, and light, and the oxygen supply, *are above the surface* of the earth, the vertical attenuation of these influences is one of the most striking peculiarities of animal habitats, both in water (where the causes have long been recognized) and upon land. Any covering of the earth, even the surface layer of vegetation, soil and water, tends to shut off heat, light, and oxygen. At the same time such a layer tends to shut in those influences which originate primarily in or below it. Thus carbonic acid originating under the cover, by organic decay, breathing animals, or bacteria, or washed in by the rain, tends to be shut in. Furthermore, heat once reaching here, either in water or on land, tends toward slow radiation. Thus we may look upon the surface layer as a partition which is under pressure from both sides, and through which constant interchange is in progress, as the process of dynamic equilibrium operates.

This attenuation of intensities, above and below the surface, produces vertical layers of relatively equal strength or pressure. Thus the attenuation of temperature in gases (air) and in liquids (water) causes different densities in air and in water which modify to an important degree the physical and chemical conditions in these media. This results in their stratification: when the heavier layers are below, stability is the tendency; and when the reverse order obtains, a change takes place toward the stable condition. With stratification, flowage tends to occur within the strata, and to be horizontal rather than vertical; additional pressure is therefore necessary to cause the vertical currents or circulation under such conditions. This is why carbonic acid accumulates in the soil and in small deep lakes abounding in organic debris, this accumulation being largely due, in both cases, to the slow rate of exchange caused by the stratification produced by differences in density. This same relative stagnation is a primary factor in the vertical differences in the relative evaporating power of the air within a vegetable layer of the prairie or the forest. Though on the prairie the vegetational layer is generally but a few inches or a few feet thick, in the forest it is about eighty feet, or more, thick; and the forest thus influences atmospheric conditions solely as a *thick* layer of vegetation.

Differences, then, in the character, structure, or composition of the surface of the substratum are of fundamental importance in understanding its relative influence upon animals. Primarily these differences are due to temperature, secondarily to temperature in combination with moisture; and they result in the relative humidity and the relative evaporating power of the air. The most important difference in the surface layer in the Charleston region is that of prairie and forest, and therefore the main features of these habitats will now be summarized. It should not be overlooked that conditions on the prairie are likely to be quite representative of open places in general, though they will probably be somewhat unrepresentative in the case of open places having wet or extremely dry substrata. It is also true that the conditions produced by the forest are comparable, in some degree, with those due to the influence of an elevation.

SUMMARY OF ENVIRONMENTAL FEATURES OF THE PRAIRIE AND THE DECIDUOUS FOREST  
—TEMPERATURE, HUMIDITY, AND EVAPORATION—DURING THE GROWING SEASON

*Above the Vegetation*

*Prairie*

*Forest*

In sun, maximum heated stratum.  
Cooler above and below this stratum.  
Absolute humidity less than in or over forest.

Above crown, in sun, maximum heated stratum. A thin layer. Cooler above and below this stratum.  
Absolute humidity greater than in the open.

*Among the Vegetation*

*Prairie*

*Forest*

Temperature lower and higher than in the forest—more extreme.  
Temperature lower toward the soil, and warmer than in the forest.  
Absolute humidity progressively increases toward the soil.  
Relative evaporation decreases toward the soil; greater than in the forest.

Temperature moderated—not as low or as high as on the prairie.  
Temperature lower toward the soil, and cooler than in the open.  
Absolute humidity progressively increases toward the soil.  
Relative evaporation decreases toward the soil; less than in the open.

*In the Soil*

*Prairie*

*Forest*

Temperature averaging warmer than forest, warmer near surface in summer, and cooler in winter. Warmer in sun and cooler at night than in forest.  
Temperature progressively more stable downward. Soil moisture increases downward.

Temperature cooler on the average and in summer, and warmer in winter, near the surface, than in the open. Cooler in sun and warmer at night than in the open.  
Temperature progressively more stable downward. Soil moisture, below the surface layer, increases downward.

The conditions on the prairie and in the forest may be graphically shown as in the following diagrams, Figure 14 showing the temperature relations, and Figure 15 showing the relative evaporating power of the air.

CLIMAX FOREST

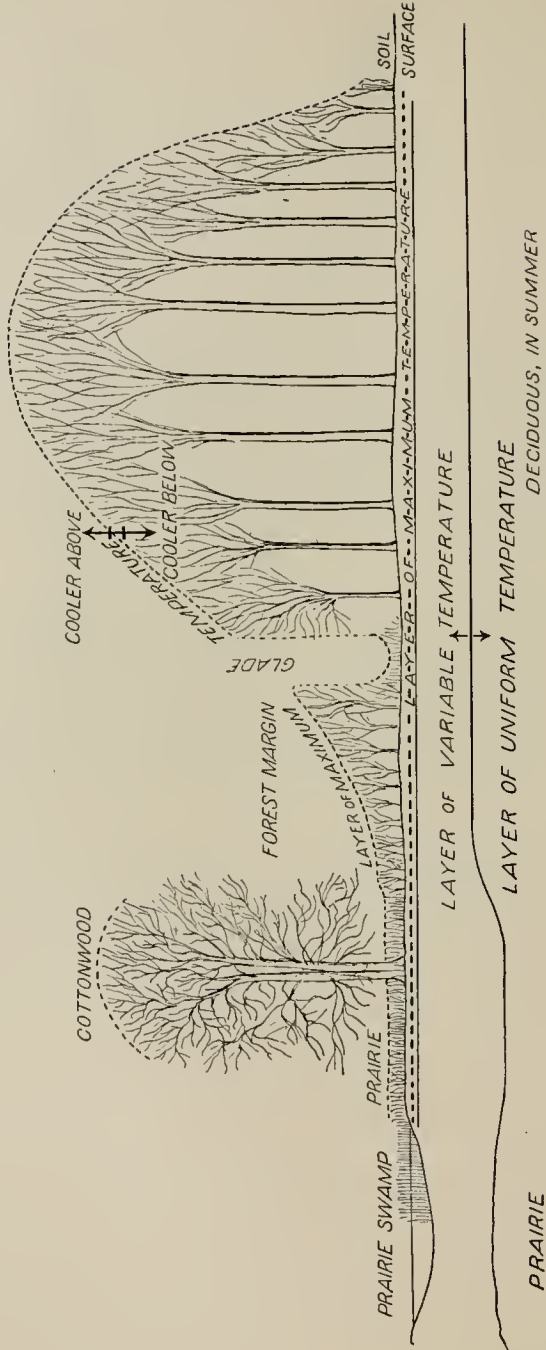


FIG. 14. Diagram showing temperature relations of prairie and forest as influenced by vegetation.

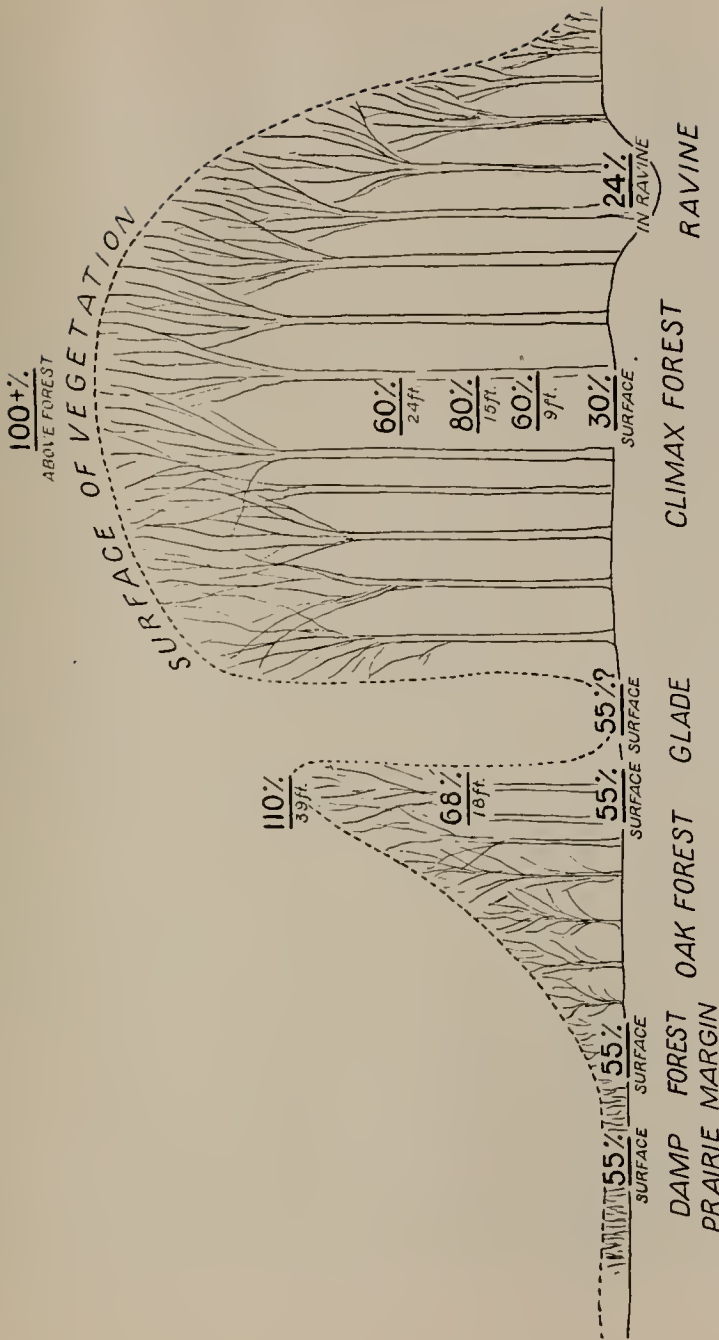


Fig. 15. Diagram showing relative evaporating power of air as influenced by prairie and forest vegetation.

10. *Sources and Rôle of Water used by  
Prairie and Forest Animals*

The bodies of animals contain a very large proportion of water—from 60 to 95 per cent. Growing animals in particular require water in relatively large amounts. Practically all foods gain entrance into the body in aqueous solutions, and are transported by water to all parts; and by the same means, the waste products, with the exception of the excretion of carbonic acid, are removed. The methods by which aquatic animals secure water are relatively simple, because they live in a liquid medium; but the conditions upon land are quite different. Here osmotic pressure does not operate as in water, and the air varies from saturation to a very dry condition. This dryness tends to cause strong evaporation from animals living in such a medium, and a proper balance between intake and water-loss is one of the most potent influences in the life of land animals. In this relation lies the importance of the sources of water available to them. These sources are as follows: with the food, by drinking, from the atmosphere, and by metabolism. The loss is by excretion and evaporation, the relative humidity and the evaporating power of the air being, therefore, important considerations. The loss of water is retarded in many ways. Some animals possess a relatively impermeable skin, or a covering, as hair or feathers, which retards air currents and evaporation through the skin, just as a cover of vegetation retards soil evaporation. Other animals conserve their moisture by modes of behavior, being active mainly during the cooler night, thus escaping the excessive evaporation of the heated day; and still others live in burrows in the soil, where the humidity is higher than in the air. Many animals can live only where the air is humid. There is thus an almost endless series of conditions relating animals to the supply and loss of water.

On account of the herbivorous food habits of so many animals a large number secure much water with the juicy vegetation eaten, and others from nectar or from the sap drawn or escaping from plants. The predaceous animals secure a large amount of water from the fluids of the animals they devour or the juices sucked from their bodies, as in the case of certain *Hemiptera* and some parasites. In addition to the fluids derived from plants and animals, many animals also drink water, some in small amounts and others in large quantities. Innumerable observations have been made by naturalists on the drinking habits of animals, but I know of no general discussion of this subject, and particularly of none from the standpoint of the variation of their behavior in this respect in different environments. But the sources of water mentioned are not the only ones available to animals, although

they are the most obvious, and familiar to us. An important additional source is that formed within the body of the animal by the processes of respiration and dehydration; this is metabolic water. The relation of this source to others and to water-loss has recently been summarized in an important paper by Babcock ('12: 87, 88, 89-90, 91, 160, 161, 171-172, 174-175, 175-176, 181). The following quotations from this paper will serve to give a concise statement of the general principles involved in this important process. He says (pp. 87-88): "There are, however, particular stages in the life history of both plants and animals in which metabolic water is sufficient for all purposes for considerable periods of time. . . . This is also true in the case of hibernating animals that receive no water from external sources for several months, although water is constantly lost through respiration and the various excretions. In addition many varieties of insects such as the clothes moths, the grain weevils, the dry wood borers, etc., are capable of subsisting, during all stages of development, upon air-dried food materials containing less than ten per cent water; in these cases, nearly all of the water required is metabolic. . . . Many organisms also, when deprived of free oxygen, are capable of maintaining for a short time, certain of the respiratory functions, and deriving energy from food material and from tissues by breaking up the molecular structure into new forms of a lower order. This is known as intramolecular respiration, and like direct respiration, results in the production of both water and carbon dioxide." (Pp. 89-90): "The substances oxidized by both plants and animals, to supply vital energy, consist of carbohydrates, fats, and proteins. All of these substances contain hydrogen, and their complete oxidation produces a quantity of water equal to nine times the weight of hydrogen present in the original substances. . . . Most of the the fats yield more than their weight of water, while proteins, when completely oxidized, give from 60 to 65 per cent of water. . . . Animals, however, are unable to utilize the final products of protein metabolism which are in most cases poisonous and must be removed from the tissues by excretion in various forms, the principal of which are urea, uric acid, and ammonia. . . . The amount of metabolic water formed by oxidation during any period is proportional to the rate of respiration. . . . (Page 91): "With parasitic plants, and with animals, which derive all of their organic nutrients from chlorophyl producing plants, imbibed water is not so essential to life; with these the chief function of imbibed water is to aid in the removal of waste products, the metabolic water being in most cases sufficient for transferring nutrients and for replacing the ordinary losses incurred by respiration and evaporation." . . . (Page 160): "Another and more im-

portant difference is the inability of animals to resynthesize the organic waste products of respiration into substances that may be again utilized as nutrients. . . . This is especially the case with the soluble products arising from protein metabolism. With most animals these nitrogenous products are excreted in solution through the kidneys, chiefly as urea, but birds, reptiles, and all insects excrete most of the nitrogenous waste matter as uric acid, or its ammonia salt, which being practically insoluble in the body fluids, is voided in a solid condition." (Page 61): "The need for water is much less for animals that excrete uric acid than for those that excrete urea, since uric acid, being practically insoluble in the the body fluids, is not so poisonous as urea and is voided solid with a minnum loss of water. Many animals that excrete uric acid instead of urea never have access to water and subsist in every stage of their development upon air dried food which usually contains less than 10 per cent water. The most striking illustrations of this kind are found among insects such as the clothes moths, the grain weevils, the dry wood borers, the bee moths, etc. The larvæ of these insects contain a high per cent of water, and the mature forms, in spite of the development of wings which are relatively dry, rarely contain less than 50 per cent of water." (Pp. 171-172): "Serpents and other reptiles that live in arid regions and rarely if ever have access to water, except that contained in their food, are said by Vauquelin to excrete all of the waste nitrogen as salts of uric acid. The same is true of birds that live on desert islands where only salt water is available. It is essential that animals of these types should produce as much metabolic water as possible from the assimilated food, and the waste of water through the excretions should be reduced to a minimum. Since the food is largely protein both of these ends are attained by the excretion of uric acid which, as already stated, contains the least hydrogen of any nitrogenous substance excreted by animals so that the maximum amount of metabolic water has been derived from the food consumed." (Pp. 174-175): "There are many animals that are able to go long periods without having access to water except that contained in their food, in which water usually amounts to less than 20 per cent of total weight, and the metabolic water derived from oxidation of organic nutrients. A notable example of this is the prairie dog which thrives in semi-arid regions. These small animals feed upon the native herbage which for months at a time is as dry as hay. It has been surmised that the burrows in which they live extend to underground water courses, but this does not seem likely since in many of these regions wells must be sunk hundreds of feet before water is reached. It is more probable that they depend chiefly upon metabolic water. They feed mostly at night when the temperature is low and



during the hottest hours of day remain in their burrows where the air is more nearly saturated with moisture and evaporation is relatively small." (Pp. 175-176): "An application of these principles would undoubtedly serve to prolong life, when suitable water for drinking is not available. In such cases the food should consist of carbohydrates and fats. Proteins should not be used. . . . The water required for preventing uremic poisoning under these conditions is small and if the relative humidity of the surrounding air is high enough to prevent rapid evaporation of water from the body, the metabolic water arising from the oxidation of nutrients may be ample for the purpose." (Page 181): "Metabolic water derived from the oxidation of organic nutrients would probably be sufficient for all animal needs were it not for the elimination of poisonous substances resulting from protein degeneration."

The preceding quotation brings out very clearly the harmful effects of an accumulation of uric acid upon the animal. This is only a special case illustrating a general law, for except water the main end products of metabolism are *acid*. There is thus a constant tendency for acid to accumulate, as Henderson ('13a: 158-159; see also '13b) has said: "This tendency toward acidity of reaction and the accumulation of acid in the body is one of the inevitable characteristics of metabolism; the constant resistance of the organism one of the fundamental regulatory processes. Now it comes about through the carbonate equilibrium that the stronger acids, as soon as they are formed, and wherever they are formed, normally find an ample supply of bicarbonates at their disposal, and accordingly react as follows . . . . The free carbonic acid then passes out through the lungs, and the salt is excreted in the urine."

Recently Shelford ('13b, see also '14a) has summarized the physiological effects of water-loss by evaporation and other methods. It is probable that the carbonic acid excretion is retarded by drying, and that by this means irritability may be increased.

It is not simply loss of water, but loss beyond certain limits that interferes with the life of animals. Thus loss is not an unmixed evil, because, in addition to removing excretions, evaporation is an important factor in the control of temperature within the bodies of animals. Loss of water also tends to concentrate the body fluids, and when this loss brings about a relatively dry condition, such tissues are in a condition which is favorable for the endurance of relatively extreme low or high temperature (Davenport, '97: 256-258), and even dryness (see references, Adams, '13: 98-99). This is a reason why it is difficult to distinguish, in nature, between the effects of aridity and temperature extremes, and hence arise the puzzling interpretations of con-

tinental climates. These extreme conditions are characteristic of many habitats.

It is readily seen how the general principles just summarized apply to the land animals of the prairie. Many of these are active during the day, live in the bare exposed places, or near the level of the vegetation, where evaporation is greatest and water-loss is correspondingly large, and feed upon the dry haylike vegetation. Others remain among the humid layers of the vegetation or in the moist soil, and feed upon juicy plants and other moist food. Predaceous and parasitic animals, deriving their moisture from their prey, occupy both the dry and humid situations. These are representative cases, between which there are a large number of intergradations.

In the forest, where evaporation is more retarded than in the open, a large number of animals live in the forest crown, at the forest margin, in glades, and in wood, of all degrees of dryness, and eat food varying similarly from juicy leaves to dry wood. On the other hand, some live in moist logs, among damp humus, or in the soil, and feed upon dripping fungi or soggy wood. Many of these animals possess little resistance to drying.

The optimum for prairie and forest animals thus involves a dynamic balance between the intake of water and its loss by evaporation and excretion.

## ANIMAL ASSOCIATIONS OF THE PRAIRIE AND THE FOREST

### I. INTRODUCTION

In an earlier chapter of this paper the habitats and animals found at the different stations were discussed, and in the preceding section the general characteristics of the physical and vegetational environment of the prairie and forest have been described and summarized. We are now in a better position to consider the relations of the invertebrates, not only to their physical environment, but also to the vegetation, and, furthermore the relations which these animals bear to one another. We wish also to consider both the prairie and the forest as separate units, and to see how the animals are related to their physical and biological environment. As previously stated, the special localities studied were described by stations both to give a precise and concrete idea of the prairie and its animals, as now existing in a limited area, and also to preserve as much of the local color as the data would permit. I wish now to reexamine these animals from another standpoint, that of the animal association as a unit. The prairie as a whole

is not homogeneous from this point of view; it is a mosaic composed of a number of minor social communities. Each of these smaller units, however, is fairly homogeneous throughout.

Our present knowledge of these minor associations is imperfect, and for this reason they are arranged in an order approximating that which we might reasonably expect to be produced if the initial stage were made to begin with a poorly or imperfectly drained area and to advance progressively with corresponding vegetational changes, toward a more perfect condition of drainage. Upon the prairie a perfect series would include every stage from lakes, ponds, and swamps to well-drained dry prairie. But cultivation and drainage have obliterated so much, that now only very imperfect remnants exist in the vicinity of Charleston. Although the sequence followed therefore does not include all stages of the process it is approximately genetic.

There are three essential features in every animal association, or community; certain physical conditions; certain kinds of vegetation, which also modify the physical conditions; and representative kinds of animals. Occasionally an effort is made to divorce these, to separate organisms from their normal habitat, but such an effort is deceptive, for no organism can live for any considerable period without a normal environment.

I have not attempted to treat these associations with equal fullness. In the sections devoted to the description of the stations it was possible in some cases, on account of the uniform character of a station, to describe the animal association rather fully. In such instances the detailed account is not repeated. In other cases I have elaborated the community relations more fully here than elsewhere. The descriptions of the stations and the associations, and the annotated lists, are intended to be mutually supplementary.

## II. THE PRAIRIE ASSOCIATIONS

### 1. Swamp Prairie Association

The swamp prairie community lives in a habitat characterized by shallow water, which stands approximately throughout the growing season of the vegetation. The soil is black, and rich in vegetable debris. The characteristic plants are bulrush (*Scirpus*), flags (*Iris*), swamp milkweed (*Asclepias incarnata*), beggar-ticks (*Bidens*), and young growths both of willow (*Salix*) and cottonwood (*Populus deltoides*). The abundant growth of vegetation and the wet soil are conditions favorable for the production and accumulation of organic debris, which tends to fill the depressions and to supplement the inwash

from the surrounding slopes. At the same time, burrowing animals, particularly the crawfish, also bury debris and work over the soil. In the Charleston area this community was developed at Station I, *d*, and in part at I, *g*.

The representative animals of this community are those living in the water, such as the prairie crawfish, *Cambarus gracilis* (Pl. XXXVI), the snail *Galba umbilicata*, and such insects as the nine-spot dragon-fly, *Libellula pulchella* (Pl. XXXVIII, fig. 2), and the giant mosquito, *Psorophora ciliata*, whose immature stages are spent in the water. In addition to these are other representative species whose presence is, to an important degree, conditioned by the presence of certain kinds of vegetation—such species, for example, as those which feed upon the dogbane (*Apocynum*), the brilliantly colored beetle *Chrysochus auratus*; upon milkweed, the milkweed bugs *Lygaeus kalmii* and *Oncopeltus fasciatus* (Pl. XL, figs. 1 and 3), and the milkweed beetle *Tetraopes*; and, finally, the rather varied series of flower visitors feeding upon pollen or nectar, such as the soldier-beetle (*Chauliognathus pennsylvanicus*), *Euphoria sepulchralis*, and several species of butterflies, moths, bees and wasps, including the honey-bee, bumblebees, and carpenter-bee (*Xylocopa virginica*), and the common rusty digger-wasp (*Chlorion ichneumoncum*). Visiting the same flowers, but of predaceous habit, were found the ambush spider (*Misumena aleatoria*) and the ambush bug (*Phymata fasciata*). Small insects were preyed upon by the dragon-flies (*Libellula pulchella*), and the dragon-flies in turn were entangled in the webs of the garden spider (*Argiope aurantia*).

No animals were taken on the flags, but Needham ('00) has made an important study of the population inhabiting flags at Lake Forest, Illinois, and shows that it is an extensive one. He gives an excellent example showing how the injury by one insect paves the way for a train or succession of others. For example: the ortolid fly *Chatopsis aenea* Wied. (Pl. XVIII, fig. 1), bores into the stem of the buds and causes them to decay (Cf. Forbes, '05, p. 164; Walton, Ent. News, Vol. 19, p. 298. 1908). This condition affords a favorable habitat for a pomace-fly (*Drosophila phalerata* Meig.\*), an oscinid (*Oscinis coxendix* Fitch, Plate XVIII, figures 3 and 4), a beetle, parasitic *Hymenoptera*, and, after the decaying buds were overgrown by fungus threads, the bibionid fly *Scatopse pulicaria* Loew. This paper by Needham is one of the very few in which the population of a plant has been studied as a biotic community. Forbes ('90, pp. 68-69; 02, p. 444) has shown that snout-beetles (*Sphenophorus ochreus* Lec., Plate

\*Mr. J. R. Malloch informs me that *D. phalerata* is not an American species.

XVIII, figures 5, 6, and 7) breed in root-bulbs of *Scirpus*, and that these beetles eat the leaves of *Phragmites*. Webster ('90, pp 52-55) observed these beetles feeding on the leaves of *Scirpus* and the larvæ feeding on its roots. I have found great numbers of these beetles cast up on the beach of Lake Michigan. Evidently they breed in the swamps about the lake, fall into it when on the wing, and are washed ashore.

## 2. The Cottonwood Community

Ordinarily we are accustomed to think of the prairie as treeless, and yet one large tree was relatively abundant upon the original prairie of Illinois, particularly upon wet prairie, or, when pools were present, even upon the uplands. This was the cottonwood, *Populus deltoides*. These trees were often important landmarks when isolated; and today the large trees or their stumps are important guides in determining the former extent of the prairie. In the region studied there were no large mature cottonwoods, although saplings were present, but north of Charleston in the adjacent fields mature trees were found. They grow normally at the margins of wet places, as about prairie ponds and swamps, or along the small ill-defined moist sags and small prairie brooks. This tree is usually solitary or in irregular scattered rows when along streams, and does not, as a rule, form clumps or groves. This relatively isolated habit may be a factor in the comparatively small number of invertebrates which are associated with it, or at least in the amount of serious injury which they do to these trees upon the prairie. Many of the larger trees are mutilated, or even destroyed by lightning (Cf. Plummer, '12), and such injury favors entrance of insects on account of the rupturing of the thick bark.

The galls on the leaves and twigs of the trees often attract attention. A large irregular gall on the ends of the twigs becomes conspicuous in winter. This is formed by the vagabond gall-louse, *Pemphigus oestlundii* Ckll. (Pl. XIX, fig. 1) (*vagabundus* Walsh, Ent. News, Vol. 17, p. 34. 1906). I have found these galls abundant upon the prairie at Bloomington, Ill. At this same locality I found a large bullet-like gall at the junction of the petiole and the leaf—that of *Pemphigus populicaulis* Fitch (Pl. XIX, fig. 2), and at Urbana, Ill., on other large prairie cottonwoods, a somewhat similar gall, on the side of the petioles, caused by *P. populi-transversus* Riley (Pl. XIX, fig. 3). I have also taken large caterpillars of the genus *Apatcla* on leaves of cottonwood, and September 3, at Urbana, upon its cultivated form, the Carolina poplar, *A. populi* Riley (Pl. XX, fig. 6). These caterpillars have bodies covered by yellow hair penciled with black. At dusk swarms of May-beetles (*Lachnosterna*) can be seen and heard feeding

among the leaves of the cottonwood and the Carolina poplar. It is noteworthy that I have made these observations at Urbana, Illinois, upon cottonwoods growing upon what was originally prairie.

Forbes ('07a) has shown, as the result of extensive collections of May-beetles from trees, that they have a decided preference for Carolina poplar (p. 456) and willow. This same paper also contains important observations on the nocturnal flights to and from the forest, from the normal habitat of the grubs, and from the daytime abode of the beetles in the open fields. Wolcott ('14) has recently emphasized the point that the grubs live only in open places in proximity to woodland where the beetles can secure food. These observations show very clearly that May-beetles are animals primarily of the *prairie* or forest margin, and probably lived upon the original prairie, scattered, where cottonwoods or willows grew. A glance at the map of the prairie and forest (frontispiece) shows that the marginal area was very extensive, and must have furnished an optimum habitat for these beetles. This is a good illustration of the fact that the cottonwood exerted an influence upon the prairie far beyond its shadow.

In some localities another beetle (*Melasma scripta* Fabr.) feeds upon the leaves of the cottonwood, and may become a serious pest to poplars and willows, but I have not seen this species abundant on isolated mature trees upon the prairie. I have taken these beetles (July 2) under cottonwoods at Bloomington, Ill. Packard ('90, pp. 426-474) has published a list of the insects known to feed upon *Populus*.

Willows (*Salix*) are frequently associated with the cottonwoods upon the prairie, but, in marked contrast with these, they generally grow in colonies and are eaten by a great variety of insects. Packard ('90, pp. 557-600) lists 186 species of insects on them, and Chittenden ('04, p. 63) extends the number to 380 species. Of course in any given locality the number of species found will be relatively small, and the number is further limited by the environmental conditions—whether the land is upland or low and flooded. The degree of proximity of willows and cottonwood is likely to influence the relative abundance of the insects feeding upon these trees, since a large number of insects which feed upon willow also feed upon the cottonwood. Colonies of willow are thus likely to become sources of infestation for the cottonwood; this relation, however, is a mutual one. Walsh ('64) and Heindel ('05) have published very interesting studies of the community life of the insect galls on Illinois willows. Cockerell ('97, pp. 770-771) has listed the scale insects found upon willows and poplars.

### 3. Swamp-grass Association

The prairie swamp-grasses, slough grass (*Spartina*), and wild rye (*Elymus*) were growing in relatively pure stands or colonies in depressions which were dry in the late summer. The prolonged wetness of the habitat and the dominance of the few kinds of grasses are characteristic features of the environment of this association. These conditions were found at Station I, *a* and *c*, north of Charleston. As these stations were rather homogeneous and have already been discussed somewhat fully, only a summary will be given here.

On account of the grassy vegetation the abundance of *Orthoptera* is not surprising. Representative species are *Melanoplus differentialis*, *M. fcmur-rubrum*, *Scudderia texensis*, *Orchelimum vulgare*, *Xiphidium strictum*, *Æcanthus nigricornis*, and *Æ. quadripunctatus*. Other representative animals are *Argiope aurantia* and the swamp fly *Tetanocera plumosa*. The list of species is probably very incomplete; during the wet season there are undoubtedly a number of aquatic; furthermore, there are still other species which feed upon *Spartina* and *Elymus*, particularly some *Hemiptera*, and stem-inhabiting *Hymenoptera*, and certain *Diptera*. Thus Webster ('03a, pp. 10-13, 26, 32, 38) has recorded a number of chalcids of the genus *Isosoma* which live in the stems of *Elymus virginicus* and *canadensis*. In this same paper he discusses their parasitic and predaceous enemies (pp. 22, 27, 33). A fly also breeds in *Elymus*, the greater wheat stem-maggot, *Meromyza americana* Fitch (Pl. XX, figs. 1-5), as recorded by Fletcher (l. c., p. 48). This species is of economic importance, having spread from grasses to the cultivated grains. It has been studied in Illinois by Forbes ('84). He found a fly parasite of this species, and Webster reports a mite preying on it. Webster (l. c., p. 53) reports another fly, *Oscinis carbonaria* Loew, bred from *Elymus* by Fletcher.

In another paper Webster ('03b) has published a list of insects inhabiting the stems of *E. canadensis* and *virginicus*. Osborn and Ball ('97b, pp. 619, 622; '97a) have discussed the life histories of certain grass-feeding *Jassidæ* which feed upon *Elymus*. Osborn ('92, p. 129) records a plant-louse, *Myzocallis*, from *Elymus canadensis* in Iowa, and a species of leaf-hopper has been recorded by Osborn and Ball ('97b, p. 615) from *Spartina*. On the same plant, Osborn and Serrine ('94, p. 897) record a plant-louse on the roots. In a list of the plant-lice of the world and their food plants Patch ('12) lists a few from *Spartina*. This same list includes (pp. 191-206) many grasses and the associated aphids, those on *Elymus* on page 196.

## 4. Low Prairie Association

The moist black soil prairie, a degree removed from the wet or swamp condition, with ground water in the spring relatively near the surface, is fairly well characterized by the rosin-weed (*Silphium*), particularly *S. tercbinthinaccum*. Other plants likely to be associated with *S. tercbinthinaccum* are *Silphium laciniatum* and *S. integrifolium*, *Eryngium yuccifolium*, *Lepachys pinnata*, and, to a less degree, *Lactuca canadensis*.

In the Charleston area this condition is represented by Station I, *a*, north of the town, and Station III, *a*, and in part *b*, east of the town. The proximity of ground water is shown at Station I, *c*, by the presence of crawfish burrows, probably those of *Cambarus gracilis*. At Station III the proximity of water was also evident where *S. tercbinthinaccum* was most abundant in the railway ditches. Such perennial plants are indicative of the physical conditions for a period of years, and are thus a fairly reliable index of average conditions—much more so than the annuals.

It is difficult to decide which kinds of animals are characteristic of this kind of prairie. Provisionally I am inclined to consider the following as being so: *Cambarus gracilis*; *Argiope aurantia*; the grasshoppers *Encoptolophus sordidus*, *Melanoplus differentialis*, *M. femurrubrum*, *Scudderia texensis*, and *Xiphidium strictum*; *Cæcanthus nigricornis*; *Phymata fasciata*; and asilids. The presence of *Lepachys* was clearly an important factor in determining the presence of *Melissodes obliqua* and *Epcolus concolor*. At Station III, *b*, east of Charleston, *Epicauta pennsylvanica* and *Bombus pennsylvanicus*, *auricomus*, and *impatiens* were taken on the flowers of *Silphium tercbinthinaccum*.

Robertson ('94, pp. 463-464; '96b, pp. 176-177) has published lists of insect visitors to the flowers of *Silphium* and *Lepachys* ('94, pp. 468-469), at Carlinville, Ill. Recently Shelford ('13a, p. 298) has published a long list of animals inhabiting *Silphium* prairie near Chicago. Forbes ('90, p. 75) has reported the snout-beetle *Rhynchites hirtus* Fabr. as feeding upon *Silphium integrifolium*.

In a colony of prairie vegetation at Seymour, Ill., which included much *Silphium* and *Eryngium*, the following insects were taken October 7 from the ball-like flower clusters of *Eryngium yuccifolium*: the bugs *Lygæus kalmii*, *Thyanta custator* Fabr., *Euschistus variolarius*, and *Trichopepla semivittata* Say (No. 539, C. C. A.), the last named in large numbers, the nymphs in several sizes as well as the adults, a fact which suggests that both may hibernate upon the prairie. Robertson ('89, pp. 455-456) has summarized his collections of insects from *Eryngium* and on *Euphorbia corollata* ('96a, pp. 74-75).



Upon remnants of prairie vegetation growing at Urbana, Illinois, I have found several kinds of insects centered about a wild lettuce, *Lactuca canadensis*. Upon the upper, tender parts of this plant, the plant-lice *Macrosiphum rudbeckiae* Fitch, thrives late in the fall, in very large numbers. Some seasons nearly every plant is infested. The lice become so abundant upon these tender parts that the entire stem for a distance of a few inches is completely covered. They migrate upward with the growth of the stem and keep on the fresh, tender parts. Among the plant-lice, and running about on the stem of the plant, attending ants abound; eggs, larvæ, and adults of lace-wing flies (*Chrysopa*) also abound; and several species of coccinellids, syrphid larvæ, and a variety of small parasitic *Hymenoptera* are present.

### 5. Upland Prairie Association

The well-drained prairie, a degree removed from the permanently moist prairie, is fairly well represented by the physical and biological conditions in which *Euphorbia corollata*, *Apocynum medium*, and *Lactuca canadensis*, are the representative plants. The plant ecologist would consider the conditions favorable to mesophytic plants. In the Charleston region these conditions are approximated at Station II, where drainage has doubtless changed the area from a somewhat moist, to its present well-drained, condition.

Representative animals of this community are as follows: *Argiope aurantia*, *Misumena aleatoria*, *Encoptolophus sordidus*, *Melanoplus bivittatus*, *M. differentialis*, *Orchelimum vulgare*, *Xiphidium strictum*, *Euschistus variolarius*, *Phymata fasciata*, *Chauliognathus pennsylvanicus*, *Epicauta marginata* and *E. pennsylvanica*, *Rhipiphorus dimidiatus* and *R. limbatus*, *Ammalo*, *Exoprosopa fasciata*, *Promachus vertebratus*, *Bombus pennsylvanicus*, and *Mysine sexcincta*.

On dry prairie at Mayview, Ill., September 26, I found the plant-lice *Aphis asclepiadis* Fitch on the leaves and stems of the dogbane (*Apocynum*) and the lice attended by the ant *Formica fusca* L. A beetle, *Languria mozardi* Latr., whose larva is a stem-borer, inhabits *Lactuca canadensis*. Its life history and habits have been discussed by Folsom ('09, pp. 178-184).

### 6. The *Solidago* Community

A common community in the late summer and early fall is centered about the goldenrod (*Solidago*). This plant was not abundant or in blossom at any of the stations studied in detail, but it grew in small widely scattered colonies or clumps. Observations were made in two

colonies, north of Charleston, both west of Station I, *a*, and I, *g*. The collections made (Nos. 20, 26, 42, 43) are as follows:

Ambush Bug	<i>Phymata fasciata</i>	20, 26
Stink-bug	<i>Euschistus variolarius</i>	26
Black Blister-beetle	<i>Epicauta pennsylvanica</i>	26
Noctuid moth	<i>Spragueia leo</i>	20, 26
Conopid fly	<i>Physocephala sagittaria</i>	26
Empidid fly	<i>Empis clausa</i>	43
Halictid bee	<i>Halictus fasciatus</i>	26
Myzinid wasp	<i>Myzine sexcincta</i>	20, 26
Ant	<i>Formica fusca subsericea</i>	20

It is important to know that these collections from *Solidago* were made just as the flowers were beginning to blossom. Collections a few weeks later would probably have given many more kinds. It should be noted, too, that all these plants were far out upon the prairie and far from woodlands—a factor which may influence to some extent the kinds of visitors. As a rule the lists which have been published state little or nothing at all as to the conditions in which the plants were growing. If this factor is neglected, the presence of some visitors remains puzzling. Thus on some goldenrods the locust beetle, *Cyllene robinia*, is abundant; but this is conditioned in part by the proximity of the yellow locust, which is absent on the Charleston prairie.

*Phymata* was found copulating upon the flower, and with an empidid fly, *Empis clausa* (No. 43), in its grasp. Two kinds of galls formed by insects were found on this plant: one formed by the fly *Cecidomyia solidaginis* (No. 43), which forms a rosette of leaves; and the other the spindle-like stem-gall, formed by a small caterpillar, *Gnorimoschema gallasolidaginis* (No. 7462 Hankinson). September 20 the moth *Scepsis fulvicollis* Hübn. was found in goldenrod flowers near Station I, *a*. Its larva feeds on grass. A large noctuid larva, *Cucullia asteroides* Guen., was found in a mass of flowers. As the day was cloudy and cool, *Scepsis* was resting or sleeping on the flower masses, as were also the black wasp *Chlorion atratum* Lep., and *Polistes*—both the light form *variatus* Cress., and the darker one, *pallipes* Lep. On October 23, 1893, I found the curculionid *Centrinophus helvinus* Casey (det. H. F. Wickham) on goldenrod at Bloomington, Ill.

Needham ('98, pp. 29-40) has given a good popular account of the insects associated with goldenrod, and Riley ('93, pp. 85-87) has published an extensive list and given a number of observations on their food habits.

Pierce ('04, pp. 173-188) has published a long list of bees found visiting *Solidago* in Nebraska. He also mentions the following beetles: *Chauliognathus pennsylvanicus*, *Nemognatha immaculata* and *N. sparsa*, *Zonitis bilineata*, *Epicauta pennsylvanica*, and *Myodites solidaginis* Pierce. *Myodites* is a rhipiphorid beetle which appears to lay its eggs upon *Solidago*. Here the larva develops, and from here, by attaching itself to different flower visitors, it is carried to their nests. The nesting sites are often populated by several kinds of insects, a social community, and thus the larva is thought to be carried in close proximity to the bee *Epinomia*, upon which it is parasitic. This bee does not visit *Solidago*, but frequents the sunflower (*Helianthus*), and thus is only infested at the nest (see also Canadian Entomologist, Vol. XXIV, 1902, p. 394). This is a good example of the complex relations existing among the animals of the prairie. Robertson ('94, p. 455) found *Myodites fasciatus* Say on *Solidago* at Carlinville, Ill., and he also lists (l. c. pp. 454-458) many species of insects which he found on different species of goldenrod. As *Epinomia* is not known from Illinois it is probable that some other bee is host for *Myodites*.

### 7. Dry Prairie Grass Association

The dry prairie grass association includes those animals which live on the driest of the black soil prairie among the tall prairie grasses *Andropogon* and *Sporobolus*. Upon the original prairie this was probably a relatively stable habitat.

About Charleston these grassy habitats occupied only very small areas north of the town, at Station I, *g* (in part), and Station III, *b* (in part).

Representative animals of this community are the following: *Argiope aurantia*, *Brachynemurus abdominalis*, *Chrysopa oculata*, *Syrbula admirabilis*, *Encoptolophus sordidus*, *Melanoplus differentialis*, *M. femur-rubrum*, *Scudderia texensis*, *Orchelimum vulgare*, *Conocephalus*, *Æcanthus nigricornis* and *Æ. 4-punctatus*, *Euschistus variolarius*, *Sinea diadema*, *Phymata fasciata*, *Chauliognathus pennsylvanicus*, *Tetraopes tetraophthalmus*, *Rhipiphorus dimidiatus*, *Exoprosopa fasciata*, *Promachus vertebratus*, *Bombus pennsylvanicus*, *auricomus*, *impatiens*, *fraternus*, and *separatus*, *Melissodes bimaculata*, and *Myzinc sexcincta*.

Probably a number of insects breed in the roots and stems of *Andropogon* and *Sporobolus*, but none were secured.

Although *Elymus* has contributed many insect pests to cultivated grains, it seems that *Andropogon* has not, if we except the chinch-bug (*Blissus leucopterus* Say). This insect was not related to *Andropo-*

gon as *Isosoma* is to *Elymus*, but this and other prairie grasses which grow in bunches or stools evidently formed the optimum hibernating quarters of these pests when they lived upon the original prairie (Fitch, '56, p. 283; Marlatt, '94a; Schwarz, '05) and upon the seashore. Osborn and Ball ('97a and '97b) have listed several grass-feeding *Jassida* from *Andropogon* and *Sporobolus*. Osborn and Sirrine ('94, p. 897) found a plant-louse on the roots of *Andropogon*, and Patch ('12, p. 191) lists *Schizoneura corni* Fabr. on *A. furcatus*.

#### 8. A Milkweed Community

Bordering the gravelly ballast along the rails north of Charleston at Station I (Pl. II, fig. 2) may be seen a large-leaved plant, the common milkweed (*Asclepias syriaca*). This plant flourishes along the track in many places, and wherever it was found there tended to appear a small but very well-defined animal community. To determine the composition of this social community, a few collections were made at various points within Station I. That this milkweed is the hub of this microcosm is clearly shown by the fact that no similar association was found grouped around any other plant in the area, not even about the other milkweeds, *A. sullivantii*, or *A. incarnata*. The collections are numbered as follows: Nos. 27-30, 33, 34, and 154.

The terminal young and tender leaves of the plant are often densely covered with the plant-louse *Aphis asclepiadis* Fitch (Nos. 28, 29), and these lice are attended by the workers of the ant *Formica fusca subsericea* Say (Nos. 30, 154). On another plant no plant-lice are recorded, but upon it were found their common enemy, the nine-spotted ladybird, *Coccinella 9-notata*; two species of ants (*Formica pallide-fulva schaufussi incerta*, and *Myrmica rubra scabrinodis sabuleti*); besides, running about on the leaves, the pretty, metallic, long-legged flies *Psilopus siphon* (No. 27). They run with a singular rapid glide, stop suddenly for a moment, and then continue their rapid pace. Certain flies of this family are said to be predaceous, but I have never seen *Psilopus* capture any small animal. On the same plant just mentioned a small bug, *Harmostes reflexulus*, was also taken; and in the flowers of this plant were hundreds of a small dark-colored empidid fly, *Empis clausa* (No. 27). Two other animals were found on this plant; *Zonitis bilineata* Say (No. 33), and a jumping spider (attid), which had in its jaws what appeared to be the remains of the beetle *Diabrotica 12-punctata* (No. 34). Contrary to my usual experience, these plants did not abound with milkweed beetles (*Tetraopes*) or with the common milkweed bugs (*Lygaeus kalmii* and *Oncopeltus fasciatus*), which are usually numerous. The proximity of the fragrant

blossom of *Asclepias incarnata* may explain this paucity at this time and place. The milkweed butterfly, *Anosia plexippus*, is of course a member of this community.

W. Hamilton Gibson ('00, pp. 227-237) has discussed, in a very interesting manner, the relations of this plant to its insect pollinators, and calls attention to the variety of insects which are entrapped and killed by its flowers. He also points out that the dogbane (*Apocynum*) has a similar habit.

Robertson, our leading American authority on the relations of flowers and insects, has published extensive lists of the flower visitors, not only of *A. syriaca* (*cornuti*) but of other Illinois milkweeds (Bot. Gaz., Vol. XI, pp. 262-269; Vol. XII, pp. 207-216, 244-250; and Trans. St. Louis Acad. Sci., Vol. V, No. 3, pp. 569-577).

### III. RELATION OF PRAIRIE ANIMALS TO THEIR ENVIRONMENT

The relation of prairie animals to the major features of their physical and biotic environment presents several facts of unusual interest. On account of the relatively heavy precipitation during June, the slight topographic relief of the region, and its imperfect drainage, unusually large areas of the original black soil prairie are wet or swampy. Certain animals are able to tide over this early, unfavorable wet-summer period because they are not fully roused from their winter inactivity; others, in their immature stages of development, require less food than later; still others survive by migration to the drier uplands. At the same time, other animals, preferring moist or wet habitats, flourish, and then decline in numbers as the season advances. Toward August, on account of the eastward migration of the continental peninsula of aridity and intense evaporation, those animals whose activity is retarded by the earlier wet season find the conditions progressively more favorable, and thrive and grow accordingly. This is the acme of the season for dry-prairie animals, and great numbers of slowly maturing composite plants now make the landscape yellow with their flowers. The *Orthoptera* are now mature, and when flushed, or, when not flushed, by their sounds, are noticeable. That these conditions cause these animals to thrive, is only too evident during exceptionally dry seasons, when the ordinary August drouth begins in July and extends into September.

In the conditions just indicated, the imperfect drainage, the wet season followed by the dry, we are touching closely upon the real causes of the prairie. Yet to me it seems fruitless to search for *the* cause of the Illinois prairie; the causes are probably multiple. In the midst of the Great Plains, the "short grass country" the causes of grass-land

may be relatively few, because the dominating conditions are so thoroughly established and extreme. But near the eastern margin of this dominance, upon the prairies—the “long grass country”—the number of limiting factors increases greatly, and even a relatively trivial local influence is able to overcome the slight momentum which this dominance possesses. In Illinois, then, the causes of the prairie biota, mentioning only the larger groups of influences, seem to be as follows: *a*, a sandy character of the soil, resulting in sand prairie; *b*, loam and good drainage, resulting in black soil prairie; *c*, very imperfect drainage, resulting in wet prairie. A shallow soil underlaid by rock might also produce prairie, but I have not seen any large area of this kind in Illinois.

We have, then, in the wetness and the dryness of the prairie two of the important controlling influences upon the prairie associations. On the prairie aquatic animals may thrive, particularly those which develop early and mature rapidly, and possess some power to resist or tide over the dry season, either as adults of non-aquatic habits by estivation, or in some resistant immature stage. We can see how aquatic animals, in this manner, are capable of enduring these extreme conditions and remain numerous upon the prairie. Where crawfish holes are abundant, many small aquatic animals are able to utilize them and thus escape drying. Crawfish holes should be examined during dry seasons with this idea in mind. On the other hand, the prairie is inhabited by many animals which can not endure much moisture, and live best in conditions of moderate or extreme dryness. These are the kinds which find their optimum during the driest part of the season, and in very dry years. When there is an abundance of moisture, some of these, for example the chinch-bug, are particularly susceptible to disease. The maximum development of this arid type as seen on the Illinois sand prairie has been studied by Hart ('07); more recently by one of my students, Vestal ('13b, '14); and about Chicago and northern Indiana by Shelford ('13a). An examination of the lists of sand invertebrates given by Hart (l. c., pp. 230-257) and Vestal ('13b, pp. 14-60), in comparison with those for the black soil prairie at Charleston, will show many differences, not only in kinds but also in their relative abundance. Some allowance must also be made for the fact that the animals of the black soil prairie are not as fully preserved as those of the sand areas.

### 1. *The Black Soil Prairie Community*

The soil population of both sand and black soil prairie has never received thorough study, although observations from the sand areas

have been recorded by Hart, and his observations amplified by Vestal. In the black soil area many observations have been made by Forbes ('94) on the life histories and habits of certain species of economic importance, particularly those injuring corn and grasses in the soil. In his studies are included many insects, such as elaterid larvæ, aphids, ants, and white-grubs. The physical conditions of life here yet await careful investigation.

A very large number of the animals living on and above the surface of the soil spend a part of their lives within it. Thus among the *Orthoptera*, the acridiids lay their eggs in the soil—this is probably true of most of the beetles; and even the parasitic animals often spend most of their life in the soil with their hosts. This is true also of the wasps and a great number of hibernating animals, and of a large number of grass-inhabiting, and other, *Lepidoptera*. Such characteristic flies as the asilids and bombyliids spend much of their life in the soil, as do many other flies, at least during their pupal period. It is very probable that upon the original prairie a large number of noctuid and crambid moths and tipulid and elaterid larvæ inhabited the prairie sod, and with them, of course, were associated their enemies—predaceous beetles, and parasitic flies and *Hymenoptera*. For an account of grass-feeding crambids Felt ('94) and Fernald ('96) should be consulted.

The stage of development, structure, and behavior of soil-inhabiting animals are often quite different from those living above the surface. Some kinds, as pupæ or adults, have spines or setæ, which enable them to wriggle in the soil, as, for example, do the pupal asilids or the adults of *Mysine* and *Tiphia*. Locomotion in such a dense medium is attended by many difficulties, and it is not surprising that animals living here have peculiarities of structure and behavior, and that a large number are relatively sedentary.

In the discussion of the ventilation of habitats, attention was called to the fact that soil-inhabiting animals probably possessed considerable resistance to an abundance of  $\text{CO}_2$  and to a lack of oxygen. We are all familiar with the abundance of earthworms, *Lumbricus* and its allies, crawling upon the surface and entrapped upon our walks and pavements after prolonged rains. In these cases the saturation of the soil has driven out the air. Apparently the earthworms are relatively less resistant to the lack of oxygen than many other soil animals, for they come to the surface in a much more marked degree. Since earthworms live in burrows, have an easy route to the surface, and are possessed of good powers of locomotion, they contrast strikingly with many other sedentary soil animals. Bunge ('88, p. 566) found that earthworms were able to survive one day in an oxygen-free liquid.

Cameron ('13, p. 190) speaks of the resistance to drowning of elaterid larvæ as follows: "I myself have kept specimens of the larvæ of *Agriotes lineatus*, our commonest wireworm, in water for as long as six days without their being drowned, but those which were thus treated for a period of seven or eight days did not generally recover from the deleterious effects of immersion. Leather-jackets and surface caterpillars submitted to the same treatment succumbed in a much shorter time, one to two days for the caterpillars, depending on their state of development—much shorter time than this for very young forms—and from one to three days in the case of leather-jackets, the latter being in all cases fully mature."

Dr. R. D. Glasgow informs me that it is probable that the soil-inhabiting white-grubs, *Lachnosterna*, may be able to close their spiracles when the soil is saturated and thus resist drowning, as in the case of the European *Melolontha* (Cf. Henneguy, '04, p. 105; Packard, '98, p. 442). With this closure of the spiracles there is probably correlated a power to resist a lack of oxygen and an excess of CO<sub>2</sub>. In any case, this is a subject worthy of experimental investigation. Cameron ('13, pp. 197–199) has called attention to the marked resistance to a lack of oxygen found in muscid (dipterous) larvæ; they endure submersion for long periods and recover rapidly. He says (l. c., p. 198): "A faculty of resistance and power of adaptability to adverse circumstances is of peculiar advantage to the insect inhabitants of the soil, which, owing to the varying climates and atmospheric conditions, are often subjected to the most severe extremes of heat and cold, wet and drouth. The more sluggish maggots of *Diptera* have a greater plasticity than the active larvæ of predaceous *Coleoptera*. On considering these two orders by themselves, amongst *Diptera* the larvæ of *Muscidæ* have a greater power of resistance generally than the larvæ of Nematocerous and Brachypterous families, whilst among *Coleoptera* the grubs of *Rhynchophora* are not so easily affected as those of *Carabidæ* and *Staphylinidæ* and other active families. This is just what we might expect, seeing that nature, which has deprived Dipterous maggots and Weevil grubs of legs that they might readily escape danger, has compensated them to some extent by endowing them with a greater power of resistance to adverse conditions."

Upon the black soil prairie the snout-beetles *Sphenophorus* abounded in the roots of swamp plants, where they were particularly liable to submersion with varying rainfall. It is, however, possible that this resistance may be entirely independent of the footless condition.

The optimum soil conditions for insects have thus been summarized by Cameron ('13, p. 198) as follows: "Soils that are of a light and open texture are, as we have already seen, the ones most frequented by soil insects, all other conditions, such as those of food, being



equal. . . . A porous subsoil is also conducive to the well-being of insect life, in that the rain can quickly penetrate, and, as it passes through, air is drawn into the more superficial layers in order to take its place. Hence a reason why soil insects are only rarely found in the deeper subsoil; for the increased amount of moisture, together with the decrease in aeration, is decidedly detrimental to their activities."

The density, moisture, solutions, and ventilation of the soil, its fresh and decaying vegetation, make conditions possible both for a population consisting of vegetable feeders and, preying largely upon them, a series of predaceous and parasitic associates.

It is desirable that the prairie ground fauna should be made the object of special investigation, particularly from the standpoint of soil solutions, moisture content, ventilation, humus content, and the influence of the living vegetation. For this reason several papers are here mentioned which will be valuable in such a study. Diem ('03) has made an elaborate quantitative study of the ground fauna of the Alps. He studied a variety of conditions, including pasture, meadows, and coniferous forest soils. He describes his methods of study and gives many references to the literature. Other papers which should be studied in this connection are by Dendy ('95), Cameron ('13), Motter ('08), and particularly those by Holdhaus ('10, '11a, '11b). Banta's ('07) paper on cave animals will also prove valuable because of the close relation of cave animals to those living in the smaller openings in ordinary soil.

Near the soil surface, among the stools of grass and on the ground, vegetable litter is most abundant, and humidity is high, evaporation slow, and the temperature lower and also more equable than higher up. It is in this layer that a vast number of animals hibernate, and in it also many, active at night, are hidden during the day. In this layer live the animals which feed largely on organic debris. Bumblebees often build their nests at this level, or in depressions in the ground. Some of our species of *Bombus* may nest deep in the soil and ventilate the nest by vibrating their wings, as do certain European species (Sladen, '12, pp. 47-49). This is a very interesting response to a subterranean life and merits investigation.

## 2. *The Prairie Vegetation Community*

Above the surface of the soil, among the vegetation, quite another environment exists. This varies greatly not only with the character of the substratum but also with the character and density of the prairie vegetation. The fertility of the black soil, and the rapidity with which it is occupied by vegetation, makes areas of bare soil of short duration.

The prevailing condition is therefore one of dense vegetation. I know of no detailed study of the amount of life which develops in this layer of prairie vegetation. For this reason certain observations made in meadows and pastures are of interest. McAttee ('07) examined a grassy meadow and the surface of the soil for bird food, and a corresponding area of four square feet of a forest floor. He concluded that the population in a meadow is much more dense than that in a forest. This conclusion, however, is not valid, as Banks ('07) has pointed out, because the two areas are not strictly comparable ecologically. In the meadow life is concentrated near the surface; in the forest it is largely in the trees and not on the forest floor. Clearly the ecologically comparable areas of the open and the forest are their subsurface soils, the surface soil and the layer of vegetation, and the space above the vegetational layer. As previously pointed out in this paper, the forest should be looked upon as a very thick layer of vegetation. Another estimate of the population of pasture vegetation has been made by Osborn ('90, pp. 20-23). This is a rough estimate, but it shows that there were about one million *Jassidæ* present per acre. He further estimated that the amount of vegetation per acre eaten by insects amounted to about one half of that eaten by a cow. This example aids one in understanding how it was possible for the insects of the original prairie to influence the amount of food available for the buffalo, particularly during dry seasons when there was limited grass growth, and when grasshoppers throve in large numbers. In this layer of vegetation, in addition to the general feeders, eating almost any kind of vegetation, there is a rather extensive population which has a restricted diet, feeding upon a single food plant, or on only a few species. There are a number of cases where, though an insect has several food plants, all, or nearly all, belong to the *same plant association*, and often have much the same geographic range. A good example of this among prairie animals is the case of the plant-louse *Macrosiphum rudbeckiæ* Fitch, which lives on a variety of prairie plants; as *Vernonia*, *Solidago*, *Bidens*, *Ambrosia*, *Cirsium*, *Silphium*, and *Lactuca* (Cf. Hunter, '01, p. 116). The beetle *Chrysochus* and the bugs *Lygæus kalmii* and *Onopeltus fasciatus* are often found on *Asclepias* and *Apocynum*; *Aphis asclepiadis* lives on *Asclepias* and on *Euphorbia*. Though pollen- and nectar-feeding insects often forage over many kinds of plants, some of them have clearly defined preferences, almost amounting to limitation to a single food plant. Thus the bee *Melissodes obliqua* seeks pollen largely from *Lepachys pinnata*, and the Pennsylvania soldier-beetle, though very abundant on flowers, is not numerous in corn fields even when pollen is excessively abundant.

Many kinds of insects are recorded as "sleeping" among rank growths of vegetation and on flowers. In such places on cloudy or cool days, late in the evening or in the early morning, insects are found at rest and in a sluggish or torpid condition. The cause of this behavior is not known. They may be "sleeping," or they may only have been trapped there by a lowering of the temperature, as at sundown, when their activity slowed down and they came to a rest on the last flower visited. In this connection it should be recalled that it is near the general level of the surface of the vegetation that the most extreme temperatures are found,—the most warmth in the sun and the greatest coolness at night. This is the main zone also of flowers visited by insects.

In this same layer of vegetation is found the usual grouping of vegetable feeders, scavengers, predators, and parasites. As the nectar-drinkers visit the flowers, certain predators spring upon them, just as the large members of the cat family seize their prey at the margins of streams and lakes when the herbivores come to drink. Other predaceous insects such as the wasps, robber-flies and dragon-flies, live active lives and seek their prey on the wing.

Above the general surface of the prairie vegetation no invertebrates live permanently, unless the parasites, external and internal, of the swifts and swallows can be so considered. Winged forms frequent this region during flights in which they find food and mates. Spiders, by their cottony "balloons," utilize the winds and are thus transported. All of these are transients, and not permanent inhabitants of the open area.

### 3. *Interrelations within the Prairie Association*

In concluding this discussion of the conditions of life on the prairie, we may profitably consider some parts of the network of interrelations which bind together the animals and the environment. As the kinds of animals and the number of factors involved are so numerous, only a few selected animals will be considered. In this choice I have not limited myself solely to the kinds taken at Charleston, but have utilized common and well known prairie animals. As representatives of the soil-inhabiting forms the white-grubs and May-beetles (*Lachnosteria*) and the corn-field ant (*Lasius niger americanus*) have been chosen; as representatives of those which live above the surface and mainly among the vegetation the differential grasshopper and *Bombus* have been chosen; and as representatives of the active predators and parasites, *Promachus*, *Chlorion*, *Tiphia*, and the parasitic fungi *Empusa* and *Cordyceps*. Statement of the available supply of water

and oxygen, the temperature, etc., is omitted for simplicity, not because these matters are unimportant. Some of the main features of these interrelations are summarized in the following diagram, Figure 16. This shows that the white-grubs living in the soil and devouring the roots of plants are preyed upon in turn by an aggressive fungus (*Cordyceps*) and by a wasp (*Tiphia*)—an external parasite; and that *Tiphia* is parasitized in turn by *Exoprosopa* and by the larva of the small beetle *Rhipiphorus*. The adult May-beetles feed upon the leaves of trees, and although many show a decided preference for trees living in the open, as the cottonwood and willows, others feed largely upon forest trees. Thus the prairie animals exert a direct influence upon the forest community as well as upon the prairie. The differential grasshopper feeds upon the vegetation, and jumps or flies into the webs of *Argiope*, where it may be killed even if it should not be eaten. The eggs which this grasshopper lays in the soil are devoured by the larvæ of *Chauliognathus* and *Epicauta*, and the adults are killed by the fungus *Empusa*, or mutilated by the mite *Trombidium*—an external parasite (Pl. XXI, figs. 1 and 2). The rusty digger-wasp, *Chlorion ichneumoneum*, feeds upon the nectar and pollen of flowers, and provisions its burrows in the ground for its larva with grasshoppers (*Orchelimum*); this larva, again, is probably devoured by the small parasitic fly *Mctopia*. The larvæ of the soldier-beetle *Chauliognathus* are predaceous, and eat other larvæ; thus they influence many species; the adults frequent flowers as pollen-feeders. Although *Epicauta* devours eggs of grasshoppers during its larval stage it feeds upon vegetation in the adult stage. The larvæ of *Bombus* live upon nectar and pollen supplied them by the female or worker, and the adult is also a nectar- and pollen-feeder, *Bombus* thus being solely sustained by vegetation. They are preyed upon by a host of predaceous enemies, as *Phymata* and *Promachus*; and parasites, including the flies *Frontina*, *Brachycoma*, probably *Conops*, and the false bumblebee (*Psithyrus*); their nests, moreover, form a habitation for a great variety of insects, mites, and other animals too numerous to be put in the diagram. These bees, then, on account of their large size, their large colonies, and the large amount of concentrated food which they amass at the nest, combine to make themselves attractive to a great number of animals, and become the hub of a busy microcosm, an extensive community of mutually interrelated kinds.

The root-louse of grass, *Schizoneura panicola* Thos. (Forbes, '94, pp. 85-93), through the attention of several kinds of ants, *Lasius niger americanus* Emery, *L. flavus* De G., *L. interjectus* Mayr, and *Formica schaufussi* Mayr, is cared for from the egg to the adult stage; these ants keep the plant-lice on fresh roots from which they suck their food.

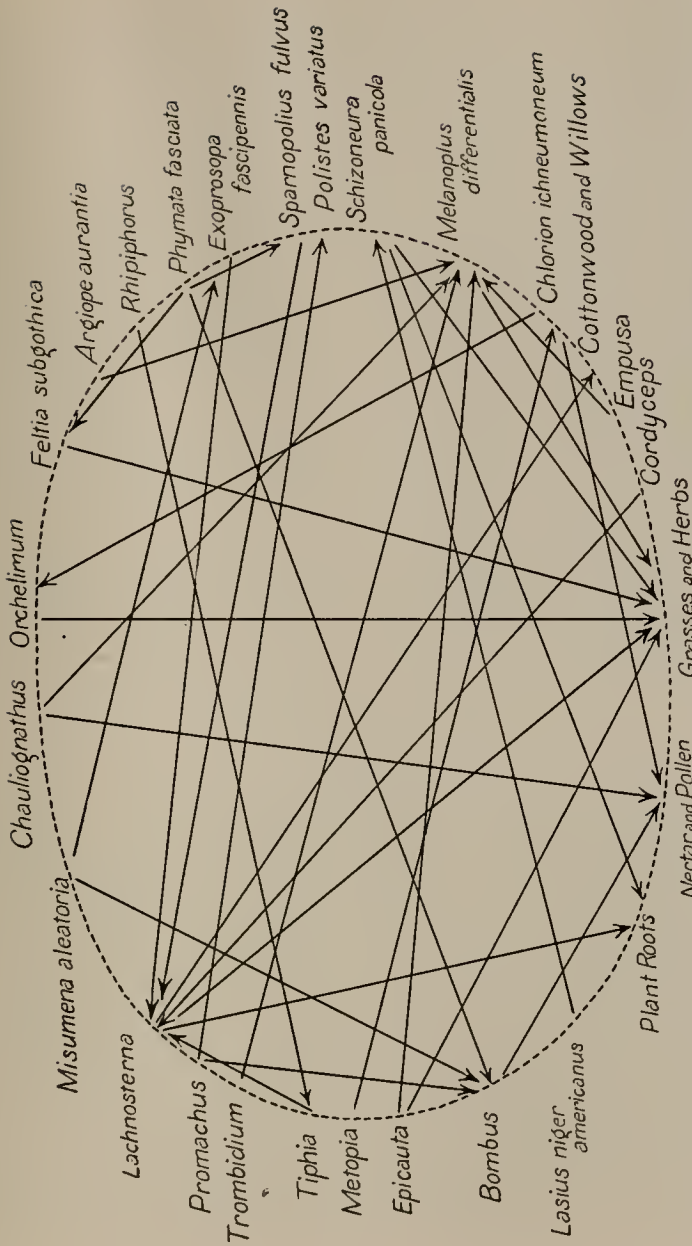


FIG. 16. Diagram showing the complex network of interrelations among prairie invertebrates, as shown by their food relations. The arrows point toward the food of the animal.

In return the ants secure honeydew and wax from the lice. A closely related aphid, *Schizoneura corni* Fabr. lives from "September until June on the dogwood (*Cornus*), and from June until September on the roots of certain grasses" (Forbes, l. c., p. 89). This insect, upon the original prairie, was probably an inhabitant of the forest margin, or lived near moist places where dogwoods abounded. (This point should be determined at some favorable locality.) In such a complex, interwoven community as that of the prairie it is immaterial where one takes up the thread of relations, for if followed carefully without interruption it will lead one about, from one animal to another successively, until the intimate life of every animal and plant in the community has been reached, and influenced to some extent. Thus the animals living in the soil, at the surface, and among the vegetation are bound together, not only by their changes of habitats, as when a subterranean maggot matures and becomes a flower fly, but also by their movements, as when an active wasp or grasshopper burrows in the soil, so that there is a complex interpenetration of relations which extends to all depths, to all horizontal relations, and binds together the entire social community.

In this discussion only the invertebrates have been considered, but this phase of the subject should not be concluded without emphasizing the fact that all the organisms of a region form a single biotic community, each member of which is related to all the others and to the physical environment.

#### IV. THE FOREST ASSOCIATIONS

##### 1. Introduction

In a study of forest animals their relation to the physical and vegetational environment must be kept constantly in mind, in order that their progressive changes may be clearly understood. If the woodland animals and associations are considered broadly, it is possible to study the progressive transformation of the habitats and associations by agencies which erode the land and thus develop the drainage, and to combine with this a study of the successive changes in the vegetation (including vegetable products). In the Charleston region this transformation includes the progressive invasion of the prairie by the forest. From this standpoint it is also possible to arrange the forest associations in a genetic series.

There is little doubt that this entire region was once treeless or prairie, that in time the forest invaded it, mainly or almost exclusively along the streams. Even at the time of settlement the forests had not spread far from the larger streams; but by normal forest extension and

drainage development the prairie was encroached upon and restricted. The trees farthest from the streams, speaking in general terms, may be looked upon as the pioneer guard of the extending forest. Such trees are oaks and hickories of various kinds, which are hardy and able to live on wet, acid, or very dry soils, as, for example, the shingle oak (*Quercus imbricaria*) and post oak (*Q. michauxii*=*minor*). In the Charleston area all such forest remnants are so closely pastured that they were not studied; therefore our series is incomplete. The upland forest in the Bates woods (Station IV, *a*) may be considered somewhat representative of a *second* stage in forest development. This, however, is not a primeval condition, but one which has been modified by man; for example, the mature trees have been removed. It is, however, clearly an oak-hickory forest.

A *third* stage in forest development is found upon the bottom, nearer the river, the most favorable habitat for tree growth in the region, where the red oak (*Quercus rubra*) and hard maple (*Acer saccharum*) form a dense, humid shady forest—a climax mesophytic forest. With these changes in the vegetation there have been corresponding changes in the physical environment. The relatively open oak-hickory forests are dry, both in the air and in the ground; they are well lighted; they are warmer and cooler relatively; and they have soil which contains less litter and humus. Fallen trees and stumps decay more slowly on account of the dry environment. As the open woods become closed by the development of a dense forest crown, these conditions are changed in important ways: the woods become progressively darker, more stable in temperature, more humid in air and soil; the litter and humus increase; and all wood decays more rapidly both on account of the moisture, fungi, etc., and the activity of animals. The earlier stages in forest development result in the combination of glade and grove—*islands of open, and islands of trees*—but with the extension of the forest by its encroachment upon the glades the forest crown becomes complete and continuous, and a climax forest has become established. These relations show what kind of factors must be considered in striving to group forest habitats in a developmental series.

The forest associations are here considered in the same sequence as that given in the description of the forest stations, and for this reason the discussion will be brief, being mainly intended to give a uniform treatment to all the animal communities studied about Charleston. A more general discussion of the ecological relations of our common forest invertebrates follows.

## 2. Dry Upland (*Quercus* and *Carya*) Forest Association

The upland oak-hickory forest community is upon high well-drained land. It is bordered by a ravine and a valley, so that the precipitation drains away rapidly. The soil, in contrast with that of the black soil prairie, is a gray loam, containing little organic debris. Through clearing, the woods have become relatively open, so that the sunny spots are rather numerous. The characteristic vegetation consists of oaks and hickories, such as white oak (*Quercus alba*), black oak (*Q. velutina*), shag-bark hickory (*Carya ovata*), pignut (*C. glabra*); and of rose, raspberry, sassafras (*Sassafras variifolium*), sumac (*Rhus glabra*), young trees, horsemint (*Monarda*) everlasting (*Antennaria*) and tick-trefoil (*Desmodium*). The conditions are those of Station IV, *a*, the upland Bates woods, and the open ravine slopes, IV, *b*.

Representative animals of this community, including numerous ground-inhabiting *Orthoptera*—many of the acridiids being short-winged forms—are *Dichromorpha viridis*, *Chloactis conspersa*, *Spharagemon bolli*, *Melanoplus atlantis*, *amplectens*, *obovatifemnis*, and *scudderi*, *Scudderia furcata*, *Microcentrum laurifolium*, *Orchelimum cuticulare*, *Niphidium nemorale*, *Nemobius fasciatus* and *maculatus*, *Apithus agitator*, *Cicindela unipunctata*, *Calosoma scrutator*, *Chrysochus auratus* (on dogbane in an open area), *Myrmecocida*, and *Sphacrophthalma*. Several species of butterflies were seen on the wing in the sunny openings. A number of cecidomyid and cynipid galls on oaks and hickories are more characteristic of the upland forest than of the lowland forest on account of paucity or absence of white and black oaks and hickories upon the bottoms. Other upland plants determine in a similar manner the presence of other animals.

As a forest develops, upon what has previously been a treeless tract, and as wood therefore becomes an available animal habitat, a very complex factor is added to the environment. Not only is a log food for certain animals, but also, if it lies upon the ground, it affords conditions favorable for still others. It tends to conserve moisture under it, and as it decays and disintegrates, fungi grow upon and in it; hence other food is produced for animals which are not eaters of wood. As decay progresses, furthermore, the log itself readily absorbs and retains moisture, thus giving to some animals within it a habitat with atmospheric conditions of relatively high humidity, in which land mollusks, diplopods, etc., thrive. Such conditions furnish an important factor in the extensive range of certain animals throughout several kinds of forest; for though the kinds of trees may change, nevertheless



when once the log habitat is developed certain animals are able to persist. Nor is the log the only factor of this character in the forest; the moist soil, abounding in vegetable debris, has a similar influence; and besides, when once a dense canopy is developed the retarded evaporation and the shade, with the accompanying reduction in heat rays, have a marked influence. The presence of logs and vegetable debris upon the forest floor determines to a very important degree the presence of the land mollusks, diplopods, *Termes*, *Galerita janus*, and *Meracantha contracta*; it determines, upon the slopes (Station IV, b), the presence of *Ischnoptera*, *Melanotus*, *Passalus cornutus*, and *Scolecocampa liburna*.; and it probably determines, too, many of the ants on the upland and on the forest slopes. Among the forest shrubby growth and tree trunks *Epeira verrucosa* and *Acrosoma rugosa* (and probably *spinca*) spread their webs and appear to thrive only in deep shady woods. A large number of butterflies and moths feed upon the foliage of forest trees, being thus distinctly arboreal, as are also *Cicada* (nymph, subterranean), *Diapheromera*, *Calosoma scrutator* (predaceous), *Tremex columba* (and its parasite *Thalessa lunator*), and *Cyrtophyllus perspicillatus*. *Geotrupes splendidus* is a ground scavenger. The presence of *Ammophila abbreviata* is due to the presence of numerous caterpillars on the foliage.

### 3. Artificial Glade Community in Lowland Forest

In the dense humid lowland forest of the Bates woods (Station IV, c) a small open area has been formed by cutting; an artificial glade, as contrasted with a natural open forest. This may be considered an experimental glade. Although it is on the river bottom and completely surrounded by a dense forest community, it is clearly not related to that community, but rather to the open upland forest, and for this reason is here interposed between the discussion of the upland and lowland associations.

The glade was about 25 feet in diameter; only on the north side, where the sun had the best access, had brush (sassafras) made much progress in closing the borders of this open area. It was therefore in direct communication with the dense surrounding lowland forest. Such a small glade permitted direct sunlight on the ground only during the middle hours of the day, and it was during this time that animal life was most active. On account of the dense shade of the surrounding forest there was little undergrowth, but in parts of the glade there was a dense growth which covered the ground. It was composed of grasses, large masses or colonies of *Eupatorium caelestinum* in flower, *Actinomeris alternifolia*, with wood nettle (*Laportea cana-*

*densis*), and clearweed (*Pilea pumila*) surviving as relics of the lowland forest vegetation.

Representative animals of this community are the following: *Misumena aleatoria*, *Lycosa scutulata*, *Epeira domiciliorum*, *Aulacizes irrorata*, *Jalysus spinosus*, *Dichromorpha viridis*, *Melanoplus amplectens*, *gracilis*, and *scudderi*, *Amblycorypha rotundifolia*, *Conocephalus nebrascensis*, *Orchelimum cuticulare* and *glaberrimum*, *Xiphidium nemorale*, *Nemobius fasciatus*, *Acanthocercus galeator*, *Autographa precatationis*, *Epargyreus tityrus* (larva on sassafras), *Deromyia discolor*, *Milesia ornata*, and, apparently as wanderers from the forest, *Calopteron reticulatum*, *Thalessa lunator*, and *Pelecinus polyturator*.

#### 4. Humid Lowland (Hard Maple and Red Oak) Forest Association

This lowland forest community is upon a well-drained but moist slope of the valley of the Embarras River. The soil is damp, and contains a large amount of vegetable debris. The forest canopy is complete, and the forest is relatively dark. Representative trees are the hard maple (*Acer saccharum*), red oak (*Quercus rubra*), and the elm (*Ulmus americana*); the herbaceous plants are nettle (*Laportea canadensis*) and the clearweed (*Pilea pumila*).

Representative animals are the various forest mollusks, *Epeira trivittata*, *Acrosoma spinca* and *rugosa*, *Acarus serotina*, *Bittacus stigmaterus* (and probably *strigosus* and *apicalis*), *Asophes memnonius*, *Calopteron terminale*, probably *Thalessa lunator*, *Pelecinus polyturator*, and *Tapinoma sessile* and other ants. *Boletotherus bifurcus* is dependent upon the shelf-fungus *Polyporus*, which grows most abundantly on decaying stumps and logs in moist woods. The species of *Bittacus* are as representative of shady, moist woods as are the nettle *Laportea* and the clearweed (*Pilea*). Such an insect as *Bittacus* might live in the park-like groves of an open forest, but its optimum habitat is in the dense climax forest. Perhaps the most striking contrast between the open and closed shady forest is due to the absence of numerous *Orthoptera* which are generally abundant in open grassy places. That these forms are able to thrive on the bottoms when the proper conditions are present is seen by their abundance in the glade in the lowland forest. In the uplands also, *Papilio* and *Polygonia* frequent the open spaces, but in the shady lowland forest the slow, low-flying *Enodia* and *Cissia* are the characteristic butterflies seen on wing.

[5. *Animal Association of a Temporary Stream*]

The prairie animal communities were arranged in an order to aid in looking upon the prairie habitats as so many different degrees or stages in the progress of drainage development, this being a dominant physical environmental factor upon the prairie. Similarly, the forest communities are easily arranged in a developmental sequence dependent upon the combined influence of the progress of erosion and drainage and the advance of forest upon the prairie. Thus the prairie and forest are given an orderly sequence, and the only remaining important habitat, in the region examined, is that of the stream series.

Very little time was devoted to the study of the stream animals, and mention of it is made here mainly because of this opportunity to show the harmony and continuity of treatment which it is possible to give to all the habitats and communities of a limited forested region.

This small temporary stream formed the southern boundary of the area which was studied in the Bates woods. It formed Station IV, *e*, and is an early stage in stream development. To understand just what this means it is necessary to consider the processes which have been in operation and which have reached the present stage of stream development. This stream flows in a steep-sided ravine cut in the unconsolidated glacial deposits which form the sides of the Embarras valley, a ravine between 75 and 100 feet deep when it enters the valley, which narrows rapidly, turns to the northwest, and soon ascends to the surface of the upland oak-hickory forest. The upper parts and head end of the ravine are dry, except during rains and soon after; but the lower part may retain water in the basins for a number of days after rains.

The same conditions which we now find at the head of this ravine once existed at the edge of the valley. That is, at one time there was no ravine in this region. As the rainfall from the uplands flowed over the edge of the valley it started a small gully; this, once formed, became the trail for waters of other rains, each shower tending to cut the ravine deeper and wider and to advance it into the upland. This process has continued until now the head of the ravine has cut back about one half of a mile. The unconsolidated debris is not composed of homogeneous materials, and has therefore been washed away more rapidly at some places than at others. In this manner pools have formed where less resistant materials were, and between these pools, over more resistant gravel or stone, miniature cascades or rapids have been formed, the tendency thus being towards an alternation of pools and cascades. In these pools Mr. T. L. Hankinson took a number of vertebrates, and upon the surface of the pools were many water-striders, *Gerris remigis*. From the burrows along the margin of the

stream Mr. Hankinson secured *Cambarus diogenes*. Thus by the growth of this ravine a new community is developing at this place—that of a temporary stream.

In time such a stream will cut down to ground-water level, the pools will become permanent, and a constant current will be maintained between the pools, and a permanent stream will become established. The manner in which this ravine and stream grow, at the expense of the upland forest, is an indication of how the upland forest may be changed and by degrees become converted into a lowland forest and even into an aquatic habitat.

#### V. RELATION OF THE DECIDUOUS FOREST INVERTEBRATES TO THEIR ENVIRONMENT

We have seen that the forest should be looked upon as a thick layer of vegetation in its effect upon the physical conditions which influence animal life. This thick layer is of relatively slow growth, and in its early stage it is composed of shrubs and young trees. But “as the vertical extent of the forest increases and the forest crown migrates upward, the intervening trunk, bark and branch habitat . . . enlarges and the leaf-eating inhabitants of the forest crown rise upward. This crown fauna retains or rather continues some of the characteristics found at the marginal zone, with which it retains direct continuity” (Adams, '09, p. 162). In addition to this vertical upward migration of the forest crown, the forest also tends to spread laterally, by arms or peninsulas of forest, which expand upon the open, or by the excentric growth of groves, which in time fuse and form a continuous forest. The original forest margin and adjacent prairie was characterized by “groves”, as they were commonly called by the early settlers, and also by more or less open woods or “oak openings,” which are the homologs of the open oak forests yet found on the Illinois sand areas. This interdigitation of forest and prairie produced peninsulas of forest extending into the prairie, peninsulas of prairie extending into the forest, islands of prairie surrounded by forest, and islands of forest surrounded by prairie. Where the forest was advancing, the open places or glades are to be considered as prairie relics; and when the prairie was for any reason encroaching on the forest the forest is to be considered the relic. The glade and the grove are thus comparable communities, and are to be considered as relics or pioneers according to the direction of advance of the local association. The development of adequate drainage and all that is associated with this process, the character of the soil, the extension or retreat of the forest, the changes in composition of the forest, and the kinds of

animals composing the communities are the dominating influences in the woodland environments. In the Charleston area the soils are loam, and therefore sand need not be considered. The forests are of two main types, the oak-hickory of the uplands and the red oak-maple of the lowland. At present the forests are declining; in fact, the lowland Bates forest has been converted into a corn field since these studies were made.

The kinds of animals present in the woods are strikingly different from those of the prairie, as is seen almost at a glance, and as is quite clear by a comparison of the annotated lists of the prairie and forest animals. Prolonged study will probably serve to enhance this difference. A small number are found both in the forest and upon the prairie, but this is the marked exception. Furthermore, the open oak-hickory woods, and the glade-like clearing which furnishes an open habitat within the woods, contained a vast majority of the animals found common to the prairie and the forest. These animals are to be looked upon as pioneers (or relics) of the prairie, and are not to be confused with the dense forest inhabitants. On a previous page attention was called to the vast importance of the marked discontinuity which exists between the kinds of animals living in the open and in the forest. This distinction is so marked as to merit comparison with the contrast existing between land and fresh-water animals. Possibly *on land* it ranks second only to this in its fundamental character. When the same kind of animal lives both in the open and in the forest, it often behaves differently in the two situations. It is significant that it required more than a generation for the southern woodland human pioneers of Illinois to change their behavior sufficiently for life on the prairie. Undoubtedly there are many examples of just such changes in behavior.

### 1. *Forest Soil Community*

The animals of our woodland soils have not been specially investigated. Many observations on the life histories of soil invertebrates have been recorded, but not as much is known of them as of prairie soil animals because of the smaller numbers which attack cultivated crops. Undoubtedly the native underground inhabitants of raspberries, currants, blackberries, and other wild shrubs have continued to thrive on the cultivated kinds (see Webster '93 for a paper on raspberry and blackberry insects), and the same is true of the crab-apples and the haws. Few subterranean animals, however, inhabiting these shrubs and trees of the forest have been studied in detail, with the notable exception of the periodical cicada. It is very probable that a number of animals which lived in the prairie soil continue to do so in

the forest glades; and many ground-inhabiting *Orthoptera* in the forest oviposit in the soil as do their congeners on the prairie. On Isle Royale, Michigan, I found that the carabid beetles which lived in the openings were likely to extend into the coniferous forest in the humus layer, which corresponds to this habitat in the open, and this is probably true to some degree in Illinois forests.

In the denser forest, in marked contrast with the prairie, there is generally a large amount of litter on the forest floor. The prairie soils are dark, but the surface contains a relatively smaller amount of organic materials comparable to forest litter. In the forest, however, though the sub-surface soil is relatively light in color, the surface contains much fresh and partially decayed organic debris.

McAtee ('07) has made a careful count of all the invertebrates found upon an area of four square feet of the forest floor, at or near the surface. This is the only quantitative study made of our forest soil animals known to me. His observations were made during the hibernating season.

Representative plant-feeding ground animals are the two cicadas *linnei* and *septendecim*, which suck sap from the roots of trees. Their underground enemies seem to be largely mites. The arboreal habit of the adults subjects them to many enemies. The periodical cicada, as the result of subterranean life, in the moist soil, displays little resistance to drying, and when exposed to the air soon shrivels, as shown by Marlatt ('07, p. 123). When conditions in the soil are unfavorable (l. c., p. 96) as the period of emergence approaches, some individuals respond by building a mud tube, similar to the crawfish chimneys, which are closed with a plug of mud. That saturated ground seems to be an unfavorable condition at this stage suggests that resistance to the lack of oxygen decreases as the insect matures. Most of the nymphs of this species live within less than two feet of the surface, though some rather inconclusive observations indicate that the nymphs have a wonderful resistance to submergence, as is shown by the following quotation from Marlatt ('07, p. 125): "A curious feature in connection with the underground life of this insect is the apparent ability to survive without injury in soil which may have been flooded for a considerable period. Doctor Smith records a case of this kind where a gentleman in Louisiana in January, 1818, built a milldam, thus overflowing some land. In March of the following year the water was drawn off and 'in removing a hard bed of pipe clay that had been covered with water all of this time some 6 feet deep the locusts were found in a fine healthy state, ready to make their appearance above ground, that being the regular year of their appearance.' Another case almost exactly similar is reported by Mr.

Barlow. In this instance the building of a dam resulted in the submerging of the ground about an oak tree during several months of every summer, ultimately resulting in the death of the tree. This went on for several years, until the dam was washed away in a freshet, when digging beneath the tree led to the discovery of the cicada larvæ in apparently healthy condition from 12 to 18 inches below the natural surface of the ground. In both of these instances the ground may have been nearly impervious, so that the water did not reach the insects nor entirely kill all of the root growth in the submerged soil."

The roots of plants, and particularly those of trees, penetrate rather deeply into the soil, but finally die, leaving a large amount of organic substance in the soil. As the large roots decay, animals are able through the tunnels made to penetrate rather deeply and to find organic food, in the shape of wood and fungi. Motter ('98, p. 225) performed an interesting experiment which shows that wood buried three feet below the surface and dug up after two or three months contained spiders, mites, *Thysanura*, psocids, a beetle, and flies. Although this wood was buried in a cemetery, it is not unlikely that woodland soils commonly have such a fauna. Davenport ('03, pp. 22-23) has tabulated the habitats of many *Collembola* and shows that many species live in damp soil, in sand, under bark, under stones, in caves, etc.—conditions corresponding to the soil habitat. These insects are very sensitive to moisture, and some are able to resist submergence in sea water from twelve to sixteen hours per day. Davenport says (page 17): "During all but about six to eight hours of the day these air-breathers are below the surface of the sand, during which time they must take in relatively little oxygen." During certain seasons, when the soil is saturated, such resistance must be of great value to its possessor. I know of no extensive observations or experiments on the resistance of these soil animals to carbonic acid, to the lack of oxygen, or to various combinations of these conditions.

That the soil conditions in glades and forests are different has already been pointed out. We have below a good example of the response of a forest animal to an artificial glade or clearing. A number of observations have also been made on the hastened rate of emergence of the periodical cicada where the soil has been abnormally warm, as in a hothouse (Schwarz, '90a, p. 230), or where the ground has been warmed by flues (Marlatt, '07, p. 90), or where a forest has been burned, and possibly the heat from the fire in combination with its greater absorption of heat after the fire, has caused the cicadas to emerge (Marlatt, '07, p. 94). In a forest glade, made by clearing, Schwarz ('90a) found the cicadas emerging when none were found in the surrounding woods. Concerning this discovery he remarks:

"Now, a clearing made in the midst of a dense forest forms a natural hothouse, the soil receiving much more warmth on such places than in the shady woods. We should thus not wonder to see the Cicada appear earlier on such cleared spaces than in the woods." There is therefore reason to expect the season to be more advanced in glades than in the surrounding woods.

The peculiar fossorial fore legs of the cicada nymphs are marked structural features associated with the subterranean habitat. Very naturally, too, cleaning reactions are correlated with such a burrower, whose legs become begrimed with the soil.

Near the surface of the soil the variety of animal life is greatly increased. Not only forms which inhabit the soil regularly are present, but many live here for short periods as adults or during some immature stage. It is not possible to draw a sharp line between the soil community, the humus layer community, and the community of the decayed and solid wood for these reasons: the slightly decomposed organic debris on the surface is progressively renewed by leaves, stems, branches, and animal remains, and is transformed below into the humus layer; this also grades upward by all degrees, through decaying wood into solid wood, and on to the living trees. The acidity of leaves during the early stages of decay and their alkalinity at an advanced stage is a fact of great importance, as has been shown by Coville ('14). This suggests the paucity or absence of animals in dense matted layers of decaying leaves.

In considering the animals that live on or near the surface of the soil in Bates woods, certain species seem more characteristic of rather bare mineral soils, others are more representative of open oak-hickory woods, and still others are representative of much humus. The acridiid locusts found in these woods, such as *Chlocaltis conspersa* and *Melanoplus amplexens*, are woodland rather than prairie in their haunts, and are commonly found near the bare soil and oviposit in it. Here live the woodland cricket *Apithus*, the tiger-beetle *Cicindela unipunctata*, the scavenger *Geotrupes splendidus*, the mutillid ant *Sphacrophthalma*, the wasp *Psammochares athiops* and *Lycosa*; and *Ammophila abbreviata* buries its eggs here in the soil.

Among the loose litter harvest spiders (*Liobunum*) were found running about, although they are not confined to these conditions, for, like *Calosoma scrutator*, they climb trees. The crickets *Nemobius* found here seem to avoid bare soil. The larva of the beetle *Mecanatha contracta* was found among decaying leaves.

The animals living in the humus layer of the soil, and in the much advanced stages of decayed wood, are not wholly identical, because in the humus layer roots of living plants and fungi are so often available



for food. On the other hand, many of the inhabitants of decayed logs, as snails and slugs, use the log as a retreat and sally forth at night and during moist weather to devour vegetation. Rotten wood also contains many fungi affording fresh, living plant tissue.

Representative animals of the forest litter, especially of its humus layer, appear to be certain millipeds, as *Callipus* and *Cleidogona*. Cook ('11b, p. 451) has said of them: "Nearly all the members of the group have essentially the same habits and live in clearly similar environments. They pass their lives buried in the humus layer of the soil or among the dead leaves or other decaying vegetable matter that furnishes them food." Elsewhere he says ('11c, p. 625): "In nature at large the millipeds have a share in the beneficial work of reducing dead plant material to humus. Prussic acid and other corrosive secretions may aid in the precipitation of colloidal substances in the humus, in addition to the protection that they give by rendering the millipeds distasteful to birds and other animals that otherwise might feed upon them. The precipitation of colloids enables the millipeds to keep their bodies clean and protects them against the clogging of their spiracles." Diem ('03, pp. 383-386) gives a good summary of the habitats and foods of certain European diplopods. I am inclined to consider the layer of litter as the habitat of the immature panorpid *Bittacus*, of which three species were found in the Bates woods. The adults fly about among the low vegetation much after the manner of the *Tipulidæ*, with which they are easily confused when on the wing. It is probable that the larva of *Panorpa confusa* West. has habits similar to those of *Bittacus*. I have taken the adult of this species but once—at Bloomington, Illinois, August 23, 1892, in dense damp woods. The larvæ of *Panorpa* are predaceous, and this is probably true of *Bittacus*. The ant *Stigmatomma pallipes* is another representative of this community (cf. Wheeler, '05, p. 373), as are probably also a number of tipulid larvæ.

The animals of the humus layer appear to live much more active lives than those deeper in the soil. This activity in itself allows them a chance to secure the necessary supply of oxygen, which tends to be deficient among the decaying vegetation; at the same time, moreover, their movements must aid in the ventilation of the soil. It is of interest to observe that millipeds abound in a habitat relatively deficient in oxygen, abounding in carbonic acid, and are producers of prussic acid (HCN), whose physiologic effect is to inhibit oxidation and nutrition. Roth (Diem, '03, p. 385) submerged some diplopods in water from six to eight hours and they survived. (For the marked resistance of geophiloids, see Ent. News, 24: 121.) In nature they must often meet with such conditions in the soil. One of the most abundant kinds

of myriapods in the debris on the forest floor is *Spirobolus marginatus* Say, taken in Urbana, Ill., in the Brownfield woods October 15, 18, and May 23 (many specimens), and in the Cottonwood forest October 8 and 13; at White Heath, Ill., May 26; at Riverside, Ill., August 23; at Tonica, Ill., in September; and at Bloomington, Ill. This is the common large brown diplopod, our largest myriapod. Another large and abundant species is *Fontaria virginicensis* Dru. This is largely brown dorsally, with marginal triangular yellow spots, yellow below. A chilopod, *Bothropolys multidentatus* Newp., was taken in the Brownfield woods October 18; and in woods at Monticello, Ill., in June (M. Waddell), with *Otocryptops sexspinosus* Say. In the Brownfield woods it was taken October 15 and 18; and here also *Polydesmus serratus* Say was taken May 23. *Callipus lactarius* Say was taken in the Cottonwood forest previously mentioned, October 8 from decayed logs, and in the Brownfield woods October 15, associated with *Scytonotus granulatus* Say and the chilopod *Lithobius voracior* Chamb. (No. 491, C. C. A.). These predaceous kinds must be considered important members of the humus and rotten-log communities, and are somewhat comparable to the predaceous clerid beetles upon the living tree trunks in their influence upon the community. They are, however, very sensitive to moisture and live in a humid atmosphere among damp debris. Shelford ('13b) has shown that *Fontaria corrugata* Wood is very sensitive to moisture. *Myriapoda* are infested by a number of gregarine parasites (Ellis, '13, pp. 287-288).

The following statement by Coville ('14, p. 337) is of much interest: "The importance of myriapods, however, as contributing to the formation of leafmold has not been adequately recognized. In the canyon of the Potomac River, above Washington, on the steeper talus slopes, especially those facing northward, the formation of alkaline leafmold is in active progress. . . . Here during all the warm weather the fallen leaves of the mixed hardwood forest are occupied by an army of myriapods, the largest and most abundant being a species known as *Spirobolus marginatus*. . . . On one occasion a thousand were picked up by Mr. H. S. Barber on an area 10 by 100 feet, without disturbing the leaves. On another occasion an area 4 by 20 feet yielded 320 of these myriapods, the leaf litter in this area being carefully searched. Everywhere are evidences of the activity of these animals in the deposits of ground-up leaves and rotten wood. Careful measurements of the work of the animals in captivity show that the excrement of the adults amounts to about half a cubic centimeter each per day. It is estimated on the basis of the moist weight of the material that these animals are contributing each

year to the formation of leafmold at the rate of more than 2 tons per acre."

The burrows of earthworms aid in the ventilation of the soil and in carrying down into it vegetable debris, as Darwin long ago observed. In the blackened decayed leaves at Urbana, Ill., on November 18, I found enchytraeid worms abundant, and in the adjacent soil, below a decayed log, a *Diplocardia* (No. 547, C. C. A.).

In the Brownfield woods at Urbana, among the dead leaves and in logs during the cool season hibernating females of the white-faced hornet, *Vespa maculata* Linn. (Pl. XXI, fig. 3) are often found. Females were taken from among leaves or in decayed wood October 8, and 12 (in rotten wood), October 15 (No. 491, C. C. A.), and November 9. The Bloomington records of hibernating females are April 23 and October 18. In such situations two ichneumons have been taken in the Brownfield woods: *Hoplismenus morulus* Say on November 14, and *Ichneumon ciucticornis* Cress., November 9; also the two ground-beetles *Anisodactylus interstitialis* Say and *Lebia grandis* Hentz (Pl. XXI, fig. 4) on October 18; and *Ccuthophilus* sp., *Lebia grandis*, *Galerita janus*, the larva of *Meracantha contracta*, and the large black predaceous bug *Melanolestes picipes* H. S. (Pl. XXII, figs. 1 and 2) October 12, under bark and under logs. *Melanolestes* was also found in the Cottonwood forest November 14, with the "slender-necked bug," *Myodochia scirripes* Oliv. (Pl. XXII, fig. 3). These examples show how during the hibernating season many animals are to be expected here which at other seasons live in other habitats. *Vespa* is arboreal, as shown by the large nests seen in these woods.

Baker ('11, p. 149) has listed many mollusks found under fallen logs and under bark in the forest of southern Michigan. As various scavengers thrive in this zone, eating not only the vegetable debris, but also the animals which die in it or fall upon it, the digestive peculiarities of these animals are in part a response to the conditions of this habitat. The animal carcasses which fall to the ground are comparable to the similar slowly falling remains which tend to accumulate upon the bottom of bodies of standing water. The student of this community will find of interest Dendy's ('95) paper on animals in the soil, under stones and bark.

## 2. The Forest Fungus Community

Many fungi grow up through the humus layer and are food for a great number of animals. Still other fungi grow only on and in wood. I will not now attempt to emphasize this difference. The fleshy fungi are very short-lived at the surface, and soon decay or are devoured by various animals. A large number, if not most, of our land *Mollusca*

devour them. On a stump in the upland Bates woods *Zonitoides arborca*, *Pyramidula perspectiva*, and *Philomycus carolinensis* were found upon a felt-like growth of fungi; it is to be remembered, too, that with the other snails lives the snail *Circinaria* which preys upon them. At the time the Bates woods was examined, it was rather dry, so that fungi were not abundant. No millipeds were found on fungi, but Cook ('11b, p. 625) states that "The mouth parts of millipeds are not adapted for biting or chewing, but are equipped with minute scrapers and combs for collecting soft, decaying materials. Dead or dying tissues are preferred. The only living plants that are regularly eaten by millipeds are the fleshy fungi. Some of the native millipeds in the vicinity of Washington, District of Columbia, feed to a considerable extent upon the local species of *Amanita*, *Russula*, and *Lactarius*. Damage is sometimes done to other plants when millipeds gain access to wounded surfaces of roots or cuttings." A horned fungus beetle, *Boletotherus bifurcus*, living on *Polyporus* on stumps, was found in the Bates woods.

At Urbana, Ill., in a dense maple-basswood forest (Brownfield) November 14 I took a very large number of the small mycetophagid beetle *Triphyllus humeralis* Kby. (No. 545, C. C. A.) on a shelf-fungus, *Polyporus tomentosus* Fries, growing on a much decayed log. On the under side of this same kind of fungus numerous tipulid flies were found, some individuals evidently ovipositing. These were determined by Mr. J. R. Malloch as belonging to the genus *Trichocera*. These are flies which thrive in the far north, as in Greenland. One species, *brumalis* Fitch (Lintner's Second Report, p. 243) is found common in forests in the winter season, and even when the temperature is below freezing they are on wing. Such northern forms are likely to be active in winter or vernal farther south. On another shelf-fungus, *Dædalia* sp. taken at Urbana, Ill., I found numerous specimens of *Arrhenoplita bicornis* Oliv. (Pl. XXIII, fig. 2). This is a small greenish tenebrionid in which the males have two large horns on the head. I have the following woodland fungus-beetles taken at Bloomington, Illinois: *Endomychidæ*—*Aphorista vittata* Fabr., April 14 (A. B. Wolcott); *Erotylidæ*—*Tritoma thoracica* Say, June 23 (on fungi) and July 26; *T. biguttata* Say (Sept. 21), *Megalodacne fasciata* Fabr., March 7 (A. B. Wolcott); *Nitidulidæ*—*Phenolia grossa* Fabr. (July 26), *Pallodes pallidus* Beauv., July 2 (on gilled fungus); *Mycetophagidæ*—*Mycetophagus bipustulatus* Mels. (April 27), *M. punctatus* Say April 18, and June 23 (on fungi); *Tenebrionidæ*—*Platydema ruficornis* Sturm. March 13 and June 23 (on fungi), *Diaperis maculata* Oliv. (*hydri* Fabr.) (Pl. XXIII, fig. 1) July 26; *Melandryidæ*—*Eustrophus bicolor* Say, June 23 (on fungi), and *E. tomentosus* Say,

June 23 (on fungi). In the Brownfield woods at Urbana, Ill., *Penthe obliquata* Fabr. and *P. pimelia* Fabr. were taken under logs October 15 (No. 491, C. C. A.). Ulke ('02, p. 53) says. "*Penthe*, on fungi growing on logs and stumps." *Cratoparis lunatus* Fabr. (*Anthribidæ*) was taken April 5 and 23, Bloomington, Ill., and August at Havana, Illinois. Figures of some of these fungus-beetles are given in Felt's report ('06, pp. 494-498).

The general animal population of fungi is so extensive, including mites, sow-bugs, myriapods, and mollusks, in addition to insects, that no attempt will be made to summarize it here. The student of Illinois fungus animals will find Moffat's paper ('09) on the *Hymenomyces* of the Chicago region very helpful. (Cf. von Schrenk and Spaulding, '09.) A few references to zoological papers will aid the student who wishes to give more attention to this interesting and increasingly important economic subject, and a short list follows.

Busck ('02). Mushroom pests.

Hubbard ('92). Insects in *Polyporus volvatus* Peck; and ('97) on the ambrosia beetles.

Johannsen ('10-'12). Mycetophilidæ.

Malloch ('12). Phoridæ in fungi.

Popenoe ('12). Mushroom pests.

Patch ('12). Aphids on fungi, page 179.

Ulke ('02). Notes on food habits of fungus-beetles, of which there are many families, including *Silphidæ*, *Staphylinidæ*, *Endomychidæ*, *Erotylidæ*, *Mycetophagidæ*, *Nitidulidæ*, *Scarabæidæ*, *Tenebrionidæ*, *Melandryidæ*, *Scolytidæ*, etc.

Jäger ('74, I, pp. 245-246) and Möller ('67, pp. 59-60) have given short lists of the German fungus insects.

The subject of fungus insects can not be dismissed without special mention of the ambrosia beetles of the family *Scolytidæ*. These small beetles have been studied by Hubbard ('97), who showed that they rear fungi in their tunnels in wood, these fungi furnishing nourishment to the larvæ and beetles. Each beetle seems to grow its own kind of fungus. They belong to the following genera: *Platypus*, *Xyleborus*, *Corthylus*, *Monarthrum*, *Xyloterus*, and *Gnathotrichus*. The beetles of the genus *Corthylus* live in a variety of hardwood trees, including maple, sassafras, dogwood, etc., and attack living trees. The ambrosia beetles are thus dependent upon fungi growing in the trees. They furnish a very striking example of a mutually dependent associational relationship. Hopkins ('99, '93a, '93b) has published much valuable data on the life history, habitats, and enemies of these beetles. A study of them as a biotic community would be very interesting and

valuable, since such a good foundation has already been built by Hubbard and Hopkins.

### 3. *The Forest Undergrowth Community*

Above the soil, in the layer of herbaceous and shrubby vegetation in the Bates woods, lives a considerably different assemblage of animals from that in the soil. Running about over this vegetation, or resting on it, are found the harvest-spiders, and in webs spread between trees and shrubs are found *Epeira insularis* and *verrucosa*, and *Acrosoma spinea* and *rugosa*.

In the Cottonwood forest at Urbana, cutting has made rather open spaces so that there is considerable undergrowth, including much spice bush (*Benzoin*); among these bushes two spiders thrive, *Epeira insularis* Hentz and *E. domiciliorum* Hentz. The leaf-footed bug, *Lepidoglossus oppositus* Say (Pl. XXII, fig. 4) also abounded on these plants. *Insularis* is also in the Brownfield woods. The jumping spider *Phidippus audax* Hentz, and *Acrosoma rugosa* were also taken in the Cottonwood forest. In a dense shady flood-plain forest at Muncie, Illinois, *Acrosoma rugosa* and *Epeira verrucosa* and *labyrinthica* were taken August 3. The harvest-spiders *Liobunum* are largely animal scavengers, but the true spiders are of course strictly predaceous. The location of the spider-webs, near the ground, attests the flight of insects upon which they depend for food. The numerous snails feed to a large degree upon the herbaceous plants of this lower layer, as do plant-feeding *Hemiptera* and the grass-eating *Lepidoptera*, including the woodland butterflies *Enodia* and *Cissia*, other *Lepidoptera*, and *Evces*, *Autographa*, *Polytonia*, and, possibly the katydid *Amblycorypha*. In the shrub layer *Epeira domiciliorum*, folded among leaves, is a characteristic animal. It seems to thrive best in more open woods than those in which *Acrosoma* abounds. Nettles (*Laportea*) and clearweed (*Pilca*) were not searched for animals, but were undoubtedly inhabited by a number of kinds. The same is true of the shrubs. Young trees in this layer appear less liable to attack by gall-producing insects than larger trees are.

The following insects feed upon woodland shrubs, and were taken at Bloomington: *Cerambycidae*—*Liopus alpha* Say, June 18 (bred from sumac by Felt, '06, p. 482), and taken by me on elm during June; *Liopus fascicularis* Harr. (*xanthoxyli* Shimer), June, recorded as from prickly ash, *Zanthoxylum* (Packard, '90, p. 659); and *Molorchus bimaculatus* Say, copulating April 17, reported from dogwood, redbud, twigs of maple and hickory, (l. c., '90, p. 293, 424). The curculionid *Conotrachelus seniculus* Lec., was taken October 10, 1891, from the inside of a very ripe papaw at Bloomington; another

specimen was captured during August at Havana, Ill. Felt ('06, p. 582) records *seniculus* as from hickory and butternut. *Attelabus rhois* Boh. was taken July 4, on hazelnut, at Bloomington. It is recorded from sumac, dogwood, alder, and oak.

For lists of *Coccidæ* living on woodland (and other) shrubs see Cockerell ('97).

#### 4. *The Forest Crown Community*

Instead of next turning to the animals of decayed wood on the forest floor, I wish to begin at the other end of a series, with the animals of the *living tree*, and then to follow an order which passes progressively through enfeebled, dying, fermenting, seasoned, and solid wood to all stages of its decay. The decay of a fallen trunk commonly begins with the sap-wood, thus loosening the bark, and extends inward until the whole becomes soft or is changed to brown powdered wood, which gradually changes to humus. This is a series of progressive humification, and, speaking in general terms, follows the course through which all forests tend to pass; although fire, flood, and animals, including man, divert much wood from such a fate.

To investigate such a series fully is far beyond the scope of the Charleston studies, and yet our material, supplemented to some degree, may serve at least to outline one. The difficulties of studying the animals of the forest crown are serious, and so far as known to me no comprehensive work on this community has been done in this country. Many members of it have been studied individually, but the animals have not been studied as a community. About the woodland insects a vast fund of facts has been accumulated in the study of the economic problems of shade, fruit, and forest trees; furthermore, investigations have shown that among the invertebrates insects have a controlling or dominating influence in the forest. But the relations of the other forest invertebrates to the forest crown have received very little attention from our students.

The animals of the forest crown, and particularly those of the foliage, are more exposed to changes of temperature, moisture, wind, and evaporation than those below the crown and protected by it. Within the crown there are, in fact, an upper, exposed part, and the lower, protected part. Many of the animals of the forest crown live relatively free from the influence of the substratum, as other animals in the open water are similarly free from the influence of the bottom. Others divide their time, part of it being spent in or on the earth, and a part of it in the trees. Conditions of poor ventilation, darkness, density of medium, relative stability, excess of moisture, and corresponding conditions in the soil, are here replaced by conditions of

good ventilation, intense light, and changing and a relatively dry medium. The problems involved in these conditions vary accordingly.

The relative scarcity of mollusks and myriapods in trees is in marked contrast with their abundance in habitats in proximity to the soil. In the Bates woods the cherry-leaf gall-mite, *Acarus*, is arboreal, but spiders are almost entirely absent. The walking-stick, *Diapheromera*, is arboreal in part, but its eggs fall to the earth and hatch there. The Severins ('10) have shown that the emergence of walking-sticks from the eggs is influenced to a very marked degree by moisture, dryness being distinctly injurious and moisture favorable. The molting of the young animals seems similarly dependent upon moisture, and may be prevented by keeping them in a "well-aerated breeding-cage" (Severins, '11c). This is another clear case of a forest animal sensitive to moisture. To the fact that there is greater moisture near the soil are therefore related the egg-laying habits and the development of the immature insect, a development in marked contrast with that of the strictly arboreal katydids. Of the katydids, *Microcentrum* and *Cyrtophyllus* are distinctly arboreal throughout life, as the eggs are attached to the twigs, and they are relatively independent of the ground. Curiously the Bates woods specimen of *Cyrtophyllus* was taken among low sprouts. *Amblycorypha*, however, lives near the ground. The cicadas are distinctly arboreal during the imago stage. The larvæ of *Papilio turnus* and *cresphontes*, *Epargyreus tityrus*, *Cressonia juglandis* (and parasite), *Telea*, *Cithronia*, *Basilona*, *Halisidota*, *Datana*, *Nadata*, *Heterocampa*, *Eustroma*, *Ypsolophus*, and the slug caterpillar are all arboreal. Many of these pupate on the branches or among the leaves and do not descend to the earth. The sphingid *Cressonia*, however, pupates in the soil. There is a marked tendency for the *Lepidoptera* to be completely arboreal. Even noctuid caterpillars such as *Peridroma saucia* and its allies, which live during the day on the ground, climb trees at night (Packard, '90, p. 173; Slingerland, '95). Many of the gall-flies are limited to certain kinds of trees and are arboreal, as, for example, the several species of *Cecidomyia* found in the Bates woods. The same is true of certain cynipid gall-makers, such as *Holcaspis*, *Amphibolips*, and *Andricus*. It will be seen that the above-listed kinds are largely defoliators and leaf-gall producers. *Ammophila* is a predator. *Trogus* and the small hymenopters (cocoons) on *Cressonia* are parasitic.

Among the animals which live for a considerable part of their lives in or on the soil and a part in the trees, are the two cicadas, *Calosoma*, *Cressonia*, *Ammophila*, and certain ants, although no special observations were made to learn to what degree the ants patrolled the



trees. The relatively large number of caterpillars present suggests that in this woods they were attended by a large number of parasitic flies and parasitic *Hymenoptera* in addition to predaceous insects. The twig-pruners, *Elaphidion*, are referred to here because they belong to the crown community for at least a part of their lives. For a summary of our knowledge of these beetles reference should be made to Chittenden ('98 and '10,) and to Forbes ('11, pp. 50-53), who gives a summary of their injury to oaks and hickories in Illinois. The oak pruner, *Elaphidion villosum* Fabr. (Pl. XXIII, figs. 3 and 4) was taken by me at Bloomington July 3. It is injurious to hickory, maple, and other trees. The normal duration of the life cycle appears to be one year, but in dry wood this period may be prolonged to four or more years (Hamilton, '87; Chittenden, '10, p. 5)—another example of the prolongation of life in dry wood. Mr. W. P. Flint informs me that *Oncideres cingulatus* Say is a common Illinois beetle, which girdles hickory branches, and that in the dead fallen branch its larva develops. It is reported from hickory and basswood by Hopkins ('93b: 198.)

Additional defoliators of trees taken at Bloomington include *Macrobasis unicolor* Kby. (Pl. XXIV, fig. 2), taken June 27 on the Kentucky coffee-tree, *Gymnocladus*. Other specimens were taken June 4 and 12. Hamilton (Can. Ent., Vol. 21, p. 103) also records this as defoliating locust. The larvæ of the curculionid *Conotrachelus elegans* Say, taken September 5, is recorded as feeding on the leaves of hickory. The imbricated snout-beetle, *Epicærus imbricatus* Say (Pl. XXIII, fig. 1), was taken June 4, and, copulating, June 27, at Bloomington. It has been recorded feeding upon the leaves of wild cherry, plum, gooseberry, etc.

The nut-weevils may be properly considered as members of the crown population. Of these *Balaninus nasicus* Say was taken August 1 (on papaw) at Bloomington, and during September at Chicago. This is recorded as from acorns, hazelnuts, and hickory-nuts. *Balaninus uniformis* Lec. was taken August 20, 21, and September 21 at Bloomington. This, too, is recorded as from acorns, as also is *B. caryæ* Horn, taken August 27. Miss Murtfeldt ('94) has observed *B. reniformis* ovipositing in acorns and has described the process. This weevil is associated and in competition with the acorn codling-caterpillar, *Melissopus latiferrreana* Walsm. These two insects pave the way for a small caterpillar of the genus *Gelechia*, and for a second caterpillar, the larva of the acorn moth, *Blastobasis glandulella* Riley, which feeds on the refuse within the acorn, and is thus a scavenger. The debris of the predecessors is an essential for the one that follows. Hamilton ('90) has given a good account of

the habits of *Balaninus* (Cf. Chittenden, '08). On a previous page mention is made of the habit of the May-beetles (*Lachnosterna*) defoliating oaks.

The invertebrate animals of the forest crown are largely insects, and for this reason some of the treatises on forest insects, and on certain families of *Lepidoptera*, make excellent manuals for this assemblage. Thus Packard's "Forest Insects" ('90) and his monographs on the arboreal bombycine moths ('95; '05; '14) are very essential. In his "Forest Insects" the various kinds of insects are grouped according to the kind of tree and the part of the tree which they inhabit, and thus one can readily find what is given concerning those living upon or in the foliage, buds, fruits, twigs, etc. A somewhat similar arrangement is found in Felt's "Insects Affecting Park and Woodland Trees" ('05, '06). The crown community varies with the kind of trees composing it, as many kinds feed upon a relatively small number of food plants, on allied kinds of plants, or on those of members of the same plant association. The herbivorous species are influenced in variety and abundance by the kind of vegetation; their predaceous and parasitic associates, however, are only indirectly influenced in this manner.

### 5. The Tree-Trunk Community

In an earlier section attention was called to the equable conditions in tree trunks, and to the available moisture in the food of wood-eating insects. The outer growing part of the tree contains the greatest amount of water, insoluble starch, soluble sugar, and other food materials; the heart-wood, on the other hand, is dead and contains only a small amount of water (see Roth, '95, p. 29). In view of these relations it is but natural that the outer parts of living trunks should be subject to attack by more animals than are the drier and less nourishing inner parts. We should expect that young animals would thrive best in the layers of the outer, moister wood, not only on account of the softer wood being less difficult to chew, but also on account of its greater nutriment and the larger supply of water in these layers. The inner parts are thus protected not only by the outer layers, but also by the general inability of many animals to digest dry wood. Many of the insects which live in wood, particularly in dry wood, require several years to attain maturity. This gradual rate of development seems to be due in part to the slowness with which metabolic water is produced by the growing larvæ. There are many cases recorded in which developing larvæ have apparently been delayed in maturing for many years by living indoors and in dry wood. Weismann ('91, p. 48) has published an interesting case of *Buprestis splen-*

*dens* which emerged from a desk which had been in use for thirty years. He suggests that such prolonged lives are a kind of starvation sleep analogous to winter sleep. McNeil ('86) records that the beetle *Eburia quadrigeminata* (Pl. XXVIII, fig. 5) emerged from a doorstep in a house which had been built nineteen or twenty years, and Packard ('90, pp. 687-688) records the emergence of the wood-boring beetle *Monohammus confusor* Kby., which came out of a piece of pine furniture which had been in use "for fully fifteen years." Felt ('05, p. 267) states that instances are recorded of *Chion cinctus* (Pl. XXVIII, fig. 2) emerging from wood several years after the furniture had been manufactured. The prolongation of the life cycle of *Elaphidion villosum* (Pl. XXIII, figs. 3 and 4) in dry wood is another case bearing upon this point. Other similar cases are known which show that larval life is greatly prolonged in dry wood, or that the adult in such conditions lives for many years. In such cases it is not known just when the adult transformed.

Animals which live in living bark and living wood are in some cases, with regard to moisture and to air, subject to peculiar conditions brought about by the sap of the tree. In the case of hardwoods the sap is watery, and in conifers the pitch or turpentine is gummy and easily mires feeble insects, or suffocates them. Why is it that in hardwoods, such as maple and box elder, all wood- and bark-boring insects are not flooded in their burrows and drowned by the flow of sap in the spring? I do not know how many factors are involved in this problem. The gummy exudation on peach and cherry trees is evidence of the influence of insects upon the flow of sap. Where sap flows from trees many insects, particularly flies and *Lepidoptera*, are attracted to and feed upon this fluid. Felt and Joutel ('04, p. 17) state that the grubs of some members of the beetle genus *Saperda* feed upon the sap, but they do not give the evidence for their opinion.

In the coniferous trees the flow of pitch has a marked influence upon the bark-inhabiting scolytids. Hopkins ('99, pp. 404) says of the pair of *Dendroctonus frontalis*, which work together to establish the brood, that "In this operation in healthy living bark filled with turpentine, it is necessary for one of the beetles to move back and forth in the burrow continually in order to keep it open and push back and dispose of the borings and inflowing turpentine. . . . From the time they penetrate the outer layer of living bark there must necessarily be an incessant struggle with the sticky, resinous mass which is constantly flowing into the burrow and threatening to overcome them." The larva of another bark-beetle, *D. terebrans*, is able to live in this sap. Thus Hopkins (l. c., p. 418) says: "This social brood chamber is often extended down towards or even into the bark of the

roots in such a manner as to hold the turpentine flowing into it. Thus the larvæ are often completely submerged in the viscid substance, which does not appear to interfere with their progress." There are thus marked differences in these beetles in their response to sap. As a result of utilization of the knowledge of this difference, the larvæ sensitive to an excess of sap may be killed in trees by diverting a large amount of it into the infested bark. This plan was proposed and practised by Robert on conifers as quoted by Packard ('90, pp. 29-30); and by Hopkins ('99, p. 391) for the elm. By "cutting narrow strips of bark from the trunks of infested elms, the Scolytids were either killed or driven out by the increased vigor of the tree and the greater flow of sap which it is well known will result from this treatment."

The trunk of a tree is of such a substantial nature that it can not be destroyed at once by animals. Such durability furnishes an opportunity to see how one kind of insect prepares the way for attack by others, as is shown by the following examples. The elm borer, *Saperda tridentata* Oliv. (Pl. XXIV, figs. 3 and 4), invades weakened trees, and it is followed (Felt, '05, p. 70) by the weevils *Magdalis armicollis* Say (Pl. XXV, figs. 1 and 2) and *M. barbata* Say, *Neoclytus erythrocephalus* Fabr., and, as a parasite of *Saperda*, *Melanobracon simplex* Cress., and *Bracon agrili* Ashm., which is a parasite of *Neoclytus* (l. c., p. 73). Four other insects have been found associated with *Magdalis barbata* (l. c., p. 74). *Xylotrechus colonus* Fabr. (Pl. XXVIII, fig. 6) appears to be able to kill hickory, and from such wood many insects have been reared by Felt ('05, p. 261). Felt and Joutel ('04, p. 18) state that in hickories dying from injury by *Scolytus quadrispinosus* Say (Pl. XXV, fig. 3) the beetle *Saperda discoidea* Fabr. follows, living under the bark.

The absence of woodland *Cerambycidae*, *Scolytidae*, and *Buprestidae* in the Charleston collections eliminates the most important and largest variety of insect inhabitants of tree trunks.\* In addition to the beetles which invade trunks, the large boring caterpillar, *Prioxystus robiniae* (cf. Packard '90, p. 53), and the horntail larva, *Tremex columba*, are able to do much injury. The caterpillar can

\*I visited the Bates woods on June 8, 1914, and found a number of insects in a recently cleared part of the upland area about a stump of a black oak (*Q. velutina*). Running about in the sun on the top of the stump was *Chrysobothris femorata* Fabr., near the stump was a cerambycid, *Stenosphenus notatus* Oliv., and on the bark, shaded by a vigorous growth of suckers, were the cockroach *Ischnoptera inaequalis* Sauss.-Zehnt., the tenebrionid beetle *Meracantha contracta* Beauv., and the otiorhynchid *Pandeletejus hilaris* Hbst. About the base of the stump was a large funnel-shaped spider-web beneath which and in its meshes were remains of the following insects: *Chion cinctus* (cerambycid), *Meracantha contracta*, *Chrysobothris femorata* (several specimens), an *Agrilus*, *Passalus cornutus*, and *Lachnosterna*.

kill living trees, but the horntail generally follows injury of some kind. Within the tree trunk there is not the safety from enemies which one might anticipate. A large number of wood-inhabiting immature insects are footless, and have relatively small powers of locomotion. Their burrows are relatively small, so that when an enemy once gains admission it can easily secure the owner. Tree trunks infested with horntails often have a large number of females of *Thallessa* on them. I have caught them literally by the handful in such places. Many other parasitic *Hymenoptera* are easily taken upon trees infested by boring larvæ if watched carefully during the warm parts of the day. Schwarz ('82) has called attention to a number of beetles which live in the burrows of wood-boring insects. These burrows may be invaded, not only while yet inhabited by their makers, but also after their abandonment. To find an insect in a burrow is therefore not proof that the insect made it. A predaceous larva which is reported to destroy bark- and wood-boring larvæ is *Alaus oculatus* L. (Pl. XVI, figs. 1, 2, and 4). I have taken this larva in the woods at White Heath, Ill., May 26, and the beetle at Savanna, Ill., May 30. The beetle was taken at Bloomington, Ill., March 23 (A. B. Wolcott); in its hibernating cell in a rotten log in the Cottonwood forest October 8 (No. 489, C. C. A.); and—an immature larva—in the Brownfield woods May 23, Urbana, Ill. Both the larva and the beetle hibernate in logs. Hopkins ('04, p. 42) says of the larva: "As a larva [it] preys upon numerous species of bark and wood-boring insects in deciduous trees." Currie ('05, p. 102) says: "The larvæ prey upon and do much toward preventing the increase of several of the destructive flat-headed borers (*Buprestidæ*) in deciduous trees." Snyder ('10, p. 8) reports the larva of *Alaus* sp. "especially injurious" to decayed poles, and Lugger ('99, p. 130) states that they live largely upon insects found in decayed wood. Evidently the food habits of these larvæ need investigation. Probably other predaceous elaterid and trogositid larvæ live in our trees. Other predaceous beetles on trees are the following, taken at Bloomington: *Chariessa pilosa* Forst., July 3, *Clerus quadriguttatus* Oliv. (Pl. XXVI, fig. 3) June 15, and *Cymatodera balteata* Lec., July and August 17. Hopkins ('93b, p. 187) reports that *Chariessa pilosa* (Pl. XXVI, fig. 6) is found under bark of walnut, and was taken in a dead grape-vine, and reports also that it is predaceous. Felt ('06, p. 504) figures this species and reports it on trees infested with borers.

The locust borer, *Cyllene robinia* Forst. (Pl. XXVII, figs. 1 and 2), is a common insect in many localities, and the beetle is frequently taken upon *Solidago* in the fall. The beetle was taken at Bloomington.

ton September 14 and October 2 (A. B. Wolcott), and on the prairie at St. Joseph, Ill., on flowers, September 26 (No. 310, C. C. A.). Hopkins ('06, p. 8) has shown that although the larvæ begin development only in living wood, they are able to complete it in dry dead wood, but in this case such conditions hasten development.

The apple borer *Saperda candida* Fabr. (Pl. XXVI, fig. 4) was taken in the woods at Bloomington July 4. In the original forests it probably bored in the wild crab apples and the haws (*Crataegus*). *S. tridentata* Oliv., the elm borer, was also taken at Bloomington. This is a serious pest to elms, and paves the way for *Magdalis* and *Neoclytus*. Mr. W. P. Flint informs me that *Saperda vestita* Say is common throughout the state in the live bark of linden, and that *Sinoxylon basilare* Say lives mainly in weakened trees and in living wood. He also tells me that *Goes debilis* Lec., *G. tigrina* DeG., and *G. pulverulentus* Hald., live in a variety of living trees.

The flat-headed apple-tree borer, *Chrysobothris femorata* Fabr. (Pl. XXVI, fig. 5), is known to attack the bark of enfeebled trees and logs and stumps of oak, hickory, maple, basswood, and apple (Hopkins, '93b, p. 183). The beetles were taken June 13, 25, 30, and August 11, at Bloomington. *Leptostylus aculiferus* Say (Pl. XXVIII, fig. 1) was taken April 17 in the same locality. Hopkins ('93b, p. 196) reports this insect infesting dying and dead maple- and apple-trees. The larvæ mine in the inner bark. Beutenmüller ('96, p. 79) states that it breeds under the bark of oak. The curculionid *Cryptorhynchus parochus* Hbst., is reported by Hopkins ('04, p. 34) to mine as a larva in "the inner bark and sapwood of weakened and recently dead walnut." It is also reported from butternut. Thirteen specimens of this species were taken at Bloomington April 17. The larvæ of *Romaleum atomarium* Dru. live in stumps and logs of recently dead oak (Hopkins, '04, p. 36), and are reported also from hackberry. The beetles were taken July 25 and August 8 at Bloomington. *Romaleum rufulum* Hald. was taken at Charleston June 17. This is reported from oak. The larvæ of *Chion cinctus* Dru. (Pl. XXVIII, fig. 2) are reported by Hopkins ('04, p. 36) to "mine the inner bark and bore into the wood of trunk and branches of dying and recently dead hickory, chestnut, oak, etc." This beetle was taken at Urbana, and at Bloomington July 12. The larvæ probably continue to live in the seasoned wood, as the beetles are recorded as emerging from dry wood some years after furniture or lumber was manufactured.

Certain species of insects live mainly in dead, though solid and seasoned, wood, before decay causes any important changes; some begin work in the living wood and continue in the dead wood; and

others begin in dead wood and continue there after it begins to decay. Among the beetles which live in dead wood the hickory borer, *Cyllene caryæ* Gahan (*pictus* Auct.) is representative. This beetle closely resembles the locust borer, but it appears in the spring and early summer, rather than in the fall as does *robinia*. I have taken *caryæ* at Bloomington April 20, 30, May 20, and June 20, and at Urbana May 16. The larvæ bore in dead branches and small trees of hickory and mulberry, according to Hopkins ('93b, p. 194). *Xylo-trechus colonus* Fabr. (Pl. XXVIII, fig. 6) lives in the bark and wood of dying and dead timber of oak, hickory, elm, and ash (Hopkins, '93, p. 194). My Bloomington records of it are May 9, June 14, 25, and July 1 and 20. *Eburia quadrigeminata* Say (Pl. XXVIII, fig. 5) is a borer in ash and honey-locust (Packard, '90, pp. 541-542), and has been taken on beech and elm (Hopkins, '93b, p. 193) and in hickory. Bloomington records of it are July, August 1 (on papaw), and August 28. Elsewhere mention has been made of its long life in dry wood. *Elaphidion mucronatum* Fabr. has been recorded by Chittenden ('98, p. 42) as emerging from dry wood as follows: "There is a divisional note on its having bred February 8, 1889, from a piece of dogwood (*Cornus*) which had been stored in a carpenter shop some years to be used for hammer handles. The larvæ had worked principally under the bark where they produced large and irregular channels, entering, when nearly full grown, the solid wood, in which they transformed." It also lives in healthy living wood. The larvæ of *Arhopalus fulminans* Fabr. is reported to live in the inner bark and sap-wood of oak. This was taken during May at Bloomington, and *Dicerca lurida* Linn., a hickory borer, was taken at Chicago August 8 and at Bloomington June 13.

The oak pruner, *Elaphidion villosum* Fabr. girdles hickory branches, which fall to the ground. From seasoned wood thus formed Hamilton ('87) reared from branches one half to one inch in diameter, the following beetles: "*Clytanthus ruricola* and *albo-fasciatus*, *Neoclytus luscus* and *erythrocephalus*, *Stenosphenus notatus*, etc." Such seasoned wood is particularly liable to attack, according to Hopkins ('09, p. 66), by beetles of the family *Lyctidæ* (cf. Kraus and Hopkins, '11). In such wood, too, white ants (*Termes*) and carpenter-ants (*Camponotus*) will make extensive excavations. The northern brentiid, *Eupsalis minuta* Dru., (Pl. XXVIII, figs. 3 and 4) occasionally lives in living weakened trees, but is generally in dead wood. Hopkins ('93b, p. 207) records it as from oak, elm, and beech, and Packard ('90, p. 69) as from white oak. I have taken it at Bloomington June 15, 25 (copulating), and July 2. *Neoclytus luscus* Fabr., a hickory and ash borer, was taken

there October 15. The larvæ of *Neoclytus erythrocephalus* Fabr. (Pl. XXVIII, fig. 4) are associated in dead elms with *Magdalis* (Packard, '90, p. 228; Felt, '05, p. 70), and appear to follow injury by *Saperda tridentata*. In hickory, *Neoclytus* has been found associated with *Xylotrechus colonus* Fabr., *Chrysobothris femorata* Fabr., *Catogenus rufus* Fabr., and *Tremex* and *Thalassa* (Felt, '05, p. 261). The cucujid *Catogenus rufus* was taken at Springfield July 20 by A. B. Wolcott. *Liopus variegatus* Hald., taken at Bloomington June 11 and July 22, is reported under the bark and from several kinds of trees. The cerambycid *Smodicum cucujiforme* Say is also reported from under bark, and was taken July 6 at Bloomington. *Calloides nobilis* Say, reported from oak stumps and hickory, was taken at Chicago in June. From oak also *Purpuricenus humeralis* Fabr. is reported. This was taken at Chicago, and June 9 at Bloomington. The rare lymexylid, *Lymexylon sericeum* Harr., "a borer in old oak wood," was taken at Bloomington July 2. The larva of the flat-headed borer *Dicerca divaricata* Say bores in the dead and rotten wood of maple, cherry, etc. The beetles were taken May 9 and June 3 at Bloomington. Other wood borers whose records for Bloomington should be given, are as follows: *Leptura proxima* Say, a maple borer, June 13; *Dorcaschema wildii* Uhler, an Osage-orange and mulberry borer, June 19; *Criocephalus obsoletus* Rand, July 14; and *Obera tripunctata* Swed., whose larvæ breed in twigs of cottonwood and blackberry, June 13 (Blatchley, '10, p. 1092).

### 6. The Decaying Wood Community

Thoroughly dry wood, or that submerged in water and thus shut away from the air, remains sound for an indefinite period. In the decay of wood, a certain amount of moisture, air, a favorable temperature, fungi, and insects, are the main agents and conditions. The fungi growing on wood remove the starch, sugar, and other food materials, or they may dissolve the wood itself. This process of course changes the character of the wood so that animals able to derive sustenance from the solid wood now find it unsuitable for their purpose; and still other kinds, on the other hand, unable to eat the solid wood, are now able to feed upon the softened product.

The rate of decay of trees varies greatly. The yellow locust (*Robinia*) red cedar (*Juniperus*), mulberry (*Morus*), and hardy catalpa (*Catalpa*) are very resistant. This catalpa is reported by von Schrenk ('02, p. 50) to serve as a railway tie for eighteen years and remain sound; as fence posts it has served from twenty-three to thirty-eight years. Large stumps of white oak and walnut are also very durable.



On the other hand, cottonwood (*Populus*), basswood (*Tilia*), and silver maple (*Acer saccharinum*) decay rather rapidly. I have found little definite information on the rate of decay of our trees. The most definite information I have found concerning the durability of wood in contact with the soil is in a study of fence posts by Crumley ('10). He shows that heartwood is particularly liable to decay (l. c., pp. 613-614). He gives (pp. 634-635) the following scale of durability, beginning with the most durable; Osage orange, yellow locust, red cedar (woodland grown), mulberry, white cedar, catalpa, chestnut, oak, and black ash. The following have poor durability: honey-locust, sassafras, black walnut (young trees; old trees are durable), butternut, and elm. Red cedar growing "in the open is about the same as oak in durability." These observations aid in giving some idea of the relative rate of decay of logs and stumps in contact with the soil. In the West, Knapp ('12, p. 7) has shown that the upper part of the bole of fire-killed Douglas fir "deteriorates more rapidly than the lower part because of the larger proportion of sapwood. . . . *Down timber* is less subject to insect attacks than standing timber but decays more rapidly." Hopkins ('09, p. 128) publishes a photograph of an Engelmann spruce forest, at an elevation of 10,000 feet on Pike's Peak, which was killed about 1853-56, about fifty years previously; there were, however, still preserved on the trunks, the markings of the beetles which killed the trees. The rate of decay in warm moist regions is relatively more rapid than that in cool and dry regions.

As wood decays it loses the characteristics which distinguish the living and solid trees. For this reason we anticipate that animals showing a preference for different kinds of trees are more characteristic of the living and sound wood, and decline in numbers as disintegration progresses, being replaced by the kinds which live in and upon decaying wood. There is thus with the decay of wood a progressive increase in the kinds of animals characteristic of humus. This is true in general terms, for certain animals even show a preference for certain kinds of decayed wood, while others are general feeders upon almost any kind of such wood. Hamilton ('85, p. 48) has observed that "*Cucujus clavipes* feeds on locust, maple, sycamore, wild cherry, hickory, white oak, elm; *Clinidium sculptile* on spruce, hemlock, tamarack, black oak, hickory, chestnut, ash, gum, poplar, birch; *Synchroa punctata* on all species of oak, hickory, apple, cherry, mulberry, Osage orange, chestnut; *Dendroides canadensis* on nearly everything."

The decay of wood begins when moisture and fungi are able to gain entrance, as at some point of injury—an insect burrow, a

broken branch, a fire scar near the soil, etc.—and spreads from such source. The time of year, and the method by which a tree is killed will often have an important influence upon the kind of invasion by animals. A tree which is killed and remains standing is not so liable to rapid decay as one which lies upon the ground and becomes moist. It is readily seen that there are a vast number of causes which operate to produce all degrees of decaying wood. A fallen hardwood trunk and its stump are liable to begin decaying at the sap-wood layer, just under the bark. The bark loosens; and moisture, fungi, and animals mutually hasten each others' activities, and the processes of disintegration. Under such bark, in the Bates woods, were found the following: queens of the carpenter-ants (*Camponotus*) establishing their colonies; the flat-bodied larvæ of *Pyrochroa*; the large Carolina slug (*Philomycus*); the beetle *Passalus cornutus*; white ants (*Termes flavipes*); the rotten-log caterpillar (*Scolecocampa liburna*); the snails *Zonitoides arborea* and *Pyramidula perspectiva*; *Polydesmus*, *Galerita janus*, and a *Melanotus* larva. These are fairly representative kinds of animals of the log community at this stage of development. It will be noted that the ants, the white ants, and *Galerita* are predaceous, but that the remainder are probably sustained largely by rotten wood, herbaceous plants, and fungi. With the progressive radiate (when beginning within) or convergent (when beginning without) growth of decay this animal community migrates into the log or stump as its favorable habitat increases in area and thickness. When this process has made considerable advance and the log has become soft, the animals which began at the surface or within are able to penetrate the entire log. This may be considered an intermediate stage in the transformation of the log to humus. This biotic community, composed of fungi and animals, commonly begins its work at the surface (most frequently, in the case of fallen trees, on the under side where the log touches the ground) and moves progressively inward, transforming the log as it goes. In its wake there follows a *later stage of the transformation*—the dark-colored humus layer, composed of decayed wood, the dead bodies of animals, and their excrement. The large number of years involved in such a transformation makes it possible for many kinds of animals to find this sort of habitat,—just as old artificial ponds are more fully stocked with animals than newly excavated ones. Slowly developing animals are thus able to live here, the conditions prevailing being at the other extreme from those suited to a life in the ephemeral fungi.

As a fallen or standing trunk dries out, particularly upon the upper surface, if fallen, the bark often curls, cracks, and loosens from the wood. In such a situation in the Cottonwood forest at Urbana,

the spider *Corirachne versicolor* Keys. was taken by me March 23. At times such places are relatively dry, and in them I have frequently found, in large numbers, the tenebrionid beetle *Nyctobates pennsylvanica* DeG. This species was taken at Bloomington March 9 and June 15. A similar-appearing relative, with enlarged femora, *Merinus laevis* Oliv., was taken June 15 and July 29. When *Nyctobates* is placed in a corked vial it proceeds to chew the cork (which is about of the firmness of the bark and wood in which it lives) and makes a fine sawdust. *Nyctobates* was taken by me November 18 under loose dry bark of the sugar maple (*Acer saccharum*) in the Cottonwood forest (No. 549, C.C.A.). The March and November records of this species clearly indicate that the beetle hibernates in the wood. *Scotobates calcaratus* Fabr. and *Xylopinus saperdioides* Oliv. are other tenebrionids which live under bark. I have taken *Scotobates* at Bloomington June 29 and July 2, and *Xylopinus* June 29, July 2 and 26. The cucujid beetle *Brontes dubius* Fabr. was taken at Bloomington March 9, April 5, July 25, 26, and September 21, and *Cucujus clavipes* Fabr. (Pl. XXVIII, fig. 8), whose larvæ Smith reports to be predatory, was taken March 6. Hopkins ('93b, p. 177) reports both of these beetles from the bark of dead deciduous trees. Townsend ('86, p. 66) reports both under the bark of decayed basswood, and Packard ('90, p. 223) records *clavipes* from under oak bark. Another common beetle, a spondylid, *Parandra brunnea* Fabr. (Pl. XXIX, figs. 1, 2, and 5), I have taken from decayed wood at Bloomington. The larvæ, pupæ, and beetles were found in rotten wood July 23, and the beetles also on July 25, 26, and August 6. Hart ('11, p. 68) calls this the heart-wood borer on account of its methods of boring in this part of several kinds of deciduous trees. It burrows largely in rotten, and, also, according to Mr. W. P. Flint, in sound, walnut heart-wood. In recent years Snyder ('11, p. 4) reports much injury by it to telephone poles. He says: "The insect attacks poles that are perfectly sound, but will work where the wood is decayed; it will not, however, work in wood that is 'sobby' (wet rot), or in very 'doty' (punky) wood." As this injury is near the ground, the invasion is probably begun in rotten wood by the young larva and extended later into the firm wood. This same author ('10, pp. 7-8) lists several other insects associated in poles with *Parandra*. Clearly this beetle is an inhabitant of wood in the early stages of decay. It apparently does not kill trees, nor remain to the last in the log with *Passalus*, but occupies an intermediate position. This is a representative of a class of insects whose ecology has been rather slighted in the past because of the economic conditions which permitted the neglect of insects which were not supposed to be of much importance.

But with increased economic efficiency this class of insects which hasten the decay of wood will receive more attention. Mr. W. P. Flint informs me that in the southern part of Illinois the white ants (*Termes flavipes*) and the ant *Cremastogaster lincolata* are very active in decaying wood. Other inhabitants of damp rotten wood, logs, and roots, are the larvæ of the large scarabæid *Xyloryctes satyrus* Fabr. I have taken them at Urbana, Ill., October 1, 12, and 15 in the Brownfield woods, and in the Cottonwood forest October 8. Smith ('10, p. 321) reports the larva feeding in the roots of ash, and Walsh (Proc. Boston Soc. Nat. Hist., Vol. 9, p. 287. 1863), from the roots of grass. *Osmoderma scabra* Beauv. (Pl. XXIX, fig. 4) was taken at Bloomington, Ill., July 26, and *O. eremicola* Knoch (Pl. XXIX, fig. 3) in June at Bloomington, and at Springfield, Ill., in July by A. B. Wolcott. The larvæ of both these species are known to live in decaying wood; the adults are found under the bark, and according to Packard ('90, p. 283) in heart-wood. *Prionus imbricornis* L. (Pl. XXIX, fig. 6) lives under bark and in decaying wood. One individual was taken at Bloomington July 22. *Orthosoma brunneum* Forst., another species with larval habits similar to *Prionus*, was taken at the same place during July. It lives in a great variety of decaying wood. The larvæ of the common rose flower-beetle, *Trichius piger* Fabr. (Pl. XXIX, fig. 7), taken by me June 16, 18, 19, 22, 25, and July 7, and at Savanna, Ill., May 30, live, according to Smith ('10, p. 322), in "old oak stumps." The larvæ of *Lucanus dama* Thunb. (Pl. XXXI, figs. 1 and 2) live in decaying wood. The beetle was taken June 30, in July, and August 1 under wood. The beetles of *Dorcus parallelus* Say were taken May 12, July 25, and August 6. *Ceruchus piccus* Web. was taken April 5, and one taken July 25 was covered with white fungus threads. The larva of *Dorcus* and *Ceruchus* feed mainly or solely in rotten wood. On Plate XXX the larva of *Meracantha contracta* is seen in its burrow in decayed wood. These insects from decayed wood are among the most common of woodland insects.

In concluding this part on insects of rotten wood the following papers should be mentioned, which will be of assistance to one pursuing this subject: Townsend ('86), on beetles in decaying basswood; Packard ('90, pp. 222-223), on insects of decaying oak, (l. c., pp. 283-284) in decaying elm, (p. 424) in decaying maple, and (p. 612) in hackberry; Felt ('06, pp. 484-494) on insects in decaying wood and bark of deciduous trees; and Shelford ('13a, pp. 245-247) on insects of decaying beech. Dury (Ent. News, Vol. 19, pp. 388-389, 1908) states that he took over three hundred species of beetles

from a much decayed log; unfortunately, however, he does not publish the list.

Some of the animals which invade the log in its earliest stages of decay continue to hold possession throughout the transformation. Thus *Passalus* arrives early, as soon as the bark begins to loosen, and remains to a late stage in the process—when the log or stump can easily be kicked to pieces. The rotten log caterpillar *Scolecocampa* has a somewhat similar history in the log. When a log reaches such a condition that it looks like brown meal, and is nearly level with the surface of the ground, it may during the summer become so dry that it affords a favorable haunt for myrmeleonid larvæ; probably the ant-lion of *Myrmeleon immaculatus* DeG., a woodland species.

In the foregoing manner the tree trunk decays and naturally sinks lower and lower, the woody fibers disappear, the debris becomes darker in color, the autumn leaves, twigs, and other litter of the forest gradually add layer to layer, and finally the remains of the log become blended with the humus of the forest floor. Thus is completed one of the most important cycles of transformation to be found in the forest habitat. The following diagram, Figure 17, has been prepared to show the general train or succession of insects corresponding to these changes in the conditions in trees.

It will simplify this discussion of changes in the animal associations, caused either by changes in the character of the forest trees or by changes in the woodland vegetable products, to state concisely the main general factors involved in these changes. To explain zoological facts it is often necessary to utilize the products of the allied sciences, and the student may even be forced to make some investigations for himself in these fields, because these sciences may not have especially treated his specific problems. All relations become of zoological significance, however, when they bear upon a zoological problem. The major group of causes or processes which operate in such a way as to initiate changes in forests may be grouped provisionally as follows.

1. Geological and physiographic processes: crustal movements of the earth, as earthquakes; the wearing down or erosion of the land, as the mowing down of forests by landslides.

2. Climatic processes: wind storms, tornadoes, ice and sleet storms, etc., which injure trees and destroy forests; lightning and fires,—in brief, any climatic factor which is able to injure or kill trees.

3. The processes of competition and succession of forest vegetation; based upon plant activities, as when an oak-hickory forest is followed by a red oak-hard maple forest, or when fungi kill trees. These causes are largely botanical problems.

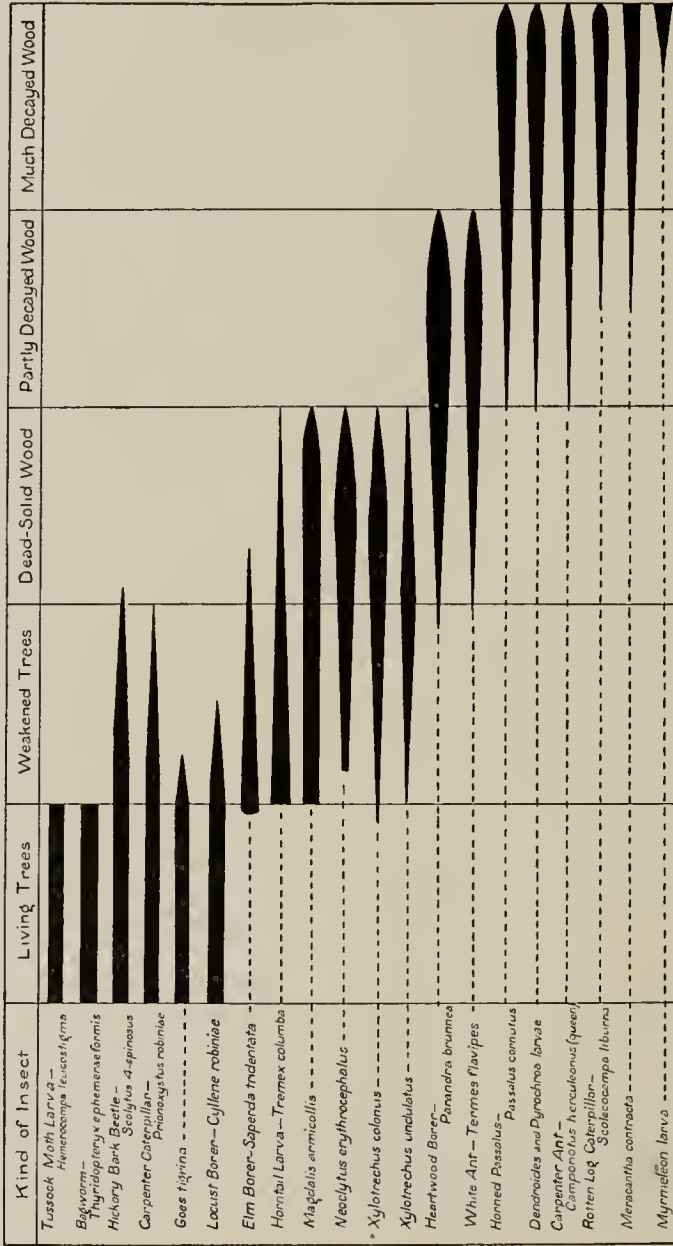


Fig. 17. Diagram showing the succession of insects living on or in trees, from the living tree—through the stages of weakened trees, dead but not solid wood, partly decayed wood—to thoroughly decayed wood. The preferences are distinctly marked. (See p. 153.)

4. Destruction of trees by animals: the processes of defoliation, borings in branches, bark, trunk, or roots, and the girdling of trees. Fires started by man, depending on the degree of destruction, cause new cycles of succession. Both beavers and man build dams, flood areas, and thus kill trees.

5. Combinations of physical and organic processes; the flooding of river bottoms by driftwood rafts which become converted into dams and thus submerge large areas.

Since it is most usual for these causes to act, not singly but in various combinations, and since they also vary greatly in their degrees of influence, their operation is extremely complex. The drowning of the forests along the Mississippi River through the sinking of the land by the New Madrid earthquake, is a good example, showing how a large tract of forest may be killed and much dead and decayed wood formed, as has been shown by Fuller ('12)—(Plate XXXII). Tarr and Martin ('12) have shown how destructive to forests the earthquakes are in Alaska. The influence of the New Madrid earthquake upon animal life has not been investigated, but it is not too late even today, after more than one hundred years, to make important studies on this subject. On the other hand, the processes of erosion operate more continuously than the periodic earthquakes, and tend to degrade the land, lower the water-level, and to change the habitats in swamp and other forests.

The results of climatic influences are seen in the amount of injury done by sleet, which, weighing down the branches, breaks many of them and leaves the fractured stubs as favorable points for attack by fungi and insects. Webb ('09) has shown that when a tornado passed through Mississippi and Louisiana the felled pine forests were from one to three miles wide. Practically all of this timber became infested with the larvæ of *Monohammus titillator* Fabr. After a severe frost in Florida the dead wood of the orange-trees became infested by wood-boring larvæ, which spread from this wood to the enfeebled living wood, as Hubbard (Howard, '95) observed. Lightning (Plummer, '12) kills and maims many trees, producing dead wood, and through fires started in the same manner much more damage is done. Hopkins ('09) considers that much of the injury attributed to fire is primarily due to insects which made the dead and dry fuel for the destructive fire work.

That competition among trees weakens some of them is well known. This weakening makes them more susceptible to attack by fungi and insects. In a forest where the shade-enduring trees can shade out all competitors, the shrubs and trees which are intolerant show just such a lack of resistance. As an example of this process

the following case may be cited: Mr. W. P. Flint informs me that he has observed that shaded, suppressed white oaks in southern Illinois are much more heavily infested by the bark-louse *Aspidiotus obscurus* Comstock, and by the beetle *Phymatodes varius* Say than are the vigorous trees.

Trees may be injured and killed by animals in many ways, as by defoliating them, boring in the twigs, trunk, or roots, and by the destruction of the bark and sap-wood of the trunk. Of injuries caused by insects the work of defoliators of hardwoods is one of the most conspicuous kinds. Repeated defoliation of elms by the elm leaf-beetle *Galerucella luteola* Müll. will, according to Felt ('05, p. 61), so weaken a tree that *Tremex columba* finds suitable food in its diseased and dying substance. With *Tremex* present its parasite *Thalessa* also arrives. The maple borer, *Plagionotus speciosus* Say, may also weaken a tree and pave the way for *Tremex* and *Thalessa*. A study of the after effects of the prominent defoliators of shade and forest trees, such as the fall web-worm (*Hyphantria cunea*), the white-marked tussock-moth (*Hemerocampa leucostigma*, Plate XXXI, figs. 3, 4 and 5), the bag-worm (*Thyridopteryx ephemeraformis*), the larch saw-fly (*Nematus erichsonii*), the gypsy moth (*Porthetria dispar*), and the brown-tailed moth (*Euproctis chrysorrhæa*), would doubtless throw much light upon the details of successions caused by insects. I have not been able to learn that this subject has been studied carefully in this country. Such injuries are clearly not limited to hardwoods, for many similar observations have been made in coniferous forests. Hewitt ('12, p. 20) has listed some of the beetles which follow the defoliation of larches by the larch saw-fly. Hopkins ('01, pp. 26-27) found that the spruces of New England were being killed by the bark-beetle *Dendroctonus picaperda* Hopkins; that following the damage done came other beetles, such as *Polygraphus rufipennis* Kby., which attacks the weakened tops of the trees, following the attack of its predecessors on the trunk or base; and that also, following *Dendroctonus*, came *Tetropium cinnamopterum* Kby., which mines in the dead trees. The yellow pines of the West are killed by the bark-beetle *Dendroctonus ponderosa*, and this is followed by many kinds of insects which live on the decaying bark and wood, as Hopkins ('02, pp. 10-16) has shown. He also states ('09, p. 68) that in the Appalachian Mountains *Dendroctonus frontalis* Zimm. killed a large part of the trees in an area "aggregating over 75,000 square miles." Such examples of multiple attack show the complexity of the causes influencing forest life. When the great amount of influence which insects are able to exert and do exert upon forests is considered, the question is raised as to what may be their



influence in determining the *kind of trees* that compose what the plant ecologists (Cowles and others) consider the climax forest of eastern North America—the maple-beech forest. It has long been known (Packard, '90, p. 515) that the beech has remarkably few insect enemies, perhaps about fifty species being recorded. Its associate, the hard maple (*Acer saccharum*), has many more, and the oaks and hickories, which are largely absent from the climax forest and characterize the changing stages preceding the climax, are preyed upon by more insects than any other of our trees, their number possibly equaling the sum total of all the other forest-tree insects.

A good example of the combined influence of physical and organic factors is seen in the huge rafts of driftwood which have accumulated in the Red River of Louisiana and Arkansas (Veatch, '06)—(Pls. XXX and XXXIV)—on such an extensive scale that hundreds of acres of the bottoms were flooded and the forests killed, producing vast quantities of dead and decaying wood. With the opening of the drainage canal, connecting Lake Michigan with the Illinois River, the bottoms were so flooded that willows, maples, cottonwoods, etc., on the lowest ground were killed along the river for many miles, and presented a view similar to that shown on Plate XXXV. In this manner vast quantities of dead and decaying wood have been made available as food and habitat for wood-inhabiting invertebrates.

### 7. *Interrelations within the Forest Association*

The dependence of the animal upon the physical and organic environment is primarily a phase of the problem of maintenance. In the forest these relations are so intricate, and involve the lives of so many kinds of animals, that a forest, like the prairie, must be looked upon as a mosaic composed of a vast number of smaller animal, or biotic communities, each one not only interrelated at many angles within itself, but similarly connected with the other communities of the forest. Walsh ('64, pp. 549–550) has given us a graphic account, not of the forest as a whole but of one of its smallest units—those which he found clustered about the galls of willow trees, the willow leaf-gall community. He says:

“Nothing gives us a better idea of the prodigious exuberance of Insect Life, and of the manner in which one insect is often dependent upon another for its very existence, than to count up the species which haunt, either habitually or occasionally, one of these Willow-galls, and live either upon the substance of the gall itself or upon the bodies of other insects that live upon the substance of the gall. In the single gall *S [alicia]. brassicoides* n. sp. there dwell the *Cecidomyia* which

is the maker of the gall—four inquilinous Cecidomyia—an inquilinous saw-fly (*Hymenoptera*)—five distinct species of Microlepidoptera, some feeding on the external leaves of the gall, and some burrowing into the heart of the cabbage, but scarcely ever penetrating into the central cell, so as to destroy the larva that provides them with food and lodging—two or three Coleoptera—a Psocus (*Pseudoneuroptera*)—a Heteropterous insect found in several other willow-galls—an Aphis which is also found on the leaves of the willow, but peculiarly affects this gall—and preying on the Aphides the larva of a Chrysopa (*Neuroptera*) and the larva of a Syrphide (*Diptera*)—besides four or five species of Chalcididæ, one Braconide Ichneumon (*Hymenoptera*) and one Tachinide (*Diptera*), which prey on the Cecidomyia and the Microlepidoptera—making altogether about two dozen distinct species and representing every one of the eight Orders. . . . If this one little gall and the insect that produces it were swept out of existence, how the whole world of insects would be convulsed as by an earthquake! How many species would be compelled to resort for food to other sources, thereby grievously disarranging the due balance of Insect Life! How many others would probably perish from off the face of the earth, or be greatly reduced in numbers! Yet to the eye of the common observer this gall is nothing but an unmeaning mass of leaves, of the origin and history of which he knows nothing and cares nothing!”

With this conception of a community in mind it is only necessary to refer to the following diagram (Fig. 18) to see how immaterial it is as to where one begins to take up this thread of interrelations, for sooner or later every animal and plant in the association will have to be passed in review and its influence recognized as a response to its conditions of life.

## ECOLOGICALLY ANNOTATED LIST

### I. PRAIRIE INVERTEBRATES

An exhaustive study of the animal ecology of a region or an association must be based upon a thorough investigation of the ecological relations of the individual animals composing it. An *ideal* annotated list in an ecological paper should, therefore, include for each species a complete account of its life history, its behavior, its physiology, and the structural features which would in any way contribute to an understanding of the response of the animal to its organic and inorganic environment. At present we have no such knowledge of the animals of any locality or of any complex association of animals.

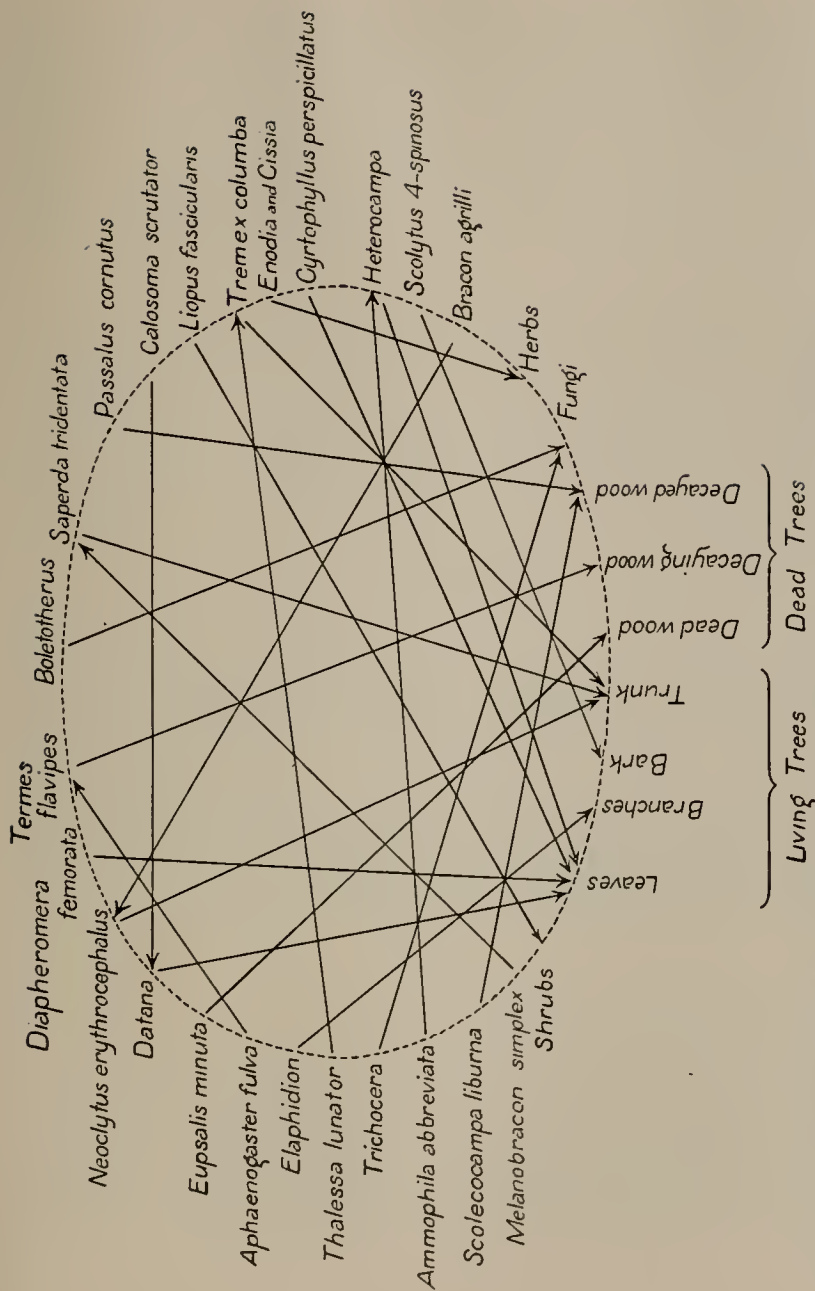


FIG. 18. Diagram showing the complex network of interrelations among forest invertebrates, as shown by their food relations. The arrows point toward the food of the animal.

In a preliminary study, like the present one, it is desirable to record rather fully the observations made in the region studied, because we have so few descriptions of the conditions of life on our prairies. An effort has been made to give for each species the date of observation or collection, the locality or "station" where found, observations on habits and life history, and the field numbers of the specimens secured. These numbers illustrate how observations may be accumulated, upon a large number of individuals, without the observer's being familiar with them, or even knowing their scientific names.

It is really surprising how little is recorded about some of the commonest animals of the prairie and forest in zoological literature. Other animals, particularly those of economic importance, are treated rather fully, but generally with little relation to their natural environment. In this list it has been considered desirable not to give an extended account of each kind of animal, but to refer to some of the most important literature concerning it, so that one may gain some general idea of the ecological potentialities of each kind of animal.

## MOLLUSCA

### PHYSIDÆ

#### *Physa gyrina* Say.

Three half-grown young and an adult shell were taken among swamp milkweed, *Asclepias incarnata* (Sta. I, *g*), Aug. 11 (No. 19). All show distinct varices; the last one formed on the adult shell is very distinct. These scars mark a period of rest or slow growth which was probably due to hibernation or the drying-up of the swamp. *Physa*, as a rule, can not endure such extreme desiccation as can *Lymnaea*, and to that degree is indicative of a more permanent water supply. Our specimens were all dead, but some of them so recently that fly maggots came from them.

### LYMNÆIDÆ

#### *Galba umbilicata* (C. B. Adams).

A single specimen of this small snail was taken among swamp milkweeds (Sta. I, *d*) Aug. 11 (No. 18). Mr. F. C. Baker, who determined the specimen, writes me that this is the first record of this species for Illinois. Baker remarks ('11, p. 240) that this species is "abundant in still water in sheltered borders of rivers, in small brooks, ditches, and streams, and in shallow overflows. Clings to dead leaves or other submerged debris, or crawls over the muddy

bottom of its habitat, in shallow water. Associated with *Galba obrussa*, *Aplexa hypnorum*, and the small planorbes (Baker). In ditches and brooks in pastures (True). Common in damp places and in ditches along roads where water collects only in rainy weather (Nylander)."

Our specimen was taken where the water was very shallow (only a few inches deep) and overgrown with vegetation. This species appears to be a strictly shallow-water marginal form, and has considerable power of enduring desiccation.

## CRUSTACEA

### ASTACIDÆ

*Cambarus gracilis* Bundy. Burrowing Prairie Crawfish. (Pl. XXXVI.)

The prairie crawfish was abundant at Sta. I, *d*, on the wet parts of the prairie. T. L. Hankinson dug some specimens from their holes, which proved to be of this species. Specimens were captured Apr. 23, 1911, and Aug. 9, 1910 (No. 7442).

Crawfish burrows were observed to traverse the dense yellow clay with which the railway embankment had been built over a swampy place at Sta. I, *d*. Burrows were also observed at Sta. I, *c*, among the colony of *Silphium terebinthinaceum* and *Lepachys pinnata*, and also at Station I, *g*.

I have found the characteristic claw of this species on wet prairie along the railway track at Mayview, Ill. At this time, September 26, 1912, burrows with fresh earth were numerous, far from any stream. (No. 482, C. C. A.)

*Cambarus diogenes* Girard. Diogenes Crawfish.

Crawfish of this species were taken by T. L. Hankinson at Sta. I, *d* (No. 8047A). The presence of this chimney builder at this station suggests that the numerous chimneys shown in Figure 2, Plate IIIB are in part the work of this species though they are in part also the work of *gracilis*.

### ARACHNIDA

#### PHALANGIIDA

#### PHALANGIDÆ

*Liobunum politum* Weed. Polished Harvest-spider. (Pl. XXXVII, fig. 3.)

Two small phalangiids, both probably of this species, were found under moist wood upon the prairie (Sta. I, *g*) Aug. 8. Concerning

these specimens, Mr. Nathan Banks writes me that they are "young, not fully colored, but probably *Liobunum politum* Weed."

Weed ('91) reports that this rather rare species occurs in fields and forests, and is seldom found about buildings. He has found it among river driftwood, and says ('92a, p. 267): "It sometimes occurs under boards in fields, and is often swept from grass and low herbage." When disturbed it emits, as do others of its family, a liquid with a pungent odor. Weed ('91) has made some observations on its breeding habits. He notes that in confinement it ate plant-lice.

*L. formosum* Wood was taken by me upon the lodged driftwood of a small brook on the border of a forest at White Heath, Ill., May 4, 1911. (No. 505, C.C.A.) This species, according to Weed ('89, p. 92), hibernates as an adult.

## ARANEIDA

### EPEIRIDÆ

*Argiope aurantia* Lucas (= *riparia* Hentz). Common Garden Spider. (Pl. XXXVII, figs. 1 and 2.)

This is very abundant, and the most conspicuous spider on the prairie. Found among the prairie grasses (Sta. I, *g*) Aug. 8 and 12 (Nos. 6 and 39); in its web among goldenrod, *Solidago* (Sta. I), Aug. 12 (No. 26); among the swamp grasses (Sta. I, *a*) Aug. 28 (No. 179); and among *Elymus* (Sta. I, *c*) Aug. 24 (No. 153); from sweepings made in the colony of *Lepachys pinnata* (Sta. I, *e*) Aug. 12 (No. 40); and on the Loxa prairie (Sta. II) Aug. 13 (No. 49), Aug. 27 (No. 178), and Aug. 28 (No. 179); in an open area in the upland Bates woods (Sta. IV, *a*) Aug. 17 (No. 93); and in an open glade in the lowland forest (Sta. IV, *c*) Aug. 22 (No. 143). In its webs in the swamp-milkweed colony (Sta. I, *d*) Aug. 9 the large dragon-fly *Libellula pulehella* Drury was found entrapped; a grasshopper, *Melanoplus differentialis* Thomas, was also found entrapped (Sta. I, *a*) Aug. 28 (No. 179); and a large butterfly, *Papilio polyxenes* Fabr., was discovered (Sta. I, *d*) Aug. 12 (No. 45).

The openness of an area rather than its prairie character appears to determine the habitat of this spider. This is evidenced by its presence in open spaces within the forest. It flourishes in gardens for similar reasons. Years ago I found this species very abundant in the late summer and fall at Bloomington, Ill., in an asparagus bed, after the plants had been allowed to grow up and form a rank mass

of vegetation. This species has received considerable study. McCook ('90) and Porter ('06) record many observations on this species. Howard ('92b) has discussed its hymenopterous parasites and those of some other spiders.

No specimens of *Argiope transversa* Emerton, the transversely black-and-yellow-banded relative of *aurantia*, were observed at Charleston, although they are fairly abundant in colonies of prairie vegetation near Urbana, e. g. at Mayview, Ill., Sept. 26, and on Nov. 26, 1911. I have seen this species only among colonies of prairie vegetation along railway rights-of-way.

#### THOMISIDÆ

*Misumena alcatatoria* Hentz. Ambush Spider.

This crab-like flower spider was abundant upon flowers: on the mountain mint, *Pycnanthemum flexuosum* (Sta. I, *g*), Aug. 8 (No. 6); on the mint, (Sta. I) with a giant bee-fly, *Exoprosopa fasciata* Macq., Aug. 12 (No. 31); on the Loxa prairie (Sta. II) with the same kind of fly, Aug. 13 (No. 47); on the prairie (Sta. I, *g*) on the flower of the swamp milkweed, *Asclepias incarnata*, Aug. 24 (No. 157) with a male bumblebee, *Bombus separatus* Cress.; on *Andropogon* (Sta. I, *g*) with a large immature female of *Conocephalus*, Aug. 24 (No. 159); on the Loxa prairie (Sta. II) on flowers of *Eryngium yuccifolium*, Aug. 27 (No. 178); in the colony of *Elymus* (Sta. I, *a*) Aug. 28 (No. 179); and in the open glade of the lowland Bates woods (Sta. IV, *c*) on the flowers of *Eupatorium caelestinum*, with a very large syrphid fly, *Milesia ornata* Fabr. (= *virginicensis* Drury), Aug. 26 (No. 184). These insects captured by the spiders vary from about five to ten times the size of their captor. There is considerable variation of color in this series of spiders.

It would be well worth while for some one to make a special study of this spider, and give us an account of its methods of capturing food and finding fresh flowers, with a full account of its life history. McCook ('90, Vol. 2, pp. 367-369) gives some information about the habits of an allied species of spider, but the account is meager. Some observations on the breeding habits of this species have been made by Montgomery ('09, p. 562); and Pearse ('11) has recently published the results of an interesting study of the relation between the color of these spiders and the color of the flowers they frequent. He concludes that although this spider may change its color slowly (from yellow to white), it does not do so with rapidity or in such a way as to match its surroundings, and, further, that it does not seek an environment or a flower colored like itself.

He finds, however, that on *white* flowers, *white* spiders occur generally, that on *yellow* flowers, *yellow* spiders occur, and also that upon flowers of colors other than white and yellow, such as purple, pink, and blue (p. 93), white spiders predominate.

#### ATTIDÆ

*Phidippus* sp.

This jumping spider was taken Aug. 12 (No. 34) on the common milkweed, *Asclepias syriaca*, along the railway tracks (near Sta. I, a), and when captured had in its jaws fragments of what seemed to be *Diabrotica 12-punctata* Oliv.; but as the fragments were lost during the process of capture, this determination was not made certain.

#### ACARINA

##### TROMBIDIIDÆ

*Trombidium* sp. Harvest-mites. Chiggers. (Pl. XXI, figs. 1 and 2.)

These are the immature six-legged stage of a mite or mites which when mature have eight legs. The young are parasitic on insects (Banks, Proc. U. S. Nat. Mus., Vol. 28, pp. 31-32, 1904); the adults prey upon plant-lice and caterpillars; one species also eats locusts' eggs.

These mites were very abundant on the prairie north of Charleston (Sta. I), and became such a pest that relief had to be sought in a liberal application of flowers of sulphur to our legs and arms, as is recommended by Chittenden ('06).

#### INSECTA

##### ODONATA

##### LIBELLULIDÆ

*Sympetrum rubicundulum* Say. Red-tailed Dragon-fly.

This dragon-fly was taken in the prairie grass zone (Sta. I, g) Aug. 8 (No. 4.) It is one of our commonest kinds. The nymphs live in small bodies of standing water. The adults forage for small insects in open places, along hedge rows, and in open forest glades. For the habitats of dragon-fly nymphs, reference should be made to Needham (Bull. 68, N. Y. State Mus., p. 275, 1903). Williamson ('00, pp. 235-236) has observed robber-flies carrying this species, and has found this and other species of dragon-flies in the webs of the spider *Argiope*.



*Libellula pulchella* Drury. Nine-spot Dragon-fly. (Pl. XXXVIII, fig. 2.)

Individuals were abundant in both colonies of swamp milkweeds (Sta. I, *d* and *g*) and several were seen entrapped in webs of *Argiope aurantia* (Sta. I, *d*) Aug. 9. This is one of the most abundant of our large dragon-flies. It frequents small bodies of water and sluggish pond-like streams. Williamson has taken it also in the webs of *Argiope*. This large powerful insect is able to do considerable damage to a spider-web and then make its escape. Among the milkweeds (Sta. I, *d*) an individual was seen by T. L. Hankinson to escape from a web. This dragon-fly, like most of its kind, captures small insects on wing; one kind, however, is reported to have dug a cricket out of the ground (Psyche, Vol. V, p. 364. 1890).

#### NEUROPTERA

##### MYRMELEONIDÆ

*Brachynemurus abdominalis* Say. Adult Ant-lion.

A single specimen was taken along the railway track north of Charleston (near Sta. I, *g*) Aug. 12 (No. 36). This is a species which frequents dry habitats. The larva is unknown, but is probably predaceous—as other ant-lion larvæ are and as the adult is supposed to be.

Two adult females were taken July 19 and 20, 1907, at Cincinnati, Ohio, in my room, to which they were attracted by the electric light. Another female was taken Aug. 8, 1901, at Gate City, Virginia (near Big Moccasin Gap). Determined by R. P. Currie.

##### CHRYSOPIDÆ

*Chrysopa oculata* Say. Lacewing. (Pl. XXXVIII, fig. 1.)

A single specimen of this insect was taken among prairie grasses (Sta. I, *g*) Aug. 12 (No. 44). The larvæ feed upon plant-lice, and the adults are also considered predaceous. Howard (Proc. Ent. Soc., Wash., Vol. 2, pp. 123–125. 1893) has given a list of their numerous hymenopterous parasites. Mr. T. L. Hankinson captured one also (Sta. I) July 3, 1911 (No. 7665). Fitch ('56) published many observations on the members of this genus; and Marlatt ('94a) has written on the life history of this species.

## ORTHOPTERA

## ACRIDIDÆ

*Syrbula admirabilis* Uhler.

One specimen of this grasshopper was found in the tall prairie grasses blue-stem *Andropogon* and *Panicum* (Sta. I, *g*) Aug. 8 (No. 3). Morse ('04, p. 29) says this species frequents "open country" and is "common in upland fields amid *Andropogon* and other coarse grasses."

*Encoptolophus sordidus* Burm. Sordid Grasshopper. (Pl. XXXIX, fig. 1.)

One nymph of this species was taken in the prairie-grass colony north of Charleston (Station I, *g*) Aug. 12 (No. 44); another (No. 158) on Aug. 24 in the colony of *Lepachys pinnata* (Sta. I, *c*); and an adult (No. 48) Aug. 13 at Loxa (Sta. II, *a*) from the flowers of *Silphium integrifolium*.

This is a species characteristic of dry open places, where the vegetation is low. The peculiar snapping sound made by the male when on wing is quite characteristic. (Cf. Hancock, '11, pp. 372-373.)

*Dissosteira carolina* Linn. Carolina Grasshopper. (Pl. XXXIX, fig. 4.)

A very reddish specimen of this species was taken in a cleared bottom forest at River View Park, about three miles southeast of Charleston, Aug. 19 (No. 95). Many specimens were observed in the pasture above the "Rocks," on the Embarras River about three miles east of Charleston. These individuals exhibited to a marked degree the hovering, undulating flight which is so characteristic of this species during the hot days of summer and early autumn. Townsend (Proc. Ent. Soc. Wash., Vol. 1, pp. 266-267. 1890) has made interesting observations on this habit, and finds that it is mostly the males which participate in this courting ceremony, as he considers it. There appears to be more or less of a gathering of individuals when one of the locusts performs. There were perhaps half a dozen performing in the colony observed at the "Rocks." Townsend (Can. Ent., Vol. 16, pp. 167-168. 1884) has considered this flight as related to breeding. Some one might study this subject with profit, and determine its meaning. Poulton's paper "On the Courtship of certain Acridiidae" (Trans. Ent. Soc. London, 1896, Pt. II, pp. 233-252) might prove helpful in this connection.

This species seems to have been influenced by man to a marked degree. Its original habitat appears to have been natural bare spots,

such as sandy beaches, banks of streams, sand-bars, and burned areas. In a humid forested area such places are usually in isolated patches, or in more or less continuous strips as along shores; but since the activities of man produce large cleared areas and bare spots, such as roads, railways, and gardens, the favorable area of habitat for this species has been vastly increased. Consult Hancock ('11, pp. 340-347) for observations on the habits of this species.

*Schistocerca alutacca* Harr. Leather-colored Grasshopper. (Pl. XXXIX, fig. 3.)

One specimen of this large grasshopper was taken east of Charleston, on the prairie which grades into the forest (Sta. III, *a*) Aug. 15 (No. 59). Morse ('04, p. 39) and Hart ('06, p. 79) recognize that this species lives among a rank growth of vegetation and brush. In general the local conditions are open or transitional, and may be compared to those of a shrubby forest margin, and not to those of the distant open prairie or to conditions within the forest. (Cf. Hancock, '11, pp. 366-370.)

*Melanoplus bivittatus* Say. Two-striped Grasshopper. (Pl. XL, fig. 3.)

This grasshopper was taken from flowers of the rattlesnake-master, *Eryngium yuccifolium*, on the prairie at Loxa (Sta. II), Aug. 13 (No. 55). It is a little surprising that it was so rare this season on the prairie areas examined, as it is usually a common species. Hancock ('11, pp. 356-359) has discussed this grasshopper.

*Melanoplus differentialis* Thomas. Differential Grasshopper. (Pl. XXXIX, fig. 5, and Pl. XL, fig. 1.)

This species was generally common in open areas, especially on the prairie, but was also found in open places in the forest. It was very abundant in the colonies of swamp prairie grasses, *Spartina* and *Elymus* (Sta. I, *a*), Aug. 28 (No. 179); in the upland prairie grasses, as *Andropogon* and *Panicum* (Sta. I, *g*), Aug. 12 (No. 39); and in colonies of *Lepachys* (Sta. I, *c*) Aug. 12 (No. 40); also at Loxa on *Silphium integrifolium* (Sta. II, *a*) Aug. 13 (No. 48).

This must be considered as one of the most common and characteristic of prairie animals. Notwithstanding the destruction of the original prairie, its habitat has been perpetuated, particularly upon waste and neglected areas, such as fence rows, roadsides, railway rights-of-way, and vacant city lots.

*Melanoplus femur-rubrum* DeG. Red-legged Grasshopper. (Pl. XXXIX, fig. 2.)

This species also is one of the most common and generally distributed insects upon open areas. It was found among the prairie grasses *Andropogon* and *Sporobolus* (Sta. I, *g*) Aug. 8 and 12 (Nos. 3 and 39); in the *Lepachys* colony (Sta. I, *e*) Aug. 12 (No. 40); and in *Elymus* and *Spartina* (Sta. I, *a* and *c*) Aug. 24 and 28 (Nos. 153, 179, and 180). As Hart ('06, p. 81) has remarked, it is common in cultivated areas. Cultivation appears to be distinctly favorable to it; *differentialis*, on the other hand, seems to thrive best in waste places.

#### LOCUSTIDÆ

*Scudderia texensis* Sauss.-Pict. Texan Katydid.

This is the common and characteristic katydid of the prairie areas. It was found (Sta. I, *g*) among the tall swamp milkweeds Aug. 8 (No. 2); in the tall blue-stem *Andropogon* and in *Panicum* Aug. 12 (No. 44); in the *Lepachys* colony (Sta. I, *e*) Aug. 12 (No. 40); and among the swamp prairie grasses *Spartina* and *Elymus* (Sta. I, *a* and *c*) Aug. 28 (Nos. 179 and 180). Consult Hancock, '11, pp. 330-331, for the life history of this species.

*Conocephalus* sp., nymph.

A large female nymph was secured on blue-stem *Andropogon* (Sta. I, *g*) Aug. 24 (No. 159), having been captured by a crab-spider, *Misumena alcatoria* Hentz.

*Orchelimum vulgare* Harr. Common Meadow Grasshopper. (Pl. XL, figs. 2 and 4.)

This grasshopper was taken east of Charleston on the flowers of broad-leaved rosin-weed, *Silphium tercbinthinaccum* (Sta. III), Aug. 26 (No. 175); on the Loxa prairie (Sta. II) Aug. 27; on the flowers of rattlesnake-master, *Eryngium yuccifolium* (No. 178); and on the prairie north of Charleston from the colony of wild rye, *Elymus* (Sta. I, *a*), Aug. 28 (No. 179). A squeaking individual (No. 180) captured here confirmed observations made in other places—particularly in the tall prairie grasses *Andropogon* and *Sporobolus* (Sta. I, *g*), where the first specimen (No. 3) was taken Aug. 8. Nymphs, very probably of this species, were also in the prairie grasses *Andropogon* and *Sporobolus* (Sta. I, *g*) Aug. 8 (No. 3); and Aug. 28 (Nos. 179 and 180) in the swamp grasses *Elymus* and *Spartina* (Sta. I, *a*, *c*). This species is preeminently a tall-grass frequenter, whose penetrating *zeeing* during the sunny hours serves to locate grass plots and low, rank weedy growths.

Blatchley ('03, p. 384) has observed the species feeding on small moths, and once saw an individual on goldenrod eating a soldier-beetle, *Chauliognathus pennsylvanicus* DeG. Forbes ('05, p. 144) reports that its food consists mainly of plant-lice, and leaves of grass, fungus spores, and pollen. It is thus evident that it eats both animal and vegetable food.

*Xiphidium attenuatum* Scudd. Lance-tailed Grasshopper. (Pl. XL, fig. 7.)

On the prairie at Loxa (Sta. II), on flowers of the arrow-leaved rosin-weed, *Silphium integrifolium*, a single individual of this species was found Aug. 13 (No. 48).

According to Blatchley ('03, pp. 380-381) it frequents the coarse vegetation bordering wet places. He also states that the eggs are placed between the stems and leaves of "tall rank grasses."

*Xiphidium strictum* Scudd. Dorsal-striped Grasshopper. (Pl. XL, fig. 6.)

This prairie species was taken on prairie clover, *Petalostemum* (Sta. I, *b*), Aug. 11 (No. 21); in sweepings among the cone-flower, *Lepachys pinnata* (Sta. I, *c*), Aug. 20 (No. 40); on the mountain mint *Pycnanthemum flexuosum* (Sta. I) Aug. 12 (No. 35); on *P. flexuosum* or *P. pilosum* (Sta. II) Aug. 13 (No. 57); among the swamp grasses *Elymus* and *Spartina* (Sta. I, *a* and *c*) Aug. 28 (Nos. 179, 180); on the Loxa prairie on *Silphium integrifolium* (Sta. II) Aug. 13 (No. 48); and on purple prairie clover, *Petalostemum purpureum* (Sta. II), Aug. 13 (No. 50).

Forbes ('05, p. 147) gives its food as plant-lice, fungi, pollen and, largely, other vegetable tissues. He also states that it frequents the "drier slopes in woods and weedy grounds" (p. 148).

#### GRYLLIDÆ

*Æcanthus nigricornis* Walk. Black-horned Meadow Cricket. (Pl. XL, fig. 5, Pl. XLI, figs. 1 and 2.)

This prairie cricket was taken in sweepings from the cone-flower (*Lepachys pinnata*) colony (Sta. I, *e*) Aug. 12 (No. 40); on the transitional prairie east of Charleston (Sta. III, *b*) Aug. 15 (No. 62); and from the swamp cord-grass, *Spartina* (Sta. I, *a*), Aug. 28 (No. 179).

Blatchley ('03, p. 451) says: "In August and September, nearly every stalk of goldenrod and wild sunflower along roadsides, in open fields or in fence corners, will have from one to a half dozen of these insects upon its flowers or branches. It is also especially abundant

upon the tall weeds and bushes along the borders of lakes and ponds, and in sloughs and damp ravines."

Blatchley (l. c., p. 452) made some incomplete observations on the peculiar courting habits of this species, a subject which has been elaborated by Hancock ('05). Hancock also describes the method of oviposition. The female first gnaws the plant stem; then bores a hole and deposits an egg; and next, again gnaws the stem. The eggs are laid in stems of blackberry, goldenrod, and horseweed (*Leptilon*).

Houghton (Ent. News, Vol. 15, pp. 57-61, 1904) has published interesting observations on the carnivorous habits of nymphs of *Æ. niveus* DeG. Cf. Parrott and Fulton, '14.

Ashmead (Insect Life, Vol. 7, 241, 1894) reports that *Æ. nigricornis* (*fasciatus*) is preyed upon by the wasp *Chlorion harrisi* Fernald (*Isodontia philadelphica* St. Farg.).

*Æcanthus quadripunctatus* Beut. Four-spotted White Cricket.

This prairie species was found among the tall prairie grasses blue-stem *Andropogon* and *Panicum* (Sta. I, g) Aug. 8 (No. 3); and among the colony of cord grass, *Spartina* (Sta. I, a), Aug. 28 (No. 179).

Blatchley ('03, p. 453) reports it on "shrubby and weeds in fence-rows and gardens; and along roadsides." This indicates how a prairie species adjusts itself to the conditions produced by man. Parrott (Journ. Econom. Ent., Vol. 4, pp. 216-218, 1911) gives figures of the eggs of this species and describes its method of oviposition in raspberry stems.

## HEMIPTERA

### CICADIDÆ

*Cicada dorsata* Say. Prairie Cicada.

Although this species was not taken at Charleston, a single specimen (No. 185) was captured at Vera, Fayette county, Ill., September 1, on a giant stool of blue-stem *Andropogon*. Osborn (Proc. Iowa Acad. Sci., Vol. 3, p. 194, 1896) reported one specimen from Iowa; Woodworth, (*Psyche*, Vol. 5, p. 68, 1888) says: "On the prairies, Illinois to Texas"; and MacGillivray (*Can. Ent.*, Vol. 33, p. 81, 1901) adds Missouri, Colorado, and New Mexico.

### MEMBRACIDÆ

*Campylenchia curvata* Fabr.

This bug was taken in sweepings made in the colony of cone-flower, *Lepachys pinnata* (Sta. I, e), Aug. 12 (No. 40).

## JASSIDÆ

*Platymetopius frontalis* Van D.

This leaf-hopper was taken in sweepings in the cone-flower colony (Sta. I, *c*) Aug. 12 (No. 40).

## APHIDIDÆ

*Microparsus variabilis* Patch.

This plant-louse infests the leaves of the Canadian tick-trefoil, *Desmodium canadense*, and causes the leaves to curl. Quite a colony of these plants found infested (near Sta. I, *f*) Aug. 24, were stunted and deformed by these plant-lice (No. 160). Consult Patch (Ent. News, Vol. 20, pp. 337-341. 1909) for a description of the insect and a plate showing the injury which it causes; also Williams (Univ. Studies, Univ. Neb., Vol. 10, p. 76, 1910) and Davis (*ibid.*, Vol. 11, p. 28. 1912).

*Aphis asclepiadis* Fitch. Milkweed Plant-louse.

Plant-lice of this species were abundant upon the younger terminal leaves of the common milkweed, *Asclepias syriaca*, along the railway track north of Charleston (Sta. I) Aug. 12 (Nos. 28, 29, and 154). Associated with them were workers of the ants *Formica fusca* Linn. var. *subsericea* Say (Nos. 28, 29, and 154) and *Formica fusca* Linn. (No. 28). On a milkweed plant which lacked the plant-lice were found associated another ant, *Formica pallide-fulva* Latr., subsp. *schaufussi* Mayr, var. *incerta* Emery, and the metallic-colored fly *Psilopus siphon* Say.

At Urbana, Ill., a very abundant plant-louse on wild lettuce, *Lactuca canadensis*, is *Macrosiphum rudbeckiae* Fitch (det. by J. J. Davis). The upper, tender branches of these plants are in the fall covered with vast numbers of these lice, both wingless and winged. That this species feeds upon a number of other prairie plants is a point of much interest because of their distinctly prairie character. It is reported from *Vernonia*, *Solidago*, *Bidens*, *Ambrosia*, *Cirsium*, *Silphium*, and *Cacalia* (Thomas, Eighth Rep. State Ent. Ill., p. 190. 1879).

## PENTATOMIDÆ

*Euschistus variolarius* Beauv. (Pl. XLI, fig. 3.)

This common plant-sucking bug was taken on flowers of the swamp milkweed, *Asclepias incarnata* (Sta. I, *d*), Aug. 9 (No. 12); from the blue-stem *Andropogon* colony (Sta. I, *g*), where a large robber-fly, *Promachus vertebratus*, was taken astride a grass stem with one of these bugs in its grasp Aug. 12 (No. 39); at Station

I by T. L. Hankinson, July 3, 1911 (No. 7665); on the Loxa prairie (Sta. II), with insects from flowers of the purple prairie clover, *Petalostemum purpureum*, Aug. 13 (No. 50); and on flowers of the mountain mint *Pycnanthemum pilosum* or *P. flexuosum* (Sta. II), Aug. 13 (No. 52). Consult Forbes ('05, pp. 195, 261) for a summary of its life history, and references to literature. It feeds upon a great variety of plants (Olsen, in Journ. N. Y. Ent. Soc., Vol. 20, p. 53. 1912) and on soft-bodied insects.

*Stiretrus anchorago* Fabr. (Pl. XLI, fig. 5.)

This highly colored bug was taken, Aug. 23 (No. 146), not upon the prairie proper but at the margin of the Bates woods (near Sta. IV, a), where the clearing had been so complete that only sprouts and young trees occurred, associated with many plants which frequent open, sunny places, such as ironweed (*Vernonia*) and *Pycnanthemum pilosum*.

This bug sometimes feeds upon the larvæ of the imported asparagus beetle, *Crioceris asparagi* (Chittenden, Circ. No. 102, Bur. Ent., U. S. Dept. Agr., p. 6. 1908). This circular contains figures of the nymph and adult. Olsen reports it as feeding upon caterpillars and beetle larvæ and on the plants *Asclepias* and *Rhus* (Jour. N. Y. Ent. Soc., Vol. 20, pp. 55, 56. 1912).

#### THYREOCORIDÆ

*Thyreocoris pulicarius* Germ. Flea Negro-bug. (Pl. XLII, fig. 2.)

This negro-bug was taken on the flowers of goldenrod, *Solidago* (near Sta. I, a), Aug. 12 (No. 26). Forbes and Hart ('00, p. 100) state that this insect abounds on *Bidens*, a plant which grew in great abundance near the goldenrod referred to. Taken (Sta. I) by T. L. Hankinson July 3, 1911 (No. 7665).

#### LYGÆIDÆ

*Ligyrocoris sylvestris* Linn.

This insect was taken while sweeping vegetation in the cone-flower (*Lepachys*) colony (Sta. I, c) Aug. 12 (No. 40).

*Lygæus kalmii* Stål. Small Milkweed Bug. (Pl. XLII, fig. 1.)

This is one of the commonest insects found upon milkweeds of the prairie. Specimens were taken on the flowers of the swamp milkweed, *Asclepias incarnata* (Sta. I, g), Aug. 8 (No. 1); on flowers of the mountain mint, *Pycnanthemum flexuosum* (Sta. I, g), Aug. 8 (No. 6); and on swamp milkweeds (Sta. I, d) Aug. 9 (No. 12).



This is another common insect about which very little is known. Its food plants and life history are worthy of study. I have taken this species from Mar. 20 (adult, 1894) to Nov. 4 (adult, 1893) at Bloomington, Ill.; at Havana, Ill., during August; and at Chicago June 8 (1902). That it probably hibernates in the adult stage is shown by the fact that I captured an adult as early as Mar. 22 at Urbana, Ill. This bug, like the squash-bug (*Anasa*), may have an active migratory period in the fall, and only those individuals survive the winter which happen to be in favorable places when the cold weather sets in. I have captured this bug in the dense Brown-field woods (Urbana), where it was crawling on a log Oct. 12 (No. 312, C.C.A.). Hart ('07, p. 237) records it from *Asclepias cornuti* (= *A. syriaca*) at Havana in the sand area, and also from Teheran, Illinois.

*Oncopeltus fasciatus* Dall. Large Milkweed Bug. (Pl. XLII, fig. 3.)

This large red plant-bug I took but once—on flowers of the swamp milkweed, *Asclepias incarnata* (Sta. I, *g*), Aug. 8 (No. 1); T. L. Hankinson, however, captured another specimen (Sta. I) July 3 1911 (No. 7665).

I have found it in years past abundant on prairie colonies of milkweed at Bloomington, Ill., from June into September, and at Havana and Chicago during August. On Sept. 26, at Mayview, Ill., along the railway among prairie plants this plant-bug was found on dogbane (*Apocynum*). A pale yellow color may replace the red.

#### COREIDÆ

*Harmostes reflexulus* Say.

This bug was found in flowers of *Asclepias syriaca* along the railway track (Sta. I) Aug. 12 (No. 27).

#### REDUVIDÆ

*Sinea diadema* Fabr. Rapacious Soldier-bug. (Pl. XLI, fig. 4.)

One specimen of this bug was taken from the flowers of the mountain mint, *Pycnanthemum flexuosum*, in the prairie grass colony (Sta. I, *g*), Aug. 8 (No. 6). I took it at St. Joseph, Ill., in a colony of prairie vegetation along the railway track Sept. 26, 1911 (No. 495, C.C.A.).

This bug preys upon caterpillars and many other insects. The little we know of its life history has been recorded by Ashmead ('95, Insect Life, Vol. 7, p. 321); its predaceous habits, however, have attracted considerable attention from economic entomologists. For

numerous references to this phase see Caudell, Jour. N. Y. Ent. Soc., 1901, Vol. 9, p. 3. The young feed upon plant-lice.

#### PHYMATIDÆ

*Phymata fasciata* Gray (*volffi* Stål). Ambush or Stinging Bug.  
(Pl. XLII, fig. 4.)

This is one of the most abundant and characteristic of prairie insects. It was taken from the flowers of the swamp milkweed, *Asclepias incarnata* (Sta. I, g), Aug. 8 (No. 11); among the same flowers, at Station I, d, Aug. 9; on goldenrod, *Solidago* (near Sta. I, a), Aug. 11 (No. 20); and again on goldenrod (Station I) Aug. 12 (No. 43), *in copula*, and with an empidid fly in its clasp; on flower of mountain mint, *Pycnanthemum flexuosum* (Sta. I), Aug. 11 (No. 24); from goldenrod (Sta. I) Aug. 12 (No. 26); in sweepings from the colony of *Lepachys pinnata* (Sta. I, e) Aug. 12 (No. 40); from the flowers of the mountain mint, *P. flexuosum*, on the Loxa prairie (Sta. II) Aug. 13, with a large bee-fly, *Exoprosopa fasciata*, in its clutches (No. 57); on the following flowers (Sta. II) Aug. 13—rosinweed, *Silphium integrifolium* (No. 48), mountain mint *Pycnanthemum pilosum* and *P. flexuosum* (No. 52), Culver's-root, *Veronica virginica* (No. 54), and rattlesnake-master, *Eryngium yuccifolium* (No. 55); in the partly cleared area north of Bates woods (Sta. IV) in flowers of the mountain mint *P. pilosum* Aug. 23 (No. 146); and on the Loxa prairie, at telegraph pole No. 12323 (Sta. II), on the flowers of rattlesnake-master Aug. 27 (No. 178).

At Mayview, Ill., in a colony of prairie vegetation, one specimen was taken by Miss Ruth Glasgow with the butterfly *Pontia protodice* Sept. 26, 1912; a second had captured a dusky plant-bug, *Adelphocoris rapidus* Say. At the same time and place Miss Grace Glasgow took from a flower another bug with the bee-fly *Sparnopolius fulvus* Wied. This fly is parasitic on white-grubs, *Lachnosterna* (Forbes, '08, p. 161). Among prairie vegetation at St. Joseph, Ill., Sept. 26, 1911, I took from a flower an ambush bug with a large cutworm moth, *Feltia subgothica* Haw. (No. 302, C.C.A.). (Pl. XLIII, figs. 1 and 2.)

Packard ('73, p. 211) records that *Phymata fasciata* had been observed feeding upon plant-lice on linden trees in Boston, and Walsh (Amer. Ent., Vol. 1, p. 141. 1869) states that it feeds habitually upon bees and wasps, and shows skill in avoiding their sting. Cook (Bee-keeper's Guide, ninth ed., pp. 323-324, 1883) reports that it destroys plant-lice, caterpillars, beetles, butterflies, moths, bees, and

wasps. The ambush bug and the ambush spider (*Misumena alcatoria* Hentz) are in active competition upon flowers for much the same kind of food.

## MIRIDÆ

*Adelphocoris rapidus* Say. Dusky Leaf-bug. (Pl. XLII, figs. 5 and 6.)

This leaf-bug was taken from the flowers of the rattlesnake-master, *Eryngium yuccifolium* (Sta. 11, a), Aug. 13 (No. 55). It was taken in a colony of prairie vegetation at Mayview, Ill., Sept. 26, 1912, by Miss Ruth Glasgow, who found it captured by *Phymata fasciata*. It feeds upon a large variety of plants.

*Lygus pratensis* Linn. Tarnished Plant-bug. (Pl. XLIII, figs. 3 and 4.)

This common plant-bug was taken, copulating, from the flowers of the swamp milkweed, *Asclepias incarnata* (Sta. I, d), Aug. 9 (No. 12). It is a common fruit and garden pest. Consult Forbes ('05, pp. 119, 263) for figures of this species and references to its life history and habits, and Crosby and Fernald ('14) for a very full account of this species.

## COLEOPTERA

## CARABIDÆ

*Leptotrachelus dorsalis* Fabr.

This ground-beetle was taken in the *Spartina* colony on the prairie north of Charleston (Sta. I, a) Aug. 28 (No. 179). It is supposed to be predaceous. Its life history is not known to the writer. Blatchley ('10, p. 138) records it as from "low herbs in open woods", and Webster ('03b, p. 22) states that the larva of this beetle destroys the larvæ of *Isosoma grande* Riley in wheat fields.

Although no special effort was made to secure members of this family of beetles from the prairie, where they must abound, it is surprising that some members of the genus *Harpalus* were not so abundant as to demand attention. More attention to the ground fauna and less to that found on vegetation would doubtless have given other results. Generally in this family the food habits are predaceous, but there are exceptions, and these include kinds which frequent open places. On September 25, 1900, the writer found specimens of *Harpalus caliginosus* Fabr. feeding on the flowers or seeds of ragweed, *Ambrosia*, which grew in a neglected field along Holston River near Rogersville, Tenn., and at Rockford, Tenn., on Sept. 25, 1901, similar observations were made upon *Harpalus pennsylvanicus* DeG. Many years ago Webster ('80, p. 164) made similar observations on this species, and also found it eating wheat, timo-

thy seeds, the prairie grass *Panicum crusgalli* Linn., and even a small beetle, *Ips 4-guttatus* Fabr. He also observed *H. caliginosus* feeding upon seeds of ragweed, *Ambrosia artemisiifolia*. (See Forbes—'80, pp. 156-157 and '83a, pp. 45-46—for further observations upon the food habits of the beetles of this genus.) Clarkson (Can. Ent., Vol. 17, p. 107, 1885) observed *caliginosus* feeding upon ragweed on Long Island; and Hamilton (Can. Ent., Vol. 20, p. 62, 1888) records similar observations for this beetle and for *pennsylvanicus*. Both species are reported to injure strawberries. Coquillett (Insect Life, Vol. 7, p. 228, 1894) observed *caliginosus* feeding upon a grasshopper.

#### COCCINELLIDÆ

*Hippodamia parenthesis* Say. Parenthetical Ladybird.

This insect was taken only by T. L. Hankinson (Sta. I) July 3, 1911 (No. 7665).

*Coccinella novemnotata* Hbst. Nine-spotted Ladybird. (Pl. XLIV, fig. 2).

This insect was taken on the common milkweed, *Asclepias syriaca*, (Sta. I) Aug. 12 (No. 27). This species is another example of one of the commonest insects to which so little attention has been given that we really have no full account of its life history and ecology. Many scattered observations have been made, but none are extensive. Forbes examined the stomach contents of five specimens and found that they had eaten plant-lice, fungus spores, and a few lichen spores ('80, pp. 157-159, and '83a, pp. 53-54).

#### LAMPYRIDÆ

*Chauliognathus pennsylvanicus* DeG. Soldier-beetle. (Pl. XLIII, figs. 5 and 6.)

This is one of the most abundant beetles found on flowers in late summer and fall, particularly upon goldenrods (*Solidago*), and other composites. The first specimens were taken in a cleared area, with much sprout growth and open patches, where the mountain mint *Pycnanthemum pilosum* abounded, (near Sta. IV, a), Aug. 23 (No. 146). On the following day they were first found on the prairie—copulating as usual—on the flowers of the swamp milkweed, *Asclepias incarnata* (Sta. I, d), Aug. 24 (No. 156.)

They were taken from the flowers of the broad-leaved rosinweed, *Silphium terbinthinaceum*, on the prairie east of Charleston (Sta. III, b) Aug. 26 (No. 175), and on the Loxa prairie (Sta. II,

Pole No. 12323) on the flowers of the rattlesnake-master, *Eryngium yuccifolium*, Aug. 27 (No. 178).

According to Riley (Second Rep. U. S. Ent. Comm., p. 261. 1880) the eggs of this species are deposited on the ground in irregular bunches. He quotes Hubbard, who says that the larvæ huddled together when ready to moult, and that afterwards they became very active. The insect passes the winter as a nearly mature larva, and matures about August. The larvæ are known to eat beetle larvæ and caterpillars; the adults feed upon nectar and pollen.

#### SCARABÆIDÆ

*Euphoria sepulchralis* Fabr. Black Flower-beetle. (Pl. XLIV, fig. 4.)

Only two specimens of this beetle were taken: one on the flowers of the swamp milkweed, *Asclepias incarnata* (Sta. I, d), Aug. 24 (No. 156); the other from the flowers of *Pycnanthemum pilosum* in the cleared area bordering the upland Bates woods (Sta. IV, a) Aug. 23 (No. 146). Blatchley ('10, p. 997) reports it at sap, on various flowers, and especially on goldenrod; and Webster has found it eating into kernels of corn (Insect Life, Vol. 3, p. 159).

*E. inda* (Pl. XLIV, fig. 3) has been observed by Wheeler ('10a, p. 384) to fly to an ants' nest and bury itself; he suggests that it may live in such nests. Schwarz ('90b, p. 245) considers the *inda* larvæ abundant at Washington in nests of *Formica integra*. For the life history of this beetle see Chittenden (Bull. 19, N. S., Bur. Ent., U. S. Dept. Agr., pp. 67-74. 1899).

*Pclidnota punctata* Linn. Spotted Grape Beetle. (Pl. XLIII, fig. 5.)

Only one specimen of this beetle was taken. It was found upon a prairie containing some forest relics, on a grape leaf (Sta. III, b) Aug. 15 (No. 58). This insect is a forest or forest-margin insect; as is indicated by the fact that the larva feeds upon the decaying roots and stumps of oak and hickory. The adult devours leaves of the grape and of the Virginia creeper (Cf. Riley, Third Rep. Insects Mo., p. 78).

#### CERAMBYCIDÆ

*Tetraopcs tetraophthalmus* Forst. Four-eyed Milkweed Beetle.

This is one of the commonest insects in the prairie parts of Illinois. Nevertheless, though almost every schoolboy who ever made a collection of insects has it in his collection, very little is known of its habits or life history.

At Charleston it was taken Aug. 8 on flowers of the swamp milkweed, *Asclepias incarnata*, at Sta. I, *g* (No. 1) and at Sta. I, *d* (No. 12); on the flowers of the mountain mint *Pycnanthemum virginianum* (Sta. I) Aug. 12 (No. 35); and T. L. Hankinson took the beetle (Sta. I) July 3, 1911 (No. 7665).

Robertson (Trans. St. Louis Acad. Sci. Vol. 5, p. 572. 1891) states that this beetle and *Epicauta vittata* Fabr. gnaw the flowers of the swamp milkweed; and in the same volume (p. 574) reports that the rose-breasted grosbeak (*Habia ludoviciana*) cleared these beetles from *A. syriaca* in his yard. Beutenmüller (Jour. N. Y. Ent. Soc., Vol. 4, p. 81. 1896) says that the larva bores into the roots and lower parts of the stems of *Asclepias*, and suggests that the other species have similar habits.

*Tetraopes femoratus* Lec. (?) Milkweed Beetle.

A peculiar individual (No. 1) was taken Aug. 8 on the swamp milkweed *Asclepias incarnata* (Sta. I, *d*). Mr. C. A. Hart, who determined the specimen, remarks that it "is very remarkable—thorax of *femoratus*, antennæ and pattern nearest to *4-ophthalmus*."

#### CHRYSOMELIDÆ

*Cryptocephalus venustus* Fabr.

This leaf-beetle was taken from the flowers of prairie clover, *Petalostemum* (Sta. I, *b*), Aug. 11 (No. 21). Blatchley ('10, p. 1123) states that it is found on the flowers of *Erigeron* in timothy fields, on ironweed, and on wild sweet potato. Chittenden ('92, p. 263) has observed the var. *simplex* Hald. on ragweed, *Ambrosia trifida*, "dodging around the stem after the manner of a squirrel or lizard on a tree-trunk. . . . The insect is a polyphagous leaf-eater."

*Chrysochus auratus* Fabr. Dogbane Beetle.

Only two specimens of this usually common metallic-green beetle were seen and secured. One (No. 14) was taken Aug. 9 on the dogbane or Indian hemp, *Apocynum medium*, growing among the swamp milkweeds, *Asclepias incarnata* (Sta. I, *d*); and the other on dogbane in the upland part of Bates woods (Sta. IV, *a*), Aug. 20, 1910 (No. 103). Later, July 3, 1911, T. L. Hankinson (Sta. I) also secured this beetle (No. 7665). The food plant was abundant, but the beetles appeared to be exceptionally rare. This is another widely recognized but really little known insect. It is also found on the leaves of milkweeds. Zabriskie (Jour. N. Y. Ent. Soc., Vol. 3, p. 192. 1895) describes the egg-capsules of this species, which he found early in July on fence posts, near plants of the spreading dogbane,

*Apocymum androsæmifolium*, and especially upon the under surface of the leaves of this plant. A single egg is deposited within a conical black mass, which is probably the excrement of the beetle. To this note Beutenmüller adds that "the larvæ, after hatching drop to the ground and live on the roots of the plant."

With so much of a clue, the complete life history of this species ought to be worked out without much difficulty. Forbes once reported this species injuring potato (Lintner, Fourth Report on the Injurious and other Insects of the State of New York, p. 142).

*Nodonota convexa* Say.

This small leaf-beetle was taken in sweepings of vegetation in a colony of the cone-flower, *Lepachys pinnata* (Sta. I, c), Aug. 12 (No. 40). Blatchley ('10, p. 1149) states that it occurs in low places on ragweed, *Ambrosia trifida*. This cone-flower colony was on rather low land containing crawfish holes.

*Trirhabda tomentosa* Linn.

This insect was taken at Station I by T. L. Hankinson July 3, 1911 (No. 7665). It is common on *Solidago*. Schwarz (Am. Nat., Vol. 17, p. 1289. 1883) reports it as a defoliator of prickly ash (*Zanthoxylum*).

*Diabrotica 12-punctata* Oliv. Southern Corn Root-worm. (Pl. XLV, fig. 3).

This common corn pest was taken in sweepings of the vegetation in a colony of *Lepachys pinnata* (Sta. I, c) Aug. 12 (No. 40), and T. L. Hankinson captured it (Sta. I) July 3, 1911 (No. 7665). A few feet away was a large corn field. It was also taken on the flowers of *Eryngium yuccifolium* on the prairie at Loxa (Sta. II) Aug. 13 (No. 55). Here also a field of corn stood only a few feet away.

*Diabrotica longicornis* Say. Western Corn Root-worm. (Pl. XLV, fig. 1.)

This beetle was found upon the flower-masses of the mountain mint *Pycnanthemum pilosum*, growing in a forest clearing (near Sta. IV, a) Aug. 23 (No. 146). It feeds upon the silk and pollen of corn, and probably on the corresponding parts of other plants.

*Diabrotica atripennis* Say.

One specimen of this beetle was taken on the flowers of the swamp milkweed, *Asclepias incarnata* (Sta. I, d), Aug. 8 (No. 1). Very little appears to be recorded on this species except that it feeds upon the pollen and silk of corn, the pollen of composites, and the blossoms of beans (Forbes, '05, p. 189).

## MELOIDÆ

*Zonitis bilincata* Say. Two-lined Blister-beetle. (Pl. XLIV, fig. 1.)

This beetle was taken on the apical leaves of the common milk-weed, *Asclepias syriaca* (Sta. I), Aug. 12 (No. 33). Blatchley ('10, p. 1356) records it as from the flowers of the wild rose.

*Epicauta vittata* Fabr. Old-fashioned Potato Beetle or Striped Blister-beetle. (Pl. XLV, fig. 5.)

Several specimens were taken by T. L. Hankinson at Station I July 3, 1911 (No. 7665).

*Epicauta marginata* Lec. Margined Blister-beetle. (Pl. XLV, fig. 2.)

This beetle was taken at Station I by T. L. Hankinson only—July 3, 1911 (No. 7665); it was taken also from the leaves of the rosin-weed, *Silphium integrifolium*, on the Loxa prairie (Sta. II) Aug. 13 (No. 48); from an open ravine in Bates woods (Sta. IV, *b*) Aug. 22 (No. 124); and in the lowland glade (Sta. IV, *c*) Aug. 22 (No. 143). For accounts of the common Illinois species of blister-beetles see Forbes and Hart ('00, pp. 487-490, and Forbes, '05, pp. 111-114).

*Epicauta pennsylvanica* DeG. Black Blister-beetle.

This beetle was collected from flowers of goldenrod, *Solidago* (Sta. I, *a*), Aug. 12 (No. 26); on the Loxa prairie (Sta. II) from flowers of the rosin-weed, *Silphium integrifolium*, Aug. 13 (No. 48); on flowers of *Silphium terebinthinaceum* (Sta. III *a*), Aug. 20 (No. 119); in the cleared margin of Bates woods (near Sta. IV, *a*), on flowers of *Pycnanthemum pilosum* Aug. 23 (No. 146); again on goldenrod, *Solidago* (near Sta. I, *a*), Aug. 24 (No. 152); and from the Loxa prairie on flowers of rattlesnake-master, *Eryngium yuccifolium*, (Sta. II, *a*) Aug. 27 (No. 178).

The larvæ of this and some other species of blister-beetles prey upon locusts' eggs. (Cf. Riley, First Rep. U. S. Ent. Comm., p. 293, 1878.) The beetle lays its own eggs in the vicinity of the locusts' eggs.

## RHIPIPHORIDÆ

*Rhipiphorus dimidiatus* Fabr.

Five specimens of this mordellid-looking little beetle were taken on flowers of the mountain mint *Pycnanthemum flexuosum* (Sta. I, *g*) Aug. 8 (No. 6); and three specimens on flowers of the mountain mints *P. flexuosum* and *P. pilosum* on the Loxa prairie (Sta. II) Aug. 13 (No. 52). Blatchley ('10, p. 1366) reports it as from the flowers of *P. linifolium* Pursh.



These small beetles are black except the basal two-thirds of the elytra, which are pale yellow. The larvæ are parasitic on wasps, as has been shown by Chapman for the European species *paradoxus* (Ann. Mag. Nat. Hist., Ser. 4, Vol. 5, p. 191, and Vol. 6, p. 314, 1870). The larvæ undergo a very peculiar metamorphosis which is related to their parasitic habit. It is desirable that the life histories of the American species should be studied.

Ashmead (Psyche, Vol. 7, p. 77, 1894) reared this beetle from the cells of the wasp *Eumenes fraterna* Say. Riley (Sixth Rep. Ins. Mo., p. 125, 1874) states that he bred *Rhipiphorus pectinatus* Fabr., var. *ventralis* Fabr., from the cocoons of the wasp (*Tiphia*) which preys upon the grubs of *Lachnosterna*. Melander and Brues ('03, p. 26) found another member of the same family of beetles, *Myodites fasciatus* Say, on wing over nests of *Halictus*. Pierce ('04) has made a valuable study of the ecology of *Myodites solidaginis*, giving particular attention to its host, a bee (*Epinomia triangulifera* Vachal). Pierce (l. c., p. 185) states that the tiger-beetle *Cicindela punctulata* Fabr. is an active enemy of *Epinomia* and *Myodites*. I have found this a very abundant beetle in open sunny places on bare ground, as, for example, along a footpath through a timothy meadow at Bloomington, Ill. Such situations are the favorite haunts of many burrowing *Hymenoptera*.

#### *Rhipiphorus limbatus* Fabr.

A single specimen was taken on the flower of the rattlesnake-master, *Eryngium yuccifolium*, on the Loxa prairie (Sta. II, a) Aug. 27 (No. 178). This species is yellow, with black elytra, and a large black spot on the dorsum of the prothorax. Blatchley ('10, p. 1367) reports it from various composites. Robertson (Trans. St. Louis Acad. Sci., Vol. 6, pp. 106, 107, 1892) reports this beetle from Carlinville, Ill., on the flowers of several species of *Pycnanthemum*, and (idem, Vol. 5, p. 571) he also records it from milkweeds (*Asclepias*).

### RHYNCHITIDÆ

#### *Rhynchites æneus* Boh.

This snout-beetle was taken on the prairie west of Loxa from flowers of the rosin-weed, *Silphium integrifolium* (Sta. II), Aug. 13 (No. 48). It has been taken from other flowers (Pierce, '07, p. 251).

### CALANDRIDÆ

#### *Sphenophorus venatus* Say (*placidus* Say). (Pl. XLV, fig. 4.)

This "bill-bug" was taken from the colony of tall blue-stem *Andropogon* and foxtail, *Panicum* (Sta. I, g), Aug. 12 (No. 39).

Forbes ('03—22d Rep. State Ent. Ill.—p. 8) gives a summary of what is known of this species. It is a corn pest, has been found widely dispersed in Illinois, and hibernates as an adult beetle. A tachinid fly has been bred from the larva of *S. robustus* Horn. (Coquillett, '97, p. 18.)

#### CURCULIONIDÆ

*Centrinus penicellus* Hbst.

This snout-beetle was taken on the flowers of goldenrod, *Solidago* (near Sta. I, a), Aug. 12 (No. 26); another specimen was taken from Sullivant's milkweed, *Asclepias sullivantii* (Sta. I), Aug. 12 (No. 41). Forbes and Hart ('00, p. 493) state that it has been taken in the "latter part of July and August." It injures beet leaves, but its early life history is not known.

*Centrinus scutellum-album* Say.

This beetle was taken at Station I, July 3, 1911, by T. L. Hankinson (No. 7665). It has been taken from a number of flowers in which it fed upon pollen (Pierce, '07, p. 284). The larva of *Centrinus picumnus* Hbst. has been found injuring *Sctaria* (Webster, in Insect Life, Vol. I, p. 374. 1889).

#### LEPIDOPTERA

##### PAPILIONIDÆ

*Papilio polyxenes* Fabr. Celery Butterfly.

This common butterfly was taken on wing along the railway track near the swamp milkweed (*Asclepias incarnata*) colony (Sta. I, d) Aug. 9 (No. 15), and from a web of the common garden spider *Argiope aurantia*, among these milkweeds (No. 45). Chittenden (Bull. 82, Bur. Ent. U. S. Dept. Agr., pp. 20-24. 1909) gives a brief account of this common species which feeds upon umbellifers. It was very abundant on parsley in the J. I. Bates garden (near Sta. IV, a) Aug. 26 (No. 174).

##### PIERIDÆ

*Pontia rapæ* Linn. Cabbage Butterfly. (Pl. XLVI, fig. 1.)

A mutilated specimen of this butterfly, which had been captured by a robber-fly, was secured by E. N. Transeau (Sta. III, b, Aug. 15; No. 61).

*Eurymus philodice* Godart.

This butterfly was taken on the flowers of *Pycnanthemum pilosum* in a cleared area bordering the Bates woods (near Sta. IV, a)

Aug. 23 (No. 146); and on flowers of the swamp milkweed, *A. incarnata* (Sta. I, *d*), Aug. 9 (No. 12).

#### NYPHALIDÆ

*Argynnis idalia* Drury. Idalia Butterfly.

This species was taken from the flowers of the swamp milkweed, *A. incarnata* (Sta. I, *d*), Aug. 12 (No. 37).

*Anosia plexippus* L. Milkweed Butterfly. (Pl. XLVI, fig. 3.)

This common butterfly was abundant upon the prairie at Station I. It was observed copulating on willows at Sta. I, *d*, Aug. 9, and when on wing was able to carry its mate, whose wings were folded. It was observed on flowers of the thistle *Cirsium discolor* at Station I (No. 155).

#### LYCENIDÆ

*Chrysophanus thoe* Boisd. & Lec. Thoe Butterfly.

This butterfly was taken on flowers of the rattlesnake-master, *Eryngium yuccifolium*, on the Loxa prairie (Sta. II) Aug. 13 (No. 55).

The caterpillar feeds upon smartweeds (*Polygonum*) and dock (*Rumex*), and also upon prickly ash, *Zanthoxylum*.

#### SPHINGIDÆ

*Hemaris diffinis* Boisd. Honeysuckle Sphinx.

This hawk-moth was taken upon flowers of the swamp milkweed, *A. incarnata* (Sta. I, *d*), Aug. 12 (No. 32), and by T. L. Hankinson July 3, 1911, at Station I (No. 7655). This moth flies during bright daylight. The caterpillar lives on bush honeysuckle, snow-berry, and feverwort.

#### ARCTIDÆ

*Ammalo cglencensis* Clem. or *tenera* Hübn.

This caterpillar was taken on dogbane, *Apocynum medium*, on the Loxa prairie (Sta. II) Aug. 13 (No. 53).

*Eglencensis* is reported to feed upon *Asclepias tuberosa* and *Apocynum*.

#### NOCTUIDÆ

*Rhodophora gauræ* Sm. and Abb.

This interesting larva was not taken at Charleston, but on the prairie near Vera, Fayette county, Ill., on *Gaura bicnnis* Sept. 1 (No. 186). This specimen was determined by W. T. M. Forbes. It

is of interest that this larva, which is recorded from the "Southern and Southwestern States" and Colorado, was found on the prairie of Illinois. It is another example illustrating the southwestern and western affinities and origin of many elements in the prairie fauna. Mr. C. A. Hart informs me that he took the moth at a light Sept. 10 and 17, 1909, at Urbana, and that it was taken at Pekin, Ill., in August.

*Spragucia leo* Guen.

This little moth was taken once on the flowers of *Solidago* (near Sta. I, *a*) Aug. 11 (No. 20); again, in a similar situation, Aug. 12 (No. 26); and a third time in the cleared area near the Bates woods on the flowers of *Pycnanthemum pilosum* (Sta. IV, *a*) Aug. 23 (No. 146, two specimens).

#### GELECHIIDÆ

*Gnorimoschema gallæsolidaginis* Riley. (Caterpillar Gall) (Pl. XLVI, fig. 4.)

This common gall was taken by T. L. Hankinson on *Solidago* at Sta. I, Aug. 8, 1910 (No. 7462).

Cf. Riley (First Rep. Ins. Mo., pp. 173-175. 1869) and Busck (Proc. U. S. Nat. Mus., Vol. 25, pp. 824-825. 1903).

#### DIPTERA

#### CECIDOMYIIDÆ

*Cecidomyia solidaginis* Loew. (Goldenrod Bunch Gall.) (Pl. XLVI, fig. 5.)

This gall was taken on *Solidago* Aug. 12 at Sta. I (No. 42), and by T. L. Hankinson at Sta. I, on Aug. 8, 1910 (No. 7462). This gall forms a rosette or terminal bunch of leaves on *Solidago*.

*Cecidomyia* sp.

A willow cone-gall was found Sept. 13 by T. L. Hankinson on willows at Sta. I. (Cf. Heindel, '05.)

#### CULICIDÆ

*Psorophora ciliata* Fabr. Giant Mosquito or Gallinipper.

This is our largest species of mosquito. It was taken among the swamp milkweeds, *Asclepias incarnata* (Sta. I, *d*), Aug. 10 (No. 13); and in the prairie grass colony (Sta. I, *g*) Aug. 12 (No. 44). Both of these places were near moist or wet areas. Individuals were not abundant, although the species is particularly adapted to living where the moisture is variable. Morgan and Dupree (Bull. 40, Div.

Ent., U. S. Dept. Agr., p. 91. 1903) have concluded that all the eggs do not hatch with the first rain after their deposition, but that hatching is completed with the alternation of wet and dry weather.

#### MYCETOPHILIDÆ

##### *Eugnoriste occidentalis* Coq.

A single specimen of this small fly was taken on the flowers of *Solidago* (Sta. I) Aug. 12 (No. 26). The specimen was determined by J. R. Malloch. It had been previously recorded from goldenrod flowers by Aldrich ('05, p. 148).

##### *Sciara* sp.

These small flies were taken from the flowers of the mountain mint, *Pycnanthemum flexuosum* (Sta. I, g), Aug. 8 (No. 6).

#### BOMBYLIIDÆ

##### *Exoprosopa fasciata* Macq. Giant Bee-fly.

This was one of the most abundant and characteristic insects of the prairies and cleared areas, and belongs in the same class as the red milkweed beetle (*Tetraopes*) and the milkweed bug, *Lygæus kalmii*. It was taken from flower masses of the mountain mint *Pycnanthemum flexuosum* (Sta. I, g) Aug. 8 (No. 6); on the flowers of *Verbena stricta* Vent. (near Sta. I, a) Aug. 11 (No. 23); again from *P. flexuosum* (Sta. I) Aug. 11 (No. 24); and on the flowers of *Liatris scariosa* (Sta. 11, a) Aug. 27 (No. 176). Two specimens had been captured by the flower spider *Misumena alcatoria* Hentz: one on flowers of the rosin-weed, *Silphium integrifolium* (Sta. II), Aug. 13 (No. 47), the other on flowers of the mountain mint *Pycnanthemum flexuosum* (Sta. I) Aug. 12 (No. 31); and a third was captured by the ambush bug, *Phymata fasciata* Gray, on the flowers of the mountain mint (Station II) Aug. 13 (No. 57).

This was a very common species on the prairie patches at Bloomington, Ill., July 26 to Aug. 23, and in pastures abounding in *Verbena* at Kappa, Ill., and Havana, Ill., in August. Graenicher ('10, pp. 94-95) has listed several species of flowers from which this fly has been taken. It is probable that it preys upon some wasps, since a related species, *E. fascipennis* Say, has been bred from the cocoons of the white-grub wasp, *Tiphia* (Forbes, '08, p. 160).

##### *Systæchus vulgaris* Loew.

In the cleared area bordering the Bates woods, on flowers of the mountain mint *Pycnanthemum pilosum* (near Sta. IV, a), a specimen

of this bee-fly was taken Aug. 23 (No. 146). Graenicher ('10, p. 93) has listed a variety of plants visited by this fly.

The habits of this species appear not to be known, but the larvæ of an allied species, *S. orcas* O. S., preys upon the eggs of grasshoppers (Riley, Second Rep. U. S. Ent. Comm., pp. 262-268. 1880). Sheldford ('13c) has found that *Spogostylum anale* Say is a parasite on the larva of *Cicindela*. A related fly, *Sparnopolius fulvius*, is parasitic on the grubs of *Lachnosterna* (Forbes, '08, p. 161). Holmes ('13) has shown the relation of light to the hovering flight of *Bombylius*.

#### MYDAIDÆ

*Mydas clavatus* Drury. Giant fly.

A single specimen of this giant fly was taken on flowers of the swamp milkweed, *Asclepias incarnata* (Station I, d), Aug. 9 (No. 12). I have taken this species at Chicago during July, and at Bloomington, Ill., on June 29.

Harris (Insects Injurious to Vegetation, p. 607. 1869) describes briefly the larva and pupa; and Washburn (Tenth Ann. Rep. State Ent. Minn., Pl. II, fig. 15. 1905) gives a colored figure of the species.

The larvæ of this family live in decaying wood and prey upon insects, and the adults are also predaceous (Hubbard '85, p. 175).

Howard (Insect Book, p. 136) states that the larva of *Mydas fulvipes* Walsh "lives in decaying sycamore trees and is probably predatory on other insects living in such locations." He also states that the adults are predaceous.

#### ASILIDÆ

*Deromyia* sp.

This robber-fly was taken on the Loxa prairie (Sta. II) Aug. 13 (No. 51).

The larvæ of some members of this family feed upon rhubarb roots (Harris, Ins. Inj. to Vegetation, p. 605. 1869), and others, as *Erax bastardi*, are known to prey upon the eggs of grasshoppers (Riley, First Rep. U. S. Ent. Comm., pp. 303-304, 317. 1878). Adults of several species of robber-flies feed upon grasshoppers; others kill bees (Riley, Sec. Rep. Ins. Mo., pp. 121-124. 1870).

*Promachus vertebratus* Say. Vertebrated Robber-fly. (Pl. XLVI, fig. 6.)

This is an abundant fly upon the prairie. A specimen was taken on the Loxa prairie (Sta. II) Aug. 13 (No. 56); and on the prairie east of Charleston (Sta. III, b) Aug. 15 (No. 62). Here a robber-fly was seen with a cabbage butterfly, *Pontia rapæ* (No. 61); since the

fly escaped, however, the species is not known. Another was found astride a grass stem (Sta. I, *g*) with the stink-bug *Euschistus variolarius* grasped in its legs Aug. 12 (No. 39). Aug. 12, among the prairie grasses (Sta. I, *g*), a pair of these flies was taken copulating (No. 44). Walsh (Am. Ent., Vol. I, pp. 140-141. 1869) states that *Asilus* preys upon *Polistes* and *Bombus*, which it grasps by the head-end, to keep out of the reach of the sting, from the bodies of which it sucks the juices. It handles a harmless grasshopper very differently.

I have observed a large species of robber-fly at Havana, Ill., which hung suspended from grass while devouring its prey; and Aldrich (Proc. Ent. Soc. Wash., Vol. 2, p. 147. 1893) observed a robber-fly suspended by its fore feet, apparently asleep, holding a large beetle. Cook (Bee-keepers' Guide, ninth ed., pp. 317-321. 1883) has seen a species of robber-fly capture a tiger-beetle, *Cicindela*; many of these flies furthermore prey upon the honey-bee. The introduction of this bee into the prairie association must have had considerable influence upon flower-frequenting insects, and especially upon the predaceous kinds.

The capture of the cabbage butterfly by an asilid is another observation which Cook has recorded for *Proctacanthus milberti* Macq. (*Asilus missouriensis* Riley). He says (l. c. p. 318): "It has been observed to kill cabbage butterflies by scores." Wallis (Can. Ent., Vol. 45, p. 135. 1913) observed this fly capturing *Cicindela*. Punnett (Spolia Zeylanica, Vol. 7, pp. 13-15. 1910) has recently shown that in Ceylon robber-flies are important enemies of large butterflies. *Proctacanthus milberti* has been observed to prey upon locusts (Riley, First U. S. Ent. Comm., p. 317. 1878). For an elaborate account of the food and feeding habits of this family see Poulton, ('07).

As very little is known of the breeding habits of the American species, the observations of Hubbard on the oviposition of *Mallophora orcina* Wied. (Second Rep. U. S. Ent. Comm., p. 262. 1880) are of interest. He saw a female of this Florida species bury its abdomen in the ground, where it deposited five or six eggs at a depth of half to two thirds of an inch. The eggs hatched in a week. *Erax lateralis* Macq. has been recorded as predaceous upon May-beetle larvæ (Titus, in Bull. 54, Bur. Ent., U. S. Dept. Agr., pp. 15-16). Titus gives figures of the larva and pupa.

#### DOLICHOPODIDÆ

*Psilopus siphon* Say. Metallic Milkweed Fly. (Pl. XLVI, fig. 2.)

This pretty metallic-colored fly, observed by almost every field student or collector, is one of our commonest insects. It runs rapidly

over the upper surface of the leaves of the common milkweed, *Asclepias syriaca*, and is so nimble that it requires a little care to catch it. A large number of the flies were secured from the common milkweed along the railway track (Sta. I) Aug. 12 (No. 27), and also on the milkweeds infested with the plant-louse *Aphis asclepiadis* Fitch. Although some species of *Dolichopodidae* are said to be predaceous, I have never seen this species attack any insect.

The peculiar breeding habits of some of the members of this family have been described by Aldrich (Am. Nat., Vol. 28, p. 35-37. 1894).

#### SYRPHIDÆ

*Syrphus americanus* Wied. (Pl. XLVII, figs. 3, 4, and 5.)

This fly was taken along the railway track (Sta. I) Aug. 9 (No. 11). Its hum when on wing sounded much like that of the small yellow-jacket, *Vespa*. Metcalf ('13, p. 55) found it feeding on aphids infesting *Phragmites*.

Certain syrphid larvæ prey upon plant-lice, and the adults are abundant on flowers, especially unbellifers, feeding on their nectar. For good accounts of both larvæ and adults consult Williston (Bull. 31, U. S. Nat. Mus., pp. 269-272. 1886) and Metcalf ('13).

*Mesogramma politum* Say. Corn Syrphid. (Pl. XLVII, figs. 1 and 2.)

This syrphid was found in great numbers on the Loxa prairie (Sta. II) Aug. 27 (No. 177).

The larvæ are pollen feeders, as has been shown by an examination of the contents of the alimentary canal (cf. Riley and Howard, Insect Life, Vol. 1, p. 6). Also consult Forbes ('05, p. 162), who figures the species. Upon the original prairie the species probably fed on the pollen of various grasses or other plants.

*Allograpta obliqua* Say. (Pl. XLVII, figs. 6 and 7.)

This insect was taken on the Loxa prairie (Sta. II) in company with great numbers of *Mesogramma politum* Say, Aug. 27 (No. 177). For figures of the larva, pupa, and adult see Washburn (Tenth Ann. Rep. State Ent. Minn., p. 101. 1905) and Metcalf ('13, p. 58). It feeds upon aphids.

#### CONOPIDÆ

*Physocephala sagittaria* Say.

This insect was taken on the flowers of goldenrod, *Solidago* (Sta. I), Aug. 12 (No. 26). Also taken on a small-flowered aster at Urbana, Ill., Oct. 8. The larvæ of this family are parasitic on other insects. There is a figure of an allied species on Plate XLVIII, figure 1.



## TACHINIDÆ

*Cistogaster immaculata* Macq.

A single specimen of this fly was taken on the flower of rattlesnake-master, *Eryngium yuccifolium* (Sta. II) Aug. 13 (No. 55).

The larva is parasitic on lepidopterous larvæ (Townsend, Psyche, Vol. 6, p. 466. 193); and has been bred from the army-worm, *Leucania unipuncta* Haw. Two undetermined species of tachinids were taken by T. L. Hankinson (Sta. I) July 3, 1911 (No. 7665).

*Trichopoda ruficauda* V. d. W.

A single specimen of this fly was taken along the railway track (Sta. I) Aug. 12 (No. 38).

An allied species, *T. pennipes* Fabr., has been bred from the squash-bug (Cook, Rep. Mich. State Board Agr., pp. 151-152. 1889), and another, *plumipes* Fabr., has been bred from a grasshopper, *Dissosteira venusta* Stål (Coquillett, '97, p. 21).

## SCIOMYZIDÆ

*Tetanocera plumosa* Loew. (Pl. XLVIII, fig. 2.)

Taken in a colony of *Spartina* (Sta. I, a) Aug. 28 (No. 179). This species is figured by Washburn (Tenth Ann. Rep. State Ent. Minn., p. 121. 1905). The larvæ of this family are aquatic. Needham (Bull. 47, N. Y. State Mus., pp. 580-581, 592, Pl. 14. 1901) describes and figures *T. pictipes* Loew. (Cf. Shelford, '13a.)

## TRYPETIDÆ

*Euaresia æqualis* Loew.

This insect was taken in sweepings among a colony of the cone-flower, *Lepachys pinnata* (Sta. I, c), Aug. 12 (No. 40). Marlatt (Ent. News, Vol. 1, p. 168) records the rearing of this fly from the seed-pod of the cocklebur (*Xanthium*).

## EMPIDIDÆ

*Empis clausa* Coq.

A specimen of this fly was taken from a pair of copulating ambush bugs, *Phymata fasciata*, on the flowers of *Solidago* (Sta. I) Aug. 12 (No. 43), and great numbers, so many that they darkened the flowers on which they rested, were seen upon *Asclepias syriaca* (Sta. I) Aug. 12 (No. 27). The specimen was determined by J. R. Malloch.

McAtee (Ent. News, Vol. 20, pp. 359-361. 1909) gives an account of the habits of *Empididæ*, and Schwarz (Proc. Ent. Soc. Wash., Vol. 20, pp. 146-147. 1893) states that one kind captures small flies, and

suspended by its foreleg, eats its prey. This position when eating is a curious habit, independently acquired by several predaceous insects, as *Bittacus*, *Vespa*, and certain *Asilidæ*.

Mr. Malloch has called my attention to British observations made upon the peculiar habits of these flies. Thus Howlett ('07) has shown that the male supplies the female with an insect for food during copulation. These observations have been confirmed by Hamm ('08). Poulton ('07) discusses the food habits of these flies in much detail.

## HYMENOPTERA

### CYNIPIDÆ

*Rhodites nebulosus* Bassett. (Rose Gall.)

This gall was taken on a wild rose, *Rosa*, in the mixed forest and prairie colony east of Charleston (Sta. III, *b*) Aug. 15 (No. 60).

### BRACONIDÆ

An undetermined species was taken from the flowers of *Pycnanthemum pilosum* in the cleared area with sprout growth bordering the Bates woods (near Sta. IV, *a*) Aug. 23 (No. 146).

### FORMICIDÆ

*Myrmica rubra* Linn., subsp. *scabrinodis* Nyl., var. *sabulcti* Meinert,

This ant was found upon the prairie on flowers of the common milkweed, *Asclepias syriaca* (Sta. I), Aug. 12 (No. 27). It was associated with *Formica fusca subsericca* Say and *Formica pallide-fulva schaufussi incerta* Emery.

Wheeler ('05, pp. 374, 384) regards this as one of the heath ants, which "inhabit rather poor, sandy or gravelly soil exposed to the sun and covered with a sparse growth of weeds or grasses . . . . . It nests in sandy or gravelly sunny places such as open pastures, roadsides, etc." These requirements are admirably met by the conditions along the gravelly and sandy road-bed of the railway where the milkweeds flourish.

*Formica fusca* Linn., var. *subsericca* Say.

This ant was found on flowers of the goldenrod, *Solidago* (near Sta. I, *c*), Aug. 11 (No. 20); on leaves of the common milkweed (*Asclepias syriaca*) infested with the plant-louse *Aphis asclepiadis* Fitch (Sta. I) Aug. 12 (No. 30) and again Aug. 24 (No. 154); and in the upland Bates woods (Sta. IV, *a*) Aug. 26 (No. 163).

According to Wheeler ('10a, p. 458) this ant is enslaved by *Formica sanguinea* Latr. and the following subspecies: *aserva* Forel, *rubi-*

*cunda* Emery, *subnuda* Emery, *subintegra* Emery, and *puberula* Emery. Wheeler has seen *Formica sanguinea* "plunder a *subsericea* nest nearly every day for a week or a fortnight." In raiding a nest the ants carry off the larvæ and pupæ to their own nests, to serve as slaves when matured.

Wheeler (l. c., p. 374) states that *subsericea* may live in a great variety of situations—an unusual trait, but indicated in our collecting by its presence in both forest and prairie.

*Formica pallide-fulva* Latr., subsp. *schaufussi* Mayr, var. *incerta* Emery.

This common reddish ant was taken on the prairie from flowers of the common milkweed, *Asclepias syriaca* (Sta. I), Aug. 12 (No. 27); and on the Loxa prairie from flowers of the mountain mint *Pycnanthemum pilosum* or *P. flexuosum* (Sta. II) Aug. 13 (No. 52).

This ant was associated on the milkweeds with *Myrmica rubra* Linn., subsp. *scabrinodis* Nyl., var. *sabuleti* Meinert, and *Formica fusca subsericea* Emery.

Wheeler ('05, pp. 373, 374) lists this species as frequenting glades, "open sunny woods, clearings, or borders of woods," and further adds that the glade and field faunas are not separated by a sharp line, for "*Formica schaufussi*, for example, seems to occur indifferently in either station." That open patches in woods or glades often contain ants which also frequent open places, is thus in harmony with a general rule for this association, not only in the case of animals but also of plants, so that it applies to the entire biota of such situations.

Wheeler ('10a, p. 393) lists a small wingless cricket, *Myrmecophila pergandei*, as living with *Formica pallide-fulva*. These lick the surfaces of the ants, and seem to feed upon the products of the dry bath.

Wheeler says ('05, p. 400) that the food of *schaufussi* appears to be "largely of the excrement of Aphides and the carcasses of insects."

Wheeler ('04, pp. 347-348) states that the nests are usually found under a stone, and that *Formica difficilis* Emery var. *consocians* Wheeler is a temporary parasite upon *incerta*, but "only during the incipient stages of colony formation" (p. 358). This is a temporary parasitism of one colony upon another, during which the parasite multiplies and becomes strong enough, at the expense of its host, to establish a new independent colony. This is what Wheeler calls a "temporary social parasite, a true cuckoo ant, which sponges on another species only so long as necessary in order to gain a successful start in life." Schwarz ('90b, p. 247) records several species of beetles as living with *schaufussi*. Not only does this species suffer from temporary ant-parasites, but it may be enslaved by some form of Amazon-

ant, as *Polyergus lucidus* (Wheeler, '10a, p. 482; Tanquary, '11, p. 302).

#### MUTILLIDÆ

*Sphacrophthalma* sp. Velvet Ant.

This wasp was taken on the bare footpath at the margin of the Bates upland woods (near Sta. IV, a) Aug. 23 (No. 151). It is probably parasitic in the nests of bees.

#### MYZINIDÆ

*Myzine scxincta* Fabr.

This black-and-yellow-banded wasp was very abundant on flowers. It was taken Aug. 8 (Sta. I, g) on flowers of *Asclepias incarnata* (No. 1) and from *Pycnanthemum flexuosum* (No. 6); from the flowers of goldenrod, *Solidago* (near Sta. I, a), Aug. 11 and 12 (Nos. 20 and 26); by T. L. Hankinson (Sta. I) July 3, 1911 (No. 7665); on flowers of *Pycnanthemum* (Sta. II) Aug. 13 (No. 52); and from the flowers of *Eryngium yuccifolium* (Sta. II) Aug. 13 (No. 55); and from the cleared area bordering Bates woods (Sta. IV, a) Aug. 23 (No. 146).

Packard (Guide to the Study of Insects, 8th ed. p. 177. 1883) states that this wasp flies "low over hot sandy places." This is one of the species found by Banks (Jour. N. Y. Ent. Soc., Vol. 10, p. 210, 1902) to sleep in grass, and by Brues (idem, Vol. 11, p. 229. 1903) resting during the day and night upon plants.

#### SCOLIDÆ

*Scolia bicincta* Fabr.

This hirsute black wasp, with two yellow transverse dorsal bands on the abdomen, is represented in our series by four specimens. Three of these were taken on flowers of *Pycnanthemum pilosum* from the clearing bordering the upland portion of the Bates woods (near Sta. IV, a) Aug. 23 (No. 146); the others, from an open space in the upland forest (Sta. IV, a) Aug. 26 (No. 163). I have also taken this species at Bloomington, Ill., Aug. 23, 1892, and Aug. 25, 1896.

Packard (Guide to the Study of Insects, 8th ed., p. 176. 1883) states that in Europe *Scolia bicincta* burrows sixteen inches in sand banks, and that it probably stores its nest with grasshoppers. Riley (First Rep. U. S. Ent. Comm., p. 319. 1878) states that species of *Scolia* are known to have the habit of stinging grasshoppers and digging nests, provisioning these with grasshoppers, on which they lay eggs as does the wasp *Chlorion cyaneum* Dahlb. (*C. caeruleum* Drury). (Cf. with Kohl, Ann. des K. K. naturhist. Hofmuseums, Bd.

5, pp. 121-122. 1890.) Forbes ('08, pp. 157-160) has found that *Tiphia* is parasitic upon the grub of the May-beetles (*Lachnosterna*). The wasp crawls into the ground in search of the larva, stings it, and lays its eggs upon it. It is not unlikely that *Scolia* has similar habits.

The sleeping habits of *bicincta* and some other *Hymenoptera* have been described by Banks (Journ. N. Y. Ent. Soc., vol. 10, pp. 127-130. 1902), Brues (idem, Vol. 11, pp. 228-230. 1903), and Bradley (Ann. Ent. Soc. Amer., Vol. 1, pp. 127-130).

*Scolia tricincta* Fabr.

One specimen was taken—in the clearing bordering the Bates woods on flowers of *Pycnanthemum pilosum* (Sta. IV, a) Aug. 23 (No. 146).

#### EUMENIDÆ

*Odynerus vagus* Sauss. Potter Mud-wasp.

An oval mud nest, about 18 mm. long and 10 mm. in diameter, was found on a stem of dogbane, *Apocynum medium* (Sta. I), Aug. 12 (No. 46). The nest was placed in a vial; and later, a single wasp of the above species came from an opening which was made at the point where the mud cell was formerly attached to the plant.

This is a predatory wasp, which stores its nest with caterpillars (Peckhams, in "Wasps, Social and Solitary," pp. 94-95. 1905).

#### VESPIDÆ

*Polistes*—probably *variatus* Cress.

A small nest was observed in a grassy area near Station I, e, but was not secured. The adults feed the young with caterpillars and nectar. See Enteman (Pop. Sci. Monthly, Vol. 61, pp. 339-351. 1902) for an excellent account of the habits and life history of these social wasps.

That these wasps will build their nests in an open area is of interest, because the nests are so commonly found under eaves and on the under side of roofs—situations which were originally lacking on the prairie.

As Walsh stated, the social wasps do not store up food, because "they feed their larvæ personally from day to day."

#### PSAMMOCHARIDÆ

*Priocnemoides unifasciatus* Say (*Priocnemis*). Spider Wasp.

This wasp was taken in the cleared area bordering the Bates woods, on flowers of *Pycnanthemum pilosum* (near Sta. IV, a) Aug. 23 (No. 146).

A specimen was taken Aug. 21 at Bloomington, Ill. The yellow wings and antennæ, and yellow subapical wing spot on the smoky wings make this a conspicuous species. The family name *Pompilidæ* was formerly used for these wasps.

## SPHECIDÆ

*Ammophila nigricans* Dahlb.

A single specimen was taken from the flowers of *Pycnanthemum flexuosum* (Sta. I) Aug. 11 (No. 24).

This is a very common Illinois species. I have taken it at Bloomington from June 22 to September 9, at Havana during August, and at Chicago, August 19 and 28. A specimen taken August 2 at Bloomington, Ill., was digging in the ground when captured.

*Chlorion ichneumoneum* Linn. (*Sphex ichneumonea* Fabr.). Rusty Digger-wasp. (Pl. I, fig. 1.)

This insect, abundant on flowers of the swamp milkweed, *Asclepias incarnata*, August 8, was taken on them at Sta. I, *g*, Aug. 8 (No. 1) and at Sta. I, *d*, Aug. 9 (No. 12); and on the mountain mint *Pycnanthemum flexuosum* (Sta. I) Aug. 8 (No. 6). It was also taken by T. L. Hankinson July 3, 1911 (No. 7665).

This is a very common insect on flowers in central Illinois. I have found it abundant at Chicago during August; at Bloomington, Ill., from June 24 to Oct. 1; at Mayview on Sept. 26 in a colony of prairie vegetation.

Packard (Guide to the Study of Insects, pp. 167-168. 1870) tells how these wasps dig holes four to six inches deep in gravel walks, and after capturing long-horned grasshoppers, *Orchelimum vulgare* or *O. gracile*, and stinging and paralyzing them, proceed to bury them. The egg is deposited on the locust before the soil is scraped in. (Cf. Walsh, Am. Ent., Vol. 1, p. 126. 1869). For an excellent account of the habits of this species consult the Peckhams, "Instincts and Habits of the Solitary Wasps" (1898). See Fernald ('06) for the recent synonymy.

*Chlorion pennsylvanicum* Linn. Pennsylvania Digger-wasp.

This wasp was taken on the flowers of *Eryngium yuccifolium* (Sta. II) Aug. 13 (No. 55). On Aug. 8, 1893, I captured a specimen at Chicago. (Cf. Fernald, '06, p. 405.)

*Chlorion harrisi* H. T. Fernald (*Isodontia philadelphica* Auct.). Harris's Digger-wasp.

One specimen of this wasp was taken on flowers of the mountain mint *Pycnanthemum flexuosum* (Sta. I) Aug. 11 (No. 24).

I have also taken this species at Bloomington, Ill., Aug. 21 and Sept. 7 and 11.

This wasp has been known in North Carolina to build its nests in the funnel-like bases of the leaves of the pitcher-plant *Sarracenia flava* (Jones, Ent. News, Vol. 15, p. 17 and Pl. III. 1904), and provisions its nest with *Æcanthus*. Ashmead (Insect Life, Vol. 7, p. 241. 1894) states that it "preys upon the cricket *Æcanthus fasciatus* Fitch."

*Chlorion atratum* Lepeletier (*Priononyx atrata* St. Farg. and *Sphex brunnicipes* Cress.). Black Digger-wasp.

This species was taken from the flowers of *Eryngium yuccifolium* (Sta. II) Aug. 13 (No. 55). I have also taken it at Havana, Ill., during August, and at Bloomington, Ill., on September 3, 5, and 12.

In a colony of prairie vegetation near St. Joseph, Ill., when out with a class on an ecological excursion, Sept. 26, 1911, I made some interesting observations on this wasp. Along the Big Four railway track between Mayview and St. Joseph, Ill., fresh sand and gravel had very recently been placed upon the road-bed. In this fresh sand we observed a large black wasp, *Chlorion atratum*, digging. The wasp was about two thirds of her length in the hole when first observed, and when captured later she was more than her length in the hole. She would scratch out the sand so that it fell near the mouth of the hole, and then come out and, standing over the pile, she would scrape it far out of the way by rapid movements of her legs. Every now and then she would come out of the hole with gravel in her jaws; several of such samples were preserved. As the sand was loose the gravel was of course not firmly imbedded. Of the small stones carried out five of the largest range from one fourth to one half an inch in diameter. In bulk each of these is larger than the thorax of the wasp. Four small flies were seen to hover about the hole; some which alighted on small stones near by were captured by a member of the party and proved to be small tachinids (No. 309, C.C.A.), which Mr. J. R. Malloch determined to be *Metopia leucocephala* Rossi. (Cf. Coquillett, '97, p. 127.) Mr. Malloch also called my attention to recorded observations on other tachinid flies which inhabit the burrows of *Hymenoptera* in Great Britain, and are parasitic in habit (Malloch, '09). Hamm ('09b) has described how one of these flies, *Setulia grisea* Mg., follows the females of *Cerceris* as she provisions her burrow with weevils. They were observed to enter and to come out of the burrow. Melander and Brues ('03, pp. 9, 20) state that *M. leucocephala* infests the bee *Halictus* by choosing "the moment when the incoming bee pauses at her threshold quickly and quietly to oviposit on her pollen mass and thus infect her offspring." This fly has been reported to be

viviparous. Cf. Aldrich ('05, p. 476). The Peckhams ('98, p. 37) observed a small fly at the burrows of *Chlorion ichneumoncum*. Brues (Jour. N. Y. Ent. Soc., Vol. 11, p. 228, 1903) has observed this species near Chicago sleeping in sweet clover. (See also Bradley, in Ann. Ent. Soc. Amer., Vol. 1, pp. 127-130, 1908.)

For the habits of this species see the Peckhams, "Instincts and Habits of the Solitary Wasps," pp. 171-173. This species provisions its nest with the Carolina locust, *Dissosteira carolina*. Coquillett (Insect Life, Vol. 7, p. 228, 1894) says that this species shows a preference for *Melanoplus femur-rubrum* DeG. in provisioning its nest.

#### STIZIDÆ

*Stizus brevipennis* Walsh. Digger-wasp.

A single specimen of this large wasp was taken on flowers of *Pycnanthemum flexuosum* (Sta. I) Aug. 12 (No. 35); another was taken by T. L. Hankinson (Sta. I) July 3, 1911 (No. 7665).

Walsh (Am. Ent., Vol. 1, p. 162, 1869) found this species on flowers of the wild parsnip at Rock Island, Ill. An allied wasp, *Sphæcius speciosus* Drury, preys upon the cicada or dog-day harvest-fly, *Cicada pruïnosa*, on which it lays its egg and upon which its larva feeds. Consult Riley (Insect Life, Vol. 4, pp. 248-252, 1891) for an excellent account of this wasp. As Walsh infers, *brevipennis* and *speciosus* probably have similar habits. A tachinid fly, *Senotainia trilineata* V. d. W., has been bred from the nest of *speciosus* (Coquillett, '97, p. 20).

#### HALICTIDÆ

*Halictus obscurus* Rob.

A single specimen was taken—on the Loxa prairie from the flowers of *Eryngium yuccifolium* (Sta. II) Aug. 13 (No. 55).

*Halictus fasciatus* Nyl.

This bee was taken Aug. 13 on the Loxa prairie (Sta. II) from the flowers of *Silphium integrifolium* (No. 48) and from those of *Pycnanthemum flexuosum* or *P. pilosum* (No. 52); and on goldenrod, *Solidago* (Sta. I), Aug. 12 (No. 26).

*Halictus virescens* Fabr.

A single male of this small bee, with metallic green head and thorax, was taken on flowers of verbena (Sta. I) Aug. 11 (No. 23).

#### NOMADIDÆ

*Epeolus concolor* Rob.

This species was taken on the heads of the cone-flower, *Lepachys pinnata* (Sta. I, c), Aug. 8 (No. 8); very abundantly from flowers of



the mountain mint *Pycnanthemum flexuosum* (Sta. I, *g*) Aug. 8 (No. 6); from flowers of *Silphium integrifolium* (Sta. II) Aug. 13 (No. 48); and from flowers of *Pycnanthemum flexuosum* or *pilosum* (Sta. II) Aug. 13 (No. 52).

It is said to be "parasitic on the species of *Colletes*," but Robertson ('99, pp. 35, 37) does not accept this view, and Ashmead (*Psyche*, Vol. 7, pp. 41-42. 1894) states that *Epeolus donatus* Smith makes a nest in the ground and provisions it with a honey-paste. He describes the burrows, egg, and larva.

Robertson has published keys to the Carlinville (Ill.) species of *Epeolus* (*Can. Ent.*, Vol. 35, pp. 284-288. 1903).

#### EUCERIDÆ

*Melissodes aurigena* Cress.

A single female of this species was taken from flowers of ver-bena( near Sta. I, *b*) Aug. 11 (No. 23).

The homing behavior of this genus of bees has been studied by Turner (*Biol. Bull.*, Vol. 15, 247-258. 1908). He concludes that memory is utilized.

*Melissodes bimaculata* St. Farg.

This bee was taken from the heads of the cone-flower, *Lepachys pinnata* (Sta. I, *e*), Aug. 8 (No. 8); abundantly from flowers of the mountain mint *Pycnanthemum flexuosum* (Sta. I, *g*) Aug. 8 (No. 6); on the Loxa prairie on flowers of the rosin-weed, *Silphium integrifolium* (Sta. II), Aug. 13 (No. 48; and on the cleared margin of the Bates woods on flowers of the mountain mint, *P. pilosum* (Sta. IV, *a*), Aug. 22 (No. 146).

Some observations on the "sleeping habits" of this bee and of other *Hymenoptera* have been made by Banks (*Journ. N. Y. Ent. Soc.*, Vol. 10, pp. 209-214. 1902). Graenicher ('05, p. 164) has recorded observations on the habits of *M. trinodis* Rob. and also on its bee parasite *Tricpeolus*. Ashmead (*Psyche*, Vol. 7, p. 25. 1894) found the burrows of *bimaculata* eight inches deep in the soil.

*Melissodes desponsa* Smith.

This bee was taken on the cleared margin of the Bates woods on flowers of the mountain mint *Pycnanthemum pilosum* (near Sta. IV, *a*) Aug. 22 (No. 146).

*Melissodes obliqua* Say.

This bee was found abundant upon flowers of the cone-flower, *Lepachys pinnata* (Sta. I, *e*), Aug. 8 (No. 8); it was taken from flowers of the white mint, *Pycnanthemum flexuosum* (Sta. I), Aug. 11 (No.

24); and a female was taken from the flowers of *Silphium integrifolium* (Sta. I) Aug. 13 (No. 48). According to Robertson (Trans. Acad. Sci. St. Louis, Vol. 6, p. 468. 1894) this bee is the most abundant bee visitor to the cone-flower, and it also shows a marked preference for this plant.

#### MEGACHILIDÆ

*Megachile mendica* Cress. Leaf-cutting Bee.

A single specimen was taken on flowers of the swamp milkweed, *Asclepias incarnata* (Sta. I, *g*), Aug. 8 (No. 1).

The habits of our leaf-cutting bees have received little attention, although the circular areas which they cut from rose leaves are a familiar sight. Putnam (Proc. Essex Inst., Vol. 4, pp. 105-107. 1864) describes the nests of *Megachile centuncularis* Linn., and Packard, one of its hymenopterous parasites (idem, pp. 133-137).

*Megachile brevis* Say. Short Leaf-cutting Bee.

A single female was taken by T. L. Hankinson (Sta. I) July 3, 1911 (No. 7665). This species is known to use plum leaves for its nest. Its habits have been briefly described by Reed (Sec. Rep. Ent. Soc. Ont., pp. 24-26. 1872; Can. Ent., Vol. 3, pp. 210-211. 1871). The nest is formed of a leaf which is wrapped about the disks cut from the leaves, and is not in the ground or in cavities in wood as is the case with many species. Packard (Jour. N. Y. Ent. Soc., Vol. 5, p. 109-111. 1897) describes and gives figures of the immature stages of what is possibly *M. centuncularis* Linn. See also Packard ('73), Ashmead ('92), and Howard ('92a).

Some of the species of this genus are parasitized by bees of the genera *Stelis* and *Calioxys* as has been shown by Graenicher ('05); some also are parasitized by certain flies (Howard, in Proc. Ent. Soc. Wash., Vol. 2, p. 248. 1893).

#### XYLOCOPIDÆ

*Xylocopa virginica* Drury. Carpenter-bee. (Pl. XLIX.)

Only four specimens of this bee were taken, and these were found on flowers of the swamp milkweed, *Asclepias incarnata* (Sta. I, *d*), Aug. 8 (No. 1) and 24, (No. 156).

The carpenter-bee has much the appearance of a large bumblebee. The female cuts tunnels in wood to make a nest for the young. Packard has described the larva (Journ. N. Y. Ent. Soc., Vol. 5, p. 113. 1897). The same author records observations by Angus on the boring habits of this species (Our Common Insects, pp. 21-24. 1873). He found the larva of a bee-fly, *Anthrax sinuosa* Wied., parasitic on the

larva of the carpenter-bee. Felt, ('05, Pl. 39, and '06, p. 484) has given figures of the nest and has briefly described it. The burrows are made in the seasoned lumber of houses, in telegraph poles, and in similar situations. On the prairie at Charleston, fence posts, telegraph poles, and railway ties constitute the supply of wood available for nesting purposes. It thus appears probable that this bee was not particularly abundant on the original prairie, far from the forests or cottonwoods, for such nesting habits imply a supply of wood for the burrows. The larva is said to feed upon pollen, on which the eggs are placed.

#### BOMBIDÆ

*Bombus pennsylvanicus* DeG. Pennsylvania Bumblebee.

This species was taken on the Loxa prairie from flowers of the purple prairie clover, *Petalostemum purpureum* (Sta. II), Aug. 13 (No. 50); on flowers of the mountain mint, *Pycnanthemum pilosum* or *P. flexuosum* (Sta. II) Aug. 13 (No. 52); on flowers of the rattlesnake-master, *Eryngium yuccifolium* (Sta. II), Aug. 13 (No. 553); in an open glade in the lowland forest (Sta. IV, c) Aug. 22 (No. 143); on flowers of the thistle *Cirsium discolor* (near Sta. I, d) Aug. 24 (No. 155); from the flowers of the broad-leaved rosin-weed, *Silphium terebinthinaceum* (Sta. III, b), Aug. 26 (No. 175); and on the prairie west of Loxa on the flowers of the blazing star, *Liatris scariosa* (Sta. II), Aug. 27 (No. 176).

Banks (Jour. N. Y. Ent. Soc., Vol. 10, p. 212. 1902) has recorded this species as sleeping on flowers.

The following papers on the habits and life history of the bumblebees will aid in the study of these neglected insects:

Coville, Notes on Bumble-Bees. Proc. Ent. Soc. Wash., Vol. 1, pp. 197-202. (1890)—Putnam, Notes on the Habits of some Species of Bumble Bees. Proc. Essex Inst., Vol. 4, pp. 98-104. (1864)—Packard The Humble Bees of New England and their Parasites; with notices of a new species of Anthophorabia, and a new genus of Proctotrupidæ. Proc. Essex Inst., Vol. 4, pp. 107-140. (1865)—Marlatt, An Ingenious Method of Collecting *Bombus* and *Apathus*. Proc. Ent. Soc. Wash., Vol. 1, p. 216. (1890)—Howard, The Insect Book, (1904), pp. 12-16; and Sladen, The Humble-Bee (1912). Marlatt describes the use of a jug of water in collecting bees from the nest. (This has long been the common method of destroying these bees used by country boys and farmers of central Illinois.)

A very important systematic paper, which also contains much on the life history and habits of the American *Bombidæ* has recently been published by Franklin ('13).

A tachinid fly, *Brachycoma davidsoni* Coq. (Coquillett, '97, p. 10) has been bred from a larva of *Bombus fervidus* Fabr. The larva of the syrphid fly *Volucella* lives as a scavenger in *Bombus* nests (Cf. Metcalf, '13, p. 68). The conopid flies *Physocephala* and *Conops* are parasitic on *Bombus*. A nematode parasite, *Sphaerularia bombi*, infests hibernating queens. It has been found in *B. pennsylvanicus*, *fervidus*, and *consimilis* (Cf. Stiles '95).

*Bombus auricomus* Rob.

Two males of this species were taken from flowers of the large-leaved rosin-weed, *Silphium terebinthinaceum*, on the prairie area east of Charleston (Sta. III, *b*), Aug. 26 (No. 175). This bumblebee was also taken by T. L. Hankinson (Sta. I) July 3, 1911 (No. 7665). (Cf. Franklin, '13, Pt. I, p. 413.)

*Bombus impatiens* Cress. Impatient Bumblebee.

A single female was taken from the flowers of the broad-leaved rosin-weed, *Silphium terebinthinaceum*, east of Charleston (Sta. III, *b*), Aug. 26 (No. 175).

*Bombus fraternus* Smith.

Two females of this species were taken on flowers of the swamp milkweed, *Asclepias incarnata*: one of them (No. 1) at Station I, *g*, Aug. 8; and the other (No. 12) at Station I, *d*, Aug. 9.

*Bombus separatus* Cress.

This species was collected from the swamp milkweed, *Asclepias incarnata*, as follows: Station I, *g*, Aug. 8 (No. 1); Station I, *d*, Aug. 9 (No. 12); Station I, *d*, Aug. 24 (No. 157)—the latter had been captured by the flower spider *Misumena aleatoria* Hentz; and one male from flowers of the horse mint, *Monarda* (Sta. I), Aug. 11 (No. 22).

*Psithyrus variabilis* Cress. False Bumblebee.

A single female was taken from the flowers of the horse mint, *Monarda* (Sta. I), Aug. 11 (No. 22); and a male was taken on the prairie west of Loxa from flowers of the blazing star, *Liatris scariosa* (Sta. II), Aug. 27 (No. 176). These bees are parasitic in the nests of *Bombus*. For an excellent account of the habits of the British species, Sladen ('12, pp. 59-72) should be consulted.

#### APIDÆ

*Apis mellifera* Linn. Honey-bee.

Workers of this species were extremely abundant on flowers of the milkweed *Asclepias incarnata* (Sta. I, and Sta. I, *d, g*) Aug. 8

(No. 1). Milkweed flowers play a double rôle as food and enemy. Robertson (Trans. St. Louis Acad. Sci., Vol. 5, p. 573) states that honey-bees are frequently found hanging dead from the flowers of the common milkweed, *A. syriaca*, and Gibson (Harper's Mag., Vol. 95, pp. 519-520. 1897) has found many of them entrapped by this milkweed. Bees are not the only insects captured by this insect trap, for Gibson found gnats, crane-flies, bugs, wasps, beetles, and small butterflies hanging from the flowers. He also found that the dogbane *Apocynum* thus captures moths.

## II. FOREST INVERTEBRATES

### MOLLUSCA

#### HELICIDÆ

*Polygyra albolabris* Say. (Pl. LI, figs. 2 and 3.)

A single adult dead shell (No. 91) of this woodland species was found in the upland forest (Sta. IV, a). It is our largest species of snail.

The natural history of our land-snails has received little attention, but is worthy of careful study. The best account of the life history and habits of this species is by Simpson ('01).

*Polygyra clausa* Say.

A single dead immature shell was taken under a small decayed limb on the ravine slope (Sta. IV, b) Aug. 26 (No. 164), associated with many individuals of *Pyramidula perspectiva*, and one individual each of *Vitrea indentata* and *V. rhoadsi*.

Shimek ('01, p. 200) groups this species with those which frequent "higher, more deeply shaded (often mossy and rocky) banks and slopes, sometimes in deep woods."

#### CIRCINARIIDÆ

*Circinaria concava* Say. Predaceous Snail.

A large dead shell (No. 71) and several living specimens were found in a decayed stump in the upland forest (Sta. IV, a). A young individual (No. 113), diameter 6 mm., was taken Aug. 20 among the vegetable debris washed from a ravine and deposited as a low fan in the lowland forest (Sta. IV, c). With it were associated *Vitrea indentata*, and some kind of large snail eggs (No. 114). This is a carnivorous species.

## ZONITIDÆ

*Vitrea indentata* Say.

One specimen (No. 113) was taken Aug. 20, among a mass of drifted rotten wood and dead leaves deposited at the mouth of a ravine in the lowland forest (Sta. IV, *c*), in company with a young specimen of the carnivorous *Circinaria concava*; and another (No. 140), on Aug. 22, under leaves at the base of a ravine slope (Sta. IV, *b*), in woods so dense that there was very little herbaceous vegetation, but a thick ground cover of leaves and vegetable mold. The interesting ant *Stigmatomma pallipes*, *Myrmica rubra scabrinodis schencki*, and the larva of *Meracantha contracta* were found here. Specimens were also taken Aug. 26 (No. 164) under a small decayed limb on the ravine slope (Sta. IV, *b*) in company with *Vitrea rhoadsi*, *Polygyra clausa*, and *Pyramidula perspectiva*.

*Vitrea rhoadsi* Pilsbry.

This snail was taken under a small damp decayed limb on a wooded ravine slope (Sta. IV, *b*) in company with *V. indentata*, *Pyramidula perspectiva*, and *Polygyra clausa* (No. 64). Mr. F. C. Baker informs me that this species has not previously been recorded from Illinois.

*Zonitoides arborea* Say.

This snail was taken on a fungus which was growing on a decayed stump in the upland forest (Sta. IV, *a*) Aug. 17 (No. 71), in company with the mollusks *Pyramidula perspectiva*, *Circinaria concava*, and *Philomycus carolinensis*, the ant *Aphanogaster fulva*, and the white ant *Termes flavipes*. Also taken from a moist rotting stump, on the slope of the valley (Sta. IV, *b*), Aug. 17 (No. 84), in company with the snail *P. perspectiva*, the slug *P. carolinensis*, newly established colonies of the ant *Camponotus herculeanus pennsylvanicus*, and the beetle *Passalus cornutus*.

This snail appears to be mainly a species of the woodland, where it occurs under decaying wood and vegetable debris.

Motter ('98, p. 219) records this species from an old grave. This suggests a subterranean habit. (Cf. Baker, '11, p. 155.)

## PHILOMYCIDÆ

*Philomycus carolinensis* Bosc. Carolina Slug.

Several young specimens of this slug (No. 71), about 5 mm. long when contracted in alcohol, were found (Sta. IV, *a*) Aug. 17 in the upland forest on a well rotted stump overgrown in part by a felt-like fungous growth. The finding of these young slugs and the finding

elsewhere in the forest of eggs, possibly of this species (Nos. 86 and 114), is of special interest. On the forested ravine slope (Sta. IV, *b*) in another decaying stump, in which the bark was loosened and the sap-wood quite decayed, soft, large examples of this slug were found in abundance Aug. 17 (No. 89). They were associated with newly established colonies of the carpenter-ant *Camponotus herculeanus pennsylvanicus*, and the horned Passalus, *Passalus cornutus* (No. 85). The association of these three species is not an accident, but indicates clearly a certain stage in the decay of a log or stump which is favorable to their development. Another colony was found under the bark of an oak stump (Sta. IV, *b*) in which the sap-wood had decayed, but the remainder of which was solid though discolored. A very large individual and several young slugs ranging in length from about half an inch to an inch and a half were found in a cavity under the bark Aug. 22 (No. 125).

A batch of eggs, found with specimens No. 89, and presumably of this species, was taken Aug. 17 (No. 86). These eggs, pearl-like translucent spheres, twenty-two in number, were in a small cluster. The other lot of eggs (No. 114) was taken Aug. 20 among dead leaves and rotten-wood drift at the mouth of a ravine in the lowland forest (Sta. IV, *c*), where *Vitrea indentata* was taken (No. 113). The large size of these eggs, which even when shriveled in alcohol are over 2 mm. in diameter, the paucity of other large pulmonates throughout these woods, the abundance of *Philomycus*, and the presence of small young at this season are indicative that the eggs belong to this slug.

Little seems to be recorded concerning the life history of this species or its habits. An individual kept by Binney (Bull. 28, U. S. Nat. Mus., pp. 243-244. 1885) deposited thirty eggs June 30. These hatched July 10 and grew very rapidly. Baker ('02, p. 203) states that it ascends trees to a "height of over fifty feet, and is most frequently found under bark which has become 'started'." He also states that it is "solitary in habit." My own observations of this species confirm his statement as to its preference for wood in which the sap-wood has decayed, but I have often found several specimens in close proximity, as was the case with specimens No. 89.

#### ENDODONTIDÆ

*Pyramidula alternata* Say. Alternate Snail.

A single dead shell (No. 173) of this common species in forests, was taken at the mouth of a ravine in the lowland forest (Sta. IV, *c*).

This is generally a woodland species. At Mackinaw Dells, along

the Mackinaw bottoms in Woodford county, Ill., I have found large numbers late in the fall hibernating in hollow trees about five feet above the ground. A very large colony—perhaps several hundred specimens—was once found some little distance from woods along a moist railway embankment south of Bloomington, Ill. Baker ('02, p. 208) states that the eggs, from twenty to eighty, are laid early in June and hatch in about thirty days.

*Pyramidula perspectiva* Say.

The decayed stump in the upland forest (Sta. IV, *a*) which was overgrown with a layer of fungus (see under *P. carolinensis*) contained Aug. 17, a very large number of young and adults of this species (No. 71). The shell is distinguished by the large open umbilicus, which leaves the upper whorls exposed.

This is the most abundant mollusk in the forest. It was found associated with *Circinaria concava*, *Zonitoides arborea*, and *Philomycus carolinensis*. In small cavities in the wood encrusted with the fungus, large numbers of *P. perspectiva* were found crowded together. Apparently this snail fed upon the fungus, the moist surface possibly adding attractiveness. In this stump was a large nest of the ant *Aphanogaster fulva* (No. 79) and one of white ants, *Termes flavipes* (No. 72). *P. perspectiva* was also taken from a decaying stump on the wooded ravine slope (Sta. IV, *b*) Aug. 17 (No. 84) in association with *Zonitoides arborea*, *Philomycus carolinensis*, the ant *Camponotus herculeanus pennsylvanicus*, and the beetle *Passalus cornutus*; under decayed logs in the upland oak forest (Sta. IV, *a*) Aug. 17 (No. 88); and under a small much-decayed limb on the wooded ravine slope (Sta. IV, *b*) Aug. 26 (No. 164) in company with *Polygyra clausa*, *Vitrea indentata*, and *Vitrea rhoadsi*.

Shimek ('01, pp. 200, 202) says that this species is common on shaded banks, under decaying logs, and lists it with those which frequent "higher, more deeply shaded (often mossy and rocky) banks and slopes, sometimes in deep woods."

## CRUSTACEA

### ASTACIDÆ

*Cambarus diogenes* Girard. Diogenes Crawfish.

This crawfish was taken Aug. 17, 1911, in the south ravine (Sta. IV, *d*), where Mr. Hankinson also took it in 1910 in the following situations: from a pool in the stream Aug. 17; from burrows, with chimneys, in the bed of the stream, Aug. 20; and from under flat stones in the bed of this stream, three specimens. Aug. 22.



For detailed accounts of the ecological relations of this species see Ortmann ('06) and Harris ('03).

*Cambarus propinquus* Girard. Neighborhood Crawfish.

This species also was taken from a small pool in the south ravine (Sta. IV, *d*), Aug. 20, 1910, by Hankinson.

Consult Ortmann ('06) and Harris ('03).

*Cambarus immunitis* Hagen. Immune Crawfish.

This species was taken from pools in the temporary stream (Sta. IV, *d*) by Hankinson Aug. 17 and 20, 1910.

Consult Harris ('03).

## MYRIAPODA

### LYSIOPETALIDÆ

*Callipus lactarius* Say.

This myriapod was taken among dead leaves and rotten wood in the forest bottom at the mouth of a ravine (Sta. IV, *c*) Aug. 20 (No. 113).

There is hardly a more neglected group of animals in Illinois than the *Myriapoda*. The ecological relations of our American myriapods offer a virgin field for study. A few observations upon the habitat of the humus-inhabiting Texas species have been made by Cook ('11a, pp. 147-150).

### CRASPEDOSOMIDÆ

*Cleidogona casioannulata* Wood.

This myriapod was taken under damp leaves on the lower slopes of the lowland forest (Sta. IV, *b*) Aug. 22 (No. 140), associated with the old-fashioned ant, *Stigmatomma pallipes*.

### POLYDESMIDÆ

*Polydesmus* sp.

This myriapod was taken under the bark of an oak stump in the early stages of decay—all sap-wood being honeycombed; the remainder solid though discolored—(Sta. IV, *b*) Aug. 22 (No. 125), associated with *Philomyces carolinensis*.

## ARACHNIDA

### PHALANGIDA

#### PHALANGIDÆ

*Liobunum vittatum* Say. Striped Harvest-spider.

One female was taken in the upland Bates forest, while running about on the dry leaves lying around a decayed stump (Sta. IV, *a*)

Aug. 17 (No. 82), and two males were found in the same forest Aug. 22 (No. 123).

Weed ('89, p. 87) states that this species is very abundant on rocky ledges in parts of southern Illinois. He is of the opinion that the winter is passed in the egg stage, and maturity is reached in July. The young prefer grass, low vegetation, and piles of rubbish, but when mature are found in a "great variety of situations," as in the corn fields of the prairie parts of Illinois, in grasslands, among brush, and in the forest ('92c, p. 1006).

*Liobunum ventricosum* Wood. (Pl. LI, fig. 1.)

Three specimens of this "daddy-long-legs" were taken in the upland Bates forest (Sta. IV, a) Aug. 22 (No. 123b)

The young of this species hibernate, and maturity is reached early in June (Weed, '92b, p. 264). This is exceptional, as most species of this group pass the winter in the egg stage. The food of daddy-long-legs consists mainly of dead insects (Weed, '89, p. 80).

*Liobunum grande* Say. Stout Harvest-spider.

This stout-bodied and short-legged species was found running about on dry leaves in the upland forest (Sta. IV, a) Aug. 17 (No. 82); and in a damp ravine (Sta. IV, b) Aug. 20 (No. 111).

Consult Weed ('92b and '93) for descriptions and figures of this species. Very little appears to be recorded about it.

## ARANEIDA

### EPEIRIDÆ

*Epeira insularis* Hentz. Island Epeirid. (Pl. LII, figs. 1, 2, and 3.)

This spider was taken from a web stretched between trees in the upland forest (Sta. IV, a), Aug. 16 (No. 70).

McCook ('89, Vol. 1, pp. 117, 118, 273, 330, 337; '90, Vol. 2, pp. 20, 86-87, 208, 214, 289, 441, 453) records a number of interesting observations on this spider. The Peckhams ('87) give an account of their observations on its senses.

*Epeira domiciliorum* Hentz. Tent Epeirid.

This spider was taken at the margin of the low, damp forest (Sta. IV, c) Aug. 22 (No. 137); from the margin of a large web among the branches of trees in the upland forest (Sta. IV, a) Aug. 26 (No. 167); and, on the same date, from the glade in the lowland forest (Sta. IV, c), folded in a sassafras leaf (No. 173).

I have found the species at the margin of its webs, in a leafy tent, in dense woodlands near Urbana, Ill., in the Brownfield woods Oct.

18, and in the Cottonwood forest Oct. 13. It was abundant among the leaves of a shrub—the spice-bush (*Benzoin*).

McCook ('89, Vol. 1, pp 78-79, 116, 255, 288, 339, and '90, Vol. 2, pp. 86-88, 224, 334) records many observations on the habits of this species, and, more recently, Porter ('06) has studied an allied species.

*Epeira trivittata* Keys. Three-lined Spider. (Pl. LIII, figs. 1 and 2.)

A single specimen was taken on a web in the lowland forest (Sta. IV, c) Aug. 22 (No. 138).

*Epeira verrucosa* Hentz. White-triangle Spider. (Pl. LIII, figs. 3 and 4.)

This species was taken from webs stretched between trees in the forest (Sta. IV) Aug. 16 (No. 70); and again at the same Station Aug. 22 (No. 126). The individuals taken were always at the center of their webs.

The peculiar whitish, leaf-like triangular area on the dorsal surface of the abdomen is a striking peculiarity of this species. It is associated in habitat with *Acrosoma spinca* Hentz, and *A. rugosa* Hentz.

*Acrosoma spinca* Hentz. Spined Spider. (Pl. LIV, figs. 1-5.)

From webs connecting trees in the damp lowland forest (Sta. IV, c) this spider was taken Aug. 22 (No. 138) and Aug. 26 (No. 172); and another individual (No. 148) was taken Aug. 23 (Sta. IV) from a small web on a low sassafras shrub within two feet of the ground. It feigned death when placed in a vial, the hind legs being closely applied to the abdomen, the others being folded against the cephalothorax. The two large posterior spines on the abdomen of this species make it conspicuous.

This is a representative forest-inhabiting species; its web and those of *rugosa*, generally placed at about the height of a man's head, are often so abundant, at least during August, as to be bothersome when one after another is swept from the trees by one's face. Because of the tension of these threads few persons care to have them accumulate on the face.

McCook ('89, Vol. 1, pp. 126-127) has recorded observations on this species.

*Acrosoma rugosa* Hentz. (*gracile* Walck.). Rugose Spider.

This spider was taken from webs connecting trees and shrubs in the upland forest (Sta. IV, a) Aug. 16 (No. 70) and Aug. 22 (No. 126); on a web in the forest (Sta. IV) Aug. 23 (No. 147), with the apex of the ventral abdominal cone turned uppermost at the cen-

ter of the web; and from webs in the shady lowland forest (Sta. IV, *c*) Aug. 26 (No. 172).

Montgomery ('03, pp. 119-120 and '09) has made observations on the breeding habits of this species, and McCook ('89, Vol. 1, pp. 64, 73, 125-127, 254, 338, and '90, Vol. 2, pp. 285, 289, 375) describes its webs and gives observations on its habits.

#### LYCOSIDÆ

*Lycosa scutulata* Hentz.

A single immature specimen was taken from the low vegetation in an open glade in the lowland part of the Bates woods (Sta. IV, *c*) Aug. 22 (No. 144).

For the breeding habits of this species see Montgomery ('03, pp. 72-76).

*Lycosa* sp.; young.

This spider was taken in the upland woods (Sta. IV, *a*), running upon the ground, Aug. 23 (No. 150). Another undetermined species was taken in the pathway entering the upland forest from the cleared area (Sta. IV, *a*). This spider was dug from a burrow about two inches deep, in the solid clay of the pathway, Aug. 22 (No. 142).

#### ACARINA

##### ERIOPHYIDÆ

*Acarus scrotinæ* Beut. Cherry-leaf Gall-mite. (Pl. LV, fig. 1.)

This small mite was taken in the lowland portion of the Bates woods (Sta. IV, *c*) Aug. 20 (No. 116). It forms a gall on the upper side of the leaves of the wild cherry, *Prunus scrotina*.

#### INSECTA

##### PLATYPTERA

##### TERMITIDÆ

*Termes flavipes* Koll. White Ant. Termite. (Pl. LV, fig. 2.)

A small well-decayed stump in the upland forest (Sta. IV, *a*) was found Aug. 17 to contain a colony of these termites in large numbers—mainly workers but also some soldiers (Nos. 72, 79). In close proximity was a colony of the ant *Aphaenogaster fulva*. Some of these ants (Nos. 74-76) were observed to pick up termites and carry them away as they do their own young when a nest is disturbed. *A.*

*fulva* is known to relish the termites as food. A second colony of termites (No. 125) was found Aug. 22 under the bark of an oak stump (Sta. IV, *b*), in the early stages of decay, when the sap-wood was becoming honeycombed but the remainder of the wood was still solid. The caterpillar *Scolecocampa liburna* was found in the same stump.

As white ants feed mainly upon woody and other vegetable materials, they are active agents in hastening the decay and destruction of such substances, mainly in forested areas but also upon the prairie.

Two species have long been confused under the name of *flavipes*, and as the newly recognized one, *virginicus* Bks., may occur in extreme southern Illinois, reference is made to it. (See Banks, Ent. News, Vol. 18, pp. 392-393. 1907).

## NEUROPTERA

### MYRMELEONIDÆ

An ant-lion was taken from its inverted funnel in the dust along the path through the cleared area to the forest (near Sta. IV, *a*) Aug. 29 (No. 183).

Although ant-lions are common in many localities and widely dispersed, little is really known of the ecology of the American species. These insects reach their greatest abundance and diversity in the arid regions of the west and southwest. In the eastern forested area they are of much more local occurrence and are generally found in the dust, particularly in sheltered places—as under an overhanging cliff or even under the porches of houses, where the desirable protection from rain is afforded; or, often, in the woods, in the powdery dust that marks the final stages in the decay of a log. The log as an animal habitat has an interesting life history and a corresponding succession of animals. On the decay of the sap-wood, *Camponotus* and *Philomyces* are among the early invaders of the log; the ant-lion, present in its dust, is one of the latest. It should be noted that these isolated, dry, dusty places are the situations in the humid area which most nearly approach the conditions which on the plains, and particularly on the desert, are of nearly continuous geographic extent.

## MECAPTERA

### PANORPIDÆ

*Bittacus stigmaterus* Say. Clear-winged Scorpion-fly.

The damp, shady lowland forest, with a ground cover composed of nettles (*Laportea canadensis*) and clearweed (*Pilea pumila*),

would seem to furnish an ideal habitat for the genus *Bittacus*, but only two specimens, a male and a female, were taken (Sta. IV, c) Aug. 22 (No. 141).

The young and adults of this genus are predaceous. Brauer and Felt have described the habits of some of the adults. They capture small flies and other insects with their legs as they hang suspended. The use of the legs for suspension and for the manipulation of their food recalls somewhat similar methods used by other predaceous insects, such as robber-flies (*Asilidæ*) and hornets (*Vespa*). *Bittacus* may copulate while thus suspended and eating, as described and figured by Brauer. Either the first or second, or both pairs of legs may be used for suspension.

The larvæ are caterpillar-like, but in the case of our American species none of them are known. The European species are predaceous, and live upon the ground. According to Brauer a certain amount of drying seems necessary to the hatching of the eggs. Some species have been taken at light, where they preyed upon the congregated insects. (See Hine, '01, p. 260, and Bull. No. 7, n. s., Div. Ent., U. S. Dept. Agr., p. 86. 1897.) Papers by Brauer ('53, '55, '62, '63, '71), Felt ('95), and others by Hine ('98, '01), will be of the greatest assistance to a student of this neglected group of insects.

*Bittacus strigosus* Hag. Spotted Crane-like Scorpion-fly.

This species was taken but once—June 28, 1911, by T. L. Hankinson in the Bates woods (No. 7678). It was abundant south of Bloomington Aug. 22, 1895, where *B. stigmaterus* Say was also taken July 16, 1896. These species are characteristic of dense woods.

*Bittacus apicalis* Uhler. Brown-tipped Scorpion-fly.

This insect was taken June 28, 1911, in the Bates woods by T. L. Hankinson (No. 7678). I have found this species very abundant in dense shady woods south of Bloomington, Ill. The brown tips of the wings make it easily identifiable.

## ORTHOPTERA

### BLATTIDÆ

*Ischnoptera* sp.

This cockroach was found under leaves on the lower slopes of a ravine (Sta. IV, b) leading to the lowland Aug. 22 (No. 140). Hancock ('11, pp. 416-418) discusses the habits and habitat of *I. pennsylvanica* (Pl. LVI, figs. 4 and 5.)

## PHASMIDÆ

*Diapheromera femorata* Say. Forest Walking-stick. (Pl. LVI, fig. 6.)

These insects were abundant in the upland forest (Sta. IV, *a*); the following observations were made on them. A fuscous male (No. 64) was taken Aug. 16 crawling on hickory. When disturbed it fell to the ground and remained quiet. A female was taken at the base of a tree in a resting position with the antennæ closely applied and stretched forward. On August 17 a nymph was taken in an open area; Aug. 20 (No. 103), a large gray female; a copulating pair (No. 134), in which the female was gray and the male fuscous; and, finally, a small immature male (No. 163) in the before-mentioned resting position, on hickory.

On the ravine slope (Sta. IV, *b*), memoranda are as follows: Aug. 22 (No. 124a) three fuscous males, and a large gray female in the resting position, and (No. 132), in copulation, a fuscous male and a green female, the latter lacking the hind pair of legs. A green, nearly mature nymph was taken in a wood-lot adjacent to the Bates area Aug. 28 (No. 99). A large fuscous male was taken east of Charleston on the Embarrass River at the "Rocks" Aug. 10 (No. 17).

This walking-stick is distinctly a forest-inhabiting insect, but we have another, *Bacunculus blatchleyi* Caud., which frequents the prairie, though it was not found about Charleston. Occasionally *femorata* becomes of economic importance. Riley (Rep. U. S. Dept. Agr., 1878, pp. 241-245) studied its life history and habits and found that some predaceous bugs prey upon it. The Severins (Jour. Economic Ent., Vol. 3, pp. 479-481. 1910) have shown experimentally that the hatching of the eggs is facilitated by moisture. T. I. Hankinson found a phasmid nymph, about an inch long, June 28, 1911, in the woods (No. 7678).

The behavior of our species is worthy of more attention than it has received. In such a study, reference should be made to a suggestive paper by Stockard on the "Habits, Reactions and Mating Instinct of the 'Walking-Stick' *Aplopus Mayeri*" (Pub. No. 103, Carnegie Institution, pp. 43-59. 1908); or, if the color changes are studied, Schleip's paper on "Der Farbenwechsel von *Dixippus morosus* (Phasmidae)" (Zool. Jahrb. Bd. 30, Abt. Allgem. Zool. u. Physiol., pp. 45-132. 1910) should be consulted. Cf. Caudell, Proc. U. S. Nat. Mus., Vol. 26, pp. 863-885, 1903.

## ACRIDIDÆ

*Tettigidea lateralis* Say. (Pl. LVII, fig. 3.)

A grouse locust was found in the dry upland forest (Sta. IV, *a*) on the ground Aug. 20 (No. 109).

Morse ('04, p. 16) states that this species has a preference for "wet meadows and swales."

*Tettigidea parvipennis* Morse. Short-winged Grouse Locust.

A single specimen was secured in the upland forest (Sta. IV, a) on dry leaves Aug. 22 (No. 122).

Hancock ('02, p. 149) found this species very abundant in moist, dense woods.

*Dichromorpha viridis* Scudd. Short-winged Grasshopper. (Pl. LVII, fig. 7.)

A green short-winged female was taken from the tall prairie grass (*Andropogon* and *Sporobolus*) colony (Sta. I, g) Aug. 12 (No. 39). The following were taken from the upland forest (Sta. IV, a): Aug. 16 (No. 67) on dry leaves, a nymph, a long-winged male, and three short-winged females; Aug. 17 (No. 92) in an open space, a copulating pair, both of which were brown and short-winged, and a brown short-winged female (No. 93); Aug. 22 two more copulating pairs, one (No. 121) brown short-winged forms, the other (No. 122) green short-winged individuals. In a glade in the lowland forest where grasses, *Eupatorium celestinum*, and young sasfras abounded (Sta. IV, c), a nymph, a brown short-winged female, and three males, two brown and one green, were taken Aug. 20 (No. 117), and on Aug. 22 a green female nymph and green and brown short-winged males (No. 143); and on the slopes of the valley (Sta. IV, b) a green short-winged female was secured Aug. 20 (No. 110).

On account of the disparity in the size of the sexes—the males being much smaller than the females—it is possible for copulating females to jump about and carry the males with them, the pair No. 121 affording an example.

According to Morse ('04, p. 19, 32) this is a forest and thicket species which also frequents "tangled herbaceous growths whenever found." In New England it frequents "grass fields on wet soil, near the margins of ponds and streams; in the South and Central States it is more commonly found in rank herbage along ditches and streams, and in the edge of moist woodlands. Its haunts are thus intermediate in character between those of a campestral and sylvan species, and so likewise are the structural adaptations presented by it, a very large proportion of the females being brachypterous."

It will be noted that the Charleston series is mainly from the forest area, only one individual coming from the true (moist) prairie; also that the forest, even the upland part, is in close proximity to a



humid lowland forest tract. Hancock ('11, pp. 297, 392-394) has discussed the habitat of this species.

*Chlocaltis conspersa* Harr. Sprinkled Grasshopper. (Pl. LVII, fig. 6.)

This locust was taken from the ground, mainly among leaves, in the upland forest (Sta. IV, *a*) Aug. 16 (No. 67); in sunny open places Aug. 17 (No. 93); and along a path through the forest among dry leaves Aug. 22 (No. 122).

Morse ('04, p. 19) considers this a forest, forest-margin, and thicket species, and Hart ('06, p. 75) says it frequents "open woods on ground encumbered with leaves, branches, and bushes." Consult Scudder (Final Report upon the Geology of New Hampshire, Vol. 1, pp. 371-372, 1874) for an account of the egg-laying habits of this species; also Hancock ('11, pp. 347-351) for its habits.

*Spharagemon bolli* Scudd. Boll's Grasshopper. (Pl. LVII, fig. 4.)

A male of this species was taken on the ground on leaves in the upland forest (Sta. IV, *a*) Aug. 16 (No. 67); a dead female was found clinging to the tip of a plant stem on the most open part of the slope (Sta. IV, *b*) from the upland forest to the lowland Aug. 22 (No. 133); and a female was taken among leaves on the ground in the upland forest (Sta. IV, *a*) Aug. 23 (No. 150). T. L. Hankinson found an adult and a nymph in the Bates woods June 28, 1911 (No. 7678). (Cf. Hancock, '11, pp. 362-364.)

The positive heliotropism or negative geotropic response shown in diseased grasshoppers is of interest. It may be caused either by a fungous or bacterial disease. (Cf. Gillette, Bull. No. 6, n. s., Div. Ent. U. S. Dept. Agr., pp. 89-93, 1896.)

Morse ('04, p. 15) considers this an exceptional ground-inhabiting or geophilous species since it is "an inhabitant of xerophytic forests as well as of open fields, and in the Southern States is found quite as often in the forest as on the open plain."

*Melanoplus differentialis* Thomas. Differential Grasshopper.

Consult the list of prairie invertebrates, p. 167.

*Melanoplus atlantis* Riley. Lesser Grasshopper. (Pl. LVII, fig. 8.)

A single specimen was taken on the ground in the upland forest (Sta. IV, *a*) Aug. 16 (No. 67). The open character of parts of this dry forest affords favorable conditions for this species.

Morse ('04, pp. 19, 42) considers this a characteristic species of open country, but "likely to be found anywhere." Hancock ('11, pp. 415-416) has described the habitat of this species.

*Melanoplus amplexans* Scudd.

This locust and nymphs doubtfully regarded as of the same species were taken from the ground, mainly among leaves, in the upland forest (Sta. IV, *a*) Aug. 16 (No. 67); other collections are as follows: in the glade in the lowland forest (Sta. IV, *c*) Aug. 20 (No. 117); on the open ravine slope (Sta. IV, *b*) Aug. 22, a male (No. 124a); and on the same date, in the glade of the lowland forest (Sta. IV, *c*), a nymph and an adult female (No. 143).

This is the largest of the short-winged locusts in the forest, and an abundant species. Morse ('04, pp. 19, 50, Pl. 7) described its haunts as in thickets, forest margins, open forests, and occasionally in grassy clearings and fields.

*Melanoplus gracilis* Bruner.

Two males were found Aug. 20 in a glade in the lowland forest (Sta. IV, *c*) where there was a luxuriant cover of vegetation, and nettles and *Eupatorium calcestinum* abounded; and Aug. 22, in the same location, one female was found (No. 143).

The wings are very rudimentary in this species. Hart ('06, p. 82) describes its habitat as follows: "On tall grasses and weeds in ravines and about marshes, masses of wild vines along railroads, weedy growths in the beds of small streams, and in like situations." These conditions are found in open areas with an abundance of vegetation.

*Melanoplus obovaticornis* Blatch.

This small species, similar to *scudderi*, was found in the upland forest (Sta. IV, *a*) Aug. 17 (No. 93). A nymph taken Aug. 22 from the forest (Sta. IV) is doubtfully regarded as of this species (No. 124).

Hart ('06, p. 81) gives the habitat of this species as "High wooded hillsides throughout Illinois." Blatchley ('03, p. 308) states that it frequents "for the most part, high, dry, open woods, especially those in which beech and oak trees predominate." He further states that in a dry season it may be found associated with *Dichromorpha viridis* and *Truxalis brevicornis* "among the reeds and tall rank grasses near the borders of marshes."

*Melanoplus scudderi* Uhl. Scudder's Grasshopper.

A single female was found in the open glade in the lowland forest (Sta. IV, *c*) Aug. 20 (No. 117); and a nymph taken Aug. 22 from the open ravine slope (Sta. IV, *b*) is doubtfully referred to this species (No. 124).

Hart ('06, p. 81) describes the habitat of this grasshopper as "open woods and thickets, and along rail fences and roadsides." Species which now characterize our open, partly cleared woodlands, in the primeval forest probably frequented forest margins, bluffs, and the borders of streams, or open patches in woods where a tree had fallen, and similar situations. With a thinning out of the forest (up to a certain degree) their habitat is increased in area, but when by clearing the woods disappear, their habitat vanishes.

#### LOCUSTIDÆ

*Scudderia furcata* Bruner. Forked Katydid. (Pl. LVII, fig. 5.)

One female was taken in an open area in the upland forest on low shrubs (Sta. IV, a) Aug. 20 (No. 109). Another specimen was taken near Vera, Fayette county, Ill., on a finely developed colony of prairie vegetation among *Andropogon*, Sept. 1 (No. 185).

Blatchley ('03, p. 349) states that it is "most frequently seen on the low bushes and trees about the margin of thickets and along fence rows, but in the prairie country north [in Indiana] it frequents coarse grasses and weeds."

*Amblycorypha rotundifolia* Scudd. Round-winged Katydid. (Pl. LVII, fig. 2.)

A single female of this species was taken in the glade in the lowland forest (Sta. IV, c) Aug. 20 (No. 117); and also a freshly emerged female (No. 143). Blatchley ('03, p. 352) states that this is "more of a terrestrial species than *oblongifolia*, being often seen on the ground, or on clumps of tall grass and weeds which grow in damp ravines." Hart ('06, p. 84) says that this species is found "On grasses and weeds in damp ground."

*Microcentrum laurifolium* Linn. Angle-winged Katydid. (Pl. LVII, figs. 1 and 2.)

Males were found on hickory sprouts at the cleared margin of the upland forest (near Sta. IV, a) Aug. 22 (No. 135). They were chirping loudly, in the early afternoon, on sprouts less than two feet high.

*Cyrtophyllus perspicillatus* Linn. Common Katydid. (Pl. LVIII, fig. 1.)

One male was taken in the partly cleared area bordering the forest (near Sta. IV, a) Aug. 23 (No. 145). Here, among stump sprouts of hickory, oak, and young sassafras, about two to three feet high, stood this male stridulating in the sun at 2:30 p. m., but the note did not seem exactly normal, that is, as when heard at night.

This species is so distinctly arboreal and nocturnal that I was surprised to find it stridulating during the day, and so near the ground. I have camped for days in a grove where these insects made a great din at night, but found none on the low vegetation or on the ground (as at Kappa, Ill). Years ago a large colony flourished in Franklin Park at Bloomington, Ill.

*Conocephalus nebrascensis* Bruner. Nebraska Cone-nose.

A female was taken in the glade in the damp lowland forest (Sta. IV, c) Aug. 20 (No. 117).

The female of this species has been observed to oviposit "between the stem and root-leaves of *Andropogon*", a typical prairie plant, but little appears to be recorded of its habitat. A large nymph of this genus, and probably of this species (No. 159), was taken on the prairie grass *Andropogon* (Sta. I, g) Aug. 24. It had been captured by the crab-spider *Misumena alcatoria* Hentz (No. 159).

*Orchelimum cuticulare* Redt.

A specimen was taken in the upland forest (Sta. IV, a) Aug. 16 (No. 67); another, from the open areas of the upland forest (Sta. IV, a) Aug. 17 (No. 93); and a third, from the glade in the damp lowland forest (Sta. IV, c) Aug. 22 (No. 143). All of these were males.

*Orchelimum glaberrimum* Burm.

This insect was found in abundance in the glade in the lowland forest (Sta. IV, c) Aug. 20 (No. 117), and a nymph was taken in the same place Aug. 22 (No. 143).

The abundance of this species in this damp area, with its profusion of low vegetation, indicates that the conditions were favorable.

*Xiphidium nemorale* Scudd.

Nymphs and adults were found in the glade in the lowland forest (Sta. IV, c) Aug. 20 (No. 117) and Aug. 22 (No. 143); in the openings in the upland forest (Sta. IV, a) Aug. 17 (No. 93), and Aug. 20 (No. 103).

Blatchley ('03, p. 374) states that it abounds along the "borders of dry, upland woods, fence rows, and roadsides, where it delights to rest on the low shrubs, blackberry bushes, or coarse weeds usually growing in such localities."

#### GRYLLIDÆ

*Nemobius fasciatus* DeG. Striped Cricket. (Pl. LVIII, fig. 6.)

Nymphs of this species were found in the upland forest on the

ground (Sta. IV, *a*) Aug. 16 (No. 67); in the upland forest area also, in an open place, was found a short-winged male Aug. 17 (No. 93); along a path in the upland forest, among dry leaves, a short-winged female was taken Aug. 22 (No. 122); and an abundance of short-winged males and females, and nymphs (No. 143) were found Aug. 22 in the glade in the lowland forest (Sta. IV, *c*).

This small cricket is generally abundant among the litter on the forest floor.

*Nemobius maculatus* Blatch. Spotted Cricket.

A nymph was taken in the upland forest (Sta. IV, *a*) among leaves Aug. 22 (No. 122).

Blatchley ('03, p. 425) states "It is found in low open woods, usually in the vicinity of or beneath logs"; Hart, ('06, p. 89) states that it is found "About logs and dead wood in sparse woods and near streams."

*Apithus agitator* Uhl. Woodland Cricket.

A nymph was taken from the open area in the upland forest (Sta. IV, *a*) Aug. 17 (No. 93); another from an open ravine slope (Sta. IV, *b*) Aug. 22 (No. 124). No adults were secured.

Blatchley ('03, pp. 458-459) records this species as from forests, noting its preference for prickly ash. It is also recorded as from grape-vines and dense shrubbery. The females deposit eggs in the twigs of the white elm, *Ulmus americana* Linn.

## HEMIPTERA

### CICADIDÆ

*Cicada linnei* Grossb. (*Cicada tibicen* L.). Dog-day Harvest-fly. Pl. LV, fig. 5.)

This insect was found at the cleared margin of the upland forest (near Sta. IV, *a*) on low hickory sprouts Aug. 26 (No. 162).

It is said to require two years to mature. T. L. Hankinson reports that *Tibicen septendecim* L. (Pl. LV, figs. 3 and 4) was found about Charleston in 1907, and branches scarred by the ovipositing females were observed in the Bates forest (Sta. IV, *a*).

Felt ('05, pp. 237-238) describes the emergence of the adult *Tibicen* from the nymph skin. For the recent synonymy see Smith and Grossbeck (Ent. News, Vol. 18, pp. 116-129, 1907).

### FULGORIDÆ

*Ormenis pruinosa* Say (?). Mealy Flata. (Pl. LVI, figs. 1 and 2.)

This insect was taken by T. L. Hankinson June 28, 1911, in the

Bates woods (No. 7678). It appears to feed upon a large variety of trees, shrubs, and herbaceous plants. Its normal habitat is probably in open woods or the forest margin. Swezey ('04, pp. 8-9) gives full references to the life history of this insect and a list of the food plants.

#### TETTIGONIELLIDÆ

*Aulacizes irrorata* Fabr. (Pl. LVI, fig. 3.)

A few specimens were taken, the collection data being as follows: from an open glade in the lowland forest (Sta. IV, *c*) Aug. 20 (No. 117); and from the smaller branches of sassafras bushes (Sta. IV, *c*) Aug. 22 (No. 143).

This insect is often taken on grapes, and in the South on cotton. Sanderson (Bull. 57, Bur. Ent., U. S. Dept. Agr., p. 58. 1906) describes briefly the egg-laying habits and figures the adult insect.

*Gypona pectoralis* Spangb.

This species was taken June 28, 1911, in the Bates woods (Sta. IV) by T. L. Hankinson (No. 7678).

#### PENTATOMIDÆ

*Euschistus fissilis* Uhl.

This bug was taken in Bates forest (Sta. IV) Aug. 22 (No. 124). It has been known to feed upon wheat (Webster, Rep. U. S. Dept. Agr., 1885, p. 317). It also feeds upon corn, and on the moth *Aletia*. It is parasitized by the proctotrypid *Trissolcus euschisti* Ashm. (Olsen, in Journ. N. Y. Ent. Soc., Vol. 20, p. 52. 1912).

*Mormidea lugens* Fabr.

A nymph of this bug was taken by T. L. Hankinson in the Bates woods (Sta. IV) June 28, 1911 (No. 7678).

*Hymenarcys nervosa* Say.

This insect was taken on the ground from among dead leaves and decayed wood which had drifted to the mouth of a ravine in the lowland forest (Sta. IV, *c*) Aug. 20 (No. 113). In the South this insect feeds upon cotton.

#### MIRIDÆ

*Lygus pratensis* Linn. Tarnished Plant-bug.

This bug was taken in the Bates woods (Sta. IV) June 28, 1911, by T. L. Hankinson (No. 7678). See prairie list, page 175.

## COREIDÆ

*Alydus quinquespinosus* Say.

This bug was taken by T. L. Hankinson June 28, 1911, in the Bates woods (No. 7678), and July 10 (No. 7693) on the undergrowth in the woods (Sta. IV).

*Acanthocercus galeator* (*Euthoetha*) Fabr. (Pl. LVI, fig. 8.)

Six large nymphs of this plant-bug were taken on the apical part of a tall herb, *Actinomeris alteruifolia* Linn., growing in the open glade of the lowland forest (Sta. IV, c; Pl. XIV) Aug. 29 (No. 182).

This bug has been reported to suck the juice from the plum, and it injures the tender parts of orange plants. Hubbard (Insects Affecting the Orange, U. S. Dept. Agr., Div. Ent., p. 163. 1885) gives figures of the adult insect and describes briefly the eggs and young. Forbes and Hart ('00, p. 445) have summarized the little that is known of this insect.

*Jalysus spinosus* Say. Spined Stilt-bug. (Pl. LVI, fig. 7.)

This bug was found Aug. 20 in the open glade of the lowland forest (Sta. IV, c), where there was a luxuriant growth of herbaceous vegetation (No. 117). It was also taken (Sta. IV) by T. L. Hankinson June 28, 1911 (No. 7678). Luger reports it from oak woods. It feeds upon plants.

## GERRIDÆ

*Gerris remigis* Say. Water-strider. (Pl. L, fig. 2.)

This water-strider was abundant in the pools of the small temporary stream in the ravine bordering the southern part of the Bates woods (Sta. IV, d) Aug. 22 (No. 129).

It is an important enemy of mosquito larvæ.

## REDUVIDÆ

*Sinea diadema* Fabr. Rapacious Soldier-bug.

A nymph of this predaceous bug was captured by T. L. Hankinson in the Bates woods (Sta. IV) June 28, 1911 (No. 7678). See list of prairie animals, page 173.

## COLEOPTERA

## CICINDELIDÆ

*Cicindela unipunctata* Fabr. Woodland Tiger-beetle.

One specimen of this tiger-beetle was taken along the path through the cleared area as it entered the forest (Sta. IV, a) Aug. 22 (No. 136).

Tiger-beetles are generally most abundant in open places, but this beetle seems to be a woodland species like the brilliantly colored *C. sexguttata* Fabr. Wickham ('99, pp. 210-211) records *unipunctata* from wooded areas. It is rare and difficult to catch, and is said to be nocturnal in habit.

#### CARABIDÆ

*Calosoma scrutator* Fabr. Caterpillar-hunter.

This common arboreal beetle was taken Aug. 16 (No. 64) in the upland Bates wood (Sta. IV, a), where it attracted attention by the rustling sound it made in crawling among the dry leaves on the ground. Specimens of these beetles I could easily secure by remaining quiet and listening for this rustling of the leaves. One specimen was seen to crawl up the trunk of a small oak-tree, three or four inches in diameter, for about seven feet. Another individual I took from my neck. It may have fallen upon me from a tree, but more probably it climbed upon me as it does a tree. In woods adjacent to the Bates forest, a caterpillar-hunter (No. 97) was found Aug. 20 with what appeared to be the damp cast skin of some large bombycid larva, which was also claimed by an ant, *Camponotus herculeanus* Linn., subsp. *pennsylvanicus* DeG., var. *ferrugineus* Fabr. On the ravine slope (Sta. IV, b) Aug. 20 T. L. Hankinson captured one of these beetles (No. 100) with a caterpillar about an inch long, which it had partly mangled in the thoracic region with its formidable jaws. On the upper slopes of the ravine (Sta. IV, b) Aug. 23 another beetle (No. 149) was found on the ground under a hickory tree, eating a *Datana* larva. Along this same rather open forested slope another individual was observed to run from the ground up the trunk of a small white oak (six or seven inches in diameter) for three or four feet, and then to return to the ground. The climbing individuals observed took a relatively straight course up the trunk, making no effort to climb in a spiral direction, and made the descent head foremost.

At Bloomington, Ill., while picking cherries I have taken the beetle in trees. Although the arboreal habit is evidently very well developed in this species, it is also very much at home on the ground. The rapidity and apparent ease with which it ran over dry oak leaves in the upland Bates woods surprised me.

The active foraging habits of this beetle are well shown by Herman's observations (Journ. Cincinnati Soc. Nat. Hist., Vol. 21, p. 80. 1910) on its killing nestlings of the cardinal grosbeak (*Cardinalis cardinalis*) in bushes three feet from the ground. Harris (In-



sects Injurious to Vegetation, p. 470. 1869) states that it preys upon canker-worms, both on the ground and by ascending trees.

*Galerita janus* Fabr.

A specimen was found under the bark of a decaying log in the upland Bates forest (Sta. IV, *a*) Aug. 23 (No. 171). This common beetle is frequently found in such situations, and seems to have a preference for relatively damp places. I have taken the adult as early as March 23 under bark of logs in the sap-wood stage of decay at Urbana, Ill., where it was found associated with single dealated females of *Camponotus herculeanus pennsylvanicus*, *Passalus cornutus*, pyrochroid larvæ, the caterpillar *Scolecocampa liburna*, and the slug *Philomycus carolinensis*.

This species is a fairly common one. I found it abundant at Bloomington, Ill., where it was taken April 15, May 1, and June 22.

The larva has been described by Hubbard (Psyche, Vol. 1, pp. 49-52. 1875).

#### COCCINELLIDÆ

A species of lady-beetle was found upon a fungus growing on a stump in the upland forest (Sta. IV, *a*) Aug. 17 (No. 81). Associated with the beetle on the fungus were large numbers of the snail *Pyramidula perspectiva*.

#### ELATERIDÆ

*Melanotus* sp.

A larva belonging to this genus (No. 125) was found Aug. 22 under the bark of a decaying stump (Sta. IV, *b*) in which the sap-wood was destroyed, the remainder being sound though discolored. It was associated with the slug *Philomycus carolinensis* and the caterpillar *Scolecocampa liburna*.

*Corymbites* sp.

A larva belonging to this genus (No. 113) was found in drifted leaves and dead wood at the mouth of a ravine in the lowland forest (Sta. IV, *c*).

*Asaphes mcannonius* Hbst.

This click-beetle was taken at the mouth of a ravine in the lowland forest (Sta. IV, *c*) Aug. 20 (No. 113) in drift composed of dead leaves and rotten wood.

#### LAMPYRIDÆ

*Calopteron terminale* Say. Black-tipped Calopteron.

This interesting beetle was taken in the damp lowland forest (Sta. IV, *c*) Aug. 26 (No. 173).

This species has been mentioned as an instance of mimicry because of its resemblance in shape and color-pattern to the syntomid moth *Lycomorpha pholus* Drury. Both are found in damp shady woods.

*Calopteron reticulatum* Fabr. Reticulate Calopteron. (Pl. LVIII, fig. 4.)

A single specimen was taken—in the glade in the lowland forest (Sta. IV, c) Aug. 22 (No. 143).

The larva and pupa of this species are described by Coquillett (Can. Ent., Vol. 15, pp. 97-98. 1883). July 10 he found a pupa "suspended by the hind end of its body beneath a log."

*Photuris pennsylvanica* DeG. Pennsylvania Firefly. (Pl. LVIII, fig. 3.)

This large firefly was taken June 28, 1911, in the Bates woods (Sta. IV) by T. L. Hankinson (No. 7678).

McDermott ('10, '11) Knab ('05), and Mast ('12) should be consulted for discussions on the natural history and ecology of our fireflies. McDermott gives many observations on *P. pennsylvanica*.

*Chauliognathus marginatus* Fabr. Margined Soldier-beetle.

This predaceous beetle was taken June 28, 1911, in the Bates woods (Sta. IV) by T. L. Hankinson (No. 7678). (Cf. Lintner, Fourth Rep. Injurious and other Ins. N. Y., 1888, pp. 74-88.) This is a predaceous species in the larval stage, feeding on immature insects. The adults feed on pollen (Riley, in Fifth Rep. Ins. Mo., p. 154. 1873).

*Telephorus* sp.

This was taken June 28, 1911, in the Bates woods (Sta. IV) by T. L. Hankinson (No. 7678). See *T. bilineatus*, Pl. XLIV, fig. 1.

#### LUCANIDÆ

*Passalus cornutus* Fabr. Horned Passalus. (Pl. LVIII, fig. 5.)

This common woodland beetle was found under the bark of a decaying stump on the slope of a ravine (Sta. IV, b) Aug. 17 (No. 85). One specimen, with a chestnut thorax and yellowish wings, had just shed the pupal skin. Another, a fully matured specimen, carried a large colony of mites. Ewing (Univ. Studies, Univ. Ill., Vol. 3, p. 24. 1909) states that nymphs of uropod mites are often attached to insects for transportation. It has generally been assumed that they are parasitic.

This *Passalus* seems to be one of the most common insects found in decaying logs and stumps. I have found it very abundant at

Bloomington, Ill. The beetles evidently hibernate, for I have taken them at Urbana, Ill., as late as October 18, and as early in the spring as March 23.

This beetle invades logs and stumps as soon as the sap-wood begins to be well decayed, and evidently advances into the log with the progress of decay. As it invades logs in the sap-wood stage of decay, it is often associated with *newly founded* colonies of the ant *Camponotus herculeanus pennsylvanicus*, pyrochroid larvæ, the slug *Philomycus carolinensis*, and the caterpillar *Scolecocampa liburna*. For physiological studies of *cornutus* see Schafer (Mich. Agr. Coll. Exper. Sta., Tech. Bull. No. 11. 1911).

#### SCARABÆIDÆ

*Geotrupes splendidus* Fabr. Splendid Dung-beetle.

This dung-beetle was dug from a hole, an inch or so below the surface, in the hard clay of the pathway near the margin of the forest bordering the cleared area (Sta. IV, *a*) Aug. 22 (No. 120). As cattle and horses were pastured in this forest, its presence is readily accounted for.

*Pelidnota punctata* Linn. Spotted Grape Beetle.

Only one specimen of this beetle was taken. It was found on a grape leaf (Sta. III, *b*) Aug. 15 (No. 58). This insect is primarily a forest or forest-margin insect. The larva feeds upon the decaying roots and stumps of oak and hickory. The adult devours leaves of the grape and of the Virginia creeper.

Many undetermined scarabæid larvæ were found in a much-decayed stump in the ravine near the small temporary stream (near Sta. IV, *d*) Aug. 22 (No. 130).

#### CHRYSOMELIDÆ

*Chrysochus auratus* Fabr. Dogbane Beetle.

This characteristic species of the prairie (No. 103) was taken Aug. 20 in an open place in the upland oak-hickory forest (Sta. IV, *a*) on the dogbane *Apocynum medium*. See list of prairie invertebrates, p. 178.

*Cryptocephalus mutabilis* Mels.

This leaf-beetle was taken June 28, 1911, in the Bates woods (Sta. IV) by T. L. Hankinson (No. 7678). It has been reported on *Ceanothus*, *Viburnum*, hazel, and oak by J. B. Smith. Evidently this is a woodland beetle.

*Coptocycla clavata* Fabr. Clubbed Tortoise-beetle.

This leaf-beetle was taken in the south ravine of the Bates woods (Sta. IV, *b*) by T. L. Hankinson June 28, 1911 (No. 7678). It is known to injure the potato, tomato, eggplant, and bitter-sweet. The larvæ and adults feed upon the same kinds of plants (Lintner, Sixth Rep. Injurious and other Ins. N. Y., pp. 126-127. 1890).

#### TENEBRIONIDÆ

*Boletotherus bifurcus* Fabr. Horned Fungus-beetle. (Pl. LIX, figs. 1, 2, and 3.)

This curious-looking beetle was found on the shelf-fungus *Polyporus* in the lowland forest (Sta. IV, *c*) Aug. 26 (No. 173).

I have found this species very abundant near Bloomington, Ill., where at times it was difficult to find an example of *Polyporus* which was not thoroughly honeycombed by the larvæ of these beetles. A single shelf has been found to contain several beetles. They were generally discovered within galleries excavated within the fungus. On July 11 in such a shelf I found larvæ and pupæ in abundance. Other dates of capture are June 3 and July 6. Riley and Howard (Insect Life, Vol. 3, p. 335. 1891) also report it from *Polyporus*. Figures of the larva and pupa are given by Packard ('83, p. 474) and descriptions by Gissler (On coleopterous larvæ of the family *Tenebrionidæ*, Bull. Brooklyn Ent. Soc., Vol. 1, pp. 85-88. 1878).

*Mcracantha contracta* Beauv.

Larvæ of this beetle were taken under dry leaves in the upland forest (Sta. IV, *a*) Aug. 17 (No. 83); and others from under damp leaves at the base of the wooded slopes of a ravine leading to the lowland forest (Sta. IV, *b*) Aug. 22 (No. 140). The latter larvæ were associated with the ant *Stigmatomma pallipes*. These larvæ are often confused with wireworms (*Elatерidae*).

I found the beetles occasionally in the forest at Bloomington, Ill., June 13; and Aug. 1 on the papaw.

I have a specimen of this larva, in very rotten wood, showing the sinuous larval boring (Pl. XXX), from the Brownfield woods, Urbana, Ill. (March 9; collector, D. M. Brumfiel). Wickham has described and figured the larva (Journ. N. Y. Ent. Soc., Vol. 4, pp. 119-121. 1896).

#### PYROCHROIDÆ

*Pyrochroa* sp.

A single specimen of a larva belonging to the above family was taken August 22 (No. 130) in the ravine (Sta. IV, *b*) from under

the bark of a decaying stump, in company with numerous scarabæid larvæ. These larvæ are very characteristic animals—under bark when decay has loosened it from the sap-wood. The accompanying figure (Pl. LIX, fig. 4) shows the general appearance of this larva and of an adult beetle. I found *Dendroides canadensis* Latr. fairly abundant at Bloomington, Ill., July 25. Larvæ belonging to this family have been taken in the Brownfield woods, Urbana, Ill., under the bark of decaying trees. It is a representative animal species in this habitat.

See Moody (*Psyche*, Vol. 3, p. 76. 1880) for descriptions of pyrochroid larvæ.

#### LEPIDOPTERA

##### PAPILIONIDÆ

*Papilio philenor* Linn. Philenor Butterfly. (Pl. LIX, fig. 5.)

The caterpillar was found crawling upon the ground in the upland forest (Sta. IV, *a*) Aug. 16 (No. 69). Aug. 26 a larva (No. 166) which had attached itself to the stem of a prickly ash (Sta. IV, *b*), was just entering upon the pupal stage, but had not yet cast the larval skin.

The larva feeds upon Dutchman's pipe, *Aristolochia*—a plant which was not observed in the forest.

*Papilio turnus* Linn. Turnus Butterfly.

The butterfly was observed on wing Aug. 16 in the open glades of the upland forest (Sta. IV, *a*).

The larva feeds upon *Prunus* and *Liriodendron*.

*Papilio cresphontes* Cram. Cresphontes Butterfly.

The butterfly was observed in the open spaces of the upland forest on wing Aug. 16.

The larva feeds upon *Zanthoxylum*, *Ptelea*, *Dictamnus*, *Citrus*, etc.

*Papilio troilus* Linn. Troilus Butterfly.

The butterfly was taken, on wing, from the open slope of the south ravine (Sta. IV, *b*) Aug. 22 (No. 161); and in the upland forest (Sta. IV, *a*) Aug. 26 (No. 163).

The larva feeds upon sassafras and *Laurus*.

##### NYMPHALIDÆ

*Polygonia interrogationis* Fabr.

The butterfly was taken in the open glade in the lowland forest (Sta. IV, *c*) Aug. 20 (No. 117).

The larva feeds upon *Humulus*, *Ulmus*, and *Urtica*.

## AGAPETIDÆ

*Enodia portlandia* Fabr. Portlandia Butterfly.

This woodland butterfly was taken in the Bates woods (Sta. IV) Aug. 15 (No. 63) and on June 28, 1911 (No. 7678), by T. L. Hankinson.

The larva feeds upon grasses. Fiske ('01, pp. 33-34) gives a good description of the haunts of this species. Years ago I found it abundant near Bloomington (Orendorf Springs), Ill., in dense, damp, shady woods. It is as characteristic of shade as most species are of sunshine.

*Cissia eurytus* Fabr. Eurytus Butterfly.

This is also a woodland butterfly. It was taken in the Bates woods by T. L. Hankinson June 28, 1911 (No. 7678). The larva feeds upon grass.

## LYCÆNIDÆ

*Everes comyntas* Gdt.

This small blue butterfly was taken on the open upper slopes of the wooded south ravine in the Bates forest (Sta. IV, b) Aug. 22 (No. 161).

The larva feeds upon red clover and *Desmodium*.

## HESPERIDÆ

*Epargyreus tityrus* Fabr. Common Skipper.

This caterpillar was found in the open glade in the lowland forest (Sta. IV, c), folded within a leaf of sassafras, Aug. 26 (No. 173).

I have taken this butterfly many times at Bloomington, Ill.; and have found the larvæ folded in leaves of the yellow locust, *Robinia*, upon which they had evidently been feeding.

## SPHINGIDÆ

*Cressonia juglandis* Sm. and Abb.

This caterpillar was taken on low branches of the shell-bark hickory, *Carya ovata*, in the upland forest (Sta. IV, a) Aug. 20 (No. 102).

The larva feeds upon walnut, ironwood, and hickory. Our specimens bore a large number of cocoons of a hymenopterous parasite. When handled, this larva makes a peculiar squeaking sound (Bull. 54, Bur. Ent., U. S. Dept. Agr., p. 80. 1905).

## SATURNIDÆ

*Telea polyphemus* Cramer. American Silkworm. (Pl. LIX, fig. 6.)

This caterpillar was taken on the ground, under hickories and white oaks on the forested slopes to the valley (Sta. IV, *b*) Aug. 26 (No. 163).

The larva feeds upon walnut, basswood, elm, maple, cherry, etc.

## CERATOCAMPIDÆ

*Citheronia regalis* Fabr. Royal Walnut Moth; Hickory Horned-devil (larval name). (Pl. LX, figs. 1 and 2.)

This larva was found on the valley slope (Sta. IV, *b*) on sumac Aug. 16 (No. 68); and on walnut Aug. 20 (No. 108). This last specimen was apparently fully mature.

The food plants of the larva are butternut, hickory, sycamore, ash, and lilac. See Packard ('05, p. 130) for many figures and a full description of this species.

*Basilona imperialis* Drury. Imperial Moth. (Pl. LXI, Fig. 1).

The larva of this species was found on the leaves of sassafras on the forested slope to the lowland forest (Sta. IV, *b*) Aug. 20 (No. 106). It feeds upon a large number of forest trees including oak, maple, wild cherry, walnut, hickory, and several conifers.

See Packard ('05, p. 125) for figures and full descriptions of this species.

## ARCTIIDÆ

*Halisidota tessellaris* Sm. and Abb. (Pl. LXI, fig. 4.)

These caterpillars were taken on hickory on the wooded slope to the lowland (Sta. IV, *b*) Aug. 26 (No. 163); and, again, abundantly (No. 168), in the upland forest (Sta. IV, *a*) on climbing buckwheat, *Polygonum convolvulus*, which was entwined about a young walnut or butternut. The yellow hairs and the tufts give this caterpillar a striking appearance.

I have found moths of this species abundant at Bloomington, Ill.

The food plants are recorded as maple, oak, hazel, and buttonwood. Though larvæ were abundant upon leaves of the climbing buckwheat, I did not observe them there eating it.

## NOCTUIDÆ

*Autographa precatationis* Guen.

The moth was taken in the open glade in the lowland forest (Sta. IV, *c*) Aug. 22 (No. 143).

The larva feeds upon plantain, burdock, and dandelion.

*Scolecocampa liburna* Geyer. Rotten-log Caterpillar.

A single caterpillar (No. 125) was taken Aug. 22 upon the slope of a wooded ravine (Sta. IV, *b*) under the bark of a stump in an early stage of decay—the sap-wood honeycombed, but the remainder solid though discolored. The larva, with its characteristic excrement, was found in a cell excavated in the rotten sap-wood.

This is another species of animal which invades wood in the sap-wood stage of decay and is so often associated with *Philomyces carolinensis*, *Passalus cornutus*, and newly established colonies of *Camponotus herculeanus pennsylvanicus*. The larva winters in logs, as is evidenced by the fact that I found it in such situations late in fall and early in spring (March 23) at Urbana, Ill. The large quantity of excrement often indicates the approximate location of the larva. This larva has been described by Edwards and Elliot (*Papilio*, Vol. 3, p. 134. 1883). It has been found in chestnut, oak, and other kinds of decaying logs. The moth is recorded in July. The pileated woodpecker, *Phlaeotomus pileatus*, has been known to eat this caterpillar (Beal, in Bull. 37, Biol. Surv., U. S. Dept. Agr., p. 34. 1911). Smith (Ann. Rep. N. Jersey State Mus., 1909, p. 471. 1910) states that the larva is found in "decaying cherry, hickory, oak and chestnut stumps."

#### NOTODONTIDÆ

*Datana angusii* G. and R.

The caterpillar of this species was found on the valley slope (Sta. IV. *b*) on bitternut hickory, *Carya microcarpa*, Aug. 20 (No. 104); in the upland forest (Sta. IV. *a*) on hickory Aug. 16 (No. 65); and at the margin of this forest Aug. 26 (No. 162).

The food plants of the larva are walnut, hickory, linden, and birch. Packard ('95, pp. 110–111) describes and gives figures of the larva and adult.

*Nadata gibbosa* Sm. and Abb. (Pl. LXI, fig. 2.)

This larva was taken on white oak, *Quercus alba*, in a forested ravine (Sta. IV, *b*) Aug. 19 (No. 94); on leaves of the white oak, upon which it had been feeding, in the upland forest (Sta. IV, *a*) Aug. 26 (No. 169).

Packard ('95, pp. 142–146) gives figures of this species and lists as food plants, oak, birch, and sugar plum. It is also reported on maple.

*Heterocampa guttivitta* Walk (?). (Pl. LXI, figs. 3 and 5.)

This larva (No. 127) was captured Aug. 22 by a digger-wasp, *Ammophila abbreviata* Fabr. which was found dragging it along the ground in the upland forest (Sta. IV, *a*). See Packard



('95, pp. 230-235) for an account of this forest-inhabiting larva.

The larva of *guttivitta* is known to feed upon red maple, oak, and viburnum.

#### GEOMETRIDÆ

*Eustroma diversilineata* Hübn. (Pl. LXII, fig. 1.)

This span-worm moth was taken in the upland forest (Sta. IV, *a*) Aug. 26 (No. 163).

Packard (Monogr. Geometrid Moths, p. 128. 1876) states that the larva feeds upon grape and *Psedera*. These are mainly forest plants, and this is probably a woodland species.

*Caberodes confusaria* Hübn.

This moth was taken near the upper slope of the south ravine in open woods (Sta. IV, *b*) Aug. 22 (No. 161).

The larva feeds upon *Trifolium*.

#### COCHLIDIDÆ

*Cochlidion* or *Lithacodes* sp. Slug Caterpillar.

This curious larva was found on a stump on the wooded ravine slope (Sta. IV, *b*) Aug. 26 (No. 165).

#### GELECHIIDÆ

*Ypsolophus ligulellus* Hübn. (?)

These small moths were taken in the upland woods (Sta. IV, *a*) by T. L. Hankinson June 28, 1911 (No. 7678). The larva is reported on apple, pear, and plum.

#### DIPTERA

##### CECIDOMYIIDÆ

*Cecidomyia holotricha* O. S. (Hairy Midge-gall.)

Abundant on the under side of hickory leaves (near Sta. IV) Aug. 20 (No. 96); and on leaves of *Carya ovata* in the upland forest (Sta. IV, *a*) Aug. 26 (Nos. 107 and 170). These brownish, hairy galls may cover large areas on the under side of some leaves. See Cook '05, p. 840, or Beutenmüller '04, p. 112.

*Cecidomyia tubicola* O. S. (Hickory Tube-gall.)

Immature galls (No. 107) were found Aug. 20 in the upland Bates woods (Sta. IV, *a*) on the lower side of leaves of *Carya ovata*.

*Cecidomyia caryocola* O. S. (Hickory Seed-gall.)

This gall was taken on *Carya ovata* leaves in the upland forest (Sta. IV, *a*) Aug. 20 (No. 107); and Aug. 26 (No. 170). Many galls are formed on hickory and other trees by plant-lice (Cf. Pergande, '02).

#### ASILIDÆ

*Deromyia discolor* Loew.

This robber-fly was taken in an open area in the lowland forest (Sta. IV, *c*) Aug. 20 (No. 117). Williston (Kingsley's Standard Natural History, Vol. 2, pp. 418-419, 1884) states that most robber-flies "rest upon the ground, and fly up when disturbed, with a quick buzzing sound only to alight again a short distance ahead. All their food, which consists wholly of other insects, is caught upon the wing . . . . Other flies and *Hymenoptera* are usually their food, but flying beetles, especially *Cicindlidæ*, are often caught, and they have even been known to seize and carry off large dragonflies. Not only will they feed upon other *Asilidæ*, but the female frequently resents the caresses of her mate by eating him up, especially if he is foolish enough to put himself in her power. In an instance the writer observed, a female seized a pair of her own species, and thrusting her proboscis into the thorax of the male, carried them both off together. . . . . The larvæ live chiefly under ground or in rotten wood, especially in places infested with grubs of beetles upon which they will feed. The young larvæ will bore their way completely within beetle larvæ and remain enclosed until they have consumed them. Many, however, are found where they evidently feed upon rootlets or other vegetable substances. They undergo their transformations in the ground. The pupæ have the head provided with tubercles, and on the abdominal segments there are also spiny protuberances and transverse rows of bristles, which aid the insects to reach the surface when they are ready to escape as flies." Marlatt (Proc. Ent. Soc. Wash., Vol. 2, p. 82, 1893) observed *D. discolor* preying upon wasps of the genus *Vespa*. By seizing the head of the wasp it avoids being stung.

*Deromyia umbrinus* Loew.

A specimen of this large robber-fly was taken in the south ravine (Sta. IV, *d*) by T. L. Hankinson, with the eucerid bee *Melissodes perplexa* Cresson in its grip, Aug. 22, 1910 (No. 7530).

## SYRPHIDÆ

*Chrysotoxum ventricosum* Loew.

This wasp-like fly was found resting on a leaf in the upland forest (Sta. IV, a) Aug. 26 (No. 163).

*Mesogramma politum* Say. Corn Syrphid.

This fly was taken by T. L. Hankinson in the Bates woods (Sta. IV) June 28, 1911 (No. 7678). See the prairie list, p. 188.

*Milesia ornata* Fabr. Vespa-like Syrphid.

This beautiful large syrphid was taken on dogbane in an open space in the upland forest (Sta. IV, a) Aug. 20 (No. 103); in the open glade in the lowland forest (Sta. IV, c) Aug. 22 (No. 143); and on Aug. 26 (No. 184) on the flowers of *Eupatorium caelestinum* in the clutches of the flower spider *Misumena aleatoria* Hentz. It was also taken in the Bates woods by T. L. Hankinson June 28, 1911 (No. 7678). Metcalf ('13, p. 73) quotes Verrall as follows concerning the subfamily *Milesiinae*: "What little is known about the metamorphosis shows that many species live in rotten wood or about the sap flowing from injured tree trunks."

## HYMENOPTERA

## SIRICIDÆ

*Tremex columba* Linn. Horntail; Pigeon Tremex.

This species was taken on wing in the upland forest (Sta. IV, a) Aug. 16 (No. 66); and on the open slope of a ravine (Sta. IV, b) Aug. 22 (No. 132).

The larva bores in the trunks of trees, as oak, elm, sycamore, and maple. Consult Packard ('90, pp. 379-381) for a description and figure of the larva. The long-sting, *Thalassa lunator*, is an external parasite upon this larva (see Riley, '88). I have taken normally colored females at Bloomington, Ill., July 25, Sept. 29, and Oct. 8. Two abnormally colored individuals were taken in September, one of them almost, and the other (taken Sept. 29) completely lacking the usual black markings. A female was taken at Milmine, Ill., in October. Consult Bradley ('13) for a key to the varieties of this species of *Tremex*.

An interesting feature in the ecological relations of this species is the fact that it appears to frequent only weakened, diseased, and dying trees, and these, not as a primary invader, but as a trailer, following insects which have done previous injury to the trees. Felt ('05, p. 61) shows that in New York successive attacks of the

elm leaf-beetle, or injury by the sugar maple borer *Plagionotus speciosus* Say, prepare the way for the horntail larva. Ecologically considered, the leaf-beetle and the borer initiate a succession of insect invasions into the tree trunk; *Tremex* follows, with its parasite *Thalassa*; and these in turn lead the way for still others; thus a succession of insects is produced.

#### CYNIPIDÆ

*Holcaspis globulus* Fitch. (Oak Bullet Gall.)

This gall was taken on white oak, *Quercus alba*, in the upland forest (Sta. IV, a) Aug. 26 (No. 170).

Consult Cook ('05) and Beutenmüller ('04) for figures and descriptions of various kinds of galls mentioned in this list.

*Amphibolips confluens* Harr. (Oak-apple or May-apple Gall.)

These galls were abundant upon the forest floor in the upland Bates woods (Sta. IV, a) during August (No. 101). The galls grow upon the leaves of several species of oaks (*Quercus*).

*Amphibolips prunus* Walsh. (Acorn Plum Gall.) (Pl. LXII, fig. 2.)

A single specimen of this gall was found on the slope of the south ravine in Bates woods (Sta. IV, b) Aug. 22 (No. 131). Another specimen came from the woods northeast of the Bates woods Aug. 20 (No. 96). It grows upon acorn cups.

*Andricus clavula* Bass. (White Oak Club Gall.) (Pl. LXII, fig. 5.)

This gall, formed in the terminal bud, was common on white oak, *Quercus alba*, in the upland Bates woods (Sta. IV, a) Aug. 26 (No. 170).

*Andricus cornigerus* O. S. (Horned Knot Oak Gall.) (Pl. LXII, fig. 3.)

This gall occurred in very large numbers on the branches of shingle oak, *Quercus imbricaria*, in a forest just northeast of the Bates woods, Aug. 20 (No. 96). The galls are old and apparently decaying.

*Andricus lana* Fitch. (Oak Wool Gall.) (Pl. LXII, fig. 4.)

Two examples of this gall were found on leaves of white oak, *Quercus alba*: one was taken near the Bates woods (Sta. IV) Aug. 20 (No. 96), and the other was found in the Bates woods (Sta. IV, a) on the petiole of a leaf, Aug. 26 (No. 170).

*Andricus seminator* Harr. (Oak Seed-gall.) (Pl. LXIII, fig. 1.)

A single specimen of this gall was found upon *Quercus alba* (Sta. IV, a) Aug. 20 (No. 101). The cotton-like masses of this

gall are conspicuous. They may be tinged with red; when dry they become brownish.

#### ICHNEUMONIDÆ

*Thalessa lunator* Fabr. Lunate Long-sting.

A female ichneumon of this species was found on a tree trunk in the open glade in the lowland forest (Sta. IV, *c*) Aug. 22 (No. 143).

The larva feeds, as an external parasite, upon the larva of the horntail, *Tremex columba*, which was also found in the Bates woods (Sta. IV). I found *T. lunator*, both males and females, abundant on shade trees at Bloomington, Ill., October 1, 1892, and also took it July 26, 1895. Riley ('88) gives an excellent account of this species accompanied by figures of the immature stages, and that of its host as well.

*Trogus obsidianator* Brullé.

This black ichneumon with fulvous antennæ was taken in the Bates woods (Sta. IV) June 28, 1911, by T. L. Hankinson (No. 7678). This wasp is known to be parasitic upon the larva of *Papilio polyxenes* Fabr. (*P. asterias*—Insect Life, Vol. 1, p. 161) and upon the caterpillar of *Pyrpharctia isabella* (?). This species has been taken in central Illinois during June and July (Weed, Psyche, Vol. 5, p. 52). (See also Riley, in Amer. Ent., Vol. 3, p. 134. 1880.)

#### PELECINIDÆ

*Pelecinius polyturator* Drury. Black Longtail. (Pl. LXIII, fig. 2.)

This remarkable looking insect was found in the glade of the lowland forest (Sta. IV, *c*) Aug. 20 (No. 117) and Aug. 22 (No. 143). Other females were seen in this forest.

I have also taken this species at Bloomington, Ill. At Evanston, Ill., during July, 1910, this species was very abundant upon some damp lawns. I have counted four or five females in sight at once. They were often found upon blue-grass sod. The male of this species is considered very rare. The only one which I ever captured was taken July 29, 1910, at Evanston, Ill. The larva is parasitic upon the grub of the May-beetle, *Lachnosterna* (Forbes, Eighteenth Rep. State Ent. Ill., p. 124. 1894). It may also prey upon other scarabæid larvæ inhabiting woodlands.

#### FORMICIDÆ

*Stigmatomma pallipes* Hald. Old-fashioned Ant.

A single wingless queen and four pupæ (No. 140) were taken Aug. 22 near the base of a ravine slope (Sta. IV, *b*) in dense shaded

woods, almost devoid of herbaceous vegetation, but with a thick layer of leaves, and other vegetable debris.

Wheeler (Biol. Bull., Vol. 2, pp. 56-69. 1901) considers this a rather rare ant, although widely distributed over eastern North America. It is subterranean in habit, and "does not come to the surface even at night." Contrary to the habits of most ants this primitive species has retained the carnivorous habits of the ancestral forms, and the young are fed on fragments of insects. They do not feed one another, or the larvæ by regurgitation, as do the specialized species of ants. They thus furnish us a glimpse at the ancient history of ants. Wheeler ('05, pp 374-375) states that this species occurs only in "rich, rather damp woods, under stones, leaf mould, or more rarely under or in rotten logs."

A worker of *Myrmica rubra* Linn., subsp. *scabrinodis* Nyl., var. *scheuchki* Emery (No. 140) was taken from the same patch of leaves.

*Cremastogaster lineolata* Say. (Pl. LXII, fig. 6.)

This ant was taken only once—in the upland part of the Bates woods (Sta. IV, a) Aug. 20 (No. 118). Large numbers of the ants were found in an oak-apple gall (*Amphibolips confluens* Harr.) lying on the forest floor. When I picked up the gall, many ants came out and ran over my hand, biting vigorously.

This is essentially a ground and forest-inhabiting ant, which forms nests in the soil, under stones, and in logs, stumps, etc. It has the peculiar instinct to make a sort of temporary nest out of debris to cover the aphids and coccids which it attends (Wheeler, Bull. Am. Mus. Nat. Hist., Vol. 22, pp. 1-18. 1906).

Several carnivorous staphylinid beetles of the genus *Myrmedonia* have been taken in the nests of these ants (Wheeler, '10a, p. 382; Schwarz, '90b, p. 247).

*Aphanogaster fulva* Roger.

A well-rotted stump in the upland Bates woods (Sta. IV, a) was found Aug. 17 to contain a moist, felt-like layer of some fungous growth, and on this was a large colony of snails (No. 71). In an adjacent part of this stump was a small colony of white ants, *Termes flavipes* Koll. (No. 72). A colony of ants which was in close proximity to the white ants, proved to be *A. fulva* Roger. As the galleries were exposed by cutting up the stump, these ants were seen to pick up the termites and carry them away, just as they do their own young on similar occasions. Five pairs—the ant and the termite which it carried—were preserved (Nos. 74-76, and 78-79). One of the termites lacks a head. All of them were workers. Larvæ and naked pupæ (No. 79) were abundant in this nest, and workers (No. 80) were abundant about the stump. On Aug. 22 another

colony of this ant (No. 125) was found under the bark of a decaying oak stump (Sta. IV) in which the sap-wood was honeycombed, but the remainder solid, though discolored.

Forel (Psyche, Vol. 9, p. 237. 1901) remarks that *Aphanogaster* is "very fond of termites, and when one uncovers and scatters about a nest of termites in a wood, they hasten to feast on the succulent morsels." These observations suggest the possible fate of the captured termites; none of the ants were seen to eat them, however. In the absence of observations, the missing head mentioned above may be variously accounted for.

This habit of carrying off termites has been observed in other species of ants. Forbes (19th Rep. State Ent. Ill., p. 198. 1896) reports that near Carterville, Mason county, Ill., Mr. John Marten observed *Formica schaufussi* (= *Formica pallide-fulva* Linn., subsp. *schaufussi* Mayr) to pick up and carry away the living termites when its nest under a log in which termites abounded, was disturbed, and McCook (Proc. Acad. Nat. Sci. Phila., 1879, p. 155) has observed similar behavior in the case of the mound-building ant, *Formica exsectoides* Forel.

The histerid beetle *Heterius blanchardi* Schwarz has been found in nests of this ant (Wheeler, '10a, pp. 388, 389); and European observers have seen ants carrying and rolling them about. Consult also Schwarz ('90b, 247) for a list of beetles found with this ant.

Wheeler ('10a, p. 206) lists *A. fulva* as a glade species which in the forests utilizes logs and branches as substitutes for stones. (See Wheeler, '05, pp. 372-373.)

#### *Aphanogaster tennesseensis* Mayr. Tennessee Ant.

A colony of this ant (No. 87) was taken Aug. 17 from a decaying stump, situated on the slope (Sta. IV, *b*) from the upland forest to the lowland on the river bottom.

According to Wheeler (Bull. Am. Mus. Nat. Hist., Vol. 20, 1904, p. 362, and Vol. 21, 1905, p. 373) this species normally nests in dead wood in rather open forests. He holds the opinion that the queen of this species can not rear her own brood, and thus establish a new colony, but must utilize a small or weak colony of the allied species *A. fulva* Roger, which lives under stones. Thus the new colonies are started under stones; later, when they become numerous, they are found in rotten wood. This, Wheeler concludes, indicates that they "migrate away from the *fulva* workers." Tanquary ('11) has performed some interesting experiments which show that queens of *tennesseensis* are adopted by colonies of other ants, a result which seems to confirm Wheeler's anticipation.

Schwarz ('90b, p. 247) records two beetles found with this ant.

*Formica fusca* Linn., var. *subsericea* Say.

This ant was taken in the upland Bates woods (Sta. IV, *a*) Aug. 26 (No. 163). See the list of prairie invertebrates, p. 190.

*Myrmica rubra* Linn., subsp. *scabrinodis* Nyl., var. *schencki* Emery.

This ant (No. 140) was found Aug. 22 under leaves in a small ravine on a shady slope (Sta. IV, *b*) from the upland forest to the valley bottoms. The soil under these leaves had been thoroughly tunneled by small mammals during the preceding winter, but recently the leaves had not been disturbed. The soil was a mixture of sand, clay, and vegetable debris, was moist, and contained few kinds of animals. A single ant of this variety (No. 140) was taken while collecting specimens of *Stigmatomma pallipes*.

This species is listed by Wheeler (Bull. Am. Mus. Nat. Hist., Vol. 21, p. 373. 1905) as a field ant which prefers to nest in grassy pastures and lawns, in situations exposed to the sun. Our specimen was, therefore, found in an unusual habitat.

*Tapinoma sessile* Say. Coconut Ant.

This coconut ant, so called because of the odor of the workers, which has been compared to that of decayed coconuts, was found in the lowland part of the Bates woods, at the base of the slope to the bottoms (Sta. IV, *c*) Aug. 22 (No. 139). A large colony was found among the surface layers of dry dead leaves; from it were secured two queens, vast numbers of eggs, and also larvæ, pupæ, and workers. Wheeler ('05, pp. 373, 389) states that this ant usually nests in open sunny woods, the borders of woods, and under stones, logs, etc.

Schwarz ('90b, p. 247) records beetles as living with this ant.

*Camponotus herculeanus* Linn., subsp. *pennsylvanicus* DeG. Carpenter Ant.

This species was taken from under the bark of a rotting stump among a dense second-growth, on the valley slope (Sta. IV, *b*) between the upland and the lowland forest Aug. 17 (No. 84). This stump was in that stage of decay so often utilized by the large Carolina slug, *Philomycus carolinensis*, and the horned Passalus beetle, *Passalus cornutus*. The colony was recently founded, for the deated female occupied a small cell excavated in the rotten sap-wood. This colony consisted of four pupæ and six larvæ of different sizes. Another colony was taken in the same stump, from the rotted sap-wood zone, in company with the snail *Philomycus carolinensis* and some kind of pulmonate snail eggs. This colony was in a more advanced stage than the preceding, about a dozen larvæ, seven pupæ.



and two adult workers being present, and about half a dozen eggs (No. 85).

Pricer ('08) has given an interesting account of the life history and habits of this ant in Illinois. He states (p. 197) that the food is largely the honeydew of plant-lice, but is supplemented by plant juices and dead insects. He found a small staphylinid beetle, *Xenodusa cava*, abundant in the nests.

I have found *pennsylvanicus* abundant at Bloomington, Ill., and represented as follows: by a male June 29; by a winged female in June; and by dealated females June 29 and July 2 and 25.

McCook ('83) has given an interesting account of the founding of colonies of this ant. See also Wheeler, '06b, pp. 38-39, Plate VIII, and '10b, pp. 335-338, for further information concerning it.

*Camponotus herculeanus* Linn., subsp. *pennsylvanicus* DeG., var. *ferrugineus* Fabr.

This variety was taken a short distance to the northeast of the Bates woods (Sta. IV) Aug. 20 (No. 97). Here the large ground-beetle *Calosoma scrutator* was found running on the ground with what appeared to be a bunch of greenish moss; a large reddish ant also struggled for possession of the prize. Upon closer examination it was found that the skin of some large lepidopterous larva was the object desired. This skin, recently shed or moistened by a recent rain, was a prize for both *ferrugineus* and *Calosoma*.

A dead wingless *ferrugineus*, covered with a fungus growth, was found in a small cell excavated in the rotten wood of a decaying log on the ravine slope (Sta. IV, b) Aug. 17 (No. 90). Apparently this female had died before her colony developed. (See Pricer, '08; Wheeler '10b, pp. 338-339.)

I have found this form abundant at Bloomington, Ill. Winged females were taken July 26, dealated ones on July 25 and 26, and males June 29, and July 9 and 25. On July 21, 1892, several males were taken at night, being attracted to a lamp located near a small brook.

A very large colony, numbering thousands of individuals, was found May 26, under a well-decayed log, in a forest at White Heath, Ill. It contained winged males, females, and workers. The winged forms were present in vast numbers. The far-advanced condition of decay of the log was in marked contrast with that in which the initial colonies are usually found. During the years of development of such a large colony the progress of decay will naturally make some changes in the habitat; reciprocally the ants will doubtless tend to monopolize the logs to the exclusion of some other animals, and

also facilitate the decay of the log by their activities. There is an "orderly sequence" of changes in the developing colony, and a similar orderly sequence of changes in the log habitat.

An ant colony in its development clearly illustrates the transformation from the individual to the associational phase of ecological relations. Beginning with the fertilized female and her progeny, the colony develops in size and in the division of labor among its members; until, finally, by the possible addition of slaves, commensals, parasites, and even predaceous enemies, the colony or association is built up in an orderly sequence, and the organisms adjust themselves to one another and to the environment in general.

#### MUTILLIDÆ

*Sphacrophthalma* sp. Velvet Ant.

This stinging, wingless velvet ant was taken at the margin of the forest near the cleared area (Sta. IV, *a*) Aug. 23 (No. 151).

#### PSAMMOCHARIDÆ

*Psammochares aethiops* Cress. (*Pompilus* Fabr.)

This large black wasp was taken by T. L. Hankinson July 10, 1911, in the Bates woods (No. 7693). It probably stores its nest with spiders.

#### SPHECIDÆ

*Ammophila abbreviata* Fabr. Short Caterpillar Wasp.

This wasp was taken on the open ravine slope (Sta. IV, *b*) Aug. 22 (No. 124). One example (No. 127) was running on the ground in the upland forest (Sta. IV, *a*) with a quiescent bombycine caterpillar—probably *Heterocampa guttivitta* Walk.—in its grip.

I took this species of wasp at Bloomington, Ill., July 26. Its copulating habits have been recorded, with figures, by Turner ('02).

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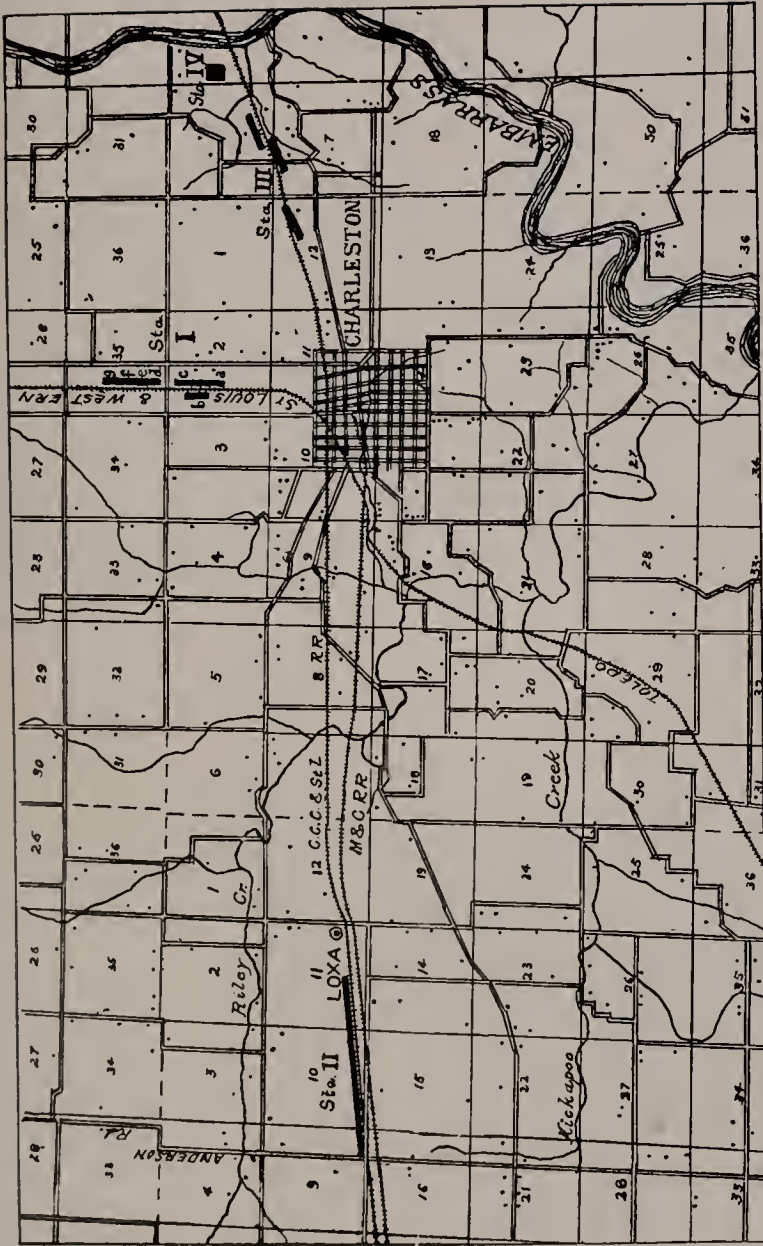
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PLATE I



Map showing location of the ecological stations.





PLATE II



Fig. 1. Colony of swamp grass (*Elymus virginicus*), Station I, c.



Fig. 2. General view, to the right of the railway track, from Station I, d, toward I, g. On the bare foreground are plants of *Asclepias syriaca*. (Photograph, T. L. Hankinson.)



PLATE III



Fig. 1. Swampy area with colony of swamp milkweed (*Asclepias incarnata*), Station I, d. (Photograph, T. L. Hankinson.)



Fig. 2. General view of Station I, g, a colony of swamp milkweed (*Asclepias incarnata*) in a ditch parallel to the rails, and of blue stem (*Andropogon*) and drop-seed (*Sporobolus*). Photograph, T. L. Hankinson.)



PLATE IIIA



Fig. 1. Flowers of the swamp milkweed (*Asclepias incarnata*) at Station I, d. These were the favorite haunts of many flower-visiting insects. (Photograph, T. L. Hankinson.)



Fig. 2. Crawfish chimney at Station I, d, Charleston, Ill. Probably formed by *Cambarus gracilis* or *atogenes*. (Photograph by T. L. Hankinson.)



PLATE IIIB



Fig. 1. Crawfish chimney at Station I, Charleston, Ill. Probably formed by *Cambarus gracilis* or *diogenes*. (Photograph by T. L. Hankinson.)



Fig. 2. General view at Station I, *d*, showing numerous crawfish chimneys, probably formed by *Cambarus gracilis* or *diogenes*. (Photograph by T. L. Hankinson.)





PLATE IV



Fig. 1. Colony of mountain mint (*Pycnanthemum flexuosum*) at Station I, g. The large upturned leaves are those of *Asclepius sullivantii*. (Photograph by T. L. Hankinson.)



General view of Station I, g, April 23, 1911, showing the submerged condition. (Photograph by T. L. Hankinson.)



PLATE V



General view of Station I, r, showing a colony of *Lepachys pinnata* (the black dots on the flower heads) and rosinweed (*Silphium terebinthinaceum*) and *Lactuca canadensis*. (Photograph, T. L. Hankinson.)



PLATE VI



General view of the black-soil prairie at Loxa, Ill., Station II, *a*. (Photograph, T. L. Haukinson.)



PLATE VII



Another view of the Loxa prairie, Station II, *a*, showing a different kind of vegetation. (Photograph, T. L. Hankinson.)





PLATE VIII



Prairie-grass area east of Charleston, Station III, *b*. The grass is *Andropogon* and the white flowers are *Euphorbia*. (Photograph, T. L. Hankinson.)



PLATE IX



Area east of Charleston with mixture of prairie and forest vegetation. Station III, *b*. (Photograph, T. L. Hankinson.)



PLATE X



Fig. 1. General view of the Bates woods. Station IV, looking to the south. August, 1910. (Photograph, C. C. Adams.)



Fig. 2. General view of the same area after clearing. June 8, 1914. (Photograph, T. L. Hankinson.)



PLATE XI



The cleared area bordering the upland part of the Bates woods, adjacent to Station IV. *a*. (Photograph, T. L. Hankinson.)





PLATE XII



The upland area of the Bates woods, Station IV, *a*; a white oak-hickory forest, showing the undergrowth in the more open places.  
(Photograph, T. L. Hankinson.)



PLATE XIII



The upland area of the Bates woods, Station IV, *a*, showing the small amount of undergrowth in the more densely shaded parts. (Photograph, T. L. Hankinson.)



PLATE XIV



The lowland forest of the Bates woods. Station IV, c, looking into the forest from a small clearing or glade. (Photograph, T. L. Hankinson.)



PLATE XV



Lowland maple-basswood forest of the Bates woods, Station IV, c. Interior view, showing absence of shrubbery. (Photograph, T. L. Hankinson.)





PLATE XVI



Fig. 1. Margin of the artificial glade in the lowland forest of Bates woods, Station IV, c. The ground cover is largely clearweed (*Pilea*). (Photograph. C. C. Adams.)



Fig. 2. Detail of vegetation in and at the margin of the artificial glade in the lowland Bates forest, Station IV, c. See Plate XIV for another view of the glade. (Photograph, C. C. Adams.)



PLATE XVII



Fig. 1. General view of the ravine with temporary stream, which bounded the Bates woods on the south, Station IV, *d*. (Photograph, T. L. Hankinson.)



Fig. 2. A pool in the temporary stream in the south ravine, Bates woods, Station IV, *d*. (Photograph, T. L. Hankinson.)

PLATE XVIII

- Fig. 1. Stalk-maggot, *Chatopsis aenea*: *a*, larva, *b*, puparium; *c*, adult.  
Enlarged as indicated. (Howard, Ins. Life.)
- Fig. 2. Frit-fly, *Oscinis coxendix*, puparium. Enlarged. (Washburn,  
Rep. State Ent. Minn.)
- Fig. 3. The same, larva. Enlarged. (Washburn, l. c.)
- Fig. 4. The same, adult. Enlarged. (Washburn, l. c.)
- Fig. 5. Bill-bug, *Sphenophorus ochreus*, dorsal view. Enlarged  $2\frac{1}{3}$   
times.
- Fig. 6. The same, side view. Enlarged  $2\frac{1}{3}$  times.
- Fig. 7. The same, larva, side view. Enlarged.

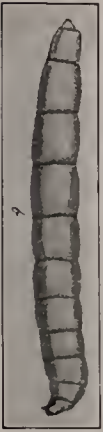
PLATE XVIII



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PLATE XIX

- Fig. 1. Gall on *Populus* caused by *Pemphigus oestlundii*. (Cook, Rep. Ind. Dept. Geol. and Nat. Res.)
- Fig. 2. Poplar Leaf Gall-louse, *Pemphigus populicaulis*, and its gall: *a*, incipient gall on under side of leaf; *b*, gall from the upper side of the leaf; *c*, mature gall, showing aperture; *d* and *e*, incipient double galls; *f*, wingless female; *g*, winged insect—*f* and *g* enlarged as indicated. (Riley, Amer. Ent.)
- Fig. 3. Poplar transverse gall and louse, *Pemphigus populi-transversus*: *a*, gall on *Populus* leaf; *b*, gall showing aperture; *c*, winged female louse; *d*, antenna of winged female. Enlarged as indicated. (Riley.)

PLATE XIX

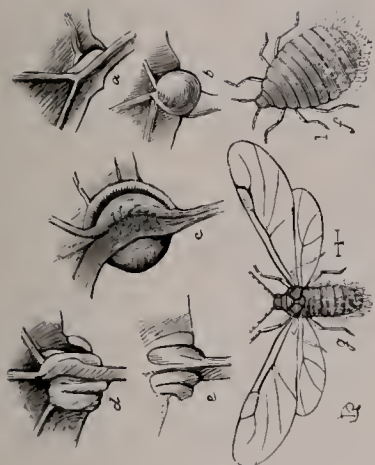
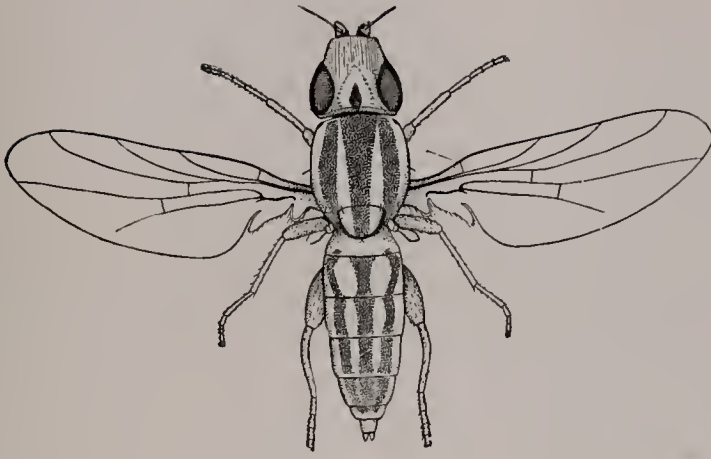


PLATE XX

- Fig. 1. The Wheat Bulb Worm, *Meromyza americana*, adult fly. Magnified twelve diameters.
- Fig. 2. Larva of same. Magnified sixteen diameters.
- Fig. 3. Work of larva (*a*), larva (*b*), and pupa (*c*) of same. (Riley, Rep. State Ent. Mo.)
- Fig. 4. Pupa of same, dorsal view.
- Fig. 5. Pupa of same enclosed in puparium. Magnified thirty diameters.
- Fig. 6. Cottonwood Dagger Caterpillar, *Apatela populi*. (Riley, Rep. State Ent. Mo.)



PLATE XX



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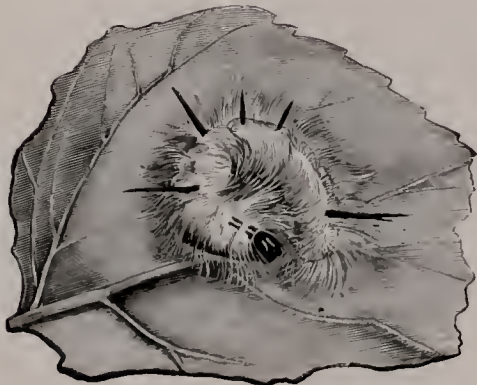
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PLATE XXI

- Fig. 1. Red Locust-mite, *Trombidium locustarum*: *a*, mature larva on wing of locust; *b*, pupa; *c*, adult male; *d*, adult female; *e*, pupal claw and thumb; *f*, pedal claw; *g*, one of the barbed hairs; *h*, striations on the larval skin; *c* and *d* enlarged as indicated. (Riley, Rep. U. S. Ent. Comm.)
- Fig. 2. The same: *a*, female with her eggs; *b*, newly hatched larva (natural size indicated by dot within the circle); *c*, egg; *d* and *e*, empty egg-shells. (Riley, l.c.)
- Fig. 3. White-faced Hornet, *Vespa maculata*. (J. B. Smith, Ins. of N. J.)
- Fig. 4. Ground-beetle, *Lebia grandis*. (After Felt, Mem. N. Y. State Mus.)

PLATE XXI

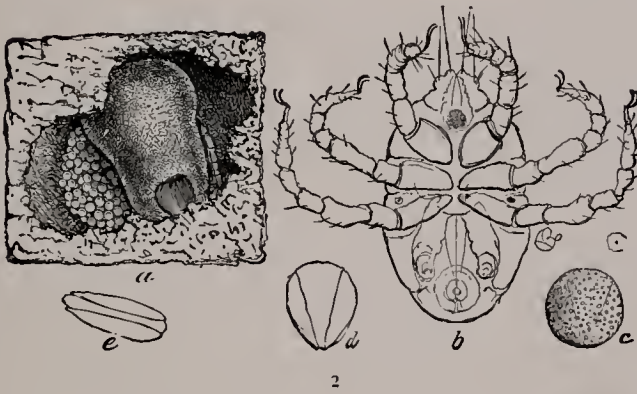
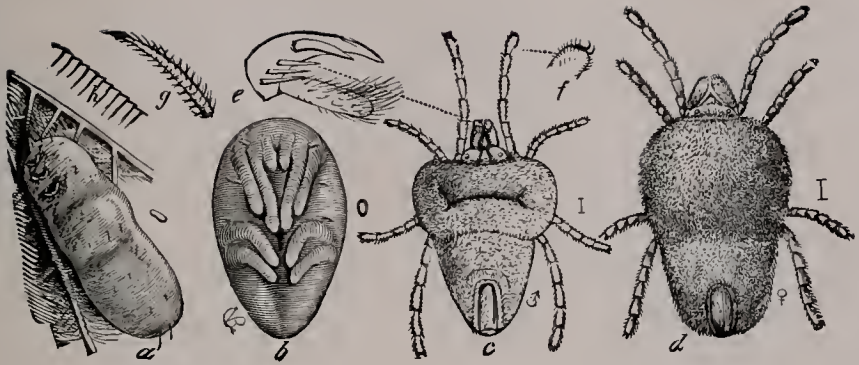


PLATE XXII

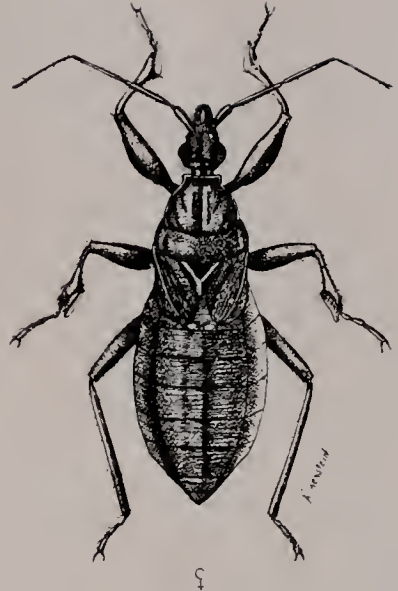
- Fig. 1. Black Pirate, *Melanolestes picipes*, male. Enlarged. (Lugger, Rep. Ent. Minn. Exp. Sta.)
- Fig. 2. The same, female. Enlarged. (Lugger, l. e.)
- Fig. 3. *Myodocha serripes*. Enlarged. (Lugger, l. e.)
- Fig. 4. Leaf-footed Bug, *Leptoglossus oppositus*. (Chittenden, Bull. Bur. Ent. U. S. Dept. Agr.)

PLATE XXII



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PLATE XXIII

- Fig. 1. *Diaperis maculata*: *a*, larva; *b*, beetle; *c*, head of larva; *d*, leg of larva; *e*, antenna of beetle. (Riley.)
- Fig. 2. Green Horned Fungus-beetle, *Arrhenoplita bicornis*. Enlarged.  
(After Felt, Mem. N. Y. State Mus.)
- Fig. 3. Twig-pruner, *Elaphidion villosum*, beetle. Enlarged.
- Fig. 4. The same, larva. Enlarged.

PLATE XXIII

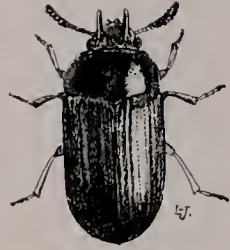
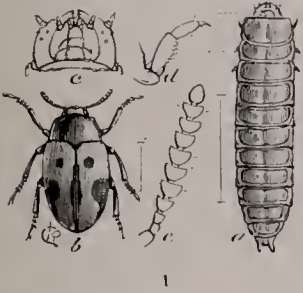
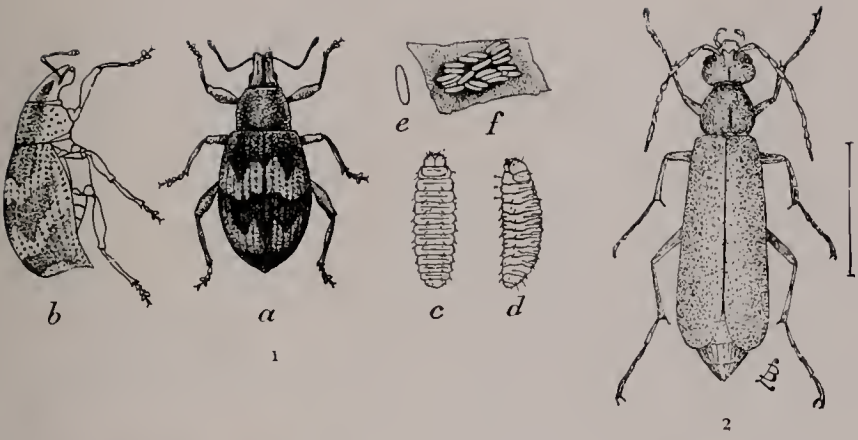


PLATE XXIV

- Fig. 1. Imbriated Snout-beetle, *Epicarus imbricatus*: *a*, dorsal view of beetle; *b*, side view of same; *c*, larva, dorsal view; *d*, side view of same; *e* and *f*, egg and egg mass. (Chittenden, Bull. Bur. Ent. U. S. Dept. Agr.)
- Fig. 2. Gray Blister-beetle, *Macrobasis unicolor*. Enlarged as indicated. (Bruner, Bull. Nebr. Exp. Sta.)
- Fig. 3. The Elm Borer, *Saperda tridentata*, larva. Enlarged.
- Fig. 4. The same, beetle. Enlarged.



PLATE XXIV



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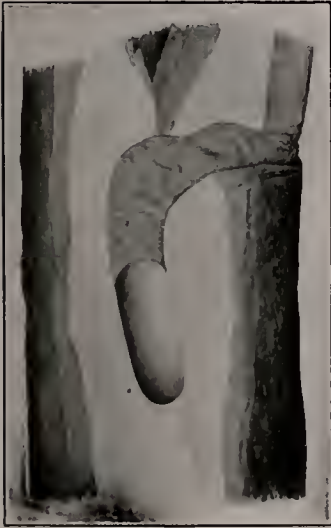
PLATE XXV

- Fig. 1. Reddish Elm Snout-beetle, *Magdalis arvicollis*: beetle, larva, and pupa. Enlarged eight diameters.
- Fig. 2. Burrow showing egg of *Magdalis arvicollis*. Enlarged three diameters.
- Fig. 3. Hickory Bark-beetle, *Scolytus 4-spinosus*: 1 and 2, work; 3, beetle, enlarged and natural size; 4, larva, side view, enlarged and natural size; 5, pupa, ventral view, enlarged as indicated; 6, *Magdalis arvicollis*, punctuation of elytra. (Riley, Rep. State Ent. Mo.)

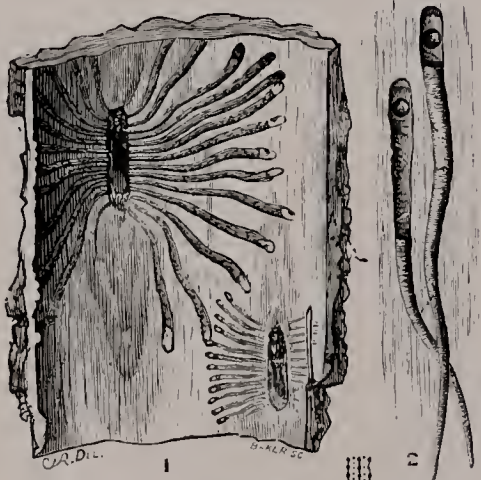
PLATE XXV



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PLATE XXVI

- Fig. 1. Larva of Eyed Elater, *Alaus oculatus*.  
Fig. 2. Beetle of same. (After Harris, Ins. Inj. Veg.)  
Fig. 3. Clerid beetle, *Clerus quadriguttatus*. Enlarged. (After Felt, Mem. N. Y. State Mus.)  
Fig. 4. Larva of Eyed Elater, *Alaus oculatus*, oblique view, to show apex of abdomen.  
Fig. 5. Flat-headed Apple-tree borer, *Chrysobothris femorata*: *a*, larva; *b*, beetle; *c*, head of male beetle; *d*, ventral view of pupa. (Chittenden, Circ. Bur. Ent. U. S. Dept. Agr.)  
Fig. 6. Clerid beetle, *Chariessa pilosa* (enlarged), with antenna of female. (After Felt, Mem. N. Y. State Mus.)  
Fig. 7. Round-headed Apple-tree Borer, *Saperda candida*: *a*, larva, side view; *b*, larva, dorsal view; *c*, beetle; *d*, pupa. (Chittenden, Circ. Bur. Ent. U. S. Dept. Agr.)

PLATE XXVI

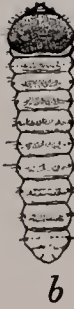
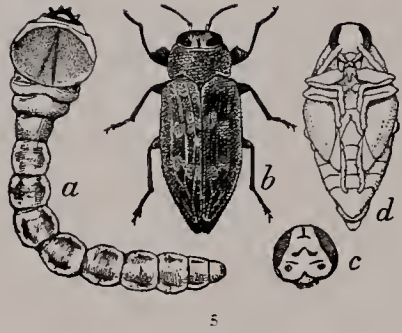
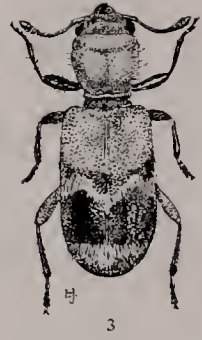
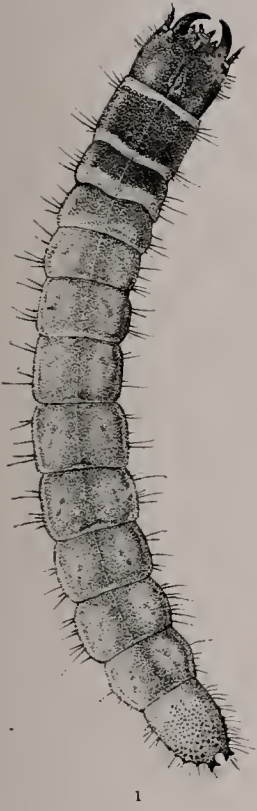
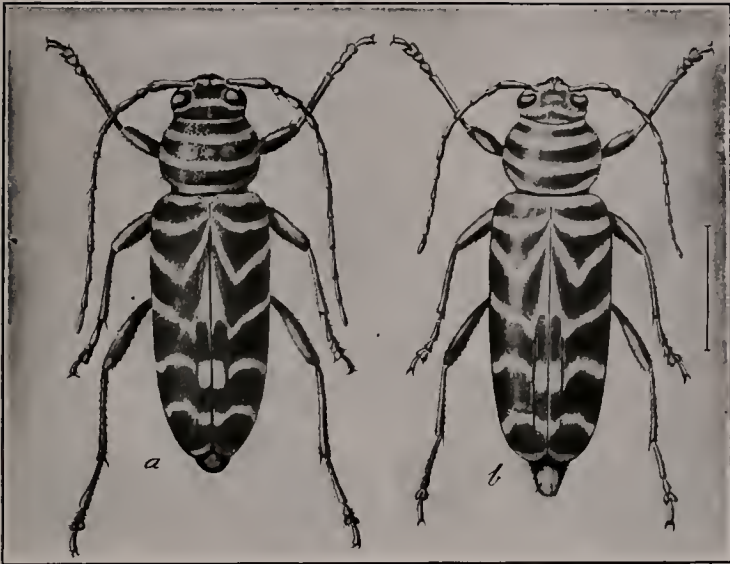


PLATE XXVII

- Fig. 1. Locust-borer, *Cyllene robinia*, adult: *a*, male; *b*, female. Enlarged as indicated. (Hopkins, Bull. Bur. Ent. U. S. Dept. Agr.)
- Fig. 2. The same, pupa: *a*, ventral end; *b*, dorsal view. Enlarged as indicated. (Hopkins, l. c.)

PLATE XXVII



1



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PLATE XXVIII

- Fig. 1. Cerambycid beetle, *Leptostylus aculiferus*. (Blatchley, Coleopt. of Ind.)
- Fig. 2. Banded Hickory Borer, *Chion cinctus*, adult.
- Fig. 3. Northern Brenthian, *Eupsalis minuta*, male. (After Felt, Mem. N. Y. State Mus.)
- Fig. 4. The same, female. (After Felt, l. c.)
- Fig. 5. Twin-spotted Eburia, *Eburia 4-geminata*. (Blatchley, Coleopt. of Ind.)
- Fig. 6. Rustic Borer, *Xylotrechus colonus*, adult. Enlarged.
- Fig. 7. Cerambycid beetle, *Neoclytus erythrocephalus*. Enlarged.
- Fig. 8. Red Cucujid, *Cucujus clavipes*: *a*, larva; *b*, beetle; *c*, apex of larval abdomen (enlarged); *d*, head of larva; *e*, side view of apex of larval abdomen. Larva and beetle enlarged as indicated. (Riley.)



PLATE XXVIII



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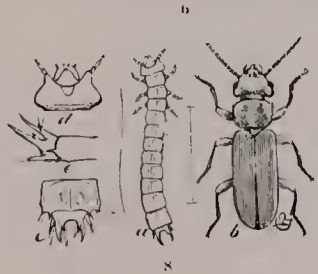




PLATE XXX

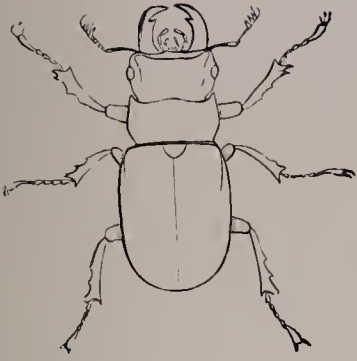


Larva of the beetle *Meracantha contracta* in its burrow in much-decayed wood. (Photograph, P. A. Glenn.)

PLATE XXXI

- Fig. 1. Pinching Bug, *Lucanus dama*. (Packard, Guide to Study of Ins.)
- Fig. 2. The same: cocoon and side view of larva. (Packard, l. c.)
- Fig. 3. White-marked Tussock-moth, *Hemerocampa leucostigma*, larva.
- Fig. 4. The same, male moth.
- Fig. 5. The same: wingless female moth and egg masses. (Britton, Rep. State Ent. Com.)

PLATE XXXI



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PLATE XXXII



View of dead timber, much of it hardwood, Reelfoot Lake, Tenn., killed by submergence caused by the sinking of the land during the New Madrid earthquake in 1811 (cf. Fuller '12). (Photograph loaned by U. S. Geol. Survey.)





PLATE XXXIII



The great Red River raft, Louisiana. Such rafts formed temporary lakes which killed trees as shown in Plate XXXIV. (Photograph loaned by U. S. Geol. Survey.)



PLATE XXXIV



Timber killed by flooding in a temporary lake, formed by a raft jam, Bossier Parish, La. (Photograph loaned by U. S. Geol. Survey.)



PLATE XXXV



Trees killed along the shores of the Illinois River by the permanent rise caused by water from Lake Michigan. Near the upper end of Quiver Lake, Havana, Ill., August, 1909. (Photograph, C. C. Adams.)



PLATE XXXVI



Prairie Crawfish, *Cambarus gracilis*: male (left), female (right), young (below). (Photograph loaned by Nellie Rietz Taylor.)

PLATE XXXVII

*Prairie Species*

- Fig. 1. Female Garden Spider, *Argiope aurantia*, in the middle of its web. Natural size. (Emerton, Common Spiders.)
- Fig. 2. Egg cocoon of same in marsh grass. Natural size. (Emerton, l.c.)
- Fig. 3. Polished Harvest-spider, *Liobunum politum*, male. Natural size. (Weed, Proc. U. S. Nat. Mus.)



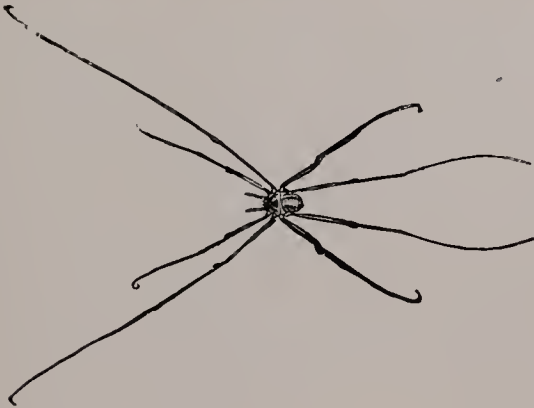
PLATE XXXVII



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PLATE XXXVIII

*Prairie Species*

- Fig. 1. Lacewing, *Chrysopa oculata*: *a*, egg; *b*, larva; *c*, tarsus of larva; *d*, larva feeding upon an insect; *e*, egg-shell; *f*, adult lacewing; *g*, head of adult; *h*, adult, natural size. (Chittenden, Bur. Ent. U. S. Dept. Agr.)
- Fig. 2. Nine-spot Dragon-fly, *Libellula pulchella*, resting on swamp plants at Station I. *d*. (Photograph, T. L. Hankinson.)

PLATE XXXVIII

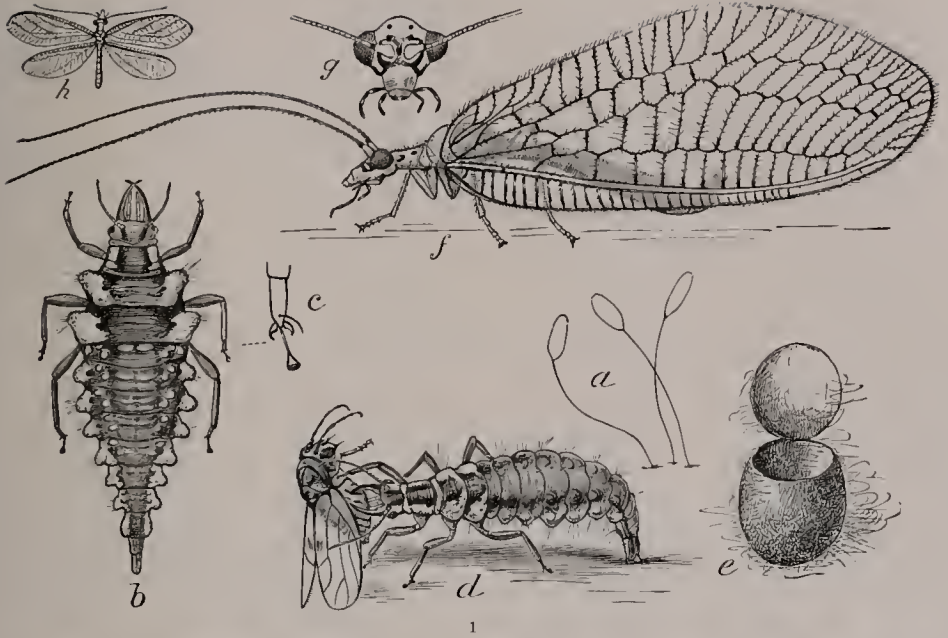


PLATE XXXIX

*Prairie Species*

- Fig. 1. Sordid Grasshopper, *Encoptolophus sordidus*, male. (Lugger, Rep. Ent. Minn. Exp. Sta.)
- Fig. 2. Red-legged Grasshopper, *Melanoplus femur-rubrum*. (Riley.)
- Fig. 3. Leather-colored Grasshopper, *Schistocerca alutacea*. (Lugger, l. e.)
- Fig. 4. Carolina Grasshopper, *Dissosteira carolina*. (Lugger, l. e.)
- Fig. 5. Differential Grasshopper, *Melanoplus differentialis*, male. (Lugger, l. e.)

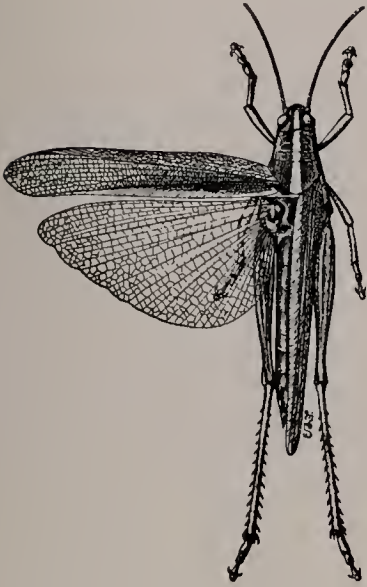
PLATE XXXIX



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PLATE XL

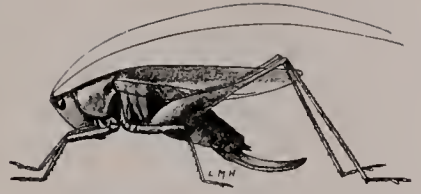
*Prairie Species*

- Fig. 1. Differential Grasshopper, *Melanoplus differentialis*, female. (Riley.)
- Fig. 2. Common Meadow Grasshopper, *Orchelimum vulgare*, female. Enlarged as indicated. (Lugger, Rep. Ent. Minn. Exp. Sta.)
- Fig. 3. Two-striped Grasshopper, *Melanoplus bivittatus*, female. (Riley.)
- Fig. 4. Common Meadow Grasshopper, *Orchelimum vulgare*, male. Enlarged as indicated. (Lugger, l. c.)
- Fig. 5. Meadow Cricket, *Æcanthus*, eggs and punctures: *a*, stem showing punctures; *b*, twig split to show eggs; *c*, a single egg; *d*, cap of egg enlarged. (Riley, Rep. State Ent. Mo.)
- Fig. 6. Dorsal-striped Grasshopper, *Xiphidium strictum*, female.
- Fig. 7. Lance-tail Grasshopper, *Xiphidium attenuatum*, female. Enlarged as indicated. (Lugger, l. c.)

PLATE XL



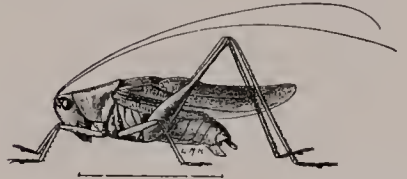
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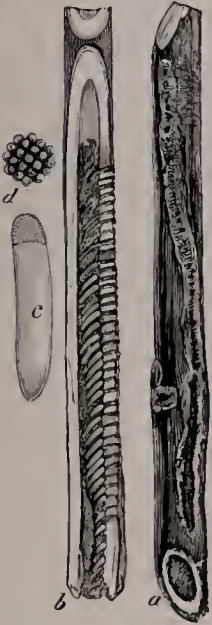
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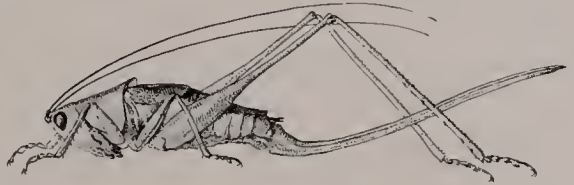
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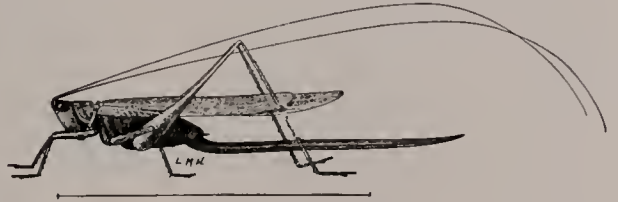
4



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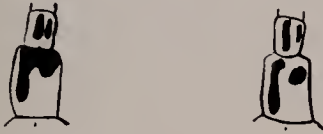
PLATE XLI

*Prairie Species*

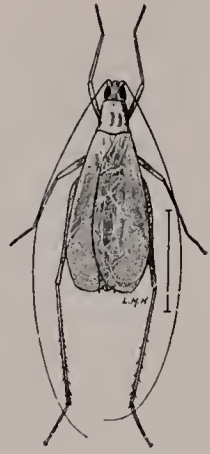
- Fig. 1. Black-horned Meadow Cricket, *Aecanthus nigricornis*, female, enlarged as indicated (Lugger, Rep. Ent. Minn. Exp. Sta.); and basal joints of antennæ of *A. nigricornis* (left) and *quadripunctatus* (right) (after Hart, Ent. News).
- Fig. 2. The same, male. (Lugger, Rep. Ent. Minn. Exp. Sta.)
- Fig. 3. Stink-bug, *Euschistus variolarius*.
- Fig. 4. Rapacious Soldier-bug, *Sinea diadema*. Enlarged as indicated. (Riley, Rep. State Ent. Mo.)
- Fig. 5. *Stiretrus anchorago*: a, adult; b, nymph. (Riley, Bur. Ent. U. S. Dept. Agr.)



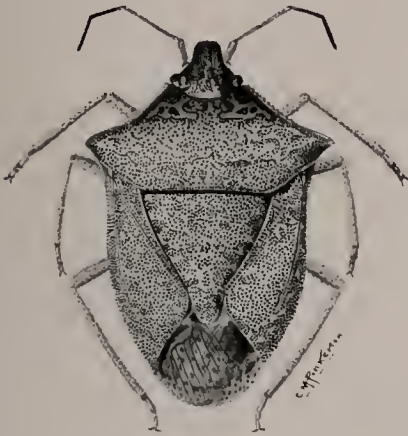
PLATE XLI



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b

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PLATE XLIII

*Prairie Species*

- Fig. 1. Small Milkweed Bug, *Lygaeus kalmii*. Enlarged.  
Fig. 2. Flea Negro-bug, *Thyreocoris pubicarius*. Enlarged.  
Fig. 3. Large Milkweed Bug, *Oncopeltus fasciatus*. (Uhler, Standard Nat. Hist.)  
Fig. 4. Ambush Bug, *Phymata fasciata*: *a*, dorsal view; *b*, side view; *e*, front clasping leg; *d*, sucking beak. (Riley, Bur. Ent. U. S. Dept. Agr.)  
Fig. 5. Dusky Leaf-bug, *Adelphocoris rapidus*, nymph.  
Fig. 6. The same, adult.

PLATE XLII



1



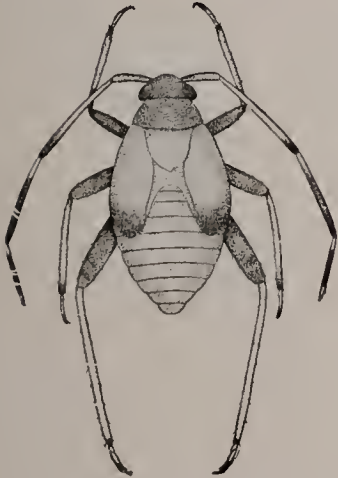
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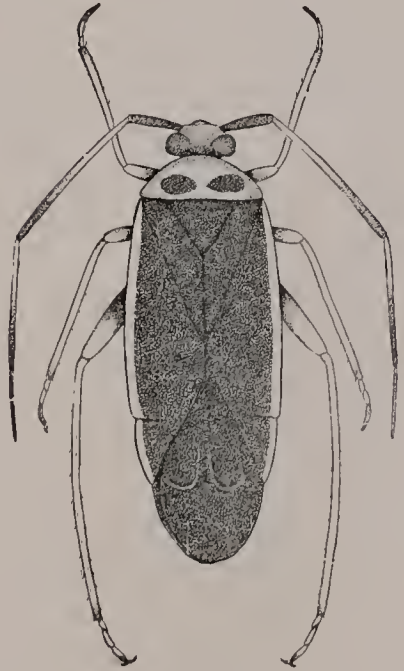
4



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PLATE XLIII

*Prairie Species*

- Fig. 1. Dingy Cutworm, *Fellia subgothica*, dorsal and lateral views.  
Fig. 2. Moth of same, with wings spread and with wings folded. (Riley, Rep. State Ent. Mo.)  
Fig. 3. Tarnished Plant-bug, *Lygus pratensis*.  
Fig. 4. Nymph of same.  
Fig. 5. Pennsylvania Soldier-beetle, *Chauliognathus pennsylvanicus*:  
    *a*, larva; *b*, head of larva (enlarged); *c*, *d*, *e*, *f*, *g*, and *h*,  
    structural details of larva. (Riley, Rep. State Ent. Mo.)  
Fig. 6. Adult of same. (Riley, l. e.)

PLATE XLIII



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PLATE XLIV

*Prairie Species*

- Fig. 1. Two-lined Soldier-beetle, *Telephorus bilineatus*: *a*, larva; *b*, head of larva; *c*, beetle. (Riley, Rep. State Ent. Mo.)
- Fig. 2. Nine-spotted Ladybird, *Coccinella novemnotata*. (After Felt, Mem. N. Y. State Mus.)
- Fig. 3. Indian Cetonia, *Euphoria inda*: *a*, beetle; *b*, egg; *c*, young larva; *d*, mature larva; *e*, pupa. About twice natural size. (Chittenden, Bull. Bur. Ent. U. S. Dept. Agr.)
- Fig. 4. Black Flower-beetle, *Euphoria sepulchralis*. Enlarged.
- Fig. 5. Spotted Grape Beetle, *Pelidnota punctata*: *a*, larva; *b*, pupa in its cell; *c*, beetle; *d*, tip of larval abdomen; *e*, antenna of larva; *f*, leg of larva. (Riley, Rep. State Ent. Mo.)

PLATE XLIV

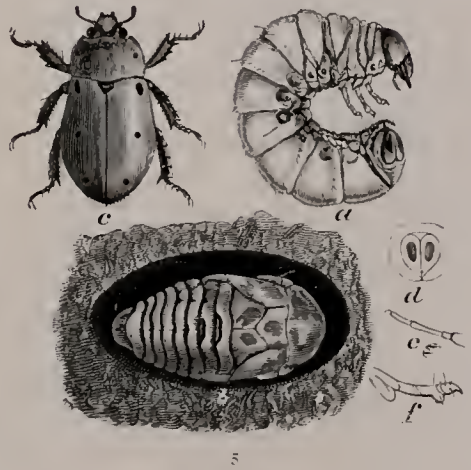
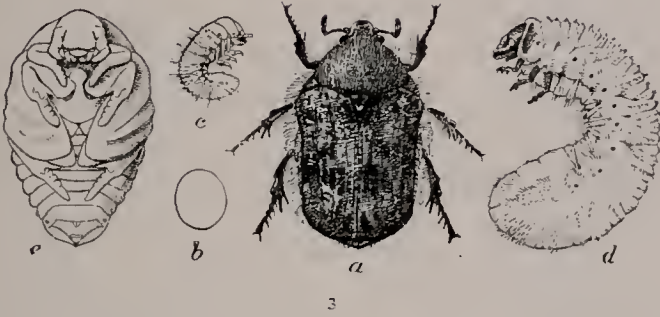
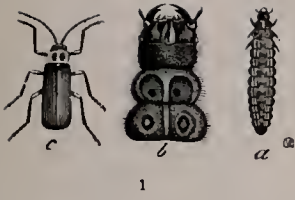


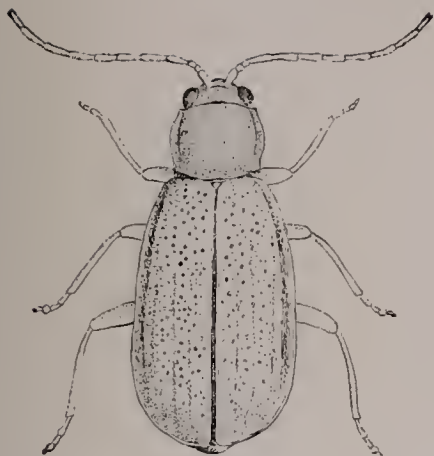
PLATE XLV

*Prairie Species*

- Fig. 1. Western Corn Root-worm beetle, *Diabrotica longicornis*. Enlarged.
- Fig. 2. Margined Blister-beetle, *Epicauta marginata*.
- Fig. 3. Southern Corn Root-worm beetle, *Diabrotica 12-punctata*. Enlarged.
- Fig. 4. Bill-bug, *Sphenophorus venatus*.
- Fig. 5. Striped Blister-beetle, *Epicauta vittata*: *a*, female beetle; *b*, eggs; *c*, young (triangulin) larva; *d*, second or caraboid stage; *e*, contracted scarabæoid stage, natural size; *f*, scarabæoid stage; *g*, coarctate larva, or winter stage. (Chittenden, Bull. Bur. Ent. U. S. Dept. Agr.; *b-g*, after Riley, Trans. St. Louis Acad. Sci.)



PLATE XLV



1



2



3



4



e



d



e



a



f



g

PLATE XLVI

*Prairie Species*

- Fig. 1. Cabbage-worm Butterfly, *Pontia rapae*, female. (Riley, Rep. State Ent. Mo.)
- Fig. 2. Metallic Milkweed Fly, *Psilopus siphon*, male. Enlarged. (Washburn, Rep. State Ent. Minn.)
- Fig. 3. Milkweed Butterfly larva, *Anosia plecippus*. (Riley, Rep. State Ent. Mo.)
- Fig. 4. Caterpillar Gall, *Gnorimoschema galle-solidaginis*. (Cook, Rep. Ind. Dept. Geol. and Nat. Res.)
- Fig. 5. Goldenrod Bunch Gall, formed by the midge *Cecidomyia solidaginis*. (Beutenmüller, Amer. Mus. Journ.)
- Fig. 6. Vertebrated Robber-fly, *Promachus vertebratus*, male. (Washburn, Rep. State Ent. Minn.)

PLATE XLVI



1



2



3



4



5



PLATE XLVII

*Prairie Species*

- Fig. 1. Corn Syrphid Fly, *Mesogramma politum*. Enlarged.  
Fig. 2. Larva of same. Enlarged. (Sanderson, Rep. Del. Exp. Sta.)  
Fig. 3. Syrphid fly, *Syrphus americanus*. (Metcalf, Bull. Ohio Biol. Surv.)  
Fig. 4. Puparium of same. (Metcalf, l. e.)  
Fig. 5. Larva of same. (Metcalf, l. e.)  
Fig. 6. Syrphid fly, *Allograpta obliqua*. (Metcalf, l. e.)  
Fig. 7. Larva of same. (Metcalf, l. e.)

PLATE XLVII

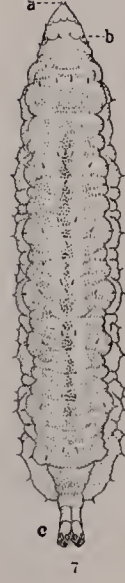
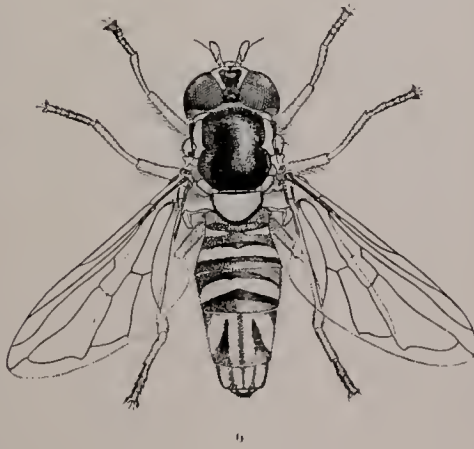
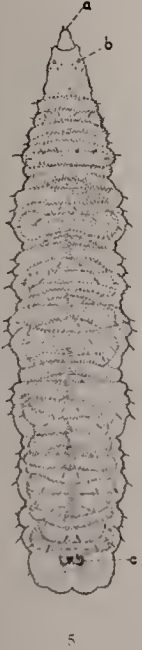
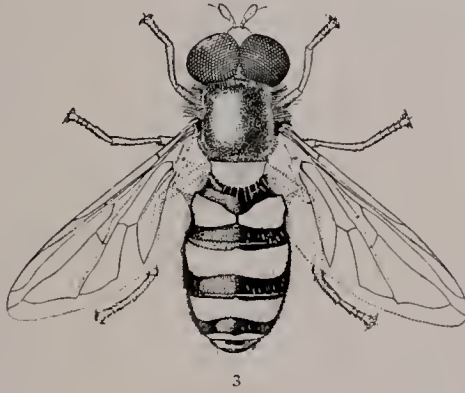
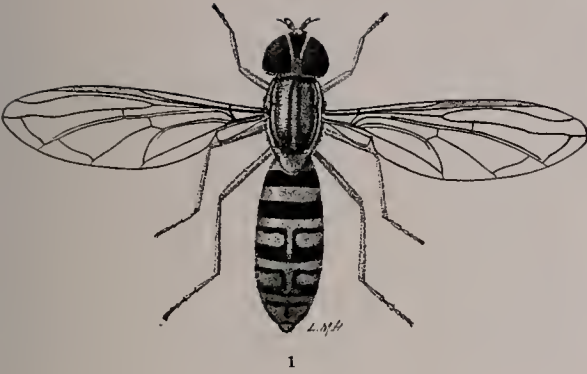


PLATE XLVIII

*Prairie Species*

- Fig. 1. Conopid fly, *Physoccephala tibialis*, and side view of head.  
(Washburn, Rep. State Ent. Minn.)
- Fig. 2. Seiomyzid fly, *Tetanocera plumosa*, and profile of antenna.  
(After Washburn, l. e.)

PLATE XLVIII



1



2





PLATE XLIX



Carpenter-bee, *Xylocopa virginica*: the bee and its tunnels in wood. (After Felt Mem. N. Y. State Mus.)

PLATE L

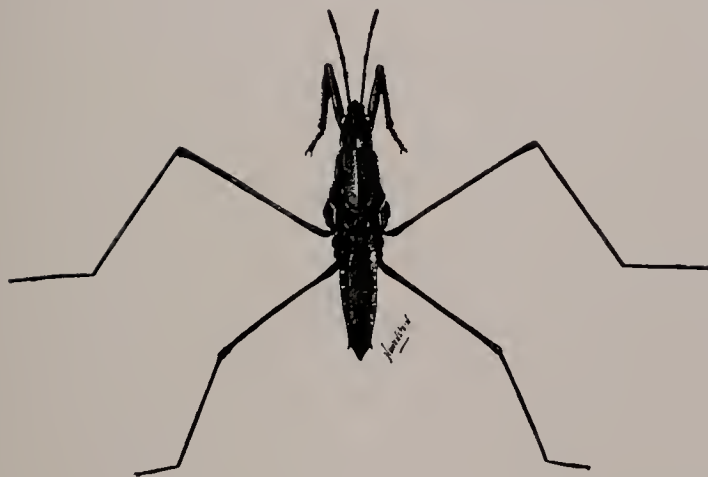
*Prairie Species*

- Fig. 1. Rusty Digger-wasp, *Chlorion ichneumoncum*. (J. B. Smith, Ins. of N. J.)
- Fig. 2. Water-strider, *Gerris remigis*. (Lugger, Rep. Ent. Minn. Exp. Sta.)

PLATE L



1



2

PLATE LI

*Forest Species*

- Fig. 1. Harvest-spider, *Liobunum ventricosum*. (Weed, Proc. U. S. Nat. Mus.)
- Fig. 2. Forest Snail, *Polygyra albolabris*, dorsal view. (Simpson.)
- Fig. 3. The same, lateral view. (Simpson.)

PLATE LI



PLATE LII

*Forest Species*

- Fig. 1. Island Epeirid, *Epeira insularis*, male. (Emerton, Common Spiders.)
- Fig. 2. The same, female. Twice enlarged. (Emerton, l. c.)
- Fig. 3. Web of *Epeira insularis*, with nest above, among leaves. One third natural size. (Emerton, l. c.)

PLATE LII



PLATE LIII

*Forest Species*

- Fig. 1. Three-lined Epeirid, *Epeira trivittata*, male. Enlarged four times. (Emerton, Common Spiders.)
- Fig. 2. The same, female. Enlarged four times. (Emerton, l. c.)
- Fig. 3. White-triangle Spider, *Epeira verrucosa*, male. Enlarged twice. (Emerton, l. c.)
- Fig. 4. The same, female. Enlarged twice. (Emerton, l. c.)



PLATE LIII



3

4

PLATE LIV

*Forest Species*

- Fig. 1. Rugose Spider, *Acrosoma rugosa*, female. Enlarged four times.  
(Emerton, Common Spiders.)
- Fig. 2. Lycosid spider, *Lycosa scutulata*, female. Twice enlarged.  
(Emerton, l. e.)
- Fig. 3. Spined Spider, *Acrosoma spinea*, male. Enlarged four times.  
(Emerton, l. e.)
- Fig. 4. The same, female. Enlarged four times. (Emerton, l. e.)
- Fig. 5. Web of Spined Spider, *Acrosoma spinea*. (Emerton, l. e.)

PLATE LIV

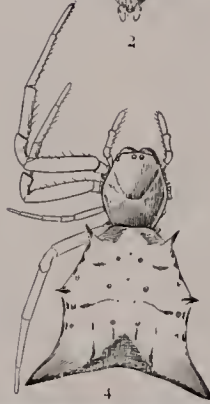
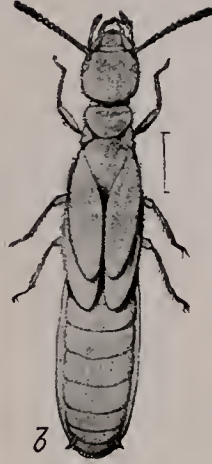
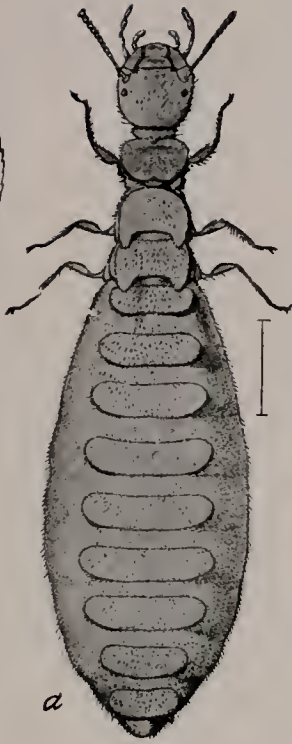
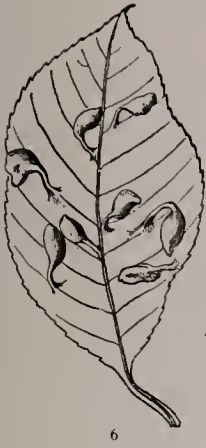


PLATE LV

*Forest Species*

- Fig. 1. Galls of Cherry-leaf Gall-mite, *Aearus serotinus*. (Beutenmüller, Bull. Amer. Mus. Nat. Hist.)
- Fig. 2. White Ant, *Termes flavipes*: *a*, queen; *b*, young of winged female; *c*, worker; *d*, soldier. All enlarged as indicated. (After Marlatt, Bull. Bur. Ent. U. S. Dept. Agr.)
- Fig. 3. Periodical Cicada, *Tibicen septendecim*. Young nymph, newly hatched. Greatly enlarged. (Lugger, Rep. Ent. Minn. Exp. Sta.)
- Fig. 4. The same: *A*, male, typical form (natural size); *c*, *d*, genital hooks of same (enlarged); *g*, sounding apparatus; *B*, male of small form (*cassinii*), natural size; *e*, *f*, genital hooks (enlarged). (Lugger, l. c.)
- Fig. 5. Dog-day Harvest-fly, *Cicada linnei*, male. (Lugger, l. c.)

PLATE LV



2



3

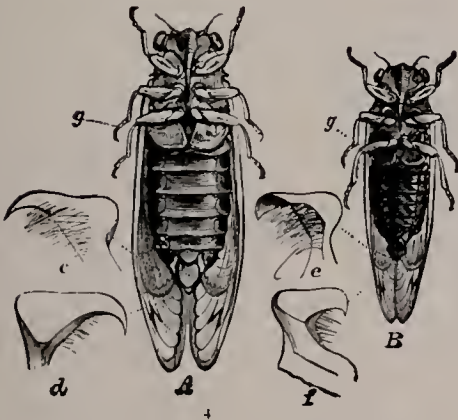


PLATE LVI

*Forest Species*

- Fig. 1. Mealy Flata, *Ormenis pruinosa*. Enlarged as indicated. (Riley, Rep. State Ent. Mo.)
- Fig. 2. Eggs of same: *a*, form and arrangement of the eggs; *b*, insertion in twig; *c*, row of eggs in twig. Enlarged. (Riley, l. c.)
- Fig. 3. Leaf-hopper, *Aulacizes irrorata*. Much enlarged. (Sanderson, Bull. Bur. Ent. U. S. Dept. Agr.)
- Fig. 4. Pennsylvania Cockroach, *Ischnoptera pennsylvanica*, male. Enlarged as indicated. (Blatchley, Rep. Ind. Dept. Geol. and Nat. Res.)
- Fig. 5. The same, female. (Blatchley, l. c.)
- Fig. 6. Forest Walking-stick, *Diaperomera femorata*, male. (Lugger, Rep. Ent. Minn. Exp. Sta.)
- Fig. 7. Spined Stilt-bug, *Jalysus spinosus*. (Lugger, l. c.)
- Fig. 8. Plant-bug, *Acanthocerus galeator*.

PLATE LVI



1



b



3



4



a

2



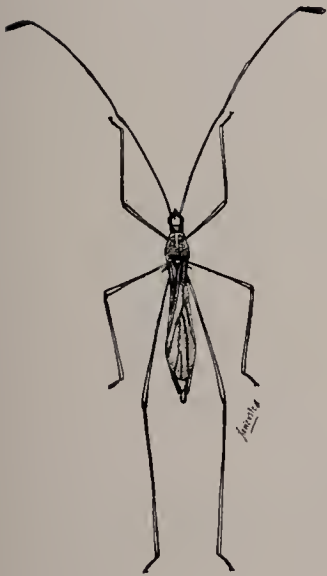
c



5



d



7



8

PLATE LVII

*Forest Species*

- Fig. 1. Common Katydid, *Cyrtophyllus perspicillatus*, male. (Lugger, Rep. Ent. Minn. Exp. Sta.)
- Fig. 2. Round-winged Katydid, *Amblycorypha rotundifolia*; *b*, apex of ovipositor (enlarged). (Riley, Rep. State Ent. Mo.)
- Fig. 3. Grouse Locust, *Tettigidea lateralis*. Enlarged as indicated. (Lugger, Rep. Ent. Minn. Exp. Sta.)
- Fig. 4. Boll's Grasshopper, *Spharagemon bolli*, male. Enlarged as indicated. (Lugger, l. c.)
- Fig. 5. Forked Katydid, *Scudderia furcata*, male. (Lugger, l. c.)
- Fig. 6. Sprinkled Grasshopper, *Chlocallis conspersa*, female. (Lugger, l. c.)
- Fig. 7. Short-winged Grasshopper, *Dichromorpha viridis*. Enlarged as indicated. (Lugger, l. c.)
- Fig. 8. Lesser Grasshopper, *Melanoplus atlantis*, female. Enlarged as indicated. (Lugger, l. c.)



PLATE LVII

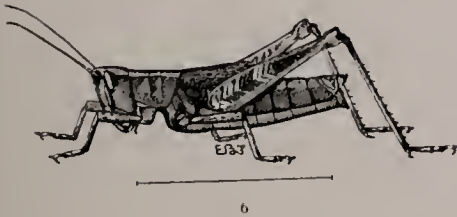
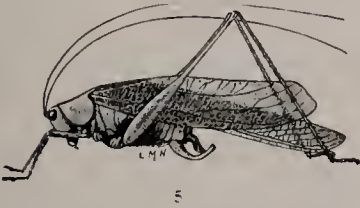
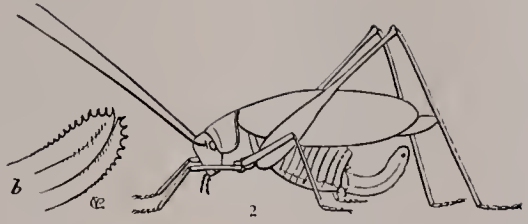
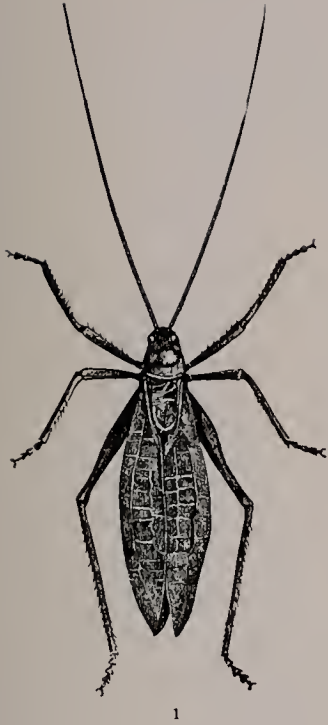
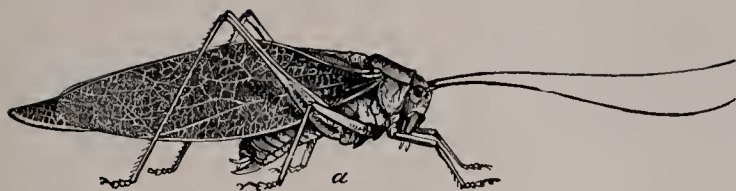


PLATE LVIII

*Forest Species*

- Fig. 1. Angle-winged Katydid, *Microcentrum laurifolium*, male.  
(Riley, Rep. State Ent. Mo.)
- Fig. 2. Female of same, ovipositing. (Riley, i. c.)
- Fig. 3. Firefly, *Photuris pennsylvanica*: *a*, larva (enlarged as indicated); *b*, leg of larva (enlarged); *c*, beetle. (J. B. Smith, Ins. of N. J.)
- Fig. 4. Reticulate Calopteron, *Calopteron reticulatum*. (Blatchley, Coleopt. of Ind.)
- Fig. 5. Horned Passalus, *Passalus cornutus*: *a*, larva; *b*, pupa, from side; *c*, beetle; *d*, ventral view of legs; *e*, rudimentary hind leg of larva. (Riley, Rep. State Ent. Mo.)
- Fig. 6. Striped Cricket, *Nemobius fasciatus*, form *vittatus*, female. (Lugger, Rep. Ent. Minn. Exp. Sta.)

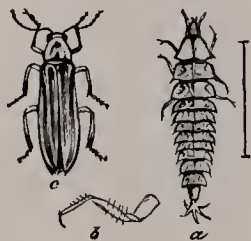
PLATE LVIII



1



2



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4



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6

PLATE LIX

*Forest Species*

- Fig. 1. Horned Fungus-beetle, *Boletotherus bifurcus*. Dorsal view of male (enlarged). (After Felt, Mem. N. Y. State Mus.)
- Fig. 2. The same, dorsal view of female (enlarged). (After Felt, l. e.)
- Fig. 3. The same, side view of male (enlarged). (After Felt, l. e.)
- Fig. 4. *Dendroides canadensis*: *a*, larva (enlarged as indicated); *b*, pupa (enlarged as indicated); *c*, female beetle (enlarged as indicated); *d*, enlarged anal fork of larva; *f*, antenna of male (enlarged). (Le Baron, Rep. State Ent. Ill.)
- Fig. 5. *Papilio philenor*, caterpillar. (Riley, Rep. State Ent. Mo.)
- Fig. 6. American Silkworm Moth, *Telea polyphemus*. (After Felt, Mem. N. Y. State Mus.)

PLATE LIX

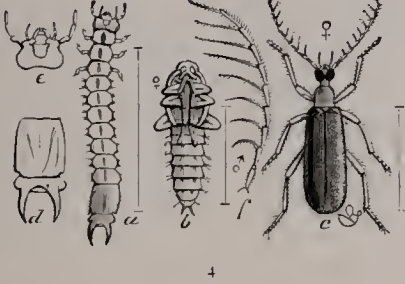
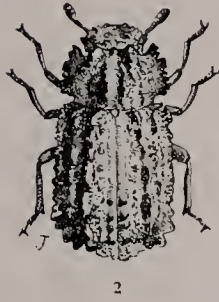


PLATE LX

*Forest Species*

- Fig. 1. Hickory Horned-devil, the larva of *Citheronia regalis*. (After Packard, Mem. Nat. Acad. Sci.)
- Fig. 2. Royal Walnut Moth, *Citheronia regalis*. (After Felt, Mem. N. Y. State Mus.)

PLATE LX



1



2

PLATE LXI

*Forest Species*

- Fig. 1. Imperial Moth, *Basilona imperialis*. (After Felt, Mem. N. Y. State Mus.)
- Fig. 2. *Nadata gibbosa*, moth. (After Packard, Mem. Nat. Acad. Sci.)
- Fig. 3. *Heterocampa guttivitta*, male moth. (After Packard, Mem. Nat. Acad. Sci.)
- Fig. 4. *Halisidola tessellaris*, moth.
- Fig. 5. *Heterocampa guttivitta*, female moth. (After Packard, Mem. Nat. Acad. Sci.)



PLATE LXI



1



2



3



4



5

PLATE LXII

*Forest Species*

- Fig. 1. Spanworm moth, *Eustroma diversilineata*.  
Fig. 2. Acorn Plum-gall, *Amphibolips prunus*. (Beutenmüller, Amer. Mus. Journ.)  
Fig. 3. Horned Knot Oak-gall, *Andricus cornigerus*. (Beutenmüller, Bull. Am. Mus. Nat. Hist.)  
Fig. 4. Oak Wool-gall, *Andricus lana*. (Beutenmüller, l. e.)  
Fig. 5. White Oak Club-gall, *Andricus clavula*. (Beutenmüller, l. e.)  
Fig. 6. Ant. *Cremastogaster lineolata*, worker.

PLATE LXII



1



2



3



4



L. AM.

6

PLATE LXIII

*Forest Species*

- Fig. 1. Oak Seed-gall, *Andricus seminator*. (Cook, Rep. Ind. Dept. Geol. and Nat. Res.)
- Fig. 2. Black Longtail, *Pelecinus polyturator*: *a*, male; *b*, female. (J. B. Smith, Ins. of N. J.)

PLATE LXIII



1



2