STATE OF ILLINOIS
DEPARTMENT OF REGISTRATION AND EDUCATION

NATURAL HISTORY SURVEY DIVISION
STEPHEN A. FORBES. *Chief*

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OF THE

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URBANA, ILLINOIS, U. S. A.

VOLUME XVI

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AUG. 26th 1818

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CONTENTS

Part I. Description of the forests:

Bottomland types:

Upland type:

Part I. Prediction procedure:

Part II. A basis for the measurement of development:

ERRATA

Page 2, line 6, for *loan* read *loam.*

Page 4, line 18 from bottom, beech (after water beech) should be followed by a semicolon.

Page 138, line 10 and line 14 from bottom, for *Dane* read *Dann.*

Page 139, line 5, for *Dane* read *Dann.*

Page 180, line 5 from bottom, delete *D.*

Page 198, line 19 from bottom, for *March* read *March 16, 1918.*

Page 221, line 22, for *data* read *date.*

Page 278, lines 17 and 18 from bottom in right-hand column, for *150* read *158.*

Page 285, line 24 in left-hand column, for *Franch* read *French.*

Page 321, table III, center column, for *1.02* read *1.00+*; for *1.04* read *1.02;* for *1.06* read *1.04*.

Page 411, line 4, for *pupation* read *breaking dormancy* .

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Vol. XVI. BULLETIN Article I.

Third Report on a Forest Survey of Illinois

BY

CLARENCE J. TELFORD

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URBANA, ILLINOIS
March, 1926

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CONTENTS

Bottomland type:

Upland type:

(1) Upland types:

(2) Bottomland type:

(3) [Fully stocked virgin stands:]

INTRODUCTION

Until very recent years definite knowledge of the amounts and condition of our timber resources and the demands upon them has been so limited that a reliable estimate of our timber requirements and supplies at any future period has been impossible. It is now common knowledge that the present forests of the United States contain an estimated total of 481,800 million cubic feet of standing timber; that the annual drain of 25,000 million cubic feet is partially offset by a growth of 6,039 million cubic feet; and that the virgin forests will carry us another twenty-five years, after which we shall probably be wholly dependent upon growth from cut-over lands. By utilizing the entire 470 million acres of forest land, at prevailing rates of growth these cut-over lands can supply us with an estimated annual yield of 14,000 million cubic feet—a little more than half our present requirements.

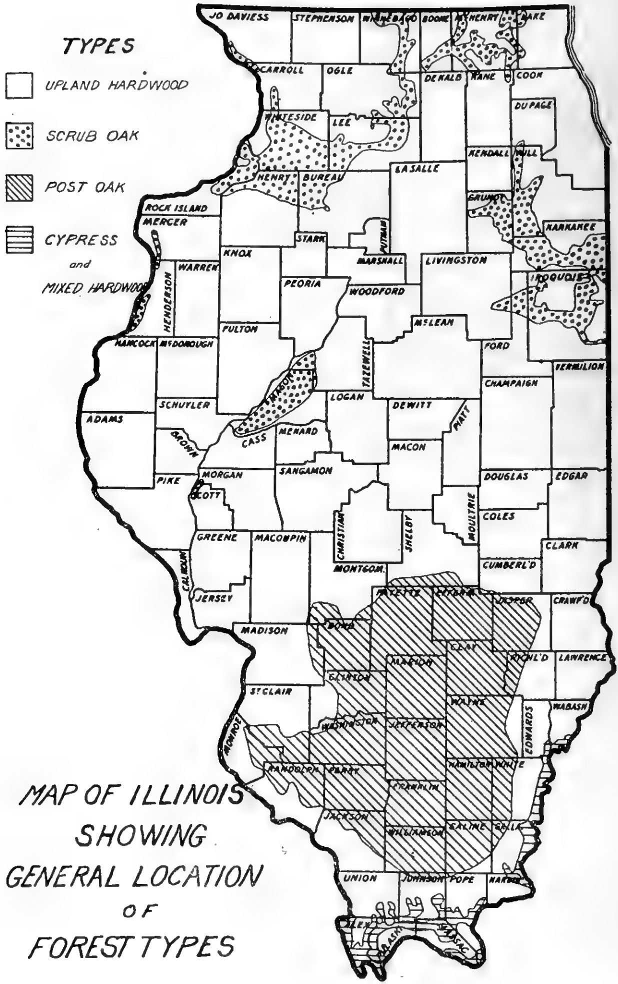
The conviction that satisfactory substitutes for wood will be found is untenable when the enormous amount of wood required is appreciated. This drain of 25,000 million cubic feet of standing timber a year means that for every hundred pounds of coal, iron, cement, petroleum, and copper consumed the forests supply 67 pounds of wood, and the crop lands supply 44 pounds of all forms of crops including cereals, seeds, clover, hay, forage, cotton, potatoes, sugar, fruit, and nuts. It is obvious that a satisfactory substitution for a commodity representing by weight two thirds of virtually all the minerals consumed, or one and a half times all crops raised in the United States, is impossible.

A timber famine will be more disastrous to Illinois than to any other state. Her manufacturing establishments employ 11.6 per cent more hands than agriculture, transportation, and mining combined, and thirty per cent of all persons employed in manufacture are in industries dependent upon wood. In the single item of lumber Illinois consumes one thirtieth the total lumber-cut of the world.

There is a striking parallel between Illinois and Great Britain in the total wood consumption and in the total area forested. Each annually consumes approximately the same quantity of wood—560,720,000 cubic feet for Illinois and 600,000,000 cubic feet for Great Britain; each has about the same area forested—3,021,650 for Illinois, and about 3,000,000 acres for Great Britain. But Great Britain, despite a population of 437.5 to the square mile as compared with 115.7 in Illinois, and the consequent pressure for land, has deliberately undertaken to replant 1,770,000 acres and this planting is being done at the rate of 20,000 acres a year. Illinois has never planted 200 acres of publicly owned forests, her farm woodlands are decreasing at the rate of 4,500 acres a year, and the unimproved and waste land on farms is increasing at the rate of 25,000 acres a year.

The State Natural History Survey has undertaken an inventory of the forests, and the purpose of this report is to present the area and condition of the forests of Illinois, and to show the productiveness of the common soil types in terms of forest crops.

Map I. Areas originally forested. Drawn from maps and data of the State Soil Survey.


TYPES
UPLAND HARDWOOD
SCRUB OAK
POST OAK
CYPRESS and MIXED HARDWOOD
MAP OF ILLINOIS SHOWING GENERAL LOCATION OF FOREST TYPES
JO DAVIESS
STEPHENSON
WINNEBAGO
BOONE
McHENRY
LAKE
CARROLL
OGLE
DE KALB
KANE
COOK
DU PAGE
WHITESIDE
LEE
KENDALL
WILL
HENRY
BUREAU
LA SALLE
GRUNDY
KANKAKEE
ROCK ISLAND
MERCER
STARK
PUTNAM
KNOX
MARSHALL
LIVINGSTON
WARREN
PEORIA
WOODFORD
IROQUOIS
HENDERSON
McLEAN
FULTON
FORD
HANCOCK
McDONOUGH
TAZEWELL
VERMILION
MASON
CHAMPAIGN
LOGAN
SCHUYLER
DEWITT
PIATT
ADAMS
CASS
MENARD
BROWN
MACON
MORGAN
SANGAMON
PIKE
SCOTT
DOUGLAS
EDGAR
COLES
MOULTRIE
SHELBY
CHRISTIAN
GREENE
MACOUPIN
CALHOUN
CLARK
MONTGOM.
CUMBERL'D
FAYETTE
EFFGHAM
JASPER
CRAWF'D
JERSEY
BOND
MADISON
CLAY
MARION
RICHL'D
LAWRENCE
CLINTON
ST. CLAIR
WAYNE
EDWARDS
WABASH
WASHINGTON
JEFFERSON
MONROE
RANDOLPH
PERRY
HAMILTON
WHITE
FRANKLIN
JACKSON
WILLIAMSON
SALINE
GALLA
UNION
JOHNSON
POPE
HARDIN
ALEX
PULASKI
MASSAC

MAP II.

Article I.—*Third Report on a Forest Survey of Illinois.* By Clarence J. Telford, Forester, Illinois State Natural History Survey.

Part I. Description of the Forests

Physiographic Features

In preglacial times Illinois was not a prairie state, but was characterized by hills and valleys such as are found in the unglaciated area of Jo Daviess county today. When the ice sheets retreated, Illinois, except for a few places, was extensively covered by a deep mantle of soil, the old valleys were filled and the preglacial eminences modified and buried until the surface was a flat to rolling upland. During the period when the glaciers were melting great quantities of water were released, found outlets across this mantle of raw soil, and quickly sluiced out wide channels. The flooding was apparently intermittent, and during the periods of restricted stream-flow the exposed deposits of finely ground glacial debris, drying, were carried widely by winds and deposited extensively over Illinois.

Thus the topography of the state is that of an elevated plain having a slight slope to the south. Large streams have cut wide channels through the deep soils, and the boundary between the uplands and the large stream valleys is characterized by the abrupt bluff condition of an upland region geologically young. Lesser streams cut through the bluffs to the main rivers, forming often a hilly topography near the bluffs, but the relief becomes less pronounced as the distance from the larger streams increases. The level expanse of the glaciated area is dissected by innumerable streams and further broken by moraines and partially buried preglacial eminences rising above the general level.

Geologists recognize at least four periods of ice invasion in the state; but for a distinction of forest from prairie soils, two divisions suffice—(1) the Lower-Middle and Lower Illinoisan and (2) all others. Forests were the prevailing type of vegetation over the first of these divisions and grassy prairie the prevailing type over the second.

The Lower-Middle and Lower Illinoisan glaciation extended farther south than any of the other ice sheets, the southern limit reaching northern Johnson county, or approximately latitude 37 degrees 45 minutes N. The northern boundary conforms to the moraines of the Wisconsin glaciation from Paris to Shelbyville, and to the division between the Middle Illinoisan and the Lower-Middle Illinoisan from Shelbyville to Carlinville, or approximately latitude 39 degrees 20 minutes N. The subsoils of extensive areas of this region are but slightly pervious and the black surface soils, whose color is due to a partial decay of grass and prairie vegetation, were wanting in this region. Forests occupied the area and open prairies were the exception.

North of this region the tight clay subsoil does not generally appear. Althought most of the other glacial deposits were made subsequent to the Lower Illinoisan deposits, yet in these other regions conditions favorable to a sod resulted in the building up of a loan rich in organic matter, the black loams of the true prairie. Tree growth here was limited to stream valleys and to eroded slopes or moraines, and grassy prairies were the rule.

Although glaciation has modified the relief throughout 93% of the state, yet the three unglaciated regions, Jo Daviess county, Calhoun county, and the entire southern 35 miles of the state, show a decidedly broken topography. The highest and lowest points in the state are within these regions, and the difference of relief may be 500 feet in a quarter section. Rock outcrops are common, clear streams follow a steep gradient over a rocky bed, and these regions present features quite at variance with the usual conception of Illinois. The soils over this unglaciated portion are not generally deep, excepting certain areas adjoining the Mississippi flood-plain where the loessial deposits occasionally attain a depth of thirty feet. These unglaciated areas were heavily forested and remain today the most picturesque and heavily wooded regions of the state.

THE ORIGINAL FORESTS OF ILLINOIS

In the solitude of the forest, surrounded by venerable trees, the impression is one of immutability as eternal as the hills. Yet change and movement is written in every chapter of forest history from that distant age when Mesozoic seas washed the roots of tree ferns, down to today. Pine followed tree fern, broad-leaved species followed pines. Long periods elapsed when soil and climatic conditions were stable, certain types of tree associations developed, and held the land until some shift of the earth's crust or change in the climate altered conditions and ushered in a new type of forest. The obliteration might be complete, as when the sea or ice came over the land, or it might be a gradual transformation. Palms and figs flourished in Illinois at certain periods; later fir and spruce followed the retreating ice sheets. Broad-leaved species eventually supplanted the conifers over most of the state. These broad-leaves were extending out onto the prairies when the white settler appeared, and along the Wabash and Ohio River they surpassed in size the hardwoods of any other region of America.

To the pioneers the prairies were a novel feature, and it naturally followed that Illinois should be called the prairie state, yet we find that her forests occupied nearly as much area as her prairies, and were unusual in both variety of species and sizes attained by individual trees. These original forests occupied something over fifteen and a quarter million acres, or 42.58 per cent of the land surface of the state. They dominated the upland and bottomland throughout the southern third of the state and along the western and northern parts, but in central Illinois were restricted to the stream valleys in the prairie counties.

The number of tree species found in these original forests was greater than in any state of similar or higher latitude and was probably surpassed by but nine in the United States. Omitting the genus Crataegus (hawthorn) Sargent '22 lists the number of native tree species in certain states as follows: Florida, 226; Texas, 186; Georgia, 175; North Carolina, 169; South Carolina, 154; Alabama, 154; Mississippi, 139; Tennessee, 130; Louisiana, 129; Arkansas, 120; California, 116; Indiana, 114; Pennsylvania, 110; New York, 102. Excluding the Crataegi there are herbarium specimens of at least 124 native tree species, and 23 additional varieties of some of them, which have been collected in Illinois, and there are 15 naturalized species.

The range in variety of species from the cypress-gum forests of southern Illinois to the larch swamps of northern Illinois was matched by very wide extremes in the development of the trees. In the lower Ohio and Wabash valleys grew the largest hardwoods on this continent, while on the sand plains of parts of the Mississippi Valley the scrub oak scarcely attained the height of a tree.

A general description of the original forests follows: In the bottomlands of the extreme southern region a belt of cypress and mixed hardwoods extended from central Wabash county down the Wabash and Ohio rivers and up the Mississippi as far as southern Union county. In the Wabash country cypress did not extend far from the main river bottom, but in the extreme southern part it grew in the sloughs of the Cache River area and extended up some of the lesser tributaries of the Cache. In this region associated species were tupelo gum, water elm, swamp cottonwood, red gum, and soft maple. Elsewhere tupelo was probably supplanted by soft maple, red gum, and elm. The cypress of Illinois never attained the size of the same species to the south, but it has been a valuable timber tree even here.

Extending along the flood-plains of the larger streams of the state was a splendid hardwood forest. That in the Ohio-Wabash region was the finest hardwood type in the country, and the forests along the other streams were scarcely less impressive in number of species and in the size of individual trees. The principal species were pecan, bitternut, shellbark and mocker-nut hickories, willows, cottonwood and swamp cottonwood, river birch, white, bur, lyre-leaved, yellow, swamp-white, cow, Schneck's, pin, shingle, and swamp Spanish oaks; white elm, hackberry, red gum, sycamore, Kentucky coffee-tree, honey locust, red and silver maples, box-elder, and blue, red, green, black, and white ashes. Catalpa grew in the Wabash-Ohio region. In the Kaskaskia bottomland pin oak had a tendency to form nearly pure stands. Towards the northern part of the state river birch was frequent on the bottomlands, but swamp cottonwood, several oaks, and red gum, did not grow there. Bur oak was largely restricted to the bottomlands in the southern part of the state; but in the northern region it grew extensively on the uplands as well. The sycamores of the Wabash bottoms attained the greatest circumference of American broad-leaves. The largest circumference on record is 42 feet 3 inches at a point 5 feet from the ground for a tree standing on the Indiana side of the Wabash (Deam '21). Another, near Mt. Carmel, Illinois, in 1875 measured 160 feet in height, with a circumference at the base of 42 feet, and a spread of crown of 134 feet. (Ridgway '82.)

Probably 80 feet represents the approximate height above ground of much of the better type of forests of Illinois that we are familiar with, and 125 feet represents the height of the present tallest broad-leaved tree, outside of this Wabash region, actually recorded in field work. These splendid bottomland forests of the Wabash country, with an average tree-top level of 130 feet (Ridgway '72), were above the height of our present highest trees, while the tallest trees were probably 200 feet in height, nearly twice the height of the tallest trees from other regions of the state. Individual acres of cypress bottomlands and of the mixed hardwoods yielded more than 25,000 B. F., and the average for the bottomland forests of the state was probably 9,000 B. F. to the acre.

Along the bottomlands of the secondary streams the forests were a rich mixture of hardwoods. Black walnut here found its best development, and in the northern part of the state basswood often formed an appreciable part of the forest. The average yield for this type in the original stands was about 8,000 B. F. per acre.

The upland forests of the state showed several notable regional differences. In the broken, hilly Ozark region, and extending over the dissected bluffs bordering the Mississippi, Illinois, Ohio, and Wabash rivers, was an excellent upland forest characterized by a greater variety and better development of species than elsewhere in the upland forests of the state. The species common to this region were black walnut; butternut; shagbark, big-shellbark, mocker-nut, and pignut hickories; ironwood, water beech; beech, white, bur, red, and black oaks; white and slippery elm, hackberry, red mulberry, cucumber-tree, tulip-poplar, papaw, sassafras, red gum, shadbush, black cherry, honey locust, Kentucky coffee-tree, hard maple, black maple, Ohio buckeye, sweet buckeye, basswood, black gum, persimmon, and white ash. Individual acres of this upland type yielded more than 12,000 B. F., and the average for the type was probably 6,000 B. F. per acre.

Over the poorly drained area of south-central Illinois where the deposits of the Lower Illinois glaciation prevail, there is an extensive region, occupied by comparatively poor forests in which but few species were represented. Open inter-stream savannas broke up the continuity of the forests; post oak grew in pure stands on the poorest soils; hickory and black oak grew on the better soils; and the average yield for this post-oak flat type was probably not more than 1,500 B. F. per acre.

Throughout the remaining forested uplands of the state the forests were largely made up of the oaks, with some hickory. These oak-hickory forests extended along the small streams and carried on a continuous struggle for possession of the prairies. The pioneers describe them as of grove-like aspect, bordering the streams and thinning rapidly as the prairie was approached. Toward the margin the forest floor was carpeted with a dense growth of seedling sprouts growing between the scattered old trees. These sprouts were annually killed by fires, the occasional survivors developing into gnarled, fire-scarred outposts of the forest margin. The average yield for this oak-hickory type was probably 3,000 B. F. per acre.

One other extensive and three limited types are worthy of mention. Throughout the northern part of the state are extensive areas of sandy soils. Whether on the flood-plain of a large river or as an interior sand hill, the type of vegetation reflects the lack of soil moisture. Characteristically desert forms, such as cactus (prickly pear) may be found. Under certain conditions the vegetation assumed the character of a forest. Scrub oak is one of the commoner species but, with increase in water content of the soil, black oak and hickory occur, and on the best sites white oak grows. Jack pine grows with the scrub oak in the sand area south of Lake Michigan. The pioneers found much of this sand land an unforested waste; and where forests prevailed the average yield was probably 1,500 B. F. per acre.

Now limited to less than a dozen small areas in Lake and McHenry counties, though probably in recent times in many other sections, are the tamarack swamps so common to Wisconsin and regions to the north. These stands occupy parts of swamps, and the trees are generally small.

In two localities in the southern part of the state may be found stands of shortleaf pine. These occupy very exposed slopes on bluffs, and the trees scarcely grow to sawlog size.

The original forest also held a few groves of white pine in addition to scattered specimens. The southern limit of the species for this region was represented by a grove of two acres on the west bluff of Spoon River about one mile south of Dahinda, Knox county. North of the Illinois River, an occasional tree grew on the stream bluffs; and there is still a healthy stand of nearly pure pine about eight miles west of Oregon, Ogle county.

Compared with the United States as a whole, Illinois had almost exactly the average relationship between forested and non-forested area. The estimated area originally forested for the United States was 43.2 per cent of the land area, that of Illinois 42.58 per cent. Comparison of average B. F. yields for the areas actually timbered shows that the United States had an estimated average of 6,326 B. F. per acre against 4,281 B. F. per acre for forested areas of Illinois. The lower yield per acre in Illinois forests is due to their predominantly hardwood character—hardwoods averaging less than half the yield of conifers under similar conditions.

Thus the original forests of Illinois are estimated to have contained 65,385,884,000 B. F. or 16,346,471,000 cubic feet of lumber. Based upon the present average wood requirements per capita for Illinois, this forest contained a quantity of lumber sufficient to supply all the wood needed from settlement until 1890, but the requirements of the state now have so increased that, whereas this original forest would have supplied sufficient wood to carry the population for the first 80 years, it contained less than a twenty-year supply under present conditions.

The table on pages 58-63 shows the forested areas present and original, by counties.

OUTLINE OF FOREST USE FROM ORIGINAL TO PRESENT FORESTS

The importance of forests to a pioneer people is admirably shown by the trend of settlement in Illinois. In 1800 Lexington, Kentucky, with 3,000 people, was the largest town west of the Alleghanies; and the total American population of Illinois was probably not as large as that of Lexington. By 1820 Illinois had a population of 55,211, practically all within the forested area. The pioneers built near the navigable rivers; succeeding settlers pushed farther from the river up smaller streams, but always settled in the forest where clear running water and material for fuel and shelter were available. Thus the initial settlement, concentrating upon the forested areas, resulted in the rapid clearing of the secondary stream-bottoms and some of the wooded uplands, and thus far pioneering in Illinois continued the practices of the older colonies. Some of the best of the original forest was destroyed to provide crop land, but there yet remained the heavy flood-plain forests of the larger rivers and a large per cent of the upland forests.

Over half the state was prairie land, until 1830 regarded as a desert. About this time the discovery that prairie land was good crop land initiated a flood of immigration. Between 1820 and 1870 the population of the United States quadrupled, while the population of Illinois increased forty-six times. In 1830 the settlement of the prairies began, and by 1840 less than one twenty-fifth remained unsettled, and this unsettled part was the finest of the black soil belt of Champaign and Ford counties. In this decade over 300,000 people settled on the prairies, creating an enormous demand for housing material, fuel, and fence posts. Railroads did not exist, and overland wagon-haul for lumber was out of the question. Under these conditions, local supplies of timber were the controlling factors in prairie settlement. Prairie land could not be sold unless several acres of forested land were included, and the relative values of prairie and forest per acre were about 1 to 7. Prairie land commonly sold for $5.00 per acre, woodland for $35.00 per acre, and frequently such woodland was several miles from the farm.

Gaged by our standards, the prairie pioneer was obliged to be wasteful. Sawmills scarcely existed. His buildings were constructed from logs, his fences from poles or rails. Open fireplaces consumed great quantities of fuel wood. He experienced a timber shortage at the very beginning; and, under pressure of dwindling local supplies, he established forest plantations about his prairie home. If he had a wood-lot he used the timber wisely. Fires were stopped and sprouts, which formerly were destroyed, developed into thrifty trees. As a consequence the limited remaining forests were building up under favorable conditions. About 1855 rail and water transportation were so developed that the prairie farmer could replace his log buildings with white pine lumber from the great pineries of the Lake States. His fuel problem was solved by the perfection of the coal stove. With the development of rail and water transportation, land values were reversed in this region. In Logan county $10.00 prairie land went to $50.00 while $50.00 timber-land dropped to $25.00 an acre. Woodland came to be regarded as an encumbrance. Arable parts were cleared, grazing was practiced, and these forests suffered a deterioration which has continued to the present day.

Coincident with the utilization of these original forests adjacent to the prairies, the process of nibbling in the non-prairie forested region continued. Here timber was destroyed and wasted as a thing of little value. Until 1860 agriculture was the only important industry in the forested area. Then progressive development of railroads made a market for ties. Wood-using industries sprang up along the river towns and furnished a market for the better grade of the better species. In 1860 the timber owner might find a market only for the best of his yellow poplar, white oak, and black walnut logs. By 1870 ninety-two of the 102 counties of the state had manufacturing establishments dependent upon wood. The total number of such establishments was 19.44 per cent of all manufacturing establishments of the state, employing 31.5 per cent of all persons engaged in manufacturing industry, and producing 20.51 per cent of the value of all manufactures of the state. To keep these industries supplied wood was imported from other states. By 1870 Rock Island county led all counties in value of the lumber sawed, with Pulaski second. Logs from the Minnesota, Wisconsin, and Michigan pineries were rafted down to Illinois towns along the Mississippi or Lake Michigan, and manufactured into lumber to a total of 26 per cent of all lumber manufactured within the state. During the eighties the Lake pineries reached their peak of production. Rock Island county sawed 70,000,000 feet annually, or a fifth of all produced within the state, and other points drew upon these pineries. By 1900 thirty-four per cent of all lumber produced in the state was sawed from imported white pine logs, and the total lumber production for Illinois reached its highest point with 381,584 M. B. F. By 1909 lumber from such imported logs ceased to be a factor and production had dropped to 170,181 M. This total production was further reduced to 64,628 M. in 1919 as the original forests were drained. Perhaps 22,000 acres of virgin forest, about one township, remain of the original 15,310,205 acres of Illinois forests. This remnant occurs chiefly on the undrained flood-lands of the large rivers. The remaining forest is a culled or second-growth type. The reduction in area and yield of Illinois forest is shown by the following tabulation.

Year	Area timbered on farms	Total area acres	Total B. F. contents
1800 (original forest).		15,273,245	65,285,884,000
1870	5,061,578	6,019,531	
1923	2,815,150	3,021,650	3,498,388,000

The original forests have been reduced in area 80.22 per cent and the estimated yields 94.64 per cent.

PRESENT FORESTS OF ILLINOIS

The field work of the survey of the present woodlands in Illinois was begun during the summer of 1921 and finished in 1924. Approximately 66 per cent of the state was systematically surveyed to determine the location, area covered, and condition of the forested areas. The 34 per cent of unsurveyed acreage is in the prairie counties where the smallest amount of woodland exists.

The methods of making the survey were as follows:

Forested areas were drawn on a base map of the region. In the very rough sections where no roads gave access to the country, the ground was covered on foot or horseback; over much of the state such mapping was done from an automobile. Distances to the wood-lot were estimated. Usually the sections are subdivided into forties by fencing, and this serves as a useful check. The estimated yield per acre of the area under observation was entered. As a check occasional samples were tallied and yields computed. The field data were worked up in the office to show the total forested areas and yields by counties. The tabulation of this information is given on pages 58 to 63. The maps III to VI reproduce, on a scale one fourth as great, nine of a series of twenty-seven maps made in the working-up of the field data.

GENERAL COMPARISON OF BOTTOMLAND AND UPLAND FORESTS

In a description of the present forests of Illinois, several natural divisions suggest themselves. The two general divisions—bottomlands and uplands—have forests of quite dissimilar composition.

The bottomland forests of the state originally bore a higher yield per acre and a greater variety of species than did the uplands. The area of bottomland estimated to have been covered by these original forests was 2,898,945 acres, virtually all of the bottomlands of the state. They probably contained 25,725,724,000 B. F. of lumber, an average of 8,875 B. F. per acre for this large area. Small areas having more than 25,000 B. F. of hardwoods to the acre still remain. The present bottomland forests cover an area of 739,508 acres, and have an estimated yield of 1,029,937,000 B. F.; an average of 1,393 B. F. per acre. Efficient logging can not ordinarily be carried on in stands of less than 2,000 B. F. to the acre. Eliminating all stands of saplings—fully stocked immature stands yet too small to produce lumber profitably—and those stands which have been culled until only occasional trees are of sawlog size, a state-wide comparison of desirable sawlog stands between uplands and bottomlands is about as follows: 8.9 per cent of the upland stands and 22.69 per cent of the bottomland stands yield 2,000 B. F. or better to the acre. Although the bottomlands occupy but one-quarter of the total forested area of the state, yet they contain almost as many acres of merchantable sawlog timber as the remaining three-quarters of upland. Approximately 12.27 per cent of the present timbered area of the state is in good sawlog sizes, 6.72 being upland and 5.55 bottomland. For the entire state an area equal to 19.74 per cent of the original forested area is still forested, while but 18.4 per cent of the upland area originally forested is timbered. Based upon good sawlog timber we have 5.79 per cent of the bottomland area originally forested still in such timber, and 1.64 per cent of the original upland area, or an average for the entire state of 2.42 per cent.

In actual quantity, including not only stands yielding enough to insure efficient logging, but including all merchantable timber of the state regardless of the expense of harvesting it, there is 4.00 per cent of sawlog timber left from the original forests of the bottomlands; and 6.24 per cent of the upland timber—5.36 per cent for the entire state. The acreage and estimated yield of bottomland forests by rivers is shown in the tabulation p. 17. Data taken in the best upland stand and the best bottomland stand show the following comparison.

	No. of trees per acre	Maximum diameter	Maximum height	Average diameter	Average height	Yield per acre B. F.	Yield per acre Cu. ft.
Upland	73	38	95	13.8	70.4	17,596	3,604
Bottomland ...	53	40	130	16.8	82.1	20,063	3,914

FOREST TYPES

The bottomland forests have been subdivided into three types: (1) cypress and mixed hardwood, (2) mixed hardwoods of the main streams, (3) mixed hardwoods of the secondary streams. The cypress and mixed hardwood type is the association common to the bayous of the lower Mississippi region but is limited by climatic factors to southern Illinois. The difference between (2) the mixed hardwoods of the main streams, and (3) those of the secondary streams, is largely due to flood conditions.

The upland forests have also been subdivided into three types, based largely upon soil conditions: (1) post oak (2) scrub oak (3) upland hardwoods. The so-called post oak type is found on the heavy, acidulous soils usually having a clay subsoil. Post oak, scrub oak, hickory, and black oak are the usual associates, post oak being the commonest tree. The so-called scrub oak type is found on the sands. Scrub oak may be entirely absent here, in which case a stunted form of black oak, Hill's oak, or bur oak, with hickory, forms the association. The heavy soils, largely south of the Sangamon River, support both post and scrub oak; while the sands, generally north of the Sangamon, support scrub or black oak, but post oak is uncommon. Both the post oak and the scrub oak types are on soils of high acidity, low in organic elements, and subject to excessive drying. The growth rates are very slow, and the species native to such sites are few. The area of forested upland in the post oak and the scrub oak types aggregates but 21 per cent of the total forested upland. The third upland type, the mixed hardwoods, constitutes the remaining 79 per cent of upland forests, and is found on all upland soils between the extremes of open sands and tight loams over clay.

Samples of each of these six types were averaged to show species represented, and the proportion of the stand represented by each species.

BOTTOMLAND TYPES

Species	Cypress and mixed hardwood			Mixed hardwood of main streams			Mixed hardwood of secondary streams		
	Total trees on 15.46 acres	Trees per acre	Per cent of stand	Total trees on 37.7 acres	Trees per acre	Per cent of stand	Total trees on 14.9 acres	Trees per acre	Per cent of stand
White oak	65	4	5.1	206	5.5	5.7	142	9	14.8
Cow oak	2	......	.1	16	.4	.1			
Bur oak	1	......	.1	18	.5	.5			
Swamp white oak	19	1	1.5	21	.6	.6			
Post oak	......	......	......	40	1.1	1.1			
Schneck's Oak	1	......	.1	12	.3	.3			
Pin oak	42	3	3.3	477	12.7	13.3			
Black oak	54	4	4.2	32	.8	.9	153	10	16.0
Swamp Spanish oak	4	......	.3	67	1.8	1.9			
Shingle oak	......	......	......	9	.2	.2			
Ash	76	5	6.0	396	10.5	11.0	162	11	16.9
Elm	125	8	9.8	502	13.3	14.0	94	6	9.8
Soft maple	58	4	4.5	819	21.7	22.8			
Hickory	32	2	2.5	197	5.2	5.5	39	3	4.1
Beech	......	......	......	......	......	......	21	1	2.2
Tulip	......	......	......	......	......	......	17	1	1.8
Black gum	20	1	1.6	18	.5	.5	6	......	.6
Hard maple	......	......	......	......	......	......	178	12	18.5
Red gum	134	9	10.5	154	4.1	4.3	15	1	1.6
Cherry	......	......	......	2	......	.1	10	1	1.0
Black walnut	......	......	......	41	1.1	1.1	49	3	5.1
Sycamore	6	......	.5	27	.7	.7	40	3	4.2
Honey locust	1	......	.1	27	.7	.7	6		6.
Hackberry	8	......	.6	52	1.4	1.4			
Basswood	......	......	......	43	1.1	1.2	23	1	2.4
Willow	17	1	1.3	93	2.5	2.6	3	......	.3
River birch	......	......	......	122	3.2	3.4			
Cottonwood	51	3	4.0	173	4.6	4.8			
Kentucky coffee-tree	......	......	......	......	......	......	1		.1
Cypress	300	19	23.5						
Pecan	......	......	......	30	.8	.8			
Catalpa	......	......	......	3	.1	.1			
Tupelo gum	252	16	19.8						
Mississippi cottonwood	7	......	.5						
Totals	1,275	82	......	3,597	95.	......	959	64	
	Species = 22			Species = 27			Species = 17		

This information is given above and on the following page. As to the general regions where the cypress, post oak, scrub oak, and upland hardwood types prevail see Map II (facing p. 1). The original woodland areas are shown by Map I (facing the Introduction). Maps III, IV, V, and VI (see folders) show forested areas for southern, south central, and northwestern Illinois respectively. The forested acreage by counties, present and original, is shown in the tabulation on pages 58-63.

UPLAND TYPES

Species	Post oak			Scrub oak			Mixed hardwoods		
	Total trees on 5.01 acres	Trees* per acre	Per cent of stand	Total trees on 7.68 acres	Trees* per acre	Per cent of stand	Total trees on 287.44 acres	Trees* per acre	Per cent of stand
White oak......	1	......	......	43	6	2.6	5,196	18	33.3
Bur oak........	......	......	......	1	......	......	49		
Acuminata.....	......	......	......	......	......	......	9		
Cow oak........	......	......	......	......	......	......	2		
Post oak........	866	173	73.8	......	......	......			
Red oak........	......	......	......	......	......	......	298	1	1.9
Black oak......	60	12	5.1	1,026	133	63.2	4,859	17	31.1
Shingle oak.....	11	2	.9	......	......	......	4		
Pin oak.........	6	1	.5	......	......	......			
Scrub oak......	140	28	11.9	416	54	25.6			
Hickory........	87	17	7.4	135	17	8.3	1,917	7	12.3
Elm............	1	......	......	......	......	......	600	2	3.8
Ash............	1	......	......	......	......	......	289	1	1.8
Hard maple.....	......	......	......	......	......	......	677	2	4.3
Beech..........	......	......	......	......	......	......	830	3	5.3
Black gum......	......	......	......	......	......	......	211	1	1.3
Tulip...........	......	......	......	......	......	......	233	1	1.5
Black walnut....	......	......	......	1	......	......	150		1.0
Red gum........	......	......	......	......	......	......	82		
Basswood.......	......	......	......	......	......	......	228	1	1.4
Cherry.........	......	......	......	......	......	......	123		
Hackberry......	......	......	......	......	......	......	45		
Honey locust....	......	......	......	......	......	......	12		
Kentucky coffee-tree..........	......	......	......	......	......	......	18		
Mulberry.......	......	......	......	......	......	......	20		
Butternut.......	......	......	......	1	......	......	11		
Buckeye........	......	......	......	......	......	......	4		
Big-toothed aspen........	......	......	......	......	......	......	32		
Sycamore.......	......	......	......	......	......	......	12		
Black locust....	......	......	......	......	......	......	5		
Total.......	1,173	233	......	1,623	211	......	15,916	55	
	* Samples from 5 counties Species = 9			* Samples from 5 counties Species = 7			* Samples from 28 counties Species = 27		

BOTTOMLAND TYPE

(1) CYPRESS AND MIXED HARDWOOD

The cypress and mixed hardwood type in the original forests bordered the sloughs and poorly drained areas of the Wabash bottoms from Mt. Carmel in Wabash county southward along the Ohio and Cache, and up the Mississippi to southern Union county (see Map II, facing p. 1). The finest stands were in the Cache River bottoms. Limited areas of pure cypress were found on the marginal areas of sloughs, but generally cypress was growing with broad-leaved species. Tupelo gum (*Nyssa aquatica*); water hickory; elm; soft maple; black and sweet gums; pin, swamp white, swamp Spanish, cow, overcup, and bur oaks; ash; hackberry; honey locust; water locust; Carolina poplar; Mississippi cottonwood; willow; sycamore; big shellbark, shagbark, mocker-nut, and bitternut hickories were associated species throughout the range. Beech was not an uncommon tree on the bottomlands of the Cache and the Mississippi, but generally was found on slight elevations subject, however, to inundation. Catalpa grew in the Wabash and the Cache basins but was absent from the Mississippi. Pecan grew in the Wabash and the Mississippi but was rare in the Cache basin.

The original forests containing cypress, pure or mixed with broadleaves, could not have exceeded 250,485 acres, and probably amounted to less. The wooded areas where cypress is now found in commercial quantities total 21,088 acres in Alexander, Pulaski, Massac, Union, Johnson, and Pope counties. This acreage has an estimated total yield of 44,563,000 B. F. for cypress and broad-leaved species. Cypress does not form more than half of the total yield, and out of a possible total cypress yield of 22,000,000 B. F. not over 15,000,000 are in the yields heavy enough to justify logging.

The following quantities are given by the U. S. Census as the cypress cut for Illinois.

1899	1,435,000 B. F.
1909	2,183,000 B. F.
1919	2,228,000 B. F.

These figures indicate that the cypress of Illinois will last about seven years, or until 1931, at the present rate of cutting.

The soils in the Cache basin are largely deep silt loams. Their recognized fertility has led to drainage projects which will eventually convert much of the cypress area into crop land. This process is well advanced in the Wabash country, and throughout the cypress mixed hardwood region all but the wettest areas have been cleared. Over the entire cypress region but 8.5 per cent of the area originally forested now has timber. Clearing has been more extensive in this and the mixed hardwoods of the secondary streams than in any of the other types. The change in water-level, incident to drainage, results in the death of established trees, and prevents re-establishment of the species, so that cypress will probably disappear from the Illinois forests.

The bottomland associations in the Cache River basin are cypress and tupelo gum near the channels and sloughs, with some willow, elm, soft maple, sycamore, Carolina poplar, Mississippi cottonwood, ash, and red and black gums. Between the sloughs and the better drained parts red gum, ash, and pin oak form the bulk of the stand and water hickory may be found. On the better drained parts of the flood lands, the stands show a greater variety of species such as white, swamp white, Spanish, cow, overcup, bur and willow oaks; ash; hackberry; shagbark, big shellbark, mocker-nut, and bitternut hickories; honey and water locust; and even beech and hard maple. Approximately 43% of the Cache bottomland is still timbered.

These forests along the course of the Cache River are rather continuously wooded areas averaging two miles in width. (See Map III D.) The cutting practice has been to harvest the so-called "soft-woods" and to leave such species as oak and hickory. Consequently, these forests are composed of groups of young trees filling in between the old trees which remain. There remain but very few forties which have not been cut over from one to four times for "softwoods". In spite of this practice the growth is very fast and the yields per acre high.

The few virgin stands remaining show yields from 10 to 15M. B. F. per acre. (See Plate VI, Fig. 1.) The average for the entire 80,199 acres of Cache bottomland is 1,956 B. F. per acre as contrasted with 1,393 B. F. per acre average for all bottomlands of the state. The representation by species as given in the tabulation (page 10) shows that 22 commercial species were found on the 15.5 acres measured, and that the oaks and hickories make up but 17 per cent of the stand, while cypress and tupelo, unimportant or entirely absent from all other bottomlands, form in the Cache bottoms 43 per cent of the stand. Representation of species by per cents based on 15.46 acres (as shown on p. 10) is as follows: cypress, 23.5; tupelo gum, 19.8; red gum, 10.5; elm, 9.8; ash, 6.0; white oak, 5.1; soft maple, 4.5; black oak, 4.2; cottonwood, 4.0; pin oak, 3.3; hickory, 2.5; black gum, 1.6; swamp white oak, 1.5; willow, 1.3; hackberry, .6; Mississippi cottonwood, .5; sycamore, .5; swamp Spanish oak, .3; honey locust, .1; Schneck's oak, .1; cow oak, .1; and bur oak, .1.

Thus the Cache bottomland forests are characterized by rather continuous uneven-aged stands, by the greatest variety of species found on the bottomlands of any river system of the state, by a high representation of "softwoods" with such unusual species as cypress and tupelo gum commonly occurring, and by a relatively high yield per acre.

Measurements on a sample acre taken in a virgin tupelo-cypress slough and representing the better stands of this association are shown below. The 51 trees 12 inches and up in diameter on this acre were buttressed so that the diameter measurement was taken at 7 feet instead of 4½ feet from the ground. The tupelo gum grows very slowly and many of the larger trees were three centuries old.

Species	Tupelo	Cypress	Mississippi cottonwood	Soft maple	Total
No. of trees per acre	252	20	7	2	281
B. F. yield per acre	15,170	7,775	77	....	22,922
Cu. ft. yield per acre	4,153	1,471	63	9	5,696
Maximum D. B. H. inches	31	32	12	8	
Maximum Ht.—Ft.	80	137	60	40	

A sample acre taken in virgin bottomland forest gave the following data on the association of trees which is common between the slough and the well-drained benches.

Species	Pin oak	Spanish swamp oak	Elm	Ash	Soft maple	Red gum	Black gum	Hick-ory	Total
No. of trees per acre............	10	2	21	6	21	9	7	1	77
B. F. yield per acre	2,360	1,500	6,504	188	3,539	3,609	273	800	18,773
Cu. Ft. yield per acre	623	443	1,343	96	953	735	123	146	4,462
Maximum D. B. H. inches	27	34	35	14	28	30	16	26	
Maximum Ht., ft..	110	100	107	80	100	115	90	110	

A sample acre taken in a virgin bottomland forest yielded the following data on the association of trees which is common on the better drained parts of the bottomland.

Species	Pin oak	Swamp Spanish oak	Swamp white oak	Cow oak	Elm	Ash	Red gum	Hickory	Mul-berry	Cotton-wood	Syca-more	Total.
No. of trees per acre ...	8	1	16	1	3	1	23	6	1	1	1	62
B. F. yield per acre	1,379	115	619	480	483	32	6,799	572	32	103	32	10,646
Cu. ft. yield per acre ...	409	43	286	85	161	21	1,620	202	21	39	21	2,908
Max. D. B. H. inches	23	15	17	....	....	....	33	22				
Max. Ht., ft...	95	85	80	....	....	......	105	95				

In the Wabash and Saline bottomlands the cypress is about cut out. In 1909 Gallatin, Saline, and Hamilton counties were reported to have cut 525,000 B. F. (Hall and Ingall 1911.) At present cypress is not of commercial importance north of Pope county. Formerly the associations were similar to those of the Cache bottomland except that tupelo gum and water hickory did not grow beyond Gallatin county. The incomparable hardwoods of the lower Wabash bottoms associated with the cypress were the same as those described under the mixed hardwoods of the main bottomlands (page 3). The removal of the cypress is altering this type along the main bottoms, and the limited forests of the future in this region will change to the mixed hardwood type.

(2) MIXED HARDWOOD BOTTOMS OF THE MAIN STREAMS

The division between the mixed hardwood type on the bottoms of the main streams, and the mixed hardwood type on the bottoms of the secondary streams is based upon flood conditions. Ordinarily the bottoms of the main streams are inundated for several weeks each year, and during this time the water outside of the channels has very little movement. On the secondary streams, however, the higher gradient insures that the excess waters will soon be drained off. These bottoms are flooded for a few days rather than for several weeks. Certain bottomland species which are not sensitive to excessive moisture, such as elm, soft maples, and sycamore, may be found well represented in each type; others, such as pecan, are naturally adjusted to protracted flood conditions, and are limited to the main bottoms; while others, such as black walnut, tulip, and basswood, do not grow well under conditions of protracted flooding, and are more characteristic of the bottoms of the secondary streams.

The original forest of this type, covering 2,283,679 acres, is now reduced to 718,303 acres, a reduction of 69 per cent in area. The estimated original quantity of 20,553,111,000 B. F. has been reduced to 985,374,000 B. F., a reduction of 95 per cent in quantity.

Based on samples totaling 37 acres from sixteen widely separated counties, the general bottomland representation by species in per cent is as follows: soft maple, 23; elm, 14; pin oak, 13; ash, 11; hickory, 6; white oak, 6; cottonwood, 5; red gum, 4; river birch, 3; willow, 3; swamp Spanish oak, 2; black oak, 1; bur oak, 1; basswood, 1; black walnut, 1; sycamore, 1; honey locust, 1; hackberry, 1; pecan, 1; Schneck's, shingle, cow, and swamp white oaks; black gum, cherry, and catalpa aggregating 2.

The detailed description of this type will be taken up by stream systems, but regional differences may be noted here. In general, the bottomland forests of the southern part of the state, (Wabash, Kaskaskia, Big Muddy, and Lower Mississippi rivers), show a greater variety of species, and trees attain greater sizes, than they do in the bottomland forests of the northern part (Illinois, Rock, and Upper Mississippi rivers). All the bottomland trees of northern Illinois are found in the bottoms of the southern part; while such trees as red and black gums, Mississippi cottonwood, catalpa, beech, and overcup, cow, swamp Spanish, and Schneck's oaks are not native to the bottomlands of the northern region at all. Elm and soft maple form about 57 per cent of the forest in the northern region, but only 21 per cent in the southern part. In the north the oaks, ashes, and hickories form 11 per cent; in the south, 66 per cent of the forest. Soft maple, the commonest tree in the northern bottomlands, makes up 43 per cent of the stand; while pin oak, the commonest tree in the southern bottomlands, makes up but 20 per cent of the total stand. Pecan is an occasional tree in the bottomlands of the Wabash, Ohio, lower Kaskaskia, lower Illinois, and entire Mississippi, rivers—extending to the Wisconsin line on the Mississippi—but does not grow on bottomlands of the Big Muddy or Rock rivers and rarely on those of the Cache.

ACREAGE AND ESTIMATED YIELDS OF BOTTOMLAND FORESTS BY RIVERS

Yields	River system							
	Cache	Wabash	Big Muddy	Kaskaskia	Illinois	Rock	Mississippi	Total
	Acreage							
C	13,105	267	1,453	....	....	....	785	15,610
S	1,130	65,352	8,745	21,495	75,914	1,968	4,537	179,141
No. 1	33,895	127,206	60,611	75,112	34,624	5,525	39,984	376,957
No. 2	29,513	22,100	4,215	53,022	11,400	5,145	26,571	151,966
No. 3	2,436	598	116	11,307	713	62	133	15,365
No. 4	120	....	....	349	....	....	....	469
Total acres	80,199	215,523	75,140	161,285	122,651	12,700	72,010	739,508
Estimated yield M. B. F.	156,869	209,057	76,267	349,827	77,025	24,130	138,979	1,032,154

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* In the Yields column, C = culled forest, merchantable trees removed; S = saplings; No. 1 = stands having an estimated yield up to 2000 B. F. per acre; No. 2 = stands having an estimated yield from 2000 to 5000 B. F. per acre; No. 3 = stands having an estimated yield from 5000 to 10000 B. F. per acre; No. 4 = stands having an estimated yield over 10000 B. F. per acre.

The Wabash River System

Included in this system are the bottomlands of the Saline, Wabash, Little Wabash, and Embarras rivers. With the exception of the Wabash, these are comparatively small streams; yet, owing to the general flatness of the country, they have bottomlands out of all proportion to the size of the stream. The soils of the Saline, Little Wabash, and Embarras bottoms, grading toward clays, are generally heavy and grayish in color; those of the Wabash, grading toward sands, are generally light. Both are very fertile. The streams have a low gradient, and water stands for considerable periods in the extensive swamps. Drainage projects are reducing the area subject to flooding, yet this region still has 207,991 acres of wooded bottomland out of an original area of 736,457 acres wooded—about 28 per cent.

The early logging operations on these bottoms removed a limited number of trees, but gradually the markets absorbed an increasing variety. These bottomlands have been rather thoroughly cut over for saw-timber, until at present only about 11 per cent of the acreage has sufficient saw-timber to insure profitable logging. The average yield for the entire area of forested bottomland is the very low figure of 970 B. F. per acre as contrasted with the average of 1,393 for all bottomlands of the state. The present stands are very well stocked with saplings and young trees, and growth is rapid.

Three extensive bodies of bottomland timber remain in the Wabash region. The main Wabash bottoms, formerly growing the largest hardwoods in America, have been cleared except for the lower 10 miles. Here several thousand acres of forested land remain between New Haven and the junction of the Wabash and the Ohio. It has been heavily cut over and the present stand consists of immature timber or a few old pecan groves. The two other large areas of timbered land in the Wabash region are on the middle reaches of the Little Wabash River. Forested bottoms on Skillet Fork below Wayne City, aggregating over 30,000 acres, still contain several thousand acres of good saw-timber; while the other extensive area of forested bottom, on the Little Wabash above Fairfield, contains about 16,000 acres, mostly of saplings and immature timber. Drainage projects are developing all three of these forested bottoms, converting forest to crop land. Elsewhere in the Wabash region, the stands are belts along the streams or limited remnants of the former extensive forests.

These bottomlands are not subject to excessive deposition or erosion; rather, the water backs up over the bottoms, deposits a fine coat of soil, and eventually recedes. Under such conditions reproduction is very excellent and forests establish themselves readily.

These forests in the past supplied immense quantities of timber, mostly rough lumber. In addition special industries drew heavily upon these rich bottomland forests for material, such as sycamore in the manufacture of tobacco cases; red gum, soft maple, elm for wooden dishes, lard and sugar containers, egg crates, fruit and berry baskets; hickory for vehicle and tool stock; and white oak and black walnut for high grade veneers. The saw-timber in the present forests is rapidly being utilized, and is largely such inferior material as pin oak and defective trees left from original operations. These stands now produce large quantities of piling, railroad car stock, and cross-ties. In the Saline bottomlands even the pole-wood is worked up into mine timbers; but over the remainder of the Wabash system, trees are rarely cut commercially until they reach pile size.

In summary; some 30 per cent of the bottomland forests in the Wabash region are in three large bodies extending back from the stream two to four miles; the stands have an abundance of saplings, approach an even-aged character, have a high representation of pin oak and sweet gum, and a relatively low representation of soft maple and elm. The "hardwoods", oak and hickory, aggregate 52 per cent of the stand; and the average sawlog yield per acre is relatively low.

The occurrence of species by per cents based on 5.53 acres of plots and line is as follows: pin oak, 30; red gum, 20; ash, 13; white oak, 9; elm, 9; hickory, 7; river birch, black gum, cow oak, black oak, swamp white oak, 2 each; soft maple, 1; with honey locust and black walnut occasional trees. Catalpa is native to these bottomlands. Pecan is common along the Wabash, but is found less frequently on the heavy soils of the lesser streams; while the big shellbark hickory is locally very abundant on these heavy soils.

The following table, derived from a sample taken in a well-drained virgin bottomland forest, shows the association and unusual sizes attained in the Wabash region.

Species	White oak	Black oak	Sweet gum	Black gum	Hickory	Elm	Honey locust	Sassafras	Ash	Black walnut	Total
No. of trees per acre..	15.5	4.3	10.2	3.3	11.2	3.6	.3	1.3	2.3	1.0	53
B. F. yield per acre....	11,081	2,133	4,556	144	1,472	92	201	31	309	44	20.063
Cu. feet yield per acre	1,891	401	993	59	379	42	36	11	88	14	3,914
Max. D. B. H., inches..	40	36	34	16	32	15	22	14	22	17	
Max. Ht., ft...........	130	120	125	70	120	95	125	80	110	70	

A fully stocked acre of 55-year-old pin oak in Hamilton county suitable for piling bore trees as follows:

Species	Pin oak	Cow oak	Schneck's oak	Swamp Spanish oak	Swamp white oak	Ash	Elm	Total	Av. Ann. growth
No. of trees per acre	58	7	1	1	1	9	4	81	
Av. D. B. H., inches.	16.9	10.0	12.0	13.0	9.0	7.7	13.0		
Average Ht., feet....	85	57	74	75	58	60	77		
Cu. ft. per acre.....	2,725.0	91.2	22.2	25.9	9.6	68.1	112.1	3,054	67.9
B. F. per acre......	9,265	126	45	75	......	22	375	9,908	180

The returns from this acre if harvested as piling are as follows: fifty-four piles totaling 2,450 linear feet at the average value of $ .12 per foot equals a gross return of $294.00 per acre. The cost of cutting, hauling, peeling, and loading averages $ .0575 per linear foot; the operators profit of 20 per cent of this cost of manufacturing is $.0115 per foot, making the total cost of production $ .069 per linear foot or $169.05 for the acre. Average taxes of $ .35 per acre compounded for 55 years at 4 per cent per year total $66.90. With the gross return $294.00 and the expenses $235.95 this acre gives a net return of $58.05 at the end of 55 years. Using 4 per cent over this period this return of $58.05 gives the soil a value of $7.60 per acre if devoted to the production of piling.

The returns from this acre if harvested as saw-timber are as follows: 9.9 M. B. F. having a stumpage value of $10.00 per M. gives a gross return of $99.00. Taxes at $ .35 annually, compounded for 55 years at 4 per cent total $66.90. Thus the acre yields a net revenue of $32.10 and this gives the soil a value of $4.20 when devoted to saw-timber production over a period of 55 years at an interest rate of 4 per cent.

Since waste bottomland in this region sells for $20.00 per acre, these unmanaged stands fail to return 4 per cent on this value. A yield of 80 piles or 3,200 linear feet in a 40 year period is possible in well-managed stands and represents a possible net return of $129.94. This return discounted at 4 per cent for 40 years gives the land a value of $34.18 per acre devoted to the production of piling, if the cost of management is met by returns from thinnings before the final crop is harvested. Under these conditions $20.00 land, instead of growing timber at a loss, produces a profit.

The Big Muddy River System

The Big Muddy is a relatively small river, with a low gradient, flowing through infertile, level uplands. Compared with the size of the stream the bottomlands are disproportionately large. The bottomland soils are deep gray silt loams approaching clays, and are fertile, though perhaps less so than most bottomland soils. The true bottomlands with these heavy loams are subject to flooding. On the lower course of the river below Benton, these true bottomlands are often narrowed where the river has cut through old river terrace formations. The benches of these formations are from forty to sixty feet above the river and extend back, occasionally, two miles from it. Generally they are not subject to flooding; and the soils are very heavy, clays being common. The forests on river terrace soils elsewhere in the state generally more closely resemble upland than bottomland types; but in this region they conform more closely to the bottomland forests and are classed with the bottomland type.

The per cent of the bottomlands which are forested is high (73) and the forested area seems to be increasing in these bottoms. No important drainage projects have developed. The coal companies acquire ownership of the farms, and the forests quickly reclaim the bottomlands. These stands have been closely culled for saw-timber, and show the lowest percentage (5.8) of area in good saw-timber for any bottomlands of the state. The average yield per acre for all bottomland forested on the Big Muddy is 1,015 B. F. as compared with the 1,393 average for all bottomlands of the state. The stands are very well stocked with saplings.

Based on measurements taken on 7.8 acres in three counties, and including both bench and true bottomland sites, the representation by species is in the following per cents: pin oak, 20; hickory, 13; white oak, 12; elm, 12; ash, 10; swamp Spanish oak, 9; post oak, 5; soft maple, 4; honey locust, 3; sycamore, 2; river birch, 2; black gum, bur, Schneck's, and shingle oaks, 1 each, with red gum, hackberry, cherry, black walnut, and cow and black oaks aggregating 4. The various oaks make up 49 per cent—a decidedly higher representation for oak than is shown for forests on the other bottomlands of the state. These and the Wabash bottoms are the only bottomlands which show a higher percentage of the so-called "hardwoods," oak and hickory, than "softwoods", gum, maple, elm, sycamore, and woods used in the manufacture of baskets and hampers. In the Big Muddy bottoms these hardwoods aggregate 63 per cent of the stand.

A plot measured in an 18-year old stand on the true bottomlands indicated the relatively high volume produced on these soils. See table following.

Species	Pin oak	Ash	Honey locust	Soft maple	Elm	Total	Av. ann. growth
No. of trees per acre	944	32	32	16	96	1,120	
Av. D. B. H., inches	3	2	3.5	4	3.7		
Av. Ht., ft.	30	30	30	32	30		
Cu. Ft. per acre	1,269	17	35	21	77	1,419	78.8

A plot measured in a 65-year old stand growing on a bench site indicates the relatively slow growth produced on these heavy soils. See table following.

Species	Post oak	White oak	Swamp Spanish oak	Shingle oak	Hickory	Black gum	Elm	Sweet gum	Total	Av. ann. growth
No. of trees per acre ..	36	12	64	8	24	8	4	4	160	
Av. D. B. H. inches	10	8	10	9.5	5.5	4	4	10		
Av. Ht., ft....	57	50	60	5.5	48	49	45	50		
Cu. Ft. per acre	513	106	828	70	68	10	25	39	1,659	25.5
B. F. per acre	772	80	820	68	......	......	......	56	1,796	27.6

This is a region where many factors favor the practice of forestry, not alone in the bottomlands, but on the uplands as well. The land is largely held by coal companies. They are heavy consumers of the kind of wood produced in this region, and import large quantities from distant regions while their local holdings are not producing to full capacity. Fires which ravage the higher lands rarely damage these bottoms. Abundant natural regeneration insures heavy stocking, and permits the encouragement of the faster growing species and the removal of inferior species. Based on an average annual growth of 40 cubic feet per acre, of which 29.6 cubic feet is merchantable material, and on the average requirement of .246 cubic feet of wood for a ton of coal mined, each acre of bottomland can supply timber for 120 tons of coal annually for all time. Thus a mine with a yearly capacity of 100,000 tons requires 833 acres of such land continuously devoted to timber production.

The Kaskaskia River System

The Kaskaskia is a medium-sized river flowing through a flat region. In certain parts the gradient is as low as 10 feet to the mile for several miles away from the river, although definite bluffs occur where the stream has cut through glacial eminences and river terraces. The soils are generally deep gray silt loams, though sandy soils are not uncommon. North of Carlyle, drainage districts are in the process of organization; south of Carlyle, few drainage projects have been attempted.

One quarter of the area in good bottomland timber for the entire state is in the Kaskaskia bottoms. Of the 161,285 acres of bottomland forest in this region 64,678 acres, or 40 per cent, are growing timber of good saw-log size; and the average yield per acre is 2,169 B. F. as compared with the 1,393 B. F. average for all bottomlands of the state. Usually the stands near the river have been culled, and defective or low-grade old trees and immature trees here form the forest. In the less accessible areas back from the river many stands of virgin timber remain. Finally, on accessible areas near the margin, even-aged stands of good saw-log size indicate that early cutting was heavy in such places. Near the channels and lower areas elm, soft maple, willow, honey locust, sycamore, and ash are the commonest trees. Farther back, on the better drained bottoms, pin oak often forms pure stands. The Kaskaskia forests have a higher percentage of ash, hickory, and white oak than any other bottomland forests of the state. They resemble those of the Big Muddy and Wabash bottoms in the high percentage (42) of "hardwoods", oak and hickory, which make up the stand; but differ by the absence of red and black gums, swamp Spanish and Schneck's oaks. Pecan is an occasional tree on the lower part of the river, extending up as far as Carlyle. Samples, aggregating 6.12 acres, taken in three counties, show that the stands are largely made up of relatively few species (12) in the following per cents: ash, 25; white oak, 14; soft maple, 13; hickory, 13; elm, 11; pin oak, 11; black oak, 4; sycamore, 3; black walnut, 3; hackberry, 2; river birch, honey locust, and cottonwood occasional. Thus 91 per cent of the forest consists of hickory, ash, oak, elm, and soft maple.

These forests are being worked up chiefly as lumber. They contain large amounts of low-grade species, such as pin oak, and lesser quantities of merchantable ash, hickory, and walnut.

A sample acre taken in virgin timber shows the following composition, yields, and sizes of individual trees which were characteristic of forests growing on the moderately well-drained flood lands.

Species	White oak	Pin oak	Hickory	Hackberry	Ash	Elm	Total
No. of trees per acre 6" D. B. H. and up......	3	14	10	2	5	11	45
B. F. yield per acre....	427	7,588	2,540	....	420	2,170	13,145
Cu. ft. yield per acre..	101	1,546	673	23	155	529	3,027
Max. D. B. H., inches...	22	39	25	9	20	32	
Max. Ht., ft..........	90	105	100	40	90	80	

The Mississippi River System

Approximately one third the entire length of the Mississippi borders Illinois. The difference in latitude between the extremes of the state is more than five degrees. The mean annual temperature of the Cairo station (58° F.) averages 10° F. warmer than that at the Dubuque, Iowa, station (48° F.). The mean annual rainfall at Cairo (41.6 inches) averages 6.6 inches greater than that at Dubuque (35.0 inches). The effect of these factors on the forest is to lessen the number of species in the association, and to cut down the growth-rates of the northern as compared with the southern forests.

From southern Union county to the Wisconsin border, there is approximately 533,350 acres of bottomland on the Illinois side. This is less than the area in bottomland on either the Wabash River or the Illinois River. The soils are very variable, but usually approach clays in the southern part and sands in the northern. The forested area, totaling 72,010 acres, or 16 per cent of the total bottomland, is about the same as the forested area on the bottomlands of the Big Muddy River. Thirty-seven per cent of this area is in timber of good saw-log size; the average yield per acre for this bottomland is 1,930 B. F.; and more than half of the forested area is in five counties. Jo Daviess, Carroll, and Whiteside counties in the north have 21,538 acres of woods on the Mississippi bottomland; while at the southern extreme Union and Jackson counties have 21,351 acres of this bottomland forested. The forests of each of these regions will be described as representing the conditions at the northern and the southern extremes where the larger bodies of timber are found.

In the southern part of the state, the bottomlands on the Illinois side are from three to four miles wide. (See Map III.) Depressions and sloughs of old river channels are frequent throughout, but usually the elevation near the bluffs is slightly less than nearer the river. Also the deposition near the bluffs is very fine, and clays are common; while much of the recent deposit along the present channel is of a sandy nature. The soils on this river plain are usually very fertile; and, despite the unfavorable factors, much of this land now forested will be developed, as virtually all is within organized drainage districts.

At present, forests are found as rather continuous bodies averaging less than a mile in width on the heavier soils near the bluffs; as strips bordering the sloughs throughout the bottomlands; and as a belt along the present river channel outside the levees.

Based on 4.6 acres measured in Union county, the representation of species in per cent is as follows: soft maple, 33; ash, 18; cottonwood, 14; elm, 12; hackberry, 10; pin oak, 3; red gum, 3; pecan, 2; river birch, 2; willow, 1; with occasional swamp white, bur, and lyre-leaved oaks.

The stands inside the levees, usually restricted to poorly drained depressions or heavy clay soils, are the remnants of the original bottomland forests. In their virgin state these forests were heavy stands of ash, elm, hackberry, soft maple, honey locust, various oaks, hickories, and gums, but logging operations have left very little of the original forests. At present these stands contain defective, or low-grade material, with valuable trees present in varying amounts. The best stands average as high as 12,000 B. F. per acre. Logging is still conducted on a limited scale. "Softwoods" suitable for fruit-containers' veneering grow very rapidly on these bottoms, and this region is the logical source of supply of this material for the adjacent fruit and truck gardening region. Pecan, being native to this region, is also encouraged and in places on these flood-plains the regular bottomland association is enriched by beech.

A sample plot taken in a 30-year-old stand shows the nature of the second growth now developing.

Species	Soft maple	Ash	Elm	Pecan	Pin oak	Willow	Box-elder	Total	Av. annual growth
No. of trees per acre	204	88	40	16	12	12	8	380	
Av. D. B. H., inches	7.0	6.0	4.6	7.0	9.0	12.0	3.5		
Av. Ht., ft.	70	60	55	76	77	90	50		
Cu. Ft. per acre	1,995	512	156	137	152	475	14	3,441	114.7
B. F. per acre	2,024	172	......	......	176	464	......	2,836	945

The belt of forested land along the river is usually outside the levees. The width is rarely more than half a mile. Such forests are subjected to frequent flooding. New channels are constantly developing and old channels filling up. The recent deposit in this region is usually of a sandy nature, rich in organic substance. Under such conditions willow, cottonwood, and sycamore show abnormally rapid growth-rates. Although of limited area and relatively unstable, such land promises to pay higher returns per acre for managed timber-production than any other forested area in the state. Usually in unmanaged stands non-commercial willows control the site, with maple, sycamore, and cottonwoods as occasional trees. Cottonwood 18 years old is now being harvested from such stands, and sold to egg-crate manufacturers for veneers. Trees attain a height of a hundred feet, and an average D. B. H. of 12 inches at this age. The best trees attain a D. B. H. of 18 inches. Under management with cottonwood given precedence, pulp-wood can be produced in 10 years, veneer and sawlogs in 18.

Data from sample taken in an 18-year old unmanaged stand where cottonwood was almost wholly in control of the site follow.

Species	Cotton-wood	Willow	Total	Av. annual growth
No. of trees per acre	88	2	90	
Av. D. B. H. inches	11.5	9		
Av. Ht., feet	92.	90		
Cu. Ft. per acre	2,198.0	25	2,223	123.5
B. F. per acre	5,174	....	5,174	287.

The value of the stand as pulp-wood at the 18-year period is as follows: 24.7 cords, valued on the stump at $1.25 per cord, totals $30,875; annual taxes at $ .40 per acre compounded at 5 per cent for 18 years total $11.25; returns as pulp-wood are $19.62 or $1.09 per acre per year.

The timber on this plot which was merchantable for veneer logs was harvested. Thirty-eight trees per acre were cut with a total scale of 5,174 B. F., Doyle rule: the stumpage value was $12.00 per M. This gives a gross return of $62.09 per acre. After the $11.25 cost of taxes and interest on taxes for 18 years has been deducted, this acre has returned $50.84 or $2.83 per year when devoted to the production of veneer logs. In addition to the 38 trees harvested for veneer, there remain 52 trees suitable for pulp, which contain 7.3 cords having a stumpage value of $1.25 per cord. Thus the acre has actually returned $50.84 over taxes, and has in addition a pulp-wood stand worth $9.12 giving the total returns, if cut clear, of $3.33 per acre annually from true waste land.

In the northern three counties, Whiteside, Carroll, and Jo Daviess, the bottomlands on the Illinois side are narrower than in the south. They average about a mile from the bluffs to the river in Jo Daviess county and widen out in Whiteside county to three miles. The bottomland soils are usually sands and gravels, and much of the land is scarcely worth development. Here also, the Mississippi flows through many channels, and the wooded islands are usually less than six feet above the general river-level. The bottomlands in Jo Daviess county are about 40 per cent wooded, and the forests frequently extend from the river to the bluffs. In Carroll and Whiteside counties the forests are on the islands, and along the river as a rather continuous belt with a maximum width of two miles, while the area near the bluffs is cleared. (See Map VI A.)

Between 1830 and 1850 these forests were heavily culled to supply fuel and building material for settlers on the neighboring prairies, and fuel for steamboats, river towns, and the Galena mines of Jo Daviess county. By 1870 the Wisconsin white pine was supplying the building material for this region. In recent years cutting has been light, reproduction by both sprouting and seedling abundant, and the stands are generally overstocked with immature trees crowding in among the occasional old and defective trees. Much of this second growth is passing from pole-wood to sawlog size.

The association is largely "softwoods"; and a half dozen of the less valuable species make up 95 per cent of the stand. Based upon measurements totaling 6.36 acres, the representation of species by per cents is as follows: soft maple, 39; elm, 22; willow, 14; river birch, 12; pin oak, 7; ash, 5.

A sample taken in a 25-year old sprout-seedling stand furnished the following data:

Species	Soft maple	Elm	Pin oak	Ash	River birch	Total	Av. annual growth
No. of trees per acre..	224	240	152	24	8	648	
Av. D. B. H., inches..	4.4	3.7	4.2	5.0	12		
Av. Ht., feet.........	38	36	38	45	60		
Cu. Ft. per acre......	494	355	377	50	142	1,418	56.7

The Mississippi bottomland between the northern and southern extremes has been developed. Forests are found rather generally on the low islands, outside the levees, and hold a very restricted area elsewhere. Also, river development, notably at Keokuk, has raised water levels over considerable areas, thus drowning out the forests outside the levees. In certain regions (Carroll and Henderson counties) sands are found on the flood-plain. Here the forest growth is altogether different from the usual bottomland association. It is described under the scrub oak type. In many instances the stands on the islands are cut regularly for cordwood from which charcoal for gunpowder is derived. A pulp manufacturing company has purchased several islands and is developing plantations of cottonwood and maple.

The association is similar to that in the extreme northern area, the soils are usually fertile, and growth rates are excellent.

The Illinois River System

The bottomlands of the Illinois River are very definitely bounded on each side by bluffs from four to ten miles apart. The soils are light, pure sands being common. Formerly this river valley contained many large areas of shallow lakes and sloughs where reeds and willows prevailed. Drainage projects have reclaimed most of this valley with the exceptions of the lower twelve miles, of the region near the junction of the Sangamon, and of the region of the Big Bend at Hennepin. These areas have some 3,000, 4,000, and 16,000 acres respectively of bottomland forested, but 77.4 per cent of the entire valley is cleared. The development of levees, in most places, has confined the river within a narrow channel, while the Chicago Sanitary Canal has increased the volume of water. Consequently, those forests outside the levees or in undrained areas have been killed by excess flooding, and throughout the lower part of the valley forest conditions have been changed by changing water-levels.

These forests have been culled heavily for saw-timber until there remains but 12,113 acres, or 9.8 per cent, in good saw-timber on a total of 122,651 acres forested. Even saplings and immature timbers are harvested for pulpwood and cordwood. Based upon samples aggregating 4.78 acres taken in two counties, the representation in per cents by species is as follows: soft maple, 55; cottonwood, 18; elm, 11; pin oak, 4.5; pecan, 3.5; ash, 3; willow, 2; river birch, 2; with infrequent bur oak, hickory, sycamore, black walnut, and honey locust. Thus soft maple, cottonwood, and elm make up 84 per cent of the stands; and oak-hickory comprise less than 5 per cent of the stands.

With the adjustment of the average water-mark to new and higher levels, there has followed a readjustment of forest associations. The cottonwood, maple, and elm have at first controlled many of the new sites. Cottonwood, on light soils such as prevail over much of these bottomlands, outstrips all competitors in growth, and is the most profitable forest tree for such land.

Measurements taken on a 20-year old stand seeded on an abandoned field show the following:

Species	Cotton-wood	Soft maple	Willow	Elm	Total	Av. annual growth
No. of trees per acre..	260	428	48	88	824	
Av. D. B. H., inches....	7.61	2.87	7.25	1.95		
Av. Ht., Ft...........	65	35	65	30		
Cu. Ft. per acre.......	1,866.0	476.0	286	50	2,678	133.9
Cords	20.7	5.3	3.2	.5	29.7	1.5

A sample acre taken in a 45-year old stand shows the relatively high yield for saw-timber, veneering, and pulpwood obtained in this period.

Species	Cotton-wood	Soft maple	Elm	Ash	Total	Av. annual growth
No. of trees per acre..	58	105	32	1	196	
Av. D. B. H., inches....	18	9	7	8		
Av. Ht., ft............	95	60	52	60		
Cu. contents per acre..	3,379	1,623	227	6	5,235	116.3
B. F. yield per acre....	13,059	3,498	104	....	16,661	370

The acre taken in the 20-year old stand has produced 23.9 cords of cottonwood and willow of a size suitable for pulpwood purposes. The elm and soft maple form an unmerchantable under-story. This pulpwood has a stumpage value of $1.25 per cord, or $29.88 per acre. The land was originally purchased for the shooting privileges. Taxes at forty cents per acre per year compounded for 20 years at 5 per cent total $13.23 per acre. This acre, if harvested at twenty years as pulpwood, will pay the carrying charges of taxes with interest on taxes; and will show a net return of $16.65 or $ .83 per acre per year from land unsuitable for agriculture.

The sample taken in the 45-year old stand shows a production of 58.1 cords of cottonwood, soft maple, and elm suitable for pulpwood, or 16,600 B. F. of material suitable for veneer logs. Devoted to pulpwood, the stumpage value for 58.1 cords at $1.25 per cord is $72.62. Taxes, at $ .40 per acre, compounded over 45 years at 5 per cent total $55.88. Thus, this acre, if harvested for pulpwood at 45 years, returns $16.74 over the carrying charge of taxes with interest on taxes; or $ .37 per acre per year.

Devoted to veneer or sawlogs, the 45-year old plot shows a yield of 16,600 B. F. per acre of this material. A stumpage value of $10.00 per M. gives the value of this acre for veneer material as $166.00, annual taxes at $ .40 per acre compounded at 5 per cent total $55.88. Thus, this acre, if harvested for veneer logs, returns $110.12 over carrying charges of taxes and interest on taxes, or $2.67 per year.

These figures serve to show that returns are dependent upon the form of product, and the period required to produce a wood crop, as well as on the amount of wood which can be grown annually. The annual increment of the twenty-year plot, 1.195 cords per acre, gives a net return of 0.83 per acre annually as pulpwood. The higher annual increment of the 45-year old plot, 1.291 cords per acre, gives a net return of but $0.37 per acre annually as pulpwood; but harvested as veneering it gives a net return of $2.67 per acre annually.

The Rock River System

The upper stretches of the Rock River flow through a region of numerous lakes. The soils over the entire drainage basin are light, gravels and sands predominating. Consequently, this river is not subject to extreme flood conditions, nor does it have extensive bottoms where water stands for several weeks. The forests in many respects resemble those described under the mixed hardwoods of bottoms of secondary streams. Approximately 92 per cent of the bottomland is cleared. The remaining bottomland forests, totaling 12,700 acres, are on the islands or as strips along the river margin. About 41 per cent of this area is in timber of good sawlog size, chiefly elm, ash, cottonwood, soft maple, bur oak, and basswood. Samples totaling 2.5 acres show the following representation of species by per cents: elm, 35; basswood, 20; ash, 16; soft maple, 11; black walnut, 11; hackberry, 5; and bur oak, 2.

Very little of the Rock River region is in organized drainage districts, and probably the present forested area will be retained. The Rockford furniture factories offer a market for high-grade logs for furniture, or low grade for crating; but in general the bottomland forests have supplied very little material.

A sample acre of virgin bottomland shows the association, sizes, and yield of such stands.

Species	Elm	Ash	Black walnut	Soft maple	Basswood	Hackberry	Bur oak	Total
No. of trees per acre	28	14	9	9	17	4	2	83
Max. D. B. H. inches	30	21	23	13	19	17	16	
Max. Ht., feet..	90	85	90	60	70	77	75	
Cu. ft. per acre.	1,281	365	363	120	435	142	33	2,739
B. F. per acre...	5,320	885	1,119	325	1,011	399	80	9,139

(3) MIXED HARDWOODS OF BOTTOMS OF SECONDARY STREAMS

The bottoms of the minor streams of the state have accumulated the wash from adjacent slopes and the deposits from occasional floods. These soils are generally mixed loams, rich, deep, well drained, and highly valued for crop land. Originally forested, they are now cleared wherever in units large enough to crop. It is a type intermediate between the association of the flood-plains of the large rivers and the upland types; and in general more nearly conforms to the sandy loam associations of the upland hardwood type than to any other. Such characteristically bottomland species as river birch, cottonwood, sycamore, and silver maple are associated with such typically upland species as basswood, hard maple, tulip-poplar, and red oak; or certain species common to both bottomland and upland, such as elm, hackberry, and honey locust, grow best on these well-drained bottoms. Black walnut makes its best growth throughout the state in this type. In the Ozark region, the species commonly found on these bottoms are beech, hard maple, red gum, tulip, shagbark and shellbark hickories, black and white walnuts, red and white oaks, white elm, hackberry, sycamore, honey locust, Kentucky coffee-tree, black gum, and white and green ash. About the same association occurs where such bottoms are wooded in the counties bordering the Wabash River, although pin oak becomes a common tree here. Along streams tributary to the Big Muddy, Kaskaskia, Saline, and Little Wabash rivers, this type has a higher percentage of the oaks. Pin and shingle oaks are the commonest trees, with white, cow, bur, and red oaks, and shagbark, bitternut, and mocker-nut hickories of frequent occurrence, and black walnut, honey locust, hard maple, black cherry, river birch, and cottonwood occasional. Red gum does not occur in the Kaskaskia region; hard maple and basswood are not common in either the Big Muddy or Kaskaskia basins; and tulip does not occur north of a line extending from southern Randolph county on the Mississippi side to southern Williamson and Saline counties, thence up the Wabash to Vermilion county, and inland to eastern Hamilton and Wayne counties.

Throughout the central and northern parts of the state, the bottoms along the secondary streams have appreciable quantities of elm. Near the heads of streams just off the prairies, soft maple and elm often form the entire stand; but honey locust, box-elder, hard maple, river birch, black and white walnuts; bur, white, swamp white, and red oaks; ash, black cherry, Kentucky coffee-tree, and shagbark and bitternut hickories may enter into the composition. Basswood, in some of these stands in La Salle county, makes up a high proportion of the forest and is a commoner tree in the northern than in the southern part of the state. Hickory forms nearly pure stands on the bottoms along Bear Creek, Hancock county. It is doubtful if beech occurs native anywhere in the central or northern part of the state north of Vermilion county, with the exception of a very few trees in Lake and Ogle counties.

A representation of species by per cents based on 14.4 acres of samples from the northern, central, and southern regions shows hard maple, 19; ash, 18; black oak, 17; white oak, 15; elm, 10; black walnut, 5; hickory, 4; basswood, 3; beech, 2; tulip, 2; cherry, 1; and black gum, honey locust, and Kentucky coffee-tree aggregating 2. Ash, black walnut, and hard maple occur more frequently in this type than in any other.

In certain parts of Boone, McHenry, and Lake counties, where stream erosion has not developed sufficiently to properly drain the recently glaciated region, a marsh or meadow type of vegetation prevails on the bottomlands, and forests are on the elevations. In Lake and McHenry counties some of these poorly drained bottoms have the tamarack bog association common to Wisconsin. This is of ecological interest as representing one phase of the initial period of forest development, just as the few beeches in the ravines of Lake county are of interest as representing the climax type or final state of forest development for the region. However, neither is important as a producer of wood, since there are only a few beeches, and since the tamarack, covering but 157 acres, is rarely more than 12″ D. B. H. (Waterman, '21.)

UPLAND TYPE

(1) *Post Oak*

The area included in this type lies largely between southern Shelby and southern Williamson counties in those regions drained by the Kaskaskia, Big Muddy, Saline, and Little Wabash rivers. Thus it extends from within ten miles of the Mississippi on the west across the interior of the state to within twenty miles of the Wabash on the east. It is somewhat less than, but almost entirely within, the area covered by the Lower and Lower Middle Illinoisan glacial invasion. (See Map II, facing p. 1.) Isolated areas of small extent are found in Knox, Massac, Hardin, Pike, Union, and other counties.

During the ice invasion, preglacial eminences were ground down and valleys were filled. The retreating ice left a deep deposit of unstratified boulders, gravel, sand, silt, and clay similar to the glacial till of northern Illinois. Following a later ice invasion (the Iowan), which was limited to the northern part of the state, a very fine soil was carried by the wind and deposited extensively over the entire state. Later ice invasions buried and modified this loessal deposit in the central and northern parts of the state, but throughout the south-central region it averages from four to ten feet in depth and forms the very fine, poorly drained soils of this post oak region. These fine-textured, gray, surface soils are generally underlaid by a stratum of silty clay. The resultant poor drainage renders these soils of low agricultural value.

The general flatness of the region is broken by occasional glacial moraines or preglacial eminences, rarely more than one hundred and fifty feet above the plain level, and by the valleys of the intersecting streams. The larger stream valleys have a wide level floor but a few feet below the general plain-level. Gradients are low and extensive bottomlands are common. About 12% of this region is bottomland, whereas the average for the entire state is 8%. Where the layer of loess has been eroded, as along the stream courses, the soil is a yellow-gray silt loam, changing to yellow silt loam as erosion progresses deeper.

Originally the forests completely covered the bottomlands and about 58 per cent of the uplands. About 63 per cent of the entire region was forested. At present 6.9 per cent of the uplands have forests, representing in area 13.4 per cent of the area originally forested.

This type extends over 8,600 square miles, and variation in the forest is consequently to be expected. Throughout this region the upland forests are of two rather distinct types, the post oak associations on the level lands (type 1), and the upland hardwood association on the slopes (type 3).

The post oak flats have a light gray soil and a very tight subsoil. On the poorest soils post oak (*Q. stellata*) may grow pure or associated with black-jack oak (*Q. marilandica*). Improved drainage conditions bring black oak, shingle oak, and hickory associated with the post oak. In the basins within these upland flats, where moisture collects but where the subsoil is somewhat more pervious, pin oak often grows. The representation of species by per cents, as given in the tabulation, page 11, based on measurements of stands totaling 5.01 acres in five counties, is as follows: post oak, 73.8; scrub oak, 11.9; hickory, 7.4; black oak, 5.1; shingle oak, .9; and pin oak, .5. On these soils all of these trees have a low growth-rate, and the stands usually have a great number of stunted, bushy trees to the acre. At 100 years, post oak averages 56 feet in height and 14 inches in diameter at the stump on these poor soils. Occasional trees may attain a height of 65 feet and a diameter up to 30 inches, but such trees represent defective and gnarled veterans upwards of 300 years old. (Plate VI, Figure 1.) Ordinarily the stands appear decadent at 100 years and do not produce trees of sawlog size. Sawlogs have been harvested from virgin stands; but such forests contain comparatively few trees to the acre, such trees are over a century in age, and the product is of low quality. This combination of the very long period required to grow sawlogs, the low yield per acre secured, and the inferior quality of logs, makes sawlog production on post oak sites a very unprofitable undertaking.

Throughout this region the coal mines use large quantities of small timber in the round for props, legs, bars, and mine ties. Seventeen counties of this region produce 73 per cent of the coal mined in Illinois. Based upon an average wood consumption for mine timbers of .246 cubic foot per ton, the mine timber consumption for this region was 14,438,753 cubic feet in 1921. A cubic foot of standing timber in the trees of the class from which mine timbers are produced will yield .74 cubic foot of mine timbers. Hence the consumption of 14,438,753 cubic feet at the mine is equivalent to 19,511,830 cubic feet of standing timber.

The annual growth per acre, for 14 plots in post oak stands taken in this region, varied between 9 and 24 cubic feet with an average of 15.8 cubic feet. The product of the entire 386,418 acres of forested upland in the post oak region, if fully stocked, would supply about 31 per cent of the mine requirements. The mines draw upon the Ozark bottomlands and uplands as well as on the post oak region for material.

The returns from post oak land devoted to raising timber crops do not pay the taxes when the crop is harvested as fuel wood, and barely pay taxes when devoted to production of fence posts or mine timber. Over 30 years are required to grow trees large enough for fence posts and from 30 to 60 for mine material. The average annual production of 15.8 cubic feet per acre of standing timber is equivalent to 11.7 cubic feet of mine timber. The net stumpage value, based on the sale value from which is deducted the cost of logging plus 20 per cent, is $ .0418 per cubic foot. Thus the annual returns on an acre devoted to the production of mine timber are $ .489. The taxes on such land average $ .50 per acre per year.

If cordwood is harvested, the annual increment of 15.8 cubic feet per acre at a net stumpage value of $ .0115 per cubic foot gives a return of $ .18 per year. Since the taxes average $ .50 this land is costing the owner $ .32 per acre yearly.

The possibilities of finding a more profitable use for this type of land seem remote. It is in timber because experience has proven that it can not be farmed at a profit, but these areas are among the least productive for forest crops of any in the state.

With improved drainage conditions post oak improves in both form and growth rate, and black, white, and shingle oaks and hickory are associated. Much of this type of land has been cleared. The remaining stands show yields intermediate between the post-oak flat stands and the upland hardwood stands of the slopes.

Samples from fully stocked stands are tabulated below.

A 40-YEAR OLD STAND, PERRY COUNTY

Species	Post oak	Scrub oak	Pin oak	Hickory	Total	Av. annual growth
No. of trees per acre.....	232	236	4	4	476	
Av. D. B. H., inches......	4.6	5.3	7.0	2.0		
Cu. ft. per acre...........	33	30	35	30		
B. F. per acre............	414	402	2	13	831	20.8

A 65-YEAR OLD STAND, FRANKLIN COUNTY

Species	Post oak	Scrub oak	Black oak	White oak	Hickory	Total	Av. ann. growth
No. of trees per acre......	84	40	40	4	20	188	
Av. D. B. H., inches......	5.0	7.4	9.6	88.0	7.4		
Av. Height, feet..........	32	32	54	45	48		
Cu. ft. per acre...........	175	179	416	19	128	917	14.1
B. F. per acre............	......	96	540	....	148	784	12

A 75-YEAR OLD STAND, RANDOLPH COUNTY

Species	Post oak	Black oak	Hickory	Total	Av. annual growth
No. of trees per acre.........	184	20	16	220	
Av. D. B. H., inches.........	7.5	8.1	5.0		
Av. height, feet.............	35	40	32		
Cu. feet per acre............	739	153	28	920	12.3

The flatness of this section is varied by occasional preglacial eminences and glacial moraines rising above the general level, and by stream courses cut nuder this level surface. In such places drainage is good, and the stands belong to the upland hardwood type found throughout the interior in the central and northern parts of the state.

On the moraines and like areas of the preglacial eminences where the soils are deep, forest growth is the best for the uplands of the region. Black oak is the commonest tree; associated species are white and red oak, hickory, ash, and cherry. These are the only upland areas within this region where black walnut grows well. On those preglacial eminences where the soils are thin, frequently a very inferior growth of scrub oak (*Q. marilandica*) occurs.

On the slopes where the flat upland breaks to the stream, the soil type changes to yellow-gray silt loam and lacks the tight subsoil. These slopes are among the best agricultural soils of the region. They were originally entirely forested, but have been cleared in those areas where the slopes permit tillage. Gully erosion was noted in Perry, Washington, Williamson, Franklin, Jefferson, Clay, Hamilton, and Wayne counties. In general the steeper slopes are forested. White oak is often the commonest tree. Shingle and black oaks together with white oak often comprise 90 per cent of the stand on the southern and the western exposures. Other species are hickory, ash, basswood, cherry, hard maple, elm, and black walnut.

The virgin forest has long since been cut from the uplands, the succeeding growth is harvested as soon as the trees grow to small sawlog size, and even the saplings are frequently worked into mine timbers; yet fire and grazing injury has not been common, the result being that the remaining stands throughout this region are better stocked than those of either the Ozark bluff region or the upland hardwood region to the north. Regeneration is by both sprouts and seedlings. The stands are uneven-aged, with full representation from saplings to small sawlog size.

(2) *Scrub Oak*

Sands and sandy loams are found throughout central and northern Illinois. Waters from the melting ice-sheets carried great quantities of soils. The coarser materials, such as gravels and sands, were quickly deposited. Receding floods exposed these deposits to wind action, and the finer sands drifted. Whenever conditions became stabilized to the extent that grasses and trees could gain control the sands were anchored. With the destruction of the vegetative cover they resumed their drifting. Forests have a very important place in the land economics of these sandy regions. Solely as protective cover they are justified. As will be shown later, they may also be developed to produce a profit.

The sandy loams, being fertile are universally cleared. The dune sands are the least fertile of any of the soils of the state. The presence of very moderate quantities of loam or loess greatly improves the quality of the sandy soils, while a very little organic matter in the surface soil binds dune sand. Thus the sandy soils are very sensitive and unstable, reacting disproportionately to very slight changes in physical composition. It follows that improper handling of these soils may not only quickly destroy their productivity but also convert them into drifting wastes which menace adjacent areas.

In Illinois the wind is a more important agent than water in eroding, transporting, and depositing sands. Bare sand washes readily, but such soils are so open that in ordinary rains there is no appreciable surface run-off nor consequent erosion. The ground surface in the sandy areas is ordinarily a series of swells and depressions, the gradient of slope is low, and gullying does not occur. Very different conditions arise when the sands are modified by strata of clay or by loess. On these modified soils the run-off increases, yet the high sand content insures good drainage under ordinary conditions. In certain parts of Whiteside and Carroll counties, however, where the slopes are considerable, the modified sands have gullied seriously. Such ravines ordinarily develop during an exceptionally heavy storm, the process of formation being very rapid. A gully several feet deep often develops in an unbroken field during a single storm. Once started it eats back into the fields. An example of such erosion in 15 years has cut back into a field 125 feet, gouging a ravine 100 feet wide and 70 feet deep. Areas as large as twenty acres are so thoroughly gullied that they can not be crossed. (See Pl. II for examples.) Ultimately such land reverts to forest. The areas where such erosion occurs aggregate several thousand acres and merit detailed study before attempting to classify the land into agricultural and absolute forest land.

The effect of wind upon sand is evident in all these sandy regions. Drifting sand forms low hills having a gentle slope on the windward side, and a steep slope to the leeward. The ridges are often in parallel alignment and move before the wind burying everything in their progression. Covered by vegetation these dunes become fixed. Destruction of the cover results, under certain conditions, in the development of crater-like depressions from which the sand is blown. In extending agriculture into these areas, man has destroyed the cover and initiated a new advance of some dunes previously fixed; he has also attempted through cover crops and forest plantations to fix sands which are in motion. The desirability of a forest cover on blow sand is apparent, but the site is so unfavorable that forests do not readily establish themselves. Bunch grass and prickly pear gain a foothold and stabilize the sands. A scrubby forest may then develop. Of the trees native to the sand areas, black oak (*Q. velutina*) is the commonest. In the southern areas black-jack oak (*Q. marilandica*) is common, and in the northern areas bur oak (*Q. macrocarpa*) occurs frequently. Hickory (*Carya cordiformis* Wang.) and white oak (*Q. alba*) are found throughout the sand regions, but their presence generally indicates better soil conditions.

The tabulation on page 11 shows that the representation of species by per cents based on measurements covering 7.68 acres in five counties, is as follows: black oak, 63.2; scrub oak, 25.6; white oak, 2.6; and hickory, 8.3.

Extensive areas of sand, in the form of dunes or river and lake deposits, are known to exist in twenty-eight counties of the central and northern parts of the state. The State Soil Survey has covered twenty-six of these counties, computing the sandy areas in twenty. In the remaining six, these areas have been estimated from maps completed but not yet measured. In two counties where sand deposits exist, no information as to their area is available. The twenty-six counties show approximately 221,000 acres of dune sand and 71,000 acres of river and lake deposit sand. The greater part of the sand deposits of the state are included in these twenty-six counties, and the total area of the state covered by sand is at least 310,000 acres. (See Map II, facing p. 1.)

The delineation of those areas in the sandy region which were originally forested is less reliable than for non-sandy soils. The organic carbon contents in the upland prairie loams are decidedly greater than in the upland timber soils, and in the field the transition from prairie to timber soil is readily apparent in the lighter color of the latter. The organic carbon content of sands is not markedly greater for prairie sand than for timbered sand, and in neither case is sufficient to give a decided color to the soil. About 75 per cent of the sand soils are classified by the Soil Survey as terrace soils. Such soils in this study are considered upland soils, and are generally regarded as originally non-forested. At present considerable areas of such land are forested with even-aged stands of an age roughly corresponding to the period which has elapsed since the region was settled.

The total area included in the scrub oak type is 2,145,120 acres, of which 20.94 per cent is estimated to have been forested originally, and of which 4.26 per cent is at present forested. Within the general areas covered by this 2,145,120 acres are 310,000 acres of pure sand and the balance of the area has soil of a generally sandy nature. The sandy loams have been cleared and the 91,611 acres of the scrub oak type now wooded are largely on poor sand land.

While forests are justified here solely on their ability to check the drift of sands upon neighboring fertile soils, yet the stands native to the site are stunted and scrubby. Black oak commonly attains a height of 50 feet with a clear bole of 10 feet and with a bushy crown. The products from such forests have little value other than for fuel and post material, the yields being very low. The annual growth on 24 plots of this type, varied between 11 and 47 cubic feet, with an average of 28.6 cubic feet per acre.

The tabulation below shows data on fully stocked stands.

A 25-YEAR OLD STAND, MASON COUNTY

Species	Scrub oak	Black oak	Hickory	Total	Av. ann. growth
No. of trees per acre	656	240	32	928	
Av. D. B. H., inches	2.8	3.5	2.0		
Av. height, feet	20	26	20		
Cu. ft. per acre	434	248	16	698	27.9

A 40-YEAR OLD STAND, KANKAKEE COUNTY

Species	Black oak	White oak	Sassafras	Total	Av. ann. growth
No. of trees per acre	240	48	176	464	
Av. D. B. H., inches	6.8	5.6	3.6		
Av. height, feet	47	40	30		
Cu. ft. per acre	1,097	154	184	1,435	35.9

A 55-YEAR OLD STAND, HENDERSON COUNTY

Species	Scrub oak	Hickory	Total	Av. ann. growth
No. of trees per acre	260	4	264	
Av. D. B. H., inches	6.7	4.0		
Av. height, feet	27	25		
Cu. feet per acre	720	4	724	13.2

A 75-YEAR OLD STAND, MASON COUNTY

Species	Black oak	Hickory	Total	Av. ann. growth
No. of trees per acre	112	24	136	
Av. D. B. H., inches	12.3	5.9		
Av. height, feet	62	55		
Cu. feet per acre	2,159	83	2,242.0	29.9
B. F. per acre	4,104		4,104	55

Taxes on the less productive soils vary from 14 to 65 cents per acre. Probably 50 cents is a fair average. The unmanaged stands of this region have an indicated yield per acre of less than one third of a cord per year. One dollar per cord is a fair price for cordwood stumpage. Thus it is evident that fuel wood returns do not pay the taxes. Such sand is ordinarily a liability, and forests are retained at a loss as insurance against sand drift, the additional cost being met from returns from the more productive parts of the farm. It is very doubtful if ideal treatment and protection would greatly improve the quality of the product or raise the yields of the stands native to this region. Fire and grazing protection would make conditions favorable for a gradual increase in the organic matter in the soils with a consequent improvement in physical and chemical composition, yet this improvement measured in increased forest returns would probably be very slow.

In attempts to anchor the sands and turn them to profitable productiveness, experiments have been made by land owners in introducing and planting species not native to these sites. Studies of these plantations and data collected in other states of growth upon similar sites, indicate that pine plantations may afford the best economic use to which the sands can be put.

Black locust has been planted more extensively than any other species. It is easily established, binds the soil with its excellent root system, and produces relatively good yields of high-grade post material. In addition to these excellent qualities, it has the ability to build up the nitrogen content of the soil. It is an ideal tree for the sand regions, but since the appearance of the locust borer in destructive numbers in 1856, only occasional plantations have been successful. The greatest insect injury occurs when the trees are from 3 to 8 inches in diameter. When locust is planted in pure stands, the borers generally destroy the plantation, whereas insect damage seems to be less severe when locust is in mixture with other species. On dune sand in Mason county, a thrifty plantation of 50-year-old trees had an average diameter of 13¼ inches inside the bark on the stump, and a height of 66 feet. From single trees were cut 40 split and 6 round posts. Such a plantation yields in 50 years 1,575 posts with a market value of 40 cents each, a gross return of $630.00 per acre.

The following costs are charged against the operation:

Taxes annually $ .50 per acre 4% for 50 years............	$ 76.33
Cost of establishing plantation $15.00 compounded 50 years	106.60
Cost of cutting and marketing $ .10 per post............	157.50
Total	$340.43

Net income at end of 50 years, $630.00 minus $340.43, equals $289.57. Discounted as a recurring crop or rental with interest at 4%, this gives the above land a value of $47.42 when devoted to locust, or an annual return at 4%, on this value, of $1.90 per acre above taxes, planting, and harvesting costs. This indicates that under favorable conditions locust plantations can be profitable.

This is one of the two types of the state where black walnut and catalpa plantations are failures. Neither should be planted on any other than fertile well-drained soils. Cottonwood (*Populus deltoides*) on these soils shows a very variable growth-rate. On a 20-year old plantation in the crater of a blowout the effect of shading was very pronounced. In the three outside rows, the trees averaged 10 inches D. B. H. and 70 feet in height. On a plot taken at least 5 rows (35′) inside the margin and representing average interior conditions, the tree average 5 inches D. B. H. and 50 feet in height, with the largest tree 9 inches D. B. H. and 52 feet in height. The plot showed an average growth per acre per year of 69.1 cubic feet as compared with 28.6 cubic feet for oak grown on similar sites. The product of the cottonwood plantation was suitable for fuel, posts, and pulp-wood. Cottonwood planted as a shelter-belt on these sands is a success; as a forest crop in plantations its value is in doubt. Thus far, experiments with the other broad-leaved species have shown that they will not produce a profitable crop on sands.

The prospect of growing certain pines on these soils at a profit is better. In general, conifers require about 1/10 the amount of water needed by broad-leaved species, are less exacting as to soil requirements, produce more trees to the acre, and have a faster rate of growth and a higher quality of product. Red, white, jack, and western yellow pines within their respective regions of growth produce valuable wood crops on sand. Plantations of white pine, already established on such soils in Illinois, are generally too immature to show the possibilities of wood production. However, they do demonstrate that white pine plantations can be established, and that the growth rates during the juvenile period is rapid. The occasional open-grown white pines planted in this region indicate that the excellent growth-rate is carried through to maturity. At 40 years such individual pine trees on sand near Amboy, Lee county, produced 38 cubic feet as compared with 4.8 cubic feet produced by black oak at the same age on sand.

Studies were made in two plantations growing on dune sand and representing 20- and 50-year age classes. The twenty year stand has an average D. B. H. of 4.1 inches and an average height of 27 feet. The largest trees are 7 inches D. B. H. and have a height of 30 feet. The mean annual growth for the twenty-year period is 95 cubic feet per acre. The trees were vigorous; the plantation well managed. (Plate I, Figures 1 and 2.)

The fifty-year plantation has an average D. B. H. of 10 inches and an average height of 55 feet. The largest trees have a D. B. H. of 15 inches and a height of 60 feet. The mean annual growth for the fifty-year period is 91 cubic feet per acre. This stand averages 27,264 B. F. per acre for the 50-year period, which is almost exactly the yield given for similar soils in Massachusetts (Hawley and Hawes '12). An increase of 318 per cent in the yields for white pine over the native hardwood stands, and an increase in the quality of product—from cordwood to excellent lumber—is indicated as possible for those in position to make the initial investment of establishing the plantation and carrying the costs from 30 to 50 years. Approximate costs and returns per acre are as follows:

*3-year old transplants, 1210 per acre	$5.50
Planting cost	7.50
	$13.00
Compounded 50 yrs. at 4% this equals	$92.387
Taxes 50 cents per acre per annum compounded 50 years equals	76.333
Total cost at 50 years	$168.72

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* Can not be bought in Illinois at a reasonable price.

The yield of 27,264 B. F. per acre at $20.00 per M. on the stump equals $545.

Net income at 50 years equals $545.00 minus $168.72, or $376.28.

Discounted as a recurring crop or rental at 4 per cent this gives the land a value of $61.62 per acre. The annual return at 4 per cent on this value is $2.46 per acre. Thus after paying all expenses such as taxes and planting costs, such a plantation returns annually $2.46 per acre per year from a timber crop on land which, devoted to natural growth of hardwoods does not return the taxes.

In conclusion:—These sandy soils require a vegetative cover; native forests are uneconomical; introduced species such as certain pines can probably be grown at a profit; and forestry in these regions is of an intensive nature, involving planting.

(3) *Upland Hardwoods*

In the third upland type, the upland hardwoods, are included 60 per cent of all the forests of the state, and 79 per cent of all upland forests. It is that upland forest which grows on soils between the extremes of open sand and tight loams over clays. The representation by species in this type is very variable. The relative stability of soil moisture appears to exert a controlling influence over the composition of the forest. In general, the fewest of species are found on those soils approaching the heavy post oak soils, and the greatest variety, on deep well-drained sandy loams. The gradation from forests made up almost entirely of oak and hickory to those showing considerable variety is not usually distinct. The following generalization for the upland hardwood type may be advanced: Forests in the southern part of the state show a greater variety than those in the northern; those on non-glaciated regions a greater variety than those on the glaciated; those on moraines a greater variety than those on the inter-morainal areas; those in the broken eroded regions a greater variety than those in the more level; those on sandy loams a greater variety than those on clayey loams; and even those in virgin all-aged forests a greater variety than those in even-aged stands.

The annual growth on 35 fully stocked plots of this type varied between 22 and 58 cubic feet per acre, with an average of 36.4 cubic feet as compared with the average of 15.8 cubic feet for the post oak type, and 28.6 cubic feet for the scrub oak type.

Certain extensive regions of the state manifest a tendency toward either the oak-hickory extreme or the rich mixture, and the general upland hardwood type will be described under two subtypes, (a) upland mixed hardwoods, less than 90 per cent oak-hickory, and (b) the oak-hickory, 90 per cent or more oak-hickory. From seventy samples taken in this type in twenty-eight counties, the oaks and hickories make up 90 per cent of the stand in thirty-six.

Subtype (a) *Upland Mixed Hardwoods*

The regions where this subtype commonly prevails are the entire nonglaciated part of southern Illinois, the deeply eroded section along the bluffs of the Mississippi River as far north as the Wisconsin line, the eroded bluffs of the Illinois River, and the modified uplands of the Wabash as far north as Vermilion county. This mixed hardwood association occurs locally in many counties of the state on moraines, well-drained slopes, and similar sites favorable to variety.

In the Ozark upland region this subtype extends completely across the state; but elsewhere the general areas where it is found are restricted to a strip, bounded on the river side by a very definite line where the uplands break to the river plain by precipitous slopes or rock ledges, often with a relief of several hundred feet. The interior boundary of this strip is not clearly demarked, as mixed hardwoods here merge with the oak-hickory extreme; but, in general, the mixed hardwood subtype is associated with deposits of deep and medium loess, and varies in width from 2 to 12 miles. The depth of the soil varies greatly in this bluff area, as it is a region where wind-carried soils built up deep deposits and where erosion has been very active. Rock outcrops are frequent along the outer rim of the bluffs and where the lesser streams have cut through the heavy soil mantle; but generally soils are deep. In texture these loessal soils are very fine-grained and may approach sands or clays, but they are characteristically porous, friable, and fertile. They readily absorb moisture, and slopes which on heavier soils will gully disastrously, are safely cleared in this bluff region.

The Ozark uplands extend from the Mississippi to the Ohio, and from the Big Muddy and Saline rivers to the Cache as an upthrust with an axis running east and west. The highest points, which are among the highest of the state, are near each end and close to the rivers. This results in a pronounced relief along the eastern and western parts, which together with the series of cliffs marking old faults along the southern part, make this a region of rugged topography, characterized by more or less gentle northern and more or less abrupt southern slopes. The older residual soils were buried under a loessal deposit of varying depth. Subsequent erosion and weathering have altered these deposits, but they form the main soils of the region. The soils of the interior section are shallower and less porous than the loessal deposits of the bluffs, hence unprotected slopes erode seriously. (Plate II.)

Originally about 95 per cent of the bluff and Ozark upland region was forested. The fertile soils have put a premium on arable land, and customarily the flat hill-tops and the narrow creek-bottoms are cleared; yet the region is so dissected that 22.6 per cent of its area is yet forested, as contrasted with an average of 6.8 per cent forested for the total of the uplands of the state. The actual reduction in area from the original forests is estimated at 76.2 per cent and the reduction in quantity of timber at 95.5 per cent.

In the Ozark region the bluffs rise abruptly several hundred feet above the Mississippi flood-plain to the general level of the uplands. These uplands are so dissected for the first three to nine miles from the bluffs that the continuity of the forests is broken only by clearings on the narrow bottoms, or infrequently on the yet narrower ridge tops. (See Map III N.) This region is the only place in Illinois where relatively continuous upland forests in a single region aggregate 100,000 acres; and this forest is a belt averaging three and one-half miles in width by fifty in length, rather than a compact area.

Rock outcrops are frequent where the uplands break to the Mississippi flood-plain, but in general loessal deposits are heavy and soils are deep. This is a limestone region, and caverns and subterranean streams usual to such formations exist. Springs of considerable volume are numerous at the base of the bluffs, but within the region itself springs are rare.

The dry slopes rising abruptly from the Mississippi flood-plain are forested save where sheer cliffs break their continuity. These forests consist of short, sturdy trees, mostly oak. The upper part of this western slope has black oaks and hickory on the more favorable sites, with post oak or red cedar on the thin soils. It is on this dry upper part of the westernmost slope in Union county that the bulk of the shortleaf pine grows, a few stragglers reaching the second western slope.

These poor forests mark only the exposed margin, and within this region of innumerable ravines and spurs a rich variety of trees may be found. In general the ridge tops and upper parts of the south and west slopes have few species other than black oak, white oak, and hickories. The north and east slopes, the lower south and lower west slopes, and the bottoms of the innumerable narrow draws, in addition to black and white oak and hickories, have red oak, tulip, beech, hard maple, black walnut, ash, cucumber-tree- butternut, basswood, elm, Kentucky coffeetree, black and red gum, and mulberry. Customarily the oaks predominate, yet it is not unusual to find nearly pure stands of beech in the draws and on lower slopes.

The difficulty of logging in this extremely broken region delayed the harvesting of the virgin stands until the more accessible areas to the east were cut out. Early operations were light and the large trees of the few more valuable species were harvested and marketed in the log. This was followed by sawmills operating chiefly in the larger oak. In recent years this region has been drawn upon heavily for sawlogs, ties, and mine timbers, and virtually every species is utilized down to very low diameters. As a consequence the forests in this region are over-cut, growth does not equal the cut, and the amount of growing timber per acre steadily diminishes. An average acre based upon a tally of all trees 6 inches D. B. H. and up, on a strip 66 feet wide totaling nearly 23 miles in length and equivalent to 181.66 acres, gives the average number of trees per acre as 37 and the average contents as 886.73 cubic feet. The same acre fully stocked with trees of the sizes present should have 108 trees and total 2,586.95 cubic feet of timber. Alexander, Union, and Jackson counties contain over 100,000 acres of such forest, averaging about one-third fully stocked (34.275 per cent). This means a loss in yields of at least 2,400,000 cubic feet of wood annually, and is equivalent to more than 200,000 first-class ties—a total annual revenue of $200,-000.00.

The average acre has 21 trees with a D. B. H. 10 inches or better; i. e. trees suitable for ties or even sawlogs, and it has 16 trees in the 6-7-8-9 inch classes. Since cutting has been comparatively light in this latter group it represents more nearly the actual association of species in the forests of the future. A comparison of the data in table p. 45 showing per cents of species represented in the smaller and larger diameter classes respectively, indicates that the future stand will have a slightly lower per cent of black oak, tulip, black gum, maple, and red gum, and a very much lower per cent of beech; also it will have a higher per cent of white oak, elm, and ash, and a very much higher per cent of hickory.

STAND TABLE BASED ON 181.66 ACRES, UNION COUNTY

	Black oak	White oak	Hickory	Beech	Tulip	Red oak	Elm	Maple	Ash	Red gum	Misc.	Total
No. trees per acre.....	13.4	8.4	5.9	4.3	1.2	1.0	.7	.7	.4	.4	.4	37.1
Per cent of present forest	36.1	22.8	16.0	11.7	3.1	2.6	1.9	1.9	1.8	1.0	1.0	100.0
Per cent of merchantable sizes (10″ and up)	21.6	11.5	6.4	9.8	2.0	.8	.8	1.2	.7	.6	.5	57.2
Per cent in future stand	33.9	26.3	22.4	4.5	2.6	2.7	2.7	1.6	2.6	1.0	1.2	100.0

A few areas yet show virgin stands. The tabulation from the sample plot on page 47 shows the association, sizes, and yields. In general, the forests are more or less culled. Down to the present, cuttings have been in the larger diameter classes alone, and the same area could be profitably logged at intervals of about twenty years. The recent cuttings have been heavy in the smaller diameter classes with a consequent increase in the interval before another cutting will be profitable.

Forest fires do more damage in this region than anywhere else in the state. An examination in 33 sections in this region in 1921 disclosed that 12 had been partially or completely burned over in the past three years. An average interval of eight years between fires is insufficient to carry the immature trees to a fire resistant stage. The reproduction is naturally excellent in this region but fires must be controlled before well-stocked stands can be realized. Growth rates vary, but generally average slightly lower than for the same species on comparable soils elsewhere in the state. (See page 47.)

East of this belt of heavily wooded hills, the Ozark upthrust continues as a divide between Saline River on the north and the Cache on the south. (See Map III C.) The average width is scarcely twenty miles, the average elevation of the divide less than 400 feet above the rivers; yet this region presents a very broken surface. Generally the divides and spurs show broad tops, breaking abruptly to the narrow valleys. Cliffs are common along lines of faulting and along the gullies cut through the the limestone by streams.

The ridge tops and rolling uplands are cultivated; the steep slopes and narrow gulches, wooded. It is a region of relatively shallow soils. Splendid forests originally grew in the protected coves and pockets where soil collected, and this region yet produces some high-grade veneer logs. The arable lands have been cleared, the forests remaining are on thin soils and precipitous slopes. Occasional patches of sawlog timber may be found in ravines and on lower slopes; but generally the stands are of a pole-wood or sapling nature and are cut closely for mine timbers. At the eastern end (Hardin county) cutting has been less severe than in the counties to the west. Cedar grows in nearly pure stands on some of the bluffs, and a rich mixture of beech, cucumber, hard maple, tulip, ash, and basswood may be found in the draws, but generally the rather poor stands of this interior region are black and white oaks and hickory.

The soil common to these uplands—yellow silt loam—is more susceptible to erosion than any other common soil type. Much of the upland in this region has been unwisely cleared as the numerous gullied and abandoned fields testify. (See Plate II.)

STAND TABLE BASED ON 181.66 ACRES, UNION COUNTY

Species	Black oak	White oak	Hick-ory	Beech	Tulip	Black gum	Elm	Hard maple	Ash	Red gum	Misc.	Total
No. of trees per acre..	13.37	8.43	5.92	4.34	1.16	.96	.71	.70	.66	.38	.37	37
Av. D. B. H., inches....	11.0	10.7	9.7	15.8	11.8	13.7	9.4	12.7	9.7	12.2	10.3	
Av. Ht., ft............	60	58	58	77	70	70	50	68	60	70		
Cu. Ft. per acre.......	275	172	92	225	26	35	10	25	9	11	7	887
B. F. per acre.........	679	496	229	885	73	169	16	87	17	30	18	2,699

SAMPLE ACRE OF VIRGIN TIMBER, UNION COUNTY

Species	White oak	Black oak	Red oak	Hickory	Ash	Tulip	Elm	Hard maple	Sweet gum	Black gum	Beech	Mul-berry	Car-pinus	Ostrya	Dog-wood	Sassa-fras	Total
No. of trees per acre	20	14	1	41	2	6	4	21	19	17	19	3	12	12	103	6	300
Max. DBH, inches..	14	20	19	19	20	14	13	8	14	15	22	7	9	5	8	8	
Max. ht., feet......	65	80	80	88	82	80	63	45	85	70	85	30	30	25	25	30	
Av. cu. ft. per acre.	119	78	63	517	37	78	27	31	324	214	425	5	20	13	109	16	2,076
B. F. per acre....	157	419	237	1,149	94	117	47	......	598	477	1,229	......	......	......	......	......	4,524

SAMPLE OF VIRGIN STAND ON FERTILE AGRICULTURAL SOIL

Species	White oak	Black oak	Hick-ory	Tulip	Black gum	Black walnut	Sassa-fras	Total
No. of trees per acre	10	12	6	8	2	2	4	44
Max. D. B. H. inches	25	31	13	27	13	15	12	
Max. Ht., feet	90	92	65	90	60	70	50	
Cu. contents per acre	359	1,000	81	808	42	55	65	2,410
B. F. contents per acre	1,376	4,380	144	3,100	94	150	124	9,368

Between the Cache and the Ohio rivers the uplands are from 3 to 12 miles wide and about 40 miles long. Gentle slopes lead up from the Cache bottoms to the rolling uplands—about 150 feet above the bottoms—and break abruptly to the Ohio. The deep fertile soils of this region early invited settlers. The remnants of the splendid forests which covered it are along the abrupt slopes. The present forests are similar to those in the heavily wooded area near the western part of the Ozark uplands; but growth rates are better here, and one additional species, chestnut, has established itself in one locality near Olmsted, Pulaski county.

This mixed hardwood subtype, with the species listed for the Ozark uplands, is not found in the interior of the state north of the Ozarks, but it extends almost to the headwaters of the Wabash to the east and to the Kaskaskia along the uplands bordering the Mississippi in the west, the variety of species decreasing in the northern advance.

In the Wabash region, the upland soils are deep; and near the main river they show a tendency toward the sandy textures. Loessal deposits occur in the form of low hills, usually within six miles of the main Wabash bottomlands. The slopes are relatively gentle, the soils deep, fertile and well drained, and conditions ideal for tree growth. It was probably on these uplands that the large tulips measured by Dr. J. Schneck were found (Ridgway, '82), and where even black walnut and red oak attained a height of 150 feet. These splendid forests have disappeared. The uplands are cultivated save for the few wood-lots covering the steeper slopes, and these contain second-growth timber. Beech and tulip extend to Vermilion county, black gum to Lawrence; cucumber-tree in Illinois does not get beyond the Ozark uplands; while red gum, which in the Ozark region extends to the upland association, in this region is restricted to the bottomlands. Basswood, ash, or hard maple may form high percentages of the stand. Beech is not a common tree.

Along the Mississippi, the transition from the upland forests of the Ozarks, with a great variety of species, to the mixed hardwoods of the central and northern part of the state, is made in the thirty miles of bluffs between the Big Muddy and the Kaskaskia rivers. This region is a continuation of the extremely dissected belt described as the western part of the Ozark uplands. Deep loess deposits extend inland to an average of nine miles from the bluffs. Sink-holes pit this region to a greater degree than elsewhere in the state. For the first mile or two from the bluffs, the forests are continuous; farther inland the ridge tops and stream bottoms are cleared, and the forests are on the slopes.

These stands consist of an uneven-aged mixture from which the larger trees have been removed. The transition of species is in about the following order: cucumber-tree and sweet gum do not grow in these uplands north of the Big Muddy; Mary's River is the upper limit for beech and tulip while black gum goes to the Kaskaskia. Two variations from the mixed hardwood association usual to this region merit mention. Piney Creek, a tributary of Mary's River, has cut a ravine about seventy feet in depth; and here, on the shallow soils of the slopes, some thirty mature shortleaf pines represent the most northern outpost of this species. (See Plate VIII.) On Rock Castle Creek, some five miles north of Piney Creek, there were formerly specimens of this tree. The shortleaf pine (*Pinus echinata*) is the yellow pine common to the clay soils of the Gulf States but it extends up into southern Missouri and southern Illinois. Its occurrence in Union and Randolph counties marks the extreme northern limit of the species. The Piney Creek ravine is also probably the northern limit in the western part of the state for tulip and beech. The second variation is found in the many sink-holes which occur in the uplands near the bluffs. These are generally circular depressions, having a diameter from thirty up to several hundred feet, and a depth often of forty feet. Water may collect and remain in these basins, but ordinarily it is drained off through underground streams. Such formations are especially numerous in Monroe county but occur in Randolph, Union, and Hardin counties. The soils, washed in from near-by fields, are fertile. The slopes are often steep and wooded. Tree growth is exceptionally rapid. Black and white oaks commonly predominate, but sycamore, elm, river birch, cherry, and cottonwood are frequent trees in this association.

North of these Ozark uplands, of the upland belt extending along the Wabash system to Vermilion county, and of the belt extending up the Mississippi to the Kaskaskia, the mixed hardwood forests, in which oak and hickory make up less than 90 per cent of the stand, are in the belt of bluffs bordering the Mississippi and Illinois rivers; on the unglaciated areas of Calhoun and Jo Daviess counties; on many of the moraines throughout the glaciated area; and occasionally on the inter-morainal areas where well-drained fertile slopes are forested.

Such southern species as red and black gums, tulip, cucumber-tree, and beech* drop out, while big-toothed aspen is added in the northern part. White and bur oaks, basswood, black walnut, ash, elm, cherry, and hackberry have a higher percentage in these mixed stands in the north than in the south, while hickory and black oak have a lower percentage

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* Small colonies of beech are reported in Lake and Ogle counties.

in the north. A comparison as to the number of trees per acre shows that the northern forests have about twice as many as the southern, and that they are often even-aged, whereas in the southern region they are rarely so. In the even-aged stands the oldest have been growing about 90 years, the majority, between 60 and 90 years; the diameters are mostly under 18 inches; 65 per cent of the trees have a D. B. H. of 10 inches or better; and the average acre has about 80 trees. The number of trees per acre and the representation of species in the stands by per cents for both the northern and the southern part of the state is shown in tabulation on page 54.

The belt of heavily wooded bluffs extending from Alexander county north, terminates at about the northern boundary of Monroe county. In this distance of more than one hundred miles, there is scarcely a break in the forests as viewed from the Mississippi bottoms. North of Monroe county, even this westernmost slope is freely cleared, and the forests are disconnected strips along the slopes, rather than a continuous belt. Only in the rougher sections of Jersey and Calhoun, and to a lesser degree in Jo Daviess counties, are there comparatively continuous upland forests.

In Jersey and Calhoun counties, the uplands bordering the Mississippi and Illinois rivers are heavily wooded. (See Map V, C.) Calhoun is a narrow unglaciated headland between the Illinois and the Mississippi rivers and is but five miles wide in its narrower parts. The divide, often 300 feet above the rivers, is buried under a shallow loessal deposit and the slopes break more abruptly on the eastern than on the western side. Air drainage and soil conditions combine to make this upland especially adapted to apple production, and the less precipitous uplands along the crest are cleared, together with much of the western slope, but the abrupt eastern slopes are wooded. Black oak is the dominant tree, and much white oak, hard maple, elm, hackberry, black walnut, and basswood occur. The stands approach the even-aged type, and are of seedling rather than sprout origin. The same rugged topography and forest conditions exist in the western six miles of the uplands of Jersey county, although the stands here have been more heavily culled for sawlog and tie material. The area forested in these rough uplands, where forests are comparatively continuous, totals approximately 50,000 acres.

The topography of Jo Daviess county, with the exception of a small strip along the eastern border which has been modified by glaciation, is that of an old eroded upland through which the southwestward flowing streams have cut deep valleys. In the north, the slopes lead back to the broad uplands and culminate in occasional conical mounds. The highest of these, Charles Mound, with an altitude of 1,241 feet above sea-level, is the highest point in the state. In the central and the southern sections the slopes rise rather moderately from the narrow stream-valleys until the upper slopes are reached. Here the slope is steep or precipitous up to the narrow flat-topped ridge. In the north-central part streams have cut through the rock, forming canyons or gorges. The most notable, Apple River Canyon, is a gorge 160 feet deep with frequent cliffs, miniature park-like bottoms, and forested slopes.

Despite the fact that there may be a difference in elevation of 400 feet between the valley floor and the neighboring ridge-top, and that cleared slopes up to twenty and even twenty-five degrees are common, gully erosion is not noticeable. These steep slopes when not wooded are pastured and protected by a sod. The soils are well drained, and in periods of drought vegetation on the thin soil suffers. Pepoon cites an instance of extreme drought in 1898 when even old trees died (Pepoon, H. S., 1919).

The present upland forests totaling about 50,000 acres, occur usually as belts along the steep upper slopes. (See Map VI N.) The lower slopes and often the ridge tops are cleared. The uplands bordering the Mississippi River are usually wooded in the southern half of the county but cleared in the northern half; and the forested region extends into the unglaciated interior region twenty-five miles from the Mississippi plain. The stands are well stocked with young as well as with merchantable timber and growth rates are excellent. They are dominantly white and black oak, containing some basswood, hickory, black walnut, elm, ash, cherry, maple, and occasionally a big-toothed aspen or Kentucky coffee-tree. Hard maple is found in almost pure stands in the northern part of the county, and white pine occurs occasionally on the rocky slopes of the gorges.

Between Calhoun and Jo Daviess counties the topography of the uplands along the bluffs becomes modified, the slopes are less precipitous, and relief less pronounced. These uplands are customarily cleared, but Mercer and Rock Island counties show somewhat more forested area on them. In parts of Henderson, Carroll, and Whiteside counties sand has blown inland; and such areas, when wooded, have the oak forests described under the scrub oak type.

Based on measurements of all trees 6 inches D. B. H. and up, on 17.4 acres, an average acre in Jo Daviess county furnishes the following data.

Species	White oak	Black oak	Bass-wood	Hick-ory	Black walnut	Elm	Ash	Cherry	Maple	Big-toothed aspen	Ky. coffee-tree	Total
No. of trees per acre..	34.4	27.7	5.6	4.2	2.6	2.7	2.1	.9	.8	.2	.06	81.3
Av. D. B. H.	10.3	12.3	11.8	7.6	10.5	9.2	9.6	8.4	10.8	9.2	8.0	
Av. Ht.	50	60	55	45	50	48	55	50	55	55	45	
Cu. Ft. per acre.......	314	483	93	8	27	26	15	4	10	2		982
B. F. per acre.........	507	1,141	207	15	66	64	31	7	26	4		2,068

Sixteen reproduction plots of a square rod each, taken at 600-foot intervals under forest conditions usual to this region, indicate that seedling reproduction is predominant.

Species	White oak	Black oak	Hick-ory	Elm	Black walnut	Cherry	Bass-wood	Hard maple	Ash	Big-toothed aspen	Total
Seedlings	80	650	130	1,130	30	100	560	60	90	10	2,840
Sprouts	....	210	40	20	....	....	....	....	30	....	300
Total per acre..............	80	860	170	1,150	30	100	560	60	120	10	3,140

Comparison of these results with the representation of species by per cent of trees per acre 6 inches D. B. H. and upwards follows.

Species	White oak	Black oak	Hick-ory	Elm	Black walnut	Cherry	Bass-wood	Maple	Ash	Poplar	Misc.
Per cent by species of trees 6" D. B. H. on av. acre........	42.4	34.2	5.0	3.2	3.2	1.1	6.9	1.0	2.6	.2	.2
Per cent by species of reproduction on av. acre........	2.6	27.3	5.4	36.6	1.0	3.1	16.4	1.9	3.8	.3	1.6

This comparison justifies the conclusion that there is a tendency toward increase in white oak and decrease in elm and basswood.

The status of a sample from a 75-year old stand of mixed hardwood in Hancock county is here shown.

Species	White oak	Black oak	Hickory	Ash	Elm	Black walnut	Cherry	Total	Av. ann. growth
No. of trees per acre	88	88	24	24	4	4	4	236	
Av. D. B. H.	5.2	10.1	5.3	8.8	10.0	5.0	12.0		
Av. Ht.	52	65	50	65	65	55	70		
Cu. Ft. per acre....	363	1,591	60	271	61	7	101	2,454	32.7
B. F. per acre.......	472	2,132	......	428	88	......	228	3,348	45

Along the Illinois River from the Hennepin bend down to Peoria, the narrow draws, running back into the western bluffs some two or three miles, as well as the face of the bluff, are wooded as a continuous belt with this mixed hardwood subtype. Elsewhere cleared bluffs and draws are as frequent as wooded ones. In the northeastern part of Calhoun and extending into the southeastern corner of Pike county is an area of upland where the soils are heavy. Here this mixed hardwood phase changes to scrub and post oak. In many places near the Illinois valley, notably in Mason county, sands have buried the old soils; and in such places the stands are of the type described under "scrub oak".

Throughout the interior of the state this mixed hardwood subtype occurs on the moraines and well-drained uplands, more frequently near the Indiana line in Vermilion county and the Wisconsin line in Winnebago and Stephenson counties; but it is usually less frequent than the oak-hickory extreme, even in these regions.

A sample plot from a virgin stand in McLean county shows the splendid sizes attained by trees under conditions favorable to this type. See table following.

Species	White oak	Black oak	Red oak	Hickory	Ash	Elm	Hard maple	Black cherry	Total
No. of trees per acre	17	5	1	8	14	10	25	1	81
Max. D. B. H. inches	38	23	8	21	25	20	9	11	
Max. Ht., feet.....	92	80	......	95	95	80	......	82	
Cu. Ft. per acre...	2,695	269	8	238	278	165	141	21	3,815
B. F. per acre.....	14,688	990	......	673	743	382	77	43	17,596

REPRESENTATION OF SPECIES BY PER CENTS AND NUMBER OF TREES PER ACRE IN SUBTYPE (*a*) UPLAND MIXED HARDWOODS (NORTH AND SOUTH) AND SUBTYPE (*b*) OAK-HICKORY

Species	Oak-hickory 90 per cent and over		Oak-hickory Less than 90 per cent			
			North		*South*	
	Trees per acre	Per cent	Trees per acre	Per cent	Trees per acre	Per cent
*White oak	52.8	47.93	25.1	34.55	8.5	22.41
*Bur oak	.8	.76	.4	.50		
*Chinquapin oak	....	....	.1	.15		
*Cow oak	....	....	....	.04		
*Red oak	2.4	2.21	2.1	2.86	....	.02
*Black oak	41.0	37.23	14.6	20.22	13.3	35.30
*Shingle oak	.1	.11				
*Swamp Spanish oak	....	.05				
Hickory	10.1	9.18	5.2	7.24	6.1	16.12
Elm	1.1	1.03	6.7	9.18	.7	1.98
Ash	.4	.34	2.4	3.31	.6	1.73
Hard maple	.1	.11	7.2	9.99	1.0	2.54
Beech	....	....	....	....	4.4	11.56
Black gum	....	....	....	....	1.1	22.89
Tulip	....	....	....	....	1.2	3.27
Black walnut	.1	.14	1.5	2.14	.2	.65
Red gum	....	....	....	....	.4	1.15
Basswood	....	....	3.6	4.91	....	.02
Cherry	.8	.70	1.5	2.09	....	.01
Hackberry	....	....	.7	.96	....	.06
Honey locust	....	....	.2	.26	....	.01
Kentucky coffee-tree	....	....	.3	.39		
Mulberry	....	.08	.1	.16	....	.08
Butternut	....	....	.1	.17	....	.04
Buckeye	....	....	....	.08		
Big-toothed aspen	....	.06	.5	.65		
Sycamore	.1	.11	....	.08	....	0.4
Black locust	....	....	....	....	....	.06
Totals	110.2		72.54		37.75	
	Per cent of oak-hickory equals 97.42.		Per cent of oak-hickory equals 65.56.		Per cent of oak-hickory equals 73.85.	
	Based on 32.4 acres measured in 20 counties.		Based on 63.2 acres measured in 15 counties.		Based on 188.4 acres measured in 3 counties.	

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* In part of the field-notes all white, bur, chinquapin, and cow oaks were tabulated as white, and all red, black, shingle, and swamp Spanish as black, consequently the figures listed for white and for black oak in the above table contain also these other oaks.

Subtype (b) *Oak-Hickory*

The total area of upland forests of the mixed hardwood type where oak-hickory makes up less than 90 per cent of the stand is estimated at

594,379 acres. Throughout the northern and the central parts of the state are broad regions where oak-hickory makes up 90 per cent or more of the stand, and such an association occurs locally even in the Ozark uplands, loessal bluffs, and post oak region. The total forested area of this oak-hickory extreme is estimated as 1,209,734 acres.

Throughout the post oak region the oak-hickory subtype is found on the slopes where the flat upland breaks to the stream bottom. The soils are usually yellow-gray silt loams. White oak is the commonest tree, shingle and black oaks, hickory with occasional ash, basswood, cherry, hard maple, elm, and black walnut form the stand.

North of this post oak region, the oak-hickory extreme prevails throughout the interior of the state. It is a region of undulating upland prairies and very deep glacial deposits. These prairies are naturally poorly drained so that, over the centuries when the prairie sod held the site, decay of grass roots has been but partial, and the rich black soils of the prairies have been built up. Below the dark prairie soils, yellow-gray and yellow silt loams are generally found. Where these soils are exposed on the slopes along the streams forests occupied the site; and on the steeper slopes of the numerous moraines, forests were found. Prairies, however, prevailed over 70 per cent of this region. About 82 per cent of the area originally forested is now cleared, and the forests remaining are small wood-lots retained on the rougher slopes. However, this is a region of relatively gentle slopes; and much land now timbered can be converted to arable land or to permanent pasture.

Soil classification, made by the University of Illinois Agricultural Experiment Station in twenty-two counties of this region, shows that 51 per cent of all timbered soils not bottomland are yellow-gray silt loams, and 33 per cent are yellow silt loams. These are comparatively heavy soils, and the yellow silt loams are those common to the less gentle slopes; consequently, erosion is a possibility where this soil type is cleared. Gully erosion was noted in Bureau, Fulton, Knox, Warren, Brown, McDonough, and Madison counties and was especially severe in Pike county.

These oak-hickory stands are usually even-aged, and occur as narrow strips along the slopes and as isolated wood-lots. Shingle oak may occur, but the commonest tree in the central region is black oak; in the northern, white oak. Oak and hickory often make up the entire stand. In the northern quarter of the state bur oak is a common tree in the association, and often forms the entire stand in wood-lots of counties along the northern border of the state. These bur oak stands are usually poorly stocked with short-boled, wide-crowned, and "limby" trees. Elsewhere the oak-hickory wood-lots usually show good stocking with trees up to small sawlog size and under 80 years of age. The usual drain on these wood-lots has been for posts and fuel. For these purposes inferior and smaller trees are customarily cut, leaving the better trees. These latter are, in most wood-lots, from 60 to 80 years old and entering into the sawlog class. The practice of grazing these wood-lots is almost universal. Statements from 430 woodland owners show that 92 per cent graze woodlands. Under this practice a sod is formed which effectively keeps out the reproduction necessary to replace the trees harvested. The presence of a sod, the lack of young trees to continue the forest, and the presence of timber of sawlog size tempt the owner to clear his land immediately rather than by the equally certain and slower process of grazing the woodlands.

The number of trees per acre and the representation of species in the stands by per cents for this oak-hickory subtype is shown in the tabulation on page 54.

Samples from fully stocked stands are shown (I, II, III, IV, V) as follows.

I. A 62-year old Stand, Whiteside County

Species	White oak	Black oak	Hickory	Black cherry	Total	Av. ann. growth
No. of trees per acre	132	49	6	6	193	
Av. D. B. H., inches	8.0	11.8	6.7	13.0		
Av. height, feet	70	70	65	70		
Cu. ft. per acre	1,440	1,029	46	152	2,668	43
B. F. per acre	2,134	1,957	41	346	4,478	72

II. An 85-year old Stand, Mercer County

Species	White oak	Black oak	Hickory	Elm	Total	Av. ann. growth
No. of trees per acre	102	16	3	6	127	
Av. D. B. H., inches	11.9	11.9	6.7	5.8		
Av. height, feet	80	80	60	55		
Cu. ft. per acre	2,402	396	17	30	2,845	33.5
B. F. per acre	6,229	887	....	....	7,116	84

III. An 85-year old Stand in Vermilion County

Species	White oak	Black oak	Red oak	Shingle oak	Hickory	Total	Av. ann. growth
No. of trees per acre	48	55	6	1	19	129	
Av. D. B. H., inches.	11.1	14.2	14.0	13.0	9.6		
Av. height, feet	70	70	70	70	67		
Cu. feet per acre	900	1,751	184	26	256	3,117	36.7
B. F. per acre	1,797	4,588	461	60	571	7,477	86

IV. An 80-year old Stand, Piatt County

Species	White oak	Black cherry	Elm	Total	Av. ann. growth
No. of trees per acre	71	3	6	80	
Av. D. B. H., inches	13.8	6.3	6.7		
Av. height, feet	70	35	35		
Cu. ft. per acre	2,062	15	16	2,093	26.2
B. F. per acre	5,309	....	....	5,109	66

V. A 90-YEAR OLD STAND, ST. CLAIR COUNTY

Species	White oak	Black oak	Hickory	Total	Av. ann. growth
No. of trees per acre	74	62	2	138	
Av. D. B. H., inches	12.1	14.8	8.0		
Av. height, feet	70	75	60		
Cu. ft. per acre	1,558	2,183	16	3,757	41.7
B. F. per acre	3,352	6,232	....	9,584	106

Forest Acreage by Counties

Counties	Type	Present (1924) acreage								Original
		Cull	Sapling	No. 1	No. 2	No. 3	No. 4	Total	County total	County total
Adams	U	....	2,187	28,202	5,208	119	....	35,716	37,871	369,523*
	B	....	225	1,343	587	....	....	2,155		
Alexander	U	8,044	286	21,470	1,936	....	....	31,736	43,847	122,655
	B	5,644	141	3,101	178	....	....	9,064		
	Cyp.	....	....	3,047	....	....	....	3,047		
Bond	U	....	3,625	12,985	341	....	....	16,951	18,813	107,539*
	B	....	146	1,716	....	....	....	1,862		
Boone	U	....	211	4,680	252	....	....	5,143	5,311	62,451
	B	....	....	168	....	....	....	168		
Brown	U	....	2,594	10,512	957	....	....	14,063	15,015	148,495
	B	....	336	599	17	....	....	952		
Bureau	U	....	239	22,084	3,957	11	....	26,291	33,973	124,581*
	B	....	7,682	....	....	....	....	7,682		
Calhoun	U	....	734	22,376	4,568	46	....	27,724	39,367	138,936
	B	....	718	5,671	5,254	....	....	11,643		
Carroll	U	10	3,187	11,167	1,214	....	....	15,578	24,911	167,162
	B	....	262	5,798	3,273	....	....	9,333		
Cass	U	....	824	9,237	2,827	....	....	12,888	32,693	91,904
	B	....	9,137	10,496	172	....	....	19,805		
°Champaign	U	....	309	4,599	1,449	43	....	6,400	6,400	47,659*

Explanation of terms, symbols, and abbreviations used.
† Counties partially covered by forest survey.
° Counties estimated but not surveyed.
* Counties having soil survey completed and area originally timbered tabulated.

Types
U=Upland
B=Bottomland
Cyp=Cypress
P=Pine
T=Tamarack

Yields
Culled=Merchantable trees removed.
No. 1=Stands having an estimated yield up to 2000 B. F. per acre.
No. 2=Stands having an estimated yield from 2000 to 5000 B. F. per acre.
No. 3=Stands having an estimated yield from 5,000 to 10,000 B. F. per acre.
No. 4=Stands having an estimated yield over 10,000 B. F. per acre.

°Christian	U	......	207	3,087	973	29	......	4,296	4,296	73,170
°Clark	U	......	5,180	16,510	958	55	......	22,703		
	B	......	2,229	5,079	597	9	......	7,914	30,617	190,865
Clay	U	......	4,581	19,869	725	......	......	25,175		
	B	......	1,619	6,406	278	......	......	8,303	33,478	170,669*
Clinton	U	......	488	2,655	177	......	......	3,320		
	B	......	6,110	28,457	14,438	3,689	......	52,712	56,032	129,702
°Coles	U	......	5,517	17,580	1,020	59	......	24,176		
	B	......	2,374	5,409	636	10	......	8,429	32,605	100,099
†Cook	U	......	1,172	15,194	6,155	397	......	22,918		
	B	......	131	113	456	267	......	967	23,885	84,593
†Crawford	U	......	2,705	10,640	1,971	413	......	15,729		
	B	......	2,749	4,717	3,831	82	......	11,379	27,108	162,234*
°Cumberland	U	......	3,710	11,821	686	39	......	16,257		
	B	......	1,596	3,637	427	7	......	5,667	21,923	99,079*
DeKalb	U	......	133	3,505	1,784	118	......	5,540		
	B	......	123	......	18	......	......	18	5,558	42,284*
°DeWitt	U	......	......	1,830	577	17	......	2,547	2,547	50,832
°Douglas	U	......	124	1,839	579	17	......	2,559	2,559	26,216*
DuPage	U	......	424	6,270	3,101	21	......	9,816	9,816	51,419*
°Edgar	U	......	6,526	20,795	1,207	69	......	28,597		
	B	......	2,808	6,398	752	12	......	9,970	38,567	137,804*
Edwards	U	......	328	6,320	1,203	......	......	7,851		
	B	......	1,810	3,744	462	......	......	6,016	13,867	119,205*
†Effingham	U	......	12,721	16,701	232	......	......	29,654	29,654	140,591
†Fayette	U	......	6,161	17,817	436	......	......	24,414		
	B	......	9,021	14,691	197	......	......	23,909	48,323	278,958
°Ford	U	......	148	2,205	695	20	......	3,068	3,068	2,974
Franklin	U	......	954	8,319	409	49	......	9,731		
	B	170	4,841	25,307	772	......	......	31,090	40,821	243,276*
Fulton	U	192	5,415	52,883	2,685	......	......	61,175		
	B	......	7,669	966	622	17	......	9,274	70,449	369,236
Gallatin	U	329	8,218	9,629	665	......	......	18,841		
	B	192	9,633	23,396	771	......	......	33,992	52,833	183,439
Greene	U	......	3,200	26,458	1,717	......	......	31,375		
	B	......	......	2,534	......	......	......	2,534	33,909	229,387
Grundy	U	......	290	4,230	151	......	......	4,671		
	B	......	53	1,757	2,187	164	......	4,161		
	P	......	......	......	......	......	5	5	8,837	11,366*

Forest Acreage by Counties—Continued

Counties	Type	Present (1924) acreage								Original
		Cull	Sapling	No. 1	No. 2	No. 3	No. 4	Total	County total	County total
Hamilton..........	U	51	3,586	11,148	617	24	....	15,426		
	B	....	1,055	11,691	6,658	....	....	19,404	34,830	245,242
Hancock..........	U	....	2,485	28,875	2,420	....	....	33,780		
	B	....	....	220	....	....	....	220	34,000	229,864*
Hardin............	U	1,729	4,692	24,093	4,426	133	....	35,073		
	B	....	....	....	....	....	....	....	35,073	108,169*
Henderson.........	U	17	6,474	11,728	1,780	8	....	20,007		
	B	....	170	1,428	1,666	....	....	3,264	23,271	148,272
Henry.............	U	....	231	11,290	2,123	10	....	13,654		
	B	....	....	....	586	....	....	586	14,240	253,667
°Iroquois..........	U	....	332	4,943	1,558	46	....	6,879	6,879	42,272*
Jackson...........	U	3,562	7,442	51,131	2,387	11	....	64,533		
	B	1,189	573	23,939	1,866	....	....	27,567	92,100	315,418
†Jasper............	U	....	3,304	14,957	2,352	....	....	20,613		
	B	....	2,769	5,889	576	....	....	9,234	29,847	165,747
Jefferson..........	U	....	5,977	26,347	948	....	....	33,272		
	B	....	1,583	2,612	....	....	....	4,195	37,467	218,770
Jersey............	U	....	7,573	34,330	643	16	....	42,562		
	B	....	332	3,952	224	....	....	4,508	47,070	170,601
Jo Daviess.........	U	....	1,827	47,296	1,385	....	....	50,508		
	B	....	7	168	9,355	....	....	9,530	60,038	292,153
Johnson...........	U	341	20,438	24,986	3,695	38	....	49,498		
	B	282	27	3,345	6,276	93	....	10,023		
	Cyp.	....	....	1,910	3,347	....	....	5,257	64,778	215,040*
Kane..............	U	....	924	6,611	1,151	....	....	8,686	8,686	103,934*
°Kankakee.........	U	....	198	2,946	928	28	....	4,100	4,100	32,448*
Kendall...........	U	....	96	3,184	4,743	....	....	8,023		
	B	....	....	340	479	....	....	819	8,842	49,245
Knox..............	U	26	1,641	32,631	1,103	....	....	35,401		
	B	....	90	774	....	....	....	864	36,265	152,422*

†La Salle	U	......	1,096	20,268	7,267	274	......	28,905	28,905	103,788*
Lake	U	......	1,392	15,713	1,582	34	......	18,721		
	B	......	59	244	160	......	......	463		
	T	......	145	......	......	......	......	145		
	P	......	......	20	......	......	......	20	19,349	159,342*
Lawrence	U	35	2,291	7,498	2,339	......	......	12,169		
	B	......	4,261	5,059	2,915	59	......	12,294	24,457	184,495
Lee	U	......	238	9,341	1,351	60	......	10,990	10,990	45,696*
°Livingston	U	......	309	4,599	1,449	43	......	6,400	6,400	28,806*
°Logan	U	......	183	2,721	857	25	......	3,786	3,786	30,874
McDonough	U	218	5,126	15,685	1,211	220	......	22,460	22,460	119,001*
McHenry	U	......	1,589	4,829	211	......	......	6,629		
	B	......	31	61	......	......	......	92		
	T	......	12	......	......	......	......	12	6,733	133,044*
°McLean	U	......	353	5,252	1,655	49	......	7,309	7,309	76,723*
°Macon	U	......	173	2,580	813	24	......	3,590	3,590	55,636*
Macoupin	U	......	18,096	41,416	1,424	......	......	60,936	60,936	273,938
Madison	U	......	4,147	13,071	5,985	243	......	23,446		
	B	......	159	1,497	3,870	513	......	6,039	29,485	278,553
Marion	U	......	12,451	28,446	537	......	......	41,434		
	B	......	55	824	......	......	......	879		198,208*
†Marshall	U	98	......	17,018	1,054	......	......	18,170		
	B	......	8,382	......	......	......	......	8,382	26,552	119,103
°Mason	U	93	2,025	28,671	1,277	31	......	32,097		
	B	......	4,987	714	729	46	......	6,476	38,573	118,977*
Massac	U	17	255	6,957	1,182	13	......	8.424		
	B	1,036	757	4,200	11,579	1,344	......	18,916		
	Cyp.	......	......	117	3,982	115	50	4,264	31,604	130,253
°Menard	U	53	1,157	16,376	729	18	......	18,333		
	B	......	2,849	408	416	26	......	3,699	22,032	79,655
Mercer	U	117	394	17,419	1,694	......	......	19,624		
	B	......	791	6,662	46	......	......	7.499	27,123	131,239*
Monroe	U	......	3,164	43,078	6,524	......	......	52,766		
	B	......	5	1,452	3,417	278	......	5,152	57,918	231,968*
†Montgomery	U	......	12,676	31,335	2,083	79	......	46,173		
	B	......	129	196	......	......	......	325	46,498	143,572
Morgan	U	......	862	10,855	985	18	......	12,720		
	B	......	170	1,776	......	......	......	1,946	14,666	179,708
°Moultrie	U	......	100	1,490	470	14	......	2,074	2,074	39,181*

FOREST ACREAGE BY COUNTIES—Concluded

Counties	Type	Present (1924) acreage								Original
		Cull	Sapling	No. 1	No. 2	No. 3	No. 4	Total	County total	County total
Ogle	U	......	1,925	22,192	3,447	......	......	27,564		
	P	......	......	......	......	......	193	......	27,757	110,970*
Peoria	U	131	2,108	44,587	1,089	125	......	48,040		
	B	......	1,977	33	......	......	......	2,010	50,050	223,907*
Perry	U	......	9,597	34,871	3,071	101	......	47,640		
	B	75	1,758	8,528	2,687	116	......	13,164	60,804	184,716
°Piatt	U	......	134	1,989	627	18	......	2,768	2,768	27,780
Pike	U	14	4,249	24,394	2,752	237	......	31,691		
	B	......	114	1,683	......	22	......	1,819	33,510	360,275*
Pope	U	141	23,715	33,626	2,855	60	......	60,397		
	B	131	......	1,442	1,059	......	30	2,662		
	Cyp.	......	......	2,200	......	......	......	2,200	65,259	208,608
Pulaski	U	14	......	1,340	64	41	......	1,459		
	B	5,936	215	7,820	2,514	400	40	16,925		
	Cyp.	......	......	4,568	96	484	......	5,148	23,532	103,117
†Putnam	U	......	......	5,408	1,209	......	......	6,617		
	B	......	12,630	......	......	......	......	12,630	19,247	58,402
Randolph	U	265	5,789	53,002	7,735	201	......	66,992		
	B	......	276	3,810	5,757	3,394	......	13,237	80,229	294,753*
Richland	U	......	2,322	13,425	1,418	44	......	17,209		
	B	......	841	3,599	691	116	......	5,247	22,456	152,922*
Rock Island	U	......	3,065	22,461	1,999	......	......	27,525		
	B	......	3,123	2,239	2,592	......	......	7,954	35,479	162,604*
St. Clair	U	......	850	9,432	6,828	902	......	18,012		
	B	......	1,115	7,905	19,110	1,454	349	29,933	47,945	291,030
Saline	U	139	3,842	20,199	315	32	......	24,527		
	B	13	167	9,816	......	......	......	9,996	34,523	207,059*
°Sangamon	U	146	3,196	45,254	2,015	49	......	50,660		
	B	......	7,872	1,127	1,151	73	......	10,223	60,883	110,558*
Schuyler	U	......	7,095	26,550	1,106	......	......	34,751		
	B	......	......	1,875	940	......	......	2,815	37,566	220,857

Scott........	U	......	806	8,827	675	......	......	10,308		
	B	......	......	464	......	......	......	464	10,772	85,056*
°Shelby........	U	......	8,112	25,852	1,501	86	......	35,551		
	B	......	3,490	7,954	935	14	......	12,393	47,944	192,920*
Stark........	U	......	36	5,905	808	......	......	6,749	6,749	29,622
Stephenson........	U	......	750	9,662	534	......	......	10,946		
	B	......	......	927	147	......	......	1,074	12,020	132,430
°Tazewell........	U	108	2,361	33,424	1,488	36	......	37,417		
	B	......	5,814	832	850	54	......	7,550	44,967	166,054*
Union........	U	2,165	4,436	41,122	11,313	511	16	59,563		
	B	861	997	8,018	1,690	33	......	11,599		
	Cyp.	......	......	1,158	131	......	......	1,289		
	P	......	......	200	......	......	......	200	72,651	218,802
°Vermilion........	U	......	273	4,061	1,280	38	......	5,652	5,652	138,311*
Wabash........	U	11	686	2,202	2,228	35	......	5,162		
	B	......	347	2,156	2,233	224	......	4,960	10,122	117,321
Warren........	U	......	350	14,603	2,346	......	......	17,299	17,299	132,603
Washington........	U	......	5,469	25,732	3,650	40	......	34,891		
	B	......	275	5,827	8,157	2,062	......	16,321	51,212	209,037
Wayne........	U	......	2,449	16,351	1,109	24	......	19,933		
	B	......	28,236	20,503	1,202	......	......	49,941	69,874	347,470
White........	U	......	1,094	7,540	1,090	114	......	9,838		
	B	......	2,596	6,525	109	82	......	9,312	19,150	252,054*
Whiteside........	U	72	699	5,819	2,932	23	......	9,545		
	B	......	680	2,399	3,967	62	......	7,108	16,653	125,984*
†Will........	U	......	1,386	15,493	797	......	......	17,676		
	B	......	......	2,202	......	......	......	2,202	19,878	53,056*
Williamson........	U	117	8,296	15,114	249	28	......	23,804		
	B	81	1,077	14,411	560	......	......	16,129	39,933	243,687
Winnebago........	U	......	2,278	11,137	1,521	......	......	14,936		
	B	......	108	2,211	622	......	......	2,941	17,877	129,338*
°Woodford........	U	88	1,927	27,276	1,215	29	......	30,535		
	B	......	4,745	679	694	44	......	6,162	36,697	98,621*
Total........	U	18,343	327,158	1,733,433	197,019	5,755	16	2,281,724		
	B	15,610	178,984	363,957	144,410	14,766	419	718,146		
	Cyp.	......	......	13,000	7,556	599	50	21,205		
	P	......	......	220	......	......	198	418		
	T	......	157	......	......	......	......	157	3,021,650	15,273,245

PLATE I

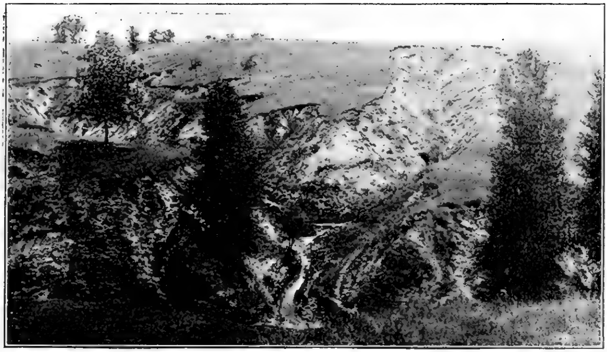
WASTE LAND.

Dune sand, Mason county. Illinois has 300,000 acres of sand.

THE CROP.

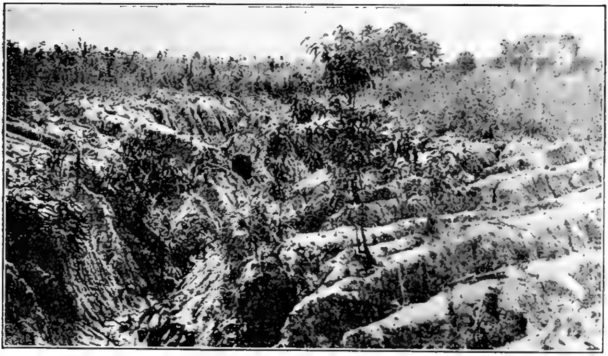
Twenty-year old white pine on dune sand.

PLATE II



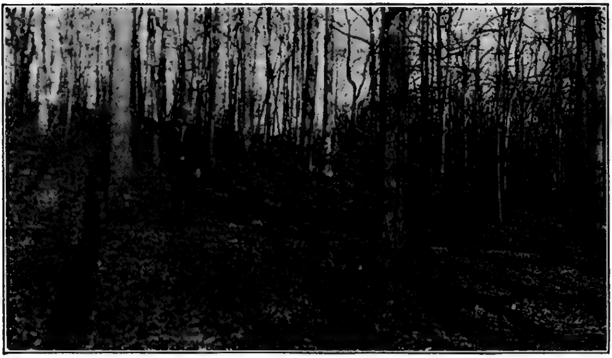
WASTE LAND.

Eroded upland, Carroll county.



Eroded upland, Union county. Illinois has nearly 5,000,000 acres of broken upland where cover crops are essential.

PLATE III



THE CROP

A 70-year old stand of white oak on broken upland, Randolph county.

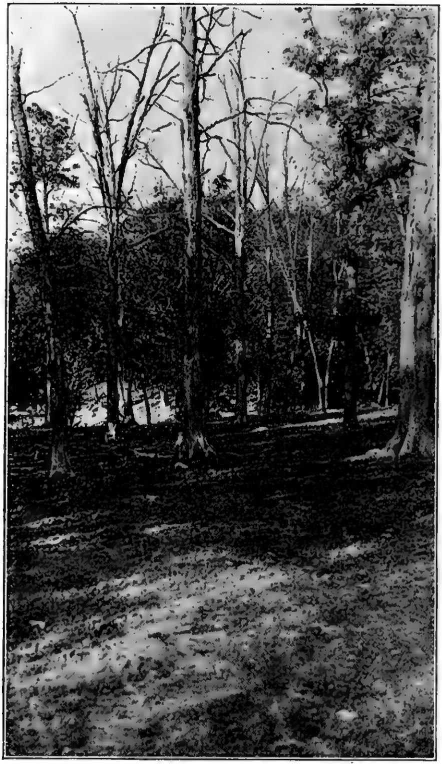
A wood-lot on broken upland in Union county yielding high-grade veneer oak.

PLATE IV

GRAZING DESTROYS WOOD-LOTS.

Wood-lot in Lee county showing contrast between grazed and ungrazed areas.

PLATE V



GRAZING DESTROYS WOOD-LOTS.

Wasteful transition of wood-lot to pasture, Grundy county.

PLATE VI

Virgin upland post-oak forest. Perry county. The scrubby small trees usually live about a century, the occasional large veterans growing to three centuries. Yields are very low.

Virgin bottomland stand. Wabash county. Large trees are red gum. Yields are very high.

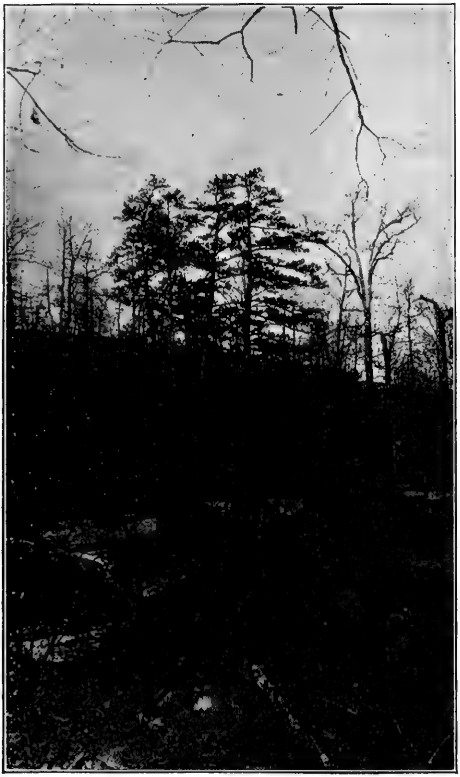
PLATE VII

OUTPOSTS.

Virgin bottomland cypress-tupelo gum stand. Massac county.

Tamarack bog. Lake county. (Photo by Waterman)

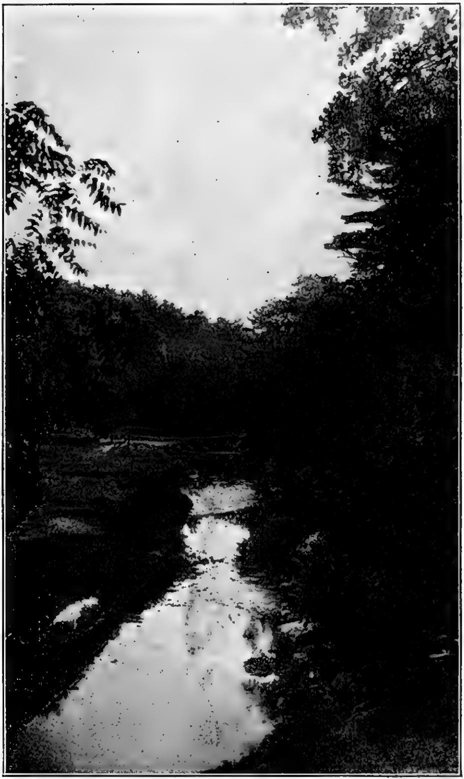
PLATE VIII



OUTPOSTS.

Northernmost group of short-leaf pine. Randolph county.

PLATE IX



OUTPOSTS.

Southernmost stand of white pine. Ogle county.

Part II. Growth and Yield Studies

The objects of the survey were twofold. The one included locating, mapping, and classifying the forests; the other was a study of the productiveness of different soils in terms of forest crops.

Growth studies were made upon individual trees, and upon plots. The studies on individual trees were made with the object of determining the average rate of growth in height, diameter, and cubic contents for a given species upon a given soil type. When a comparison is made of all species growing upon a given soil type these average growth rates show which are the fastest growing trees for that soil type. See Tables 1 and 2, pp. 78-80. When a comparison is made of the rates of growth of a single species on different types of soil, there is shown the soil type best fitted for that species. See Table 3, pp. 81-89. The studies on plots were made to determine the number of trees and volumes per acre producd on a fully stocked stand for virgin plots and for even-aged plots at ten year intervals.

(1) Studies of Growth Rates of Individual Trees

The chief factors which influence the rate of growth of a tree are (1) atmospheric, including temperature, light, humidity, and precipitation as the most important; (2) soil, including water contents, gas contents, soil composition, soil temperature, exposure, slope, character of the surface and altitude; (3) biotic, or plants and animals which react upon forest vegetation. It is impossible to secure exact duplication of these dozen or more factors even in trees growing upon the same acre, hence there results a variation in the rate of growth of individual trees quite independent of the variation due to qualities inherent in different species. In the effort to standardize as far as possible those factors which influence the rate of growth of a given species, all measurements were made on plantation or forest-grown trees; the soil type as identified by the State Soil Survey was used as a basis for soil standardization; the measurements were worked up for trees growing in even-aged stands and all-aged stands separately; and as many felled trees as possible were measured. Average, rather than abnormally rapid or slow growing trees, were measured. No division is made between data collected in different parts of the state, other than those derived from even or uneven aged stands and from the soil type.

Under the soil survey made by the University of Illinois Agricultural Experiment Station, the soils have been classified as unglaciated or as belonging to a definite period of glaciation; and as bottomland and swamp, or upland timber and prairie; and some 150 different types have been identified in the 93 counties surveyed. A list of those counties for which information is available is given on page 83. This information gives, for any definite area, the soil types represented and a description of the physical and chemical characters for each type.

The studies of growth rates are based upon this system of soil classification and are carried on separately for bottomland and upland soils as classified by the Soil Survey, but, with a single exception, separate studies were not made for growth rates when the same soil type was found on unglaciated and glaciated areas, or on areas of different periods of glaciation. The growth rates for certain acidulous upland soils of the lower Illinoisan area of glaciation were found to be so markedly lower than for similar soil types elsewhere that a special grouping of studies on these soils is made under the title Illinoisan.

The studies are incomplete in that the investigation of the growth rates for a given species was not made on each soil type upon which the species grows, nor were sufficient data collected to determine with finality the varying degrees to which growth is influenced by soil and site conditions, but the studies do show the general growth relations for the various commoner species of the state on the common soil types.

A diameter of 10 inches inside the bark on the stump is adopted as the minimum diameter at which trees will be harvested for sawlogs or for railroad ties. Such a tree will produce but one first-class tie, and in sawlog operations a 12″ stump D. I. B. more nearly represents the average cutting limit. Comparison of the periods required to attain this merchantable size (Table 1, pp. 78-79) brings out the facts that (1) on the same soil type, trees grown in even-aged stands require a shorter period than those grown in all-aged stands, that (2) there may be a very great difference in this period for different species on the same soil type, and that (3) the difference in this period for the same species growing on different soil types is not so marked.

(1) That trees grown in even-aged stands require a shorter period than those grown in all-aged stands to attain such a relatively low diameter as 10 inches is shown by the following tabulation.

Species	Soil type	Period required to attain a stump D.i.b. of 10 inches, years	
		Even-aged	All-aged
Ash	Yellow-gray silt loam	50	78
Hickory	Yellow silt loam	69	72
Swamp Spanish oak	Yellow-gray silt loam	54	58
Pin oak	Deep gray silt loam	40	50
White oak	Yellow fine sandy loam	41	62
	Yellow-gray silt loam	57	97
	Yellow silt loam	64	96
Black oak	Yellow silt loam	60	57

These six species are the only ones on which studies have been made for trees grown in both even and uneven aged stands on the same soil type. With the exception of black oak, the trees grown in all-aged stands had not yet made up for the period of initial suppression and overcome the lead of the trees grown in even-aged stands. The fact that ash on yellow-gray silt loam attained a merchantable size in 50 years grown in even-aged stands while it required 78 years to attain the same size in all-aged stands does not necessarily mean that the yields per acre are greater for the even-aged than for the all-aged, because during this initial period of suppression the area in all-aged forest is producing two crops, whereas the even-aged stand has full possession of the soil from the beginning. The importance of this study is rather in the fact that there is established a standard period required to produce merchantable sawlog or tie material when trees are grown under the more uniform conditions, such as prevail in fully stocked, even-aged stands.

(2) That there may be a very great difference in the interval required to attain merchantable size for different species on the same soil type is shown by the following tabulation.

Soil type	Interval required to produce 10" trees			
	Species	Min. years	Species	Max. years
Yellow fine sandy silt loam	Black walnut	36	Hickory	86
Yellow-gray silt loam	White pine	21	White oak	57
Yellow silt loam	Tulip	37	Hickory	69
Sand	Black locust	35	Black oak	53
Bottomland gray fine sandy loam	Cottonwood	8	Elm	101
Bottomland deep gray silt loam	Pin oak	40	Hickory	85
Bottomland drab clay	Water locust	26	Tupelo gum	75

It so happens that, of all the species studied, the fastest and the slowest diameter growth up to a 10-inch diameter was made on the same soil type. The cottonwood on bottomland gray fine sandy loam attained this average diameter in the remarkably short period of 8 years, and elm required 101 years. This contrast is modified somewhat by the fact that the cottonwood was in an even-aged group while the elm had grown in an all-aged group—yet both grew in the same stand. In the case of bottomland deep gray silt loam, pin oak and hickory grew in the same all-aged stand, yet the hickory required twice the period of pin oak to attain a merchantable size. It is apparent that in general two to three crops of the fastest growing trees come into merchantable size in the period required to grow one crop of the slowest growing trees; and the waste of permitting these slow growing trees to monopolize the site becomes more apparent when it is seen that these fast growing trees produce also the more valuable crops, rated on a board foot basis.

Although a minimum stump D. I. B. of 10 inches is used as a standard to measure the period required for a species to attain a merchantable size, the relative rating of trees for a given soil should include both diameter and height growth. The two are expressed in cubic contents, and the cubic contents grown for each 20-year period for all different species studied on a given soil type are shown in the tabulation, on pp. 72-80.

(3) That the difference in the period required to attain a merchantable size for the same species growing on different soil types is not so marked is shown by the following tabulation.

Species	Soil type	Intervals required to produce 10-inch trees	
		Even-aged	All-aged
Ash	Bottomland deep gray silt loam	....	42
"	Bottomland drab clay	....	53
"	Upland yellow fine sandy silt loam	....	66
"	Upland yellow-gray silt loam	50	78
Cottonwood	Bottomland gray fine sandy loam	8	
"	Bottomland river wash	12	
"	Upland brown prairie loam	26	
Elm	Upland yellow fine sandy silt loam	....	62
"	Bottomland drab clay	....	61
"	Bottomland gray fine sandy loam	....	101
Hickory	Bottomland deep gray silt loam	....	85
"	Upland yellow silt loam	69	72
"	Upland yellow fine sandy silt loam	....	86
"	Upland yellow-gray silt loam	....	93
Hard maple	Upland yellow fine sandy silt loam	....	76
" "	Bottomland yellow-gray silt loam	....	93
Soft maple	Bottomland gray fine sandy loam	26	
" "	Bottomland drab clay	....	32
Pin oak	Bottomland drab clay	....	29
" "	Bottomland deep gray silt loam	30	40
Red oak	Upland yellow fine sandy silt loam	....	52
" "	Upland yellow silt loam	....	56
" "	Upland yellow-gray silt loam	52	
" "	Upland red-brown fine sandy silt loam	....	66
Black oak	Upland yellow-gray sandy loam	44	
" "	Upland yellow-gray silt loam	52	
" "	Upland red-brown fine sandy silt loam	....	72
" "	Upland sand	53	
" "	Upland yellow silt loam	60	57
" "	Upland Illinoisan yellow-gray silt loam	63	
Post oak	Upland light gray silt loam on tight clay	....	66
" "	Upland yellow-gray silt loam	66	
" "	Bottomland yellow-gray silt loam on clay	....	74
White oak	Upland yellow-gray sandy loam	41	62
" "	Upland yellow silt loam	64	96
" "	Upland yellow-gray silt loam	57	97
Tulip poplar	Upland yellow fine sandy silt loam	....	42
" "	Upland yellow silt loam	....	37
Black walnut	Upland yellow fine sandy silt loam	....	36
" "	Prairie brown silt loam	40	
" "	Prairie black clay loam	49	

For the species studied, the difference in time required to attain a merchantable size is greatest for the elm and this difference is but 40 years. In the case of the white and the black oaks, where the studies have been the more complete, there is surprisingly little difference due to soil in the interval required to attain a merchantable diameter. Black oak in even-aged stands on upland yellow-gray sandy loam attained such a diameter in 44 years, on upland yellow-gray silt loam in 52 years, on dune sand in 53 years, on upland yellow silt loam in 60 years and on the heavy yellow-gray silt loams of the Illinoisan in 63 years. The influence of soil is more accurately reflected in the height growth than in diameter growth. Thus 55-year old black oak on upland yellow-gray sandy loam has a height of 61 feet, on upland yellow-gray silt loam of 55 feet, on upland yellow silt loam of 55 feet, on dune sand of 50 feet, and on the Illinoisan yellow-gray silt loam of but 40 feet. Since height and diameter determine the cubic contents, the ratings of the productiveness of soils for any given species is best expressed by cubic contents. Such a rating is shown in Table 3, pp. 72-80, in which E signifies even-aged stand, and A equals all-aged stand.

TABLE 1.—AVERAGE GROWTH IN CUBIC FEET SHOWING SPECIES BEST SUITED TO THE SPECIFIC SOIL TYPE

UPLAND SOILS

Species	20 Yrs.		40 Yrs.		60 Yrs.		80 Yrs.		100 Yrs.		150 Yrs.		Years reqiured to attain a minimum sawlog or tie size of 10-in. stump D. i. b.	
	E*	A†	E	A	E	A	E	A	E	A	E	A	E	A
Yellow fine sandy silt loam														
Black walnut	.....	1.6	.....	19.8	.....	51.5	.....	81.5	.....	.....	.....	.....	.....	36
Tulip	.....	.5	.....	6.4	.....	26.0	.....	68.2	.....	124.1	.....	.....	.....	42
Red oak	.....	.5	.....	2.3	.....	12.6	.....	55.6	.....	.....	.....	.....	.....	52
Basswood	.....	.6	.....	2.4	.....	11.2	.....	33.9	.....	70.6	.....	.....	.....	60
Elm	.....	.6	.....	2.3	.....	10.3	.....	27.3	.....	58.3	.....	135.5	.....	62
Ash	.....	.4	.....	2.0	.....	8.8	.....	27.2	.....	47.3	.....	122.0	.....	66
Hard maple	.....	.4	.....	2.0	.....	6.4	.....	17.2	.....	40.5	.....	121.3	.....	76
Hickory	.....	.4	.....	2.0	.....	6.1	.....	14.3	.....	28.7	.....	82.6	.....	86
Yellow fine sandy loam														
Beech	.....	.3	.....	1.0	.....	2.5	.....	7.7	.....	20.3	.....	84.6	.....	91
Yellow-gray sandy loam														
Black oak	1.3	.....	8.4	.....	27.1	.....	52.7	.....	.....	.....	.....	.....	44	
White oak	1.2	.5	7.9	3.0	21.1	13.1	40.1	32.1	.....	51.7	.....	118.6	41	62
Red-brown fine sandy silt loam														
Red oak	.....	.8	.....	2.8	.....	8.7	.....	23.8	.....	48.5	.....	.....	.....	66
Black oak	.....	.7	.....	2.3	.....	7.8	.....	22.0	.....	43.7	.....	.....	.....	72
Yellow-gray silt loam														
White pine	3.6	.....	31.1	.....	63.6	.....	.....	.....	.....	.....	.....	.....	21	
Red oak	.7	.....	4.1	.....	17.8	.....	39.4	.....	.....	.....	.....	.....	52	
Black oak	1.0	.....	5.2	.....	18.6	.....	37.3	.....	.....	.....	.....	.....	52	
Ash	1.1	.2	5.2	1.4	15.9	5.5	32.2	15.4	50.1	25.4	.....	59.2	50	78
Shingle oak	.....	.7	.....	3.1	.....	11.5	.....	27.3	.....	35.7	.....	.....	.....	60

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*E—Trees grown in even-aged stands. †A—Trees grown in all-aged stands.

TABLE 1.—AVERAGE GROWTH IN CUBIC FEET SHOWING SPECIES BEST SUITED TO THE SPECIFIC SOIL TYPE
UPLAND SOILS—Concluded

Species	20 Yrs.		40 Yrs.		60 Yrs.		80 Yrs.		100 Yrs.		150 Yrs.		Years required to attain a minimum saw-log or tie size of 10-in. stump D. i. b.	
	E*	A†	E	A	E	A	E	A	E	A	E	A	E	A
Yellow-gray silt loam—Concluded														
Hard maple	.....	.4	.....	1.5	.....	3.8	.....	10.0	.....	18.9	.....	46.3	.....	93
Hickory	.....	.4	.....	1.6	.....	3.5	.....	9.2	.....	17.8	.....	48.5	.....	93
White oak	.5	.1	3.0	.9	11.6	2.3	.....	4.6	.....	9.6	.....	28.8	57	97
Yellow silt loam														
Tulip	.....	2.1	.....	12.1	.....	30.3	.....	53.2	.....	.....	.....	.....	.....	37
Red oak	.....	.7	.....	3.4	.....	15.5	.....	42.7	.....	.....	.....	.....	.....	56
Black oak	.8	.8	3.7	3.7	13.4	13.6	26.7	32.1	.....	49.0	.....	.....	60	57
Hickory	.....	.5	.....	2.1	.....	6.5	.....	18.5	.....	31.2	.....	.....	.....	72
White oak	.6	.3	2.9	1.5	9.9	3.2	.....	7.1	.....	12.5	.....	35.7	64	96
Prairie brown silt loam														
Cottonwood	3.5	.....	33.2	.....	71.9	.....	.....	.....	.....	.....	.....	.....	26	
Black walnut	1.5	.....	11.1	.....	.....	.....	.....	.....	.....	.....	.....	.....	40	
Prairie black clay loam														
Black walnut	1.4	.....	8.4	.....	.....	.....	.....	.....	.....	.....	.....	.....	49	
Sand														
Black locust	2.4	.....	16.1	.....	.....	.....	.....	.....	.....	.....	.....	.....	35	
Black oak	1.0	.....	5.2	.....	13.6	.....	.....	.....	.....	.....	.....	.....	53	
Illinoisan light gray silt loam on tight clay														
Post oak	.....	.7	.....	2.8	.....	7.8	.....	.....	.....	.....	.....	.....	.....	66
Illinoisan yellow-gray silt loam														
Black oak	.8	.....	3.1	.....	8.1	.....	.....	.....	.....	.....	.....	.....	63	
Post oak	.2	.....	1.5	.....	5.1	.....	.....	.....	.....	.....	.....	.....	66	
Illinoisan yellow-gray silt loam on clay														
Post oak	.....	.3	.....	1.3	.....	4.1	.....	.....	.....	.....	.....	.....	.....	74

TABLE 2.—AVERAGE GROWTH IN CUBIC FEET SHOWING SPECIES BEST SUITED TO THE SPECIFIC SOIL TYPE

BOTTOMLAND SOILS

Species	20 Yrs.		40 Yrs.		60 Yrs.		80 Yrs.		100 Yrs.		150 Yrs.		Years reqiured to attain a minimum saw-log or tie size of 10-in. stump D. i. b.	
	E	A	E	A	E	A	E	A	E	A	E	A	E	A
						Gray fine sandy loam								
Cottonwood	70.3	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	8	
Sycamore	.....	10.8	.....	62.9	.....	101.8	.....	138.9	.....	.....	.....	.....	.....	22
Soft maple	4.5	.....	53.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	26	
Elm	.....	.7	.....	2.0	.....	3.9	.....	6.5	.....	13.4	.....	37.6	.....	101
						River wash								
Cottonwood	37.7	.....	96.7	.....	161.0	.....	.....	.....	.....	.....	.....	.....	12	
						Deep-gray silt loam								
Pin oak	3.1	1.9	23.6	10.4	.....	38.7	.....	74.3	.....	.....	.....	.....	30	40
Ash	.....	1.3	.....	10.0	.....	30.4	.....	55.4	.....	.....	.....	.....	.....	42
Schneck's oak	.8	.....	6.2	.....	33.4	.....	.....	.....	.....	.....	.....	.....	46	
Hickory	.....	.4	.....	1.5	.....	4.7	.....	13.7	.....	22.9	.....	42.3	.....	85
						Drab clay								
Honey locust	.....	2.3	.....	25.8	.....	72.0	.....	138.2	.....	191.3	.....	.....	.....	31
Water locust	.....	5.2	.....	28.5	.....	57.6	.....	.....	.....	.....	.....	.....	.....	26
Pin oak	.....	2.5	.....	25.7	.....	66.9	.....	129.9	.....	.....	.....	.....	.....	29
Soft maple	.....	2.1	.....	23.4	.....	72.0	.....	123.9	.....	.....	.....	.....	.....	32
Ash	.....	.9	.....	4.7	.....	17.0	.....	37.1	.....	50.3	.....	71.5	.....	53
Hackberry	.....	.7	.....	3.3	.....	12.1	.....	28.4	.....	45.3	.....	108.7	.....	61
Elm	.....	.7	.....	3.3	.....	11.3	.....	25.7	.....	41.0	.....	97.2	.....	61
Tupelo gum	.....	.7	.....	2.6	.....	6.4	.....	13.4	.....	23.4	.....	63.9	.....	75
						Yellow-gray silt loam								
Swamp Spanish oak	1.0	.8	4.9	4.3	14.9	13.6	29.9	29.8	.....	.....	.....	.....	54	58

TABLE 3.—AVERAGE GROWTH-RATES ON SPECIFIC SOIL-TYPES BY 20-YEAR PERIODS FOR 25 TREE SPECIES TO SHOW SOIL TYPE BEST SUITED TO SPECIES

Soil type	20		40		60		80		100		150		Basic trees	
	E*	A†	E	A	E	A	E	A	E	A	E	A	E	A
						Ash								
					Stump D. i. b. Inches									
Deep gray silt loam—B‡	.....	3.9	.....	9.6	.....	13.7	.....	17.3	.....	.....	.....	.....	...	9
Drab clay	.....	3.7	.....	7.6	.....	11.2	.....	14.6	.....	16.4	.....	19.0	...	10
Yellow fine sandy silt loam—U§	.....	1.8	.....	4.7	.....	8.2	.....	12.2	.....	15.4	.....	24.0	...	14
Yellow-gray silt loam—U	3.9	1.5	7.9	3.7	11.6	7.3	13.9	10.2	16.6	12.0	.....	17.3	10	6
					Height. Feet									
D. G. S. L.	.....	30	.....	54	.....	74	.....	86						
D. C.	.....	21	.....	43	.....	64	.....	79	.....	87	.....	93		
Y. F. S. S. L.	.....	19	.....	39	.....	62	.....	83	.....	94	.....	105		
Y. G. S. L.	26	14	44	34	58	52	78	68	84	80	.....	93		
					Contents. Cubic Feet									
D. G. S. L.	.....	1.3	.....	10.0	.....	30.4	.....	55.4						
D. C.	.....	.9	.....	4.7	.....	17.0	.....	37.1	.....	50.3	.....	71.5		
Y. F. S. S. L.	.....	.4	.....	2.0	.....	8.8	.....	27.2	.....	47.3	.....	122.0		
Y. G. S. L.	1.1	.2	5.2	1.4	15.9	5.5	32.2	15.4	50.1	25.4	.....	59.2		
						Basswood								
					Stump D. i. b. Inches									
Yellow fine sandy silt loam	.....	2.4	.....	5.7	.....	10.0	.....	15.2	.....	20.0	.....	.....	...	10
					Height. Feet									
	.....	19	.....	37	.....	55	.....	68	.....	80				
					Contents. Cubic Feet									
	.....	.6	.....	2.4	.....	11.2	.....	33.9	.....	70.6				

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*E=Trees grown in even-aged stands.
†A=Trees grown in all-aged stands.
‡B=Bottomland soil type.
§U=Upland soil type.

Average Growth-Rates on Specific Soil-Types by 20-Year Periods for 25 Tree Species to show Soil Type Best Suited to Species—Continued

Soil type	20		40		60		80		100		150		Basic trees	
	E*	A†	E	A	E	A	E	A	E	A	E	A	E	A
Beech														
Stump D. i. b. Inches														
Yellow fine sandy loam—U	.....	1.6	.....	3.2	.....	5.3	.....	8.2	.....	11.6	.....	20.8	...	10
Height. Feet														
	.....	15	.....	29	.....	42	.....	56	.....	69	.....	91		
Contents. Cubic Feet														
	.....	.3	.....	1.0	.....	2.5	.....	7.7	.....	20.3	.....	84.6		
Cottonwood														
Stump D. i. b. Inches														
Gray fine sandy loam—B	18.6	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	...	10
River wash—B	14.5	.....	21.4	.....	.....	.....	.....	.....	.....	.....	.....	.....	...	26
Brown prairie loam—U	7.4	.....	15.6	.....	21.0	.....	.....	.....	.....	.....	.....	.....	...	8
Height. Feet														
G. F. S. L.	104	.....												
R. W.	93	.....	108	.....										
B. P. L.	33	.....	69	.....	82									
Contents. Cubic Feet														
G. F. S. L.	70.3	.....												
R. W.	37.7	.....	96.7	.....										
B. P. L.	3.5	.....	33.2	.....	71.9									
Elm														
Stump D. i. b. Inches														
Yellow fine sandy silt loam—U	.....	2.6	.....	5.6	.....	9.6	.....	13.6	.....	18.4	.....	26.2	...	13
Drab clay—B	.....	2.8	.....	6.6	.....	9.8	.....	13.2	.....	16.0	.....	24.0	...	10
Gray fine sandy loam—B	.....	2.2	.....	3.9	.....	5.2	.....	6.4	.....	9.1	.....	15.0	...	3
Height. Feet														
Y. F. S. S. L.	.....	19	.....	37	.....	55	.....	68	.....	79	.....	91		
D. C.	.....	28	.....	41	.....	57	.....	68	.....	73	.....	77		
G. F. S. L.	.....	24	.....	45	.....	60	.....	70	.....	74	.....	77		

Contents. Cubic Feet														
Y. F. S. S. L.	.....	.6	.....	2.3	.....	10.3	.....	27.3	.....	58.3	.....	135.5		
D. C.	.....	.7	.....	3.3	.....	11.3	.....	25.7	.....	41.0	.....	97.2		
G. F. S. L.	.....	.7	.....	2.0	.....	3.9	.....	6.5	.....	13.4	.....	37.6		
Gum, Tupelo														
Stump D. i. b. Inches														
Drab clay	.....	3.0	.....	6.2	.....	8.3	.....	10.6	.....	13.0	.....	19.0	...	18
Height. Feet														
	.....	20	.....	36	.....	48	.....	58	.....	65	.....	81		
Contents. Cubic Feet														
	.....	.7	.....	2.6	.....	6.4	.....	13.4	.....	23.4	.....	63.9		
Hackberry														
Stump D. i. b. Inches														
Drab clay	.....	2.3	.....	6.0	.....	9.7	.....	13.6	.....	16.5	.....	25.4	...	10
Height. Feet														
	.....	26	.....	48	.....	61	.....	70	.....	76	.....	77		
Contents. Cubic Feet														
	.....	.7	.....	3.3	.....	12.1	.....	28.4	.....	45.3	.....	108.7		
Hickory														
Stump D. i. b. Inches														
Yellow silt loam—U	2.4	2.2	4.8	5.4	8.5	8.2	.....	11.8	.....	13.8	.....	.....	10	10
Deep gray silt loam—B.	.....	1.7	.....	3.8	.....	6.8	.....	9.2	.....	11.7	.....	15.4	...	24
Yellow fine sandy silt loam—U	.....	1.4	.....	3.5	.....	6.4	.....	9.1	.....	12.3	.....	20.0	...	9
Yellow-gray silt loam—U	.....	1.4	.....	3.0	.....	5.4	.....	8.4	.....	10.8	.....	15.9	...	10
Height. Feet														
Y. S. L.	.....	18	.....	35	.....	50	.....	63	.....	75				
D. G. S. L.	.....	18	.....	35	.....	52	.....	66	.....	76	.....	82		
Y. F. S. S. L.	.....	25	.....	48	.....	67	.....	78	.....	87	.....	97		
Y. G. S. L.	.....	26	.....	45	.....	54	.....	62	.....	70	.....	90		
Contents. Cubic Feet														
Y. S. L.	.....	.5	.....	2.1	.....	6.5	.....	18.5	.....	31.2				
D. G. S. L.	.....	.4	.....	1.5	.....	4.7	.....	13.7	.....	22.9	.....	42.3		
Y. F. S. S. L.	.....	.4	.....	2.0	.....	6.1	.....	14.3	.....	28.7	.....	82.6		
Y. G. S. L.	.....	.4	.....	1.6	.....	3.5	.....	9.2	.....	17.8	.....	48.5		

Average Growth-Rates on Specific Soil-Types by 20-Year Periods for 25 Tree Species to show Soil Type Best Suited to Species—Continued

Soil type	20		40		60		80		100		150		Basic trees	
	E*	A†	E	A	E	A	E	A	E	A	E	A	E	A
Locust, Black														
Stump D. i. b. Inches														
Sand—U	5.6	.....	11.4	.....	.....	.....	.....	.....	.....	.....	.....	.....	10	
Height. Feet														
	38	.....	60											
Contents. Cubic Feet														
	2.4	.....	16.1											
Locust, Honey														
Stump D. i. b. Inches														
Drab clay—B	.....	5.7	.....	13.5	.....	20.0	.....	27.0	.....	31.5	.....	.....	...	4
Height. Feet														
	.....	33	.....	66	.....	82	.....	87	.....	89				
Contents. Cubic Feet														
	.....	2.3	.....	25.8	.....	72.0	.....	138.2	.....	191.3				
Locust, Water														
Stump D. i. b. Inches														
Drab clay—B	.....	7.6	.....	14.4	.....	18.2	.....	.....	.....	.....	.....	.....	...	10
Height. Feet														
	.....	47	.....	65	.....	80								
Contents. Cubic Feet														
	.....	5.2	.....	28.5	.....	57.6								
Maple, Hard														
Stump D. i. b. Inches														
Yellow fine sandy silt loam—U	.....	2.1	.....	5.1	.....	7.6	.....	10.6	.....	15.1	.....	24.8	...	10
Yellow-gray silt loam—B	.....	1.8	.....	3.6	.....	6.1	.....	8.7	.....	11.0	.....	15.4	...	10

Height. Feet														
Y. F. S. S. L.	.....	17	.....	35	.....	55	.....	70	.....	82	.....	90		
Y. G. S. L.	.....	18	.....	38	.....	52	.....	63	.....	72	.....	91		
Contents. Cubic Feet														
Y. F. S. S. L.	.....	.4	.....	2.0	.....	6.4	.....	17.2	.....	40.5	.....	121.3		
Y. G. S. L.	.....	.4	.....	1.5	.....	3.8	.....	10.0	.....	18.9	.....	46.3		
Maple, Soft														
Stump D. i. b. Inches														
Gray fine sandy loam—B	7.1	....	17.1	.....	.....	.....	.....	.....	.....	.....	.....	.....	4	
Dray clay	.....	5.8	.....	13.0	.....	19.8	.....	24.8	.....	.....	.....	.....	...	7
Height. Feet														
G. F. S. L.	47	.....	84	.....										
D. C.	.....	32	.....	65	.....	84	.....	93						
Contents. Cubic Feet														
G. F. S. L.	4.5	.....	53.0	.....										
D. C.	.....	2.1	.....	23.4	.....	72.0	.....	123.9						
Oak, Pin														
Stump D. i. b. Inches														
Drab clay—B	.....	5.8	.....	15.4	.....	21.2	.....	27.6	.....	.....	.....	.....	...	10
Deep gray silt loam—B.	6.3	4.3	14.3	10.1	.....	16.6	.....	21.2	.....	.....	.....	.....	20	20
Height. Feet														
D. C.	.....	29	.....	59	.....	80	.....	90						
D. G. S. L.	32	29	63	58	.....	76	.....	88						
Contents. Cubic Feet														
D. C.	.....	2.5	.....	25.7	.....	66.9	.....	129.9						
D. G. S. L.	3.1	1.9	23.6	10.4	.....	38.7	.....	74.3						
Oak, Red														
Stump D. i. b. Inches														
Yellow fine sandy silt loam—U	.....	1.6	.....	3.7	.....	9.4	.....	17.7	.....	.....	.....	.....	...	3
Yellow silt loam—U	.....	2.5	.....	6.1	.....	11.0	.....	16.2	.....	.....	.....	.....	...	24
Yellow-gray silt loam—U	2.7	.....	7.0	.....	11.8	.....	16.1	.....	.....	.....	.....	.....	31	
Red-brown fine sandy silt loam—U	.....	2.4	.....	4.8	.....	8.4	.....	12.8	.....	17.3	.....	.....	...	9

Average Growth-Rates on Specific Soil-Types by 20-Year Periods for 25 Tree Species to show Soil Type Best Suited to Species—Continued

Soil type	20		40		60		80		100		150		Basic trees	
	E*	A†	E	A	E	A	E	A	E	A	E	A	E	A
Height. Feet														
Y. F. S. S. L.	.....	25	.....	45	.....	65	.....	81						
Y. S. L.	.....	22	.....	42	.....	60	.....	73						
Y. G. S. L.	.....	.....	41	.....	59	.....	68	.....						
R. B. F. S. S. L.	.....	25	.....	44	.....	57	.....	67	.....	73				
Contents. Cubic Feet														
Y. F. S. S. L.	.....	.5	.....	2.3	.....	12.6	.....	55.6						
Y. S. L.	.....	.7	.....	3.4	.....	15.5	.....	42.7						
Y. G. S. L.	.7	.....	4.1	.....	17.8	.....	39.4	.....						
R. B. F. S. S. L.	.....	.8	.....	2.8	.....	8.7	.....	23.8	.....	48.5				
Oak, Shingle														
Stump D. i. b. Inches														
Yellow-gray silt loam—U	.....	3.0	.....	6.4	.....	9.9	.....	13.6	.....	.....	.....	.....	...	6
Height. Feet														
	.....	20	.....	40	.....	57	.....	68						
Contents. Cubic Feet														
	.....	.7	.....	3.1	.....	11.5	.....	27.3						
Oak, Black														
Stump D. i. b. Inches														
Yellow-gray sandy loam—U	4.4	.....	9.2	.....	13.2	.....	17.4	.....	.....	.....	.....	.....	36	
Yellow-gray silt loam—U	3.5	.....	7.6	.....	11.6	.....	15.4	.....	.....	.....	.....	.....	61	
Red-brown fine sandy silt loam—U	.....	2.2	.....	4.6	.....	7.8	.....	11.7	.....	15.8	.....	.....	...	10
Sand—U	3.6	.....	7.8	.....	11.1	.....	.....	.....	.....	.....	.....	.....	59	
Yellow silt loam—U	3.0	2.9	6.4	6.6	10.0	10.5	12.9	14.3	.....	17.2	.....	.....	32	58
Illinoisan yellow-gray silt loam—U	3.3	.....	6.9	.....	9.7	.....	.....	.....	.....	.....	.....	.....	22	

Height. Feet														
Y. G. sandy L.	27	.....	51	.....	71	.....	80	.....						
Y. G. silt L.	25	.....	47	.....	64	.....	72	.....						
R. B. F. S. S. L.	.....	25	.....	44	.....	61	.....	73	.....	80				
S.	25	.....	45	.....	55	.....								
Y. S. L.	24	24	47	45	63	62	72	72	.....	76				
I. Y. G. S. L.	21	.....	35	.....	45	.....								
Contents. Cubic Feet														
Y. G. sandy L.	1.3	.....	8.4	.....	27.1	.....	52.7	.....						
Y. G. silt L.	1.0	.....	5.2	.....	18.6	.....	37.3	.....						
R. B. F. S. S. L.	.....	.7	.....	2.3	.....	7.8	.....	22.0	.....	43.7				
S.	1.0	.....	5.2	.....	13.6	.....								
Y. S. L.	.8	.8	3.7	3.7	13.4	13.6	26.7	32.1	.....	49.0				
I. Y. G. S. L.	.8	.....	3.1	.....	8.1	.....								
Oak, Swamp Spanish														
Stump D. i. b. Inches														
Yellow-gray silt loam—B	3.7	3.0	7.5	7.0	11.0	10.3	14.4	14.1	.....	.....	.....	.....	10	19
Height. Feet														
	23	23	46	46	60	61	66	69						
Contents. Cubic Feet														
	1.0	.8	4.9	4.3	14.9	13.6	29.9	29.8						
Oak, Schneck's														
Stump D. i. b. Inches														
Deep gray silt loam—B.	3.1	.....	8.3	.....	15.1	.....	.....	.....	.....	.....	.....	.....	10	
Height. Feet														
	24	.....	47	.....	68	.....								
Contents. Cubic Feet														
	.8	.....	6.2	.....	33.4	.....								
Oak, Post														
Stump D. i. b. Inches														
Light gray silt loam on tight clay—U	.....	3.5	.....	6.7	.....	9.6	.....	.....	.....	.....	.....	.....	...	10
Yellow-gray silt loam on clay—B	.....	1.6	.....	3.9	.....	6.9	.....	.....	.....	.....	.....	.....	...	10
Yellow-gray silt loam—U	1.7	.....	4.9	....	8.4	.....	.....	.....	.....	.....	.....	.....	29	

AVERAGE GROWTH-RATES ON SPECIFIC SOIL-TYPES BY 20-YEAR PERIODS FOR 25 TREE SPECIES TO SHOW SOIL TYPE BEST SUITED TO SPECIES—Concluded

Soil type	20		40		60		80		100		150		Basic trees	
	E*	A†	E	A	E	A	E	A	E	A	E	A	E	A
					Height.	*Feet*								
L. G. S. L. on T. C.	.....	18	.....	34	.....	46								
Y. G. S. L. on C.	.....	16	.....	31	.....	46								
Y. G. S. L.	14	.....	27	.....	40	.....								
					Contents.	*Cubic Feet*								
L. G. S. L. on T. C.	.....	.7	.....	2.8	.....	7.8								
L. G. S. L. on C.	.....	.3	.....	1.3	.....	4.1								
Y. G. S. L.	.2	.....	1.5	.....	5.1	.....								
					Oak, White									
					Stump D. i. b.	*Inches*								
Yellow-gray sandy loam —U	4.8	1.9	9.8	5.6	13.3	9.5	16.5	13.1	.....	16.2	.....	24.3	20	10
Yellow silt loam—U	2.7	1.7	6.1	3.9	9.4	6.1	.....	8.4	.....	10.4	.....	15.4	37	69
Yellow-gray silt loam—U	2.5	.9	6.4	2.7	10.6	4.7	.....	6.7	.....	9.2	.....	15.5	58	10
					Height.	*Feet*								
Y. G. sandy L.	22	24	45	48	60	69	70	86	.....	91	.....	92		
Y. S. L.	22	20	41	34	57	46	.....	53	.....	59	.....	71		
Y. G. silt L.	20	15	39	30	54	43	.....	54	.....	58	.....	60		
					Contents.	*Cubic Feet*								
Y. G. sandy L.	1.2	.5	7.9	3.0	21.1	13.1	40.1	32.1	.....	51.7	.....	118.6		
Y. S. L.	.6	.3	2.9	1.5	9.9	3.2	.....	7.1	.....	12.5	.....	35.7		
Y. G. silt L.	.5	.1	3.0	.9	11.6	2.3	.....	4.6	.....	9.6	.....	28.8		
					Pine, White									
					Stump D. i. b.	*Inches*								
Yellow-gray silt loam—U	8.6	.....	18.0	.....	22.6	.....	.....	.....	.....	.....	.....	.....	10	
					Height.	*Feet*								
	29	.....	64	.....	85	.....								
					Contents.	*Cubic Feet*								
	4.6	.....	43.2	.....	81.4	.....								

Sycamore													
Stump D. i. b. Inches													
Gray fine sandy loam—B	.....	8.8	.....	17.6	.....	22.1	.....	25.8	.....	.....	.....	.....	...	11
Height. Feet													
	.....	67	.....	96	.....	100	.....	101						
Contents. Cubic Feet													
	.....	10.8	.....	62.9	.....	101.8	.....	138.9						
Tulip-Poplar													
Stump D. i. b. Inches													
Yellow fine sandy silt loam—B	.....	2.9	.....	9.4	.....	14.9	.....	20.3	.....	25.8	.....	.....	...	10
Yellow silt loam—U	.....	5.6	.....	10.6	.....	14.2	.....	17.6	.....	.....	.....	.....	...	16
Height. Feet													
Y. F. S. S. L.	.....	19	.....	39	.....	62	.....	83	.....	94				
Y. S. L.	.....	33	.....	57	.....	75	.....	86						
Contents. Cubic Feet													
Y. F. S. S. L.	.....	.5	.....	6.4	.....	26.0	.....	68.2	.....	124.1				
Y. S. L.	.....	2.1	.....	12.1	.....	30.3	.....	53.2						
Walnut, Black													
Stump D. i. b. Inches													
Yellow fine sandy silt loam—U	.....	4.8	.....	11.3	.....	16.6	.....	20.4	.....	.....	.....	.....	...	11
Prairie brown silt loam—U	5.2	.....	10.1	.....	.....	.....	.....	.....	.....	.....	.....	.....	5	
Prairie black clay loam—U	4.0	.....	8.2	.....										
Height. Feet													
Y. F. S. S. L.	.....	30	.....	71	.....	87	.....	91						
P. B. S. L.	25	.....	54	.....										
P. B. C. L.	31	.....	60	.....										
Contents. Cubic Feet													
Y. F. S. S. L.	.....	1.6	.....	19.8	.....	51.5	.....	81.5						
P. B. S. L.	1.5	.....	11.1	.....										
P. B. C. L.	1.4	.....	8.4	.....										

Summarizing the studies of average growth, and grouping somewhat similar soil types together, the following lists show the rates on different soils for the trees studied.

UPLAND SANDY LOAMS

Species	*Cubic contents at 60 years*	
	Even-aged	All-aged
Black walnut	.....	51.5
Tulip-poplar	.....	26.0
Black oak	27.1	
White oak	21.1	13.1
Red oak	.....	10.6
Basswood	.....	11.2
Elm	.....	10.3
Ash	.....	8.8
Hard maple	.....	6.4
Hickory	.....	6.1
Beech	.....	2.5

UPLAND YELLOW AND YELLOW-GRAY SILT LOAMS

Species	*Cubic contents at 60 years*	
	Even-aged	All-aged
White pine	63.6	
Tulip-poplar	.....	30.3
Red oak	17.8	15.5
Black oak	16.0	13.6
Shingle oak	.....	11.5
Ash	15.9	5.5
Hickory	.....	5.0
Hard maple	11.6	2.3
White oak	10.7	2.7

UPLAND SAND

Species	*Cubic contents at 60 years*	
	Even-aged	All-aged
White pine	18.0	
Black oak	13.6	

HEAVY LOAMS—ILLINOISAN

Species	*Cubic contents at 60 years*	
	Even-aged	All-aged
Black oak	8.1	
Post oak	5.1	5.9

BOTTOMLAND LIGHT SOILS

Species	*Cubic contents at 40 years*	
	Even-aged	All-aged
Cottonwood	96.7	
Sycamore	.....	62.9
Soft maple	53.0	
Elm	.....	2.0

BOTTOMLAND HEAVY SOILS

Species	*Cubic contents at 40 years*	
	Even-aged	All-aged
Water locust	.....	28.5
Honey locust	.....	25.8
Soft maple	.....	23.4
Pin oak	23.6	18.0
Ash	.....	7.3
Schneck's oak	6.2	
Swamp Spanish oak	4.9	4.3
Hackberry	.....	3.3
Elm	.....	3.3
Tupelo gum	.....	2.6
Hickory	.....	1.5

The minimum-sized tree suitable for ties or sawlogs averages about 10 inches stump D. I. B. and 60 feet in height. Such a tree contains approximately 13 cubic feet of wood in the peeled stem. Using this figure as a standard, it is seen that, in the upland sandy loams, black walnut, tulip-poplar, and black and white oaks are the only species which average a sawlog tree at 60 years age. However, it is probable that red oak, basswood, elm, and ash will make such trees if grown in even-aged stands.

On the upland yellow and yellow-gray silt loams the species which average a tree of minimum sawlog size or more at 60 years are white pine, tulip-poplar, red oak, black oak, shingle oak, and ash; while hickory, hard maple, and white oak grow very slowly.

White pine and black oak were the only two species studied on the sand and each produces a merchantable tree in 60 years. On the heavy loams of the post oak region neither post oak nor black oak made sawlogs at 60 years.

The bottomland soils produce several species of very rapid growth-rates and 40 years is taken as the period of comparison. On the light soils of the bottomland, sycamore, cottonwood, and soft maple have a very high growth-rate, while elm fails to make trees of average sawlog size in the 40-year period.

On the heavy bottomland soils water locust, honey locust, soft maple, and pin oak produce merchantable trees at 40 years, while ash, Schneck's oak, swamp Spanish oak, hackberry, elm, tupelo gum, and hickory require longer periods.

Soil Reports

Reports or maps available		Information available but maps or reports not yet published		No information available
Adams	Logan	Alexander	Jo Daviess	Calhoun
Bond	McDonough	Boone	Kendall	Fayette
Bureau	McHenry	Brown	Lawrence	Jasper
Champaign	McLean	Carroll	Macoupin	Marshall
Clay	Macon	Cass	Madison	Piatt
Crawford	Marion	Christian	Massac	Putnam
Cumberland	Mason	Clark	Menard	Schuyler
DeKalb	Mercer	Clinton	Montgomery	Washington
Douglas	Monroe	Coles	Morgan	Wayne
DuPage	Moultrie	Cook	Perry	
Edgar	Ogle	DeWitt	Pope	
Edwards	Peoria	Effingham	Pulaski	
Franklin	Pike	Ford	Richland	
Grundy	Randolph	Fulton	St. Clair	
Hancock	Rock Island	Gallatin	Scott	
Hardin	Saline	Green	Shelby	
Iroquois	Sangamon	Hamilton	Stark	
Johnson	Tazewell	Henderson	Stephenson	
Kane	Vermilion	Henry	Union	
Kankakee	White	Jackson	Wabash	
Knox	Whiteside	Jefferson	Warren	
La Salle	Will	Jersey	Williamson	
Lake	Winnebago			
Lee	Woodford			
Livingston				

(2) Studies of Yields

Data were collected from 104 plots selected as representing average fully stocked stands. The 72 even-aged upland plots were divided between the upland types as follows: (1) post oak, 14 plots; (2) scrub oak, 23 plots; and (3) upland mixed hardwoods, 34 plots. There were 19 even-aged bottomland plots. The 13 all-aged virgin plots were divided as follows: upland mixed hardwoods, 7 plots; bottomland mixed hardwoods, 6 plots. The plots ranged from one-sixteenth to one acre and averaged .36 acres each. The ages ranged from 20 years to 110 years for the even-aged plots, and three quarters of the even-aged plots were fifty or more years old.

All trees on the plots were calipered at a point 4½ feet from the ground (D. B. H.) and the tally was made by species. Record was made of the soil type, density of crown-stocking, ground cover, and location. The age of each even-aged plot was secured by ring counts. The heights of trees in the dominant and other crown classes were measured and registered by diameter and species.

The even-aged plots were divided between the three upland types—post oak, scrub oak, and upland mixed hardwoods—and the one bottomland type; and the data were worked up to show, for each decade between the second and tenth, the total number of trees for a fully stocked acre, the average height of the dominant trees, the D. B. H. of the average tree, the basal area per acre, the total cubic feet contents exclusive of branchwood, and the average annual growth per acre. (Tables 4-8, pp. 95-97.)

A comparison of growth on these even-aged upland stands in Illinois and the even-aged second growth hardwoods in Connecticut and Massachusetts indicates that the Illinois post oak type has about the same number of trees per acre at a given decade as the poorest upland type in Connecticut—Quality III Oak (Frothingham '12), but that the diameter growth averages less on the post oak, and that the height growth averages decidedly lower. This Quality III Oak type in Connecticut represents thin-soiled upper slopes. It is very poor land, yet it produces better trees than the post oak type in Illinois.

A study of the scrub oak stands on the sands in Illinois shows that these sands produce trees of an average diameter and height-growth comparable to that of the better sites in Connecticut—between Quality I and Quality II Oak sites—but that the fully stocked Illinois stands do not have nearly as many trees per acre as the eastern forests.

A study of the upland mixed hardwoods type of Illinois shows that the diameter growth for such fully stocked even-aged stands averages about the same as the better sites in Connecticut (Quality I Oak), that the height growth of dominant trees averages about the same as that of the medium sites in Connecticut (Quality II Oak), and that the number of trees per acre for a given decade is again very low in Illinois. At 70 years these fully stocked stands in Illinois have but 70 per cent as many trees as such stands on the Quality I Oak site in Connecticut, and but 45 per cent as many trees as fully stocked even-aged stands of 70 years on Quality I sites in Massachusetts. (Spaeth '20.)

The annual rainfall of Connecticut is about 47 inches, and of Illinois about 37 inches. The annual evaporation for Connecticut amounts to about 39 inches, for Illinois to approximately 41 inches. The lesser amount of rain and the greater evaporation in Illinois is thus reflected in the decrease in the number of trees supported on an acre. This indicates that, in the management of the hardwood forests on the uplands of Illinois, the conservation of moisture is one of the important factors.

Post Oak Type

The post oak plots selected were on the heavy acidulous soils common to the level uplands of south-central Illinois described in Part I under the post oak type, p. 32. Post oak constitutes 74 per cent of the trees on the plots measured, scrub oak 12, with various black oaks and hickories totaling 14 per cent. An examination of the tables 4-6, pp. 95, 96, shows that these post-oak stands have a greater number of trees per acre, a smaller total basal area per acre and consequently a smaller average

D. B. H., that the height of the dominant trees is decidedly less than for the other two upland types, and that the yields for corresponding decades are the lowest. Reference to the tabulation of the D. B. H. of the average tree brings out the point that these stands do not enter the sawlog class—minimum D. B. H. 10 inches—within the first hundred years. The product is suitable for posts, mine timbers, and cordwood at about 60 years.

Scrub Oak Type

The scrub oak plots selected were on the sands in central and northern Illinois. The representation of species on the plots measured, shows black oak 62 per cent, scrub oak 29, hickory 8, and white oak 1 per cent. A marked variation in the individual plots as to growth indicates that probably in Illinois the sandy sites within this type should be classified; but insufficient data compelled a general grouping of all plots on sand. The tabulation, on page 96, brings out the fact that the diameter growth on sand in these plots averages even greater than for corresponding decades on the more fertile soils of the upland hardwoods type. This fact was also borne out in the individual tree study (see table on pp. 81-89). The height growth is less at similar periods for trees of the scrub oak type than for those of the upland hardwood type and the number of trees per acre beyond the 60-year period on sand is the least for the upland types. These stands enter the sawlog class at about 65 years. The yields given are for a fully stocked acre on which all trees are sound and free from crooks. The stands of the scrub oak type are very defective and the trees both limby and crooked, hence the use of the factor 4.4 into the cubic yield, giving a result only for sound straight trees, gives too high yields for characteristic scrub oak stands.

Upland Hardwood Type

The plots on the upland hardwood type were taken on those upland soils between sands and loams over clay. The commonest soil types are the yellow and yellow-gray silt loams, and in general the upland soils are heavier than upland soils in Connecticut and Massachusetts. The point brought out in the individual tree study that growth on the upland sandy loams is better than on the heavier loams is also apparent in the plots, as those selected on sandy loams have an average yield above the average for the general upland type. The representation of species by per cents on these plots is as follows: white oaks, 52, black oaks, 26, hickory, 11, elm, 5, hard maple and cherry totaling 4, the remaining 2 per cent being made up of nine other species. Since white oak is one of our slowest growing hardwoods and constitutes more than half of the stands on these plots, it is very evident that in managed forests of this kind yields can be increased by the substitution of such trees as tulip, red oak, and ash. Reference to the tabulation of the D. B. H. of the average tree (Table 6, p. 96) shows that these stands enter the sawlog class at about 63 years.

Bottomland Type

The bottomland forests of Illinois are not usually even-aged. On the 19 even-aged plots studied there was such a marked variation in yields for a given decade, due to the composition of the stands, that the data were worked up separately to show yields for stands composed dominantly of fast-growing species, and yields for stands composed dominantly of slow-growing species. (Tables 7, 8, pp. 96, 97.) On the 8 plots where such rapidly growing trees as cottonwood, sycamore, soft maple and sweet gum dominated, the average tree entered the sawlog class at 40 years and the acre produced 4,180 cubic feet of wood, exclusive of branch wood.

On the 11 plots where such slow-growing species as oak, elm, ash, and hickory dominated, the average tree entered the sawlog class at 63 years and the acre produced 2,757 cubic feet of wood. Thus the fast-growing species produce approximately 18,000 B. F. per acre in 40 years as compared to 12,000 B. F. per acre in 63 years for the slow growing species. The influence of soils is somewhat apparent in the per cents of occurrence of the fast- as compared to the slow-growing species. Thus the cottonwood and soft maple were abundant on the sandy loams, while the oaks, hickories, and ash were abundant on the heavier soils. Honey locust, sycamore, and red gum, trees of rapid growth, seemed to occur with equal frequency on the heavier and lighter soils.

Yield Tables for Even-aged Stands in Illinois

(1) *Upland Types*

TABLE 4.—POST OAK TYPE. BASED ON 14 PLOTS

Age Years	No. of trees per acre	Height of dominant trees Feet	D. B. H. of average trees Inches	Basal area per acre Sq. Ft.	Yields per acre in peeled stems Cu. Ft.	Average annual increment Cu. Ft.
20	1,025	22	2.8	45	250	12.5
30	775	29	3.6	56	420	14.0
40	605	35	4.4	63	610	15.2
50	470	40	5.1	67	775	15.5
60	360	43	5.9	69	950	15.8
70	285	46	6.8	71	1,150	16.4
80	235	49	7.5	73	1,360	17.0
90	195	51	8.4	75	1,550	17.2
100	170	52	9.1	77	1,780	17.4

Table 5.—Scrub Oak Type. Based on 23 Plots

Age Years	No. of trees per acre	Height of dominant trees Feet	D. B. H. of average trees Inches	Basal area per acre Sq. Ft.	Yields per acre in peeled stems Cu. Ft.	Average annual increment Cu. Ft.
20	1,035	25	2.9	47	450	22.5
30	670	36	4.0	59	775	25.8
40	400	46	5.6	68	1,075	26.9
50	260	54	7.3	75	1,400	28.0
60	180	61	9.1	81	1,750	29.2
70	120	67	11.6	88	2,075	29.7
80	90	72	13.8	93	2,375	29.7
90	75	74	....	....	2,650	29.4
100	65	77	....	....	2,920	29.2

Table 6.—Upland Hardwood Type. Based on 34 Plots

Age Years	No. of trees per acre	Height of dominant trees Feet	D. B. H. of average trees Inches	Basal area per acre Sq. Ft.	Yields per acre in peeled stems Cu. Ft.	Average annual increment Cu. Ft.
20	1,010	36	3.6	72	810	40.5
30	630	47	4.8	79	1,175	39.2
40	400	55	6.5	84	1,520	38.0
50	250	61	8.1	89	1,870	37.4
60	185	66	9.5	94	2,175	36.2
70	155	70	11.0	99	2,500	35.7
80	130	73	12.5	103	2,825	35.3
90	110	75	13.9	106	3,125	34.7
100	100	78	15.6	109	3,425	34.2

To convert cubic feet to cords divide by 86.

To convert cubic feet to board feet multiply by 4.4. Since 10″ D. B. H. is taken as the minimum cutting diameter limit, this converting factor can only be applied to those stands where the average D. B. H. is greater than 10 inches. Thus post oak has no merchantable B. F. contents. Scrub oak and upland mixed hardwoods show merchantable board-foot contents between 60 and 70 years.

Yield Table for Even-aged Stands in Illinois

(2) *Bottomland Type*

Table 7.—Rapidly growing Species, Cottonwood, Sycamore, Soft Maple, Honey Locust, Sweet Gum. Based on 8 Plots

Age Years	No. of trees per acre	Height of dominant trees Feet	D. B. H. of average tree Inches	Basal area per acre Sq. Ft.	Yields per acre in peeled stems Cu. Ft.	Average annual increment Cu. Ft.
20	450	75	6.0	87	2,450	122
30	290	82	8.6	118	3,400	113
40	230	87	10.2	130	4,180	104
50	205	90	10.9	137	4,930	99
60	190	92	11.7	143	5,600	93
70	165	94	12.7	146	6,150	88

TABLE 8.—SLOW-GROWING SPECIES. OAK, ELM, ASH, HICKORY
BASED ON 11 PLOTS

Age Years	No. of trees per acre	Height of dominant trees Feet	D. B. H. of average tree Inches	Basal area per acre Sq. Ft.	Yields per acre in peeled stems Cu. Ft.	Average annual increment Cu. Ft.
20	1,100	42	3.5	74	1,075	54
30	530	53	5.4	84	1,560	52
40	330	62	7.1	92	2,000	50
50	250	69	8.5	98	2,375	47.5
60	200	76	9.7	104	2,675	45
70	170	81	10.8	109	2,950	42
80	145	85	12.0	113	3,225	40
90	125	88	13.0	116	3,500	39
100	110	91	14.0	118	3,750	37.5

To convert cubic feet to cords divide by 86.

To convert cubic feet to board feet multiply by 4.4. Since 10″ D. B. H. is taken as the minimum cutting diameter limit, this converting factor can only be applied to those stands where the average D. B. H. is greater than 10 inches.

TABLE 9.—YIELDS FOR FULLY STOCKED VIRGIN STANDS IN ILLINOIS

Type	Av. No. of trees per acre	Height of dominant trees Feet	D. B. H. of average tree Inches	Basal area per acre Sq. Ft.	Yield per acre in peeled stems Cu. Ft.	Basis
Upland hardwoods	146.2	97.2	10.9	94.5	3,053	6 plots
Bottomland stands	69.5	98.4	16.4	101.6	3,297	5 plots

The all-aged virgin plots were separated into upland and bottomland types and the data were averaged to show the average number of trees supported on an acre, the D. B. H. of the average tree, height of dominant trees, basal area, and cubic feet yields. (Table 9, above.) Such information is based upon well-stocked virgin stands containing trees of many different-aged classes. In such stands the growth and decay balance, and the total yields per acre represent about the maximum for the type. The even-aged stands (Table 6, p. 96) show a total growth equal to the average for these all-aged virgin stands for upland hardwoods at 90 years; and for slow-growing bottomland stands (Table 8, above) the total content of the even-aged stands equals that of the virgin stands at about 80 years.

Part III. Proposed State Forest Policy

A proposed forest policy for Illinois has been outlined in two previous bulletins (Hall and Ingall '11, and Chapman and Miller '24). Three measures were recommended by Hall and Ingall:

(1) The adoption of an adequate state fire protection system, providing for forest fire wardens in those counties where this seems desirable.

(2) The inauguration of an educational campaign with the object of spreading scientific and practical forest management.

(3) Further investigation of the problems involved in developing and extending Illinois woodlands.

The measures recommended by Chapman and Miller are:

(1) Formulation and dissemination of information on wood-lot management.

(2) The teaching of farm-wood-lot management at the State University and the establishment of experimental areas.

(3) Establishment of an adequate system of fire prevention.

(4) Purchase of a considerable area in southwestern Illinois for State forests.

The information contained in this bulletin on forested areas and average rates of growth, and in the bulletin by Chapman and Miller '24, on the total amount of wood cut from the forests of Illinois, enables us to measure the forces of production and of destruction, to measure also, to a limited extent, the benefits possible from reasonable wood-lot management, and to distinguish the areas where state aid is necessary to fire protection.

The total timbered area of Illinois is 3,021,650 acres, as shown in table, pp. 58-63. The average annual volume produced per acre for each of the general forest types is shown in Tables 4-8, pp. 95-97. By multiplying the average annual growth per acre for a given type by the forested acreage of this type we may find the total yield for that type if all the timbered area were fully stocked, and a summation of these total yields for all types gives the total yields for the state which will be secured if the forests are kept fully stocked. This total is 124,333,235 cubic feet.

The total production of wood from the forests of Illinois, as given by Chapman and Miller ('24), is 115,651,960 cubic feet. This total is for the cubic contents of that part of the tree which goes into the product. In order that a proper comparison might be made between the amounts which the fully stocked forests can produce continuously, and the amounts which are now being harvested, this drain of 115,651,960 cubic feet was converted to the corresponding amount in the total peeled stems, and after slightly raising the forested acreage and consequently the production as shown in the above bulletin, the total cut from the forests of Illinois becomes 135,014,335 cubic feet. About 59 per cent of this cut is utilized as cordwood. In the computations it is assumed that but one product—either cordwood, sawlogs, ties, mine props, piling, or veneer logs—is made from a given tree, that is, for example, that approximately 65 per cent of the cubic contents of the tree is made into sawlogs, and that no use is made of the remaining 35 per cent. It is thus apparent that the total cut of 135,014,335 cubic feet will be too high by the amount utilized in making smaller products, such as mine timbers, posts, and cordwood, from this otherwise unutilized portion. But since no allowance is made for drain on the forests through decay, insects, and damage by fire and storm this figure is probably not greatly in error.

It is evident that the drain is in excess of the growth by at least 10,681,100 cubic feet per annum, but the actual excess of drain over growth is very much greater, since the forests are not fully stocked. The degree of stocking ordinarily runs from 34 per cent, as shown from extensive studies on the Ozark region (p. 45), to 80 per cent. The average product per annum for the state is probably more nearly 80,800.000 cubic feet than the 124,333,235 cubic feet possible for fully stocked forests. We are probably cutting fully 54,200,000 cubic feet annually in excess of the growth of 80,800,000 cubic feet, and continued overcutting at this rate would strip the state of forests in 31 years.

Until 1910 a larger acreage of improved land was being added annually to the farms of Illinois than there was of improved land reverting to waste; but since 1910 more improved land by 250,928 acres has reverted to waste than has been improved—most convincing evidence that development of unimproved lands to crops lands in Illinois has been carried too far. The 1920 census shows that Illinois now has 1,577,663 acres of waste land on farms. The labor and materials which are consumed in clearing, developing, and cropping such land are of greater value than the crops produced; and when ultimately the land is abandoned, it often lies idle for decades before it is restocked by a forest inferior to that originally cleared. It is probable that fully 2,700,000 acres of the present forested area of Illinois, if the drain continues unchecked, will revert to waste land unproductive of even the taxes.

The stumpage value of the timber cut to make the total of 135,014,335 cubic feet above arrived at, amounts to $4,958,331. Thus by cutting 65 per cent more than grows, an average return of $1.64 per acre is secured, from which must be paid taxes and land rental. This low return must further decline as the growing stock is reduced through excess cutting, until the wood-lots become waste land and the returns are zero. The alternatives are waste land or wood land.

By keeping the wood-lots fully stocked with the species normally represented the average growth of 41.1 cubic feet per acre annually will very nearly meet the drain of 44.7 cubic feet. By removing the slow growing and inferior trees as thinnings are required, the annual yield may be increased. The extremes in growth rates of different species of trees are greatest for the bottomland types, and consequently managed bottomland forests offer an encouraging field for increase in production, yet a greater growth per acre can be secured by encouraging the faster growing species on the uplands also. The yield tables 7, 8, pp. 96, 97, show that the faster growing species in unmanaged bottomland stands average twice the volume growth of the slower growing trees. The protection of forests from fire and grazing, and the regulation, through thinnings, of the kinds of trees which will be left, are simple forms of good management which will nearly double the annual production of cubic feet of wood. A better utilization of this product, which will enlarge the proportion of high grade material to the total production, will increase the returns. Much of the 59 per cent of the wood production of Illinois which is now used as cordwood is suitable for uses having general stumpage values from four to sixteen times that of cordwood.

That part of the 1,577,663 acres of waste land which is not reverting to productive forest land should be replanted. To the end that the land owners may have access to a supply of suitable planting stock at a reasonable price, the state should establish a forest tree nursery.

Any plan which contemplates the establishment of state-owned forests should give weight not only to the forested area of southwestern Illinois, but also to the practicability of establishing pine forests on the unforested sands of central and northern Illinois. As computed on page 37, there are at least 310,000 acres of sand, of which more than 200,000 acres is unforested. These sandy areas are often in large units, a single county containing 75,000 acres.

In outlining state aid in fire control the principle should be that such aid should be given to those regions where the forests are continuous and cover relatively large areas, but that in those regions where the wood-lots are relatively small and isolated the owners can cope with fires. The maps III to VI cover those areas in Illinois where upland forests are the most continuous. Continuous bodies of forest cover relatively large areas in the following regions:

(*a*) As shown on Map III such a forest extends along the bluffs in the western part from central Alexander county to central Monroe county and contains approximately 202,000 acres of forest.

(*b*) As shown by Map III a heavily forested area occurs at the eastern extreme of the Ozark uplands in southwestern Gallatin, southeastern Saline, eastern Pope and Hardin counties. This upland area contains approximately 86,000 acres forested.

(*c*) Possibly the region embraced in Calhoun and western Jersey counties has woodlands of such a nature as to require organized fire protection (see Map V). There are approximately 50,000 acres of such upland forest in this region. Elsewhere in the state the forests are less continuous and protection can be given by the land-owner.

CONCLUSION

Until 75 years ago poor transportation facilities resulted in low woodland values in the heavily wooded areas, while in the prairie region these values were as much as seven times those of prairie land. During the past 75 years the development in transportation has enabled Illinois and the nation at large to enjoy the products from the virgin forests of the Lake States, of the South, and of the West.

With the exhausting of the virgin forests the nation will be confronted with much the same problem as confronted the pioneer prairie farmer. The cut-over timber-lands will be called upon to meet the wood requirements of the nation. Those annual requirements are now nearly four times the average annual growth of all timber-land for the nation at large, and ten times the average annual growth for Illinois.

For the public this condition predicates a decided increase in the cost of wood products, for the wood-using manufacturers a dislocation of industry and the use of substitutes where substitutes are economically possible, but for the wood-lot owner correspondingly greater returns from the productive wood-lot.

The process of forest destruction is far advanced in Illinois. First growth or virgin timber has virtually disappeared, and the present drain on the cut-over forests and second-growth stands, unchecked, will result in an early disappearance of all forests in Illinois.

There was an increase in unforested waste land of a quarter of a million acres in the ten years from 1910 to 1920, and Illinois now has a total of 1,577,663 acres in this class. The 3,021,650 acres now forested are on lands unsuited to ordinary farming and if cleared will generally revert to waste land.

There is an urgent need for the educating of both the wood-lot owner and the public on the measures required to protect the present forests, to balance growth and cut and bring them to their fullest possible production, and to reforest as much of the 1,577,663 acres now in waste land as is economically justifiable, so that when the supplies of virgin timber fail elsewhere, the farm wood-lots of the state shall provide for the needs of the farm, and unproductive waste land be turned to profitable use.

LITERATURE CITED

Chapman, Herman H., and Miller, Robert B.

1924. Second report on a forest survey of Illinois. The Economics of forestry in the state. Bul. Ill. Nat. Hist. Surv., 15: Art. III. Urbana, Ill.

Deam, Chas.

1921. Trees of Indiana. Department of Conservation, State of Indiana publication. No. 13.

Frothingham, Earl H.

1912. Second growth hardwoods in Connecticut. U. S. Dept. Agr., Forest Service Bulletin 96.

Hall, R. Clifford, and Ingall, O. D.

1911. Forest conditions in Illinois. Bul. Ill. State Lab. Nat. Hist., 9: Art. IV.

Hawley, Ralph C., and Hawes, Austin F.

1921. Forestry in New England, p. 473. John Wiley & Sons, New York.

Pepoon, H. S.

1919. The forest lands of Jo Daviess county, Trans. Ill. Acad. Sci., 12: 183-202.

Ridgway, Robert

1872. Notes on the vegetation of the lower Wabash Valley. Amer. Nat., 6: 658-665, 724-732.

1882. Notes on the native trees of the lower Wabash and White River valleys in Illinois and Indiana. Proc. U. S. Nat. Mus. 1882, 5: 59, 74.

Sargent, Charles Sprague

1922. Manual of the trees of North America. Houghton, Mifflin & Co., New York.

Spaeth, J. Nelson

1920. Growth study and normal yield tables for second growth hardwood stands in central New England. Harvard Forest Bulletin No. 2. Petersham, Mass.

Waterman, Warren G.

1921. Preliminary report on the bogs of northern Illinois. Trans. Ill. Acad. Sci., 14: 79-84.

1923. Bogs of northern Illinois. II. *Idem,* 16: 214-225.

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Recent Insecticide Experiments in Illinois with Lubricating Oil Emulsions

BY

S. C. CHANDLER, W. P. FLINT, and L. L. HUBER

AUG. 26TH 1818

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CONTENTS

ARTICLE II.—*Recent Insecticide Experiments in Illinois with Lubricating Oil Emulsions.* BY S. C. CHANDLER, W. P. FLINT, AND L. L. HUBER.

INTRODUCTION

From 1919 to 1922 inclusive, the San Jose scale caused more damage in southern Illinois than in any equal period since it was first established in this state. Following the work of Dr. Forbes and his assistants in 1900, 1901, and 1902, liquid lime-sulfur had been considered the standard remedy for San Jose scale control. Previous to 1919, it had not failed to give a satisfactory commercial control where thoroughly applied at dilutions of from 1 to 6, to 1 to 8. During 1920 and 1921, some of the best and most careful orchardists in southern Illinois lost trees from scale although these trees had been thoroughly sprayed with lime sulfur. In some instances the failure to control with it could be accounted for by the fact that the trees had been poorly sprayed, or an insufficient amount of material had been applied. In other cases, however, the applications had been made as thoroughly as seemed possible and enough material had been put on to cover the trees thoroughly. During the years mentioned above, a series of mild winters following warm late falls had allowed the scale to increase at an unusual rate, so that trees having a small amount of live scale remaining upon them in spring were heavily infested by fall. Because of the failure of lime sulfur to give a satisfactory control of scale, a series of experiments to test other scalecides was made by the Natural History Survey during the winter of 1922.

These experiments were planned to give a comparison of commercial liquid and dry lime-sulfur with commercial miscible oils and homemade lubricating-oil emulsions. The lubricating oil emulsion used, was of the type developed by W. W. Yothers, of the United States Bureau of Entomology for combating citrus scale insects in Florida, and was made by boiling together:

Potash-fish-oil soap	1 pound
Water	½ gallon
Light grade lubricating oil........	1 gallon

The mixture was boiled for about five minutes, removed from the fire, and pumped twice under a pressure of about seventy-five pounds, and it was then diluted at the rate of three gallons of the stock emulsion to ninety-seven gallons of water.

EXPERIMENT IN JOLLY ORCHARD, OLNEY, ILLINOIS, SPRING OF 1922

A block of twenty-five-year old Ben Davis and Grimes Golden apple trees was chosen for this experiment in what was known as the Jolly orchard at Olney. These trees were heavily infested, most of them having a considerable portion of the tree incrusted. Those selected for the experiment were divided into blocks five rows long by four rows wide, the center row being Grimes Golden, and the two outside rows Ben Davis. The infested branches, which were later cut for scale examinations, were taken from the inside rows of the blocks.

The first sprays were applied on March 28, all blocks being treated within a week. Special attention was given to the application of the sprays. All trees were sprayed with rods, and the operator was followed by a third man to see that no part of the tree remained unsprayed. In the course of this work, we found that slightly more of the oil sprays was required to cover trees of a given size than was the case with the lime sulfur sprays. For the twenty-five-year old trees, twenty gallons per tree of the oil were required and fifteen to seventeen gallons per tree of lime sulfur. Forty-seven days after the treatment, samples of scale-infested twigs were taken from various parts of the trees on the inner rows of all of the blocks and examined for living and dead scale. The results of these examinations, expressed in percent of living scale, are shown in Table I.

TABLE I

Treatment	Percent of live scale
Scalecide (1 to 15)	.5
Spray Emulsion (1 to 15)	.4
Diamond Paraffin oil, fish-oil soap emulsion (2%)	1.5
Junior Red Engine-oil, fish-oil soap emulsion (2%)	7.
Commercial liquid lime-sulfur (32 Baumé, 1 to 8)	11.
Soluble sulfur, Niagara (15 lbs. to 50 gals. water)	18.5
Dry lime-sulfur (15 to 50)	41.
Check, no treatment	50.

The following conclusions, standing in the order of their importance, may be noted:

1. The oil sprays were superior to the sulfurs.
2. The oil emulsion made from Oil No. 1, the brand used in most cases in Florida, was almost as effective as the miscible oils.
3. Dry lime sulfur was not as good as liquid lime sulfur.

The fact that even after the most careful spraying, 11% of the scale was still alive on trees treated with lime sulfur, explained the failure of some growers to control scale where this material had been used. No further experiments were made in this orchard during 1922, but the remainder of it was sprayed thoroughly with commercial lime sulfur, used at 1 to 6, and in some cases at 1 to 4, dilution.

By fall of that year, the scale had so increased that but little fruit in the orchard was salable, and in the spring of 1923, the orchard was so badly infested by scale that no further attempt was made to save the trees by spraying. On May 4 of that year, however, the only trees of the orchard which were blooming, and practically the only trees alive, were those which had been given the oil sprays the previous spring. These blocks of trees were in a fairly vigorous condition, while practically all of the lime-sulfur sprayed trees around them were dead. The entire orchard was cut down during the next year because nearly all the trees had been killed by San Jose scale. (See Fig. 1 and 2.)

FIGURE 1

Outer rows of trees on separate plots, Olney, Ill., May 4, 1923. Row on the left had been sprayed with oil emulsion; row on the right, with lime sulfur. Lime-sulfur-sprayed trees all killed by San Jose scale

EXPERIMENTS IN UNIVERSITY ORCHARD, OLNEY, ILLINOIS, WINTER OF 1922-23

The objects of the investigation in the winter of 1922-23 were as follows:

1. To determine the best formula for making a stock oil-emulsion.
2. To determine the possibility of combining the oil emulsions with other spray materials.
3. To determine the efficiency of homemade oil-emulsions and commercial oil-emulsions.

Most formulae for oil emulsions have been the result of practical experience, for we know but little in regard to the various theories involved in a study of colloids, but some knowledge of the theory of emulsification is necessary if we would proceed intelligently.

THE THEORY OF EMULSION

The theory of emulsion is based on the assumption that we are dealing with two-phase systems, the oil and the water being the respective phases. The oil is the disperse or internal phase, the water is the continuous or external phase, and the two phases of the system are separated by surfaces of contact, or interfaces.

The external phase may be either a solid or a liquid. The first part of this discussion is concerned with a system in which both phases are liquids; but the latter part, with a system in which one phase is a liquid and the other a solid.

An emulsion is defined by Clayton as a system containing two liquid phases, one of which is dispersed as globules in the other. Making lubricating oil emulsion is essentially a mechanical process which has for its purpose the breaking up of the oil in the water, but as oil and water are immiscible an emulsifying agent is needed, and here again there may be two kinds of emulsions, "oil in water" and "water in oil", depending upon the nature of the emulsifying agent. The lubricating oil emulsions are of the former kind.

THE USE OF A SOLID AS AN EMULSIFIER

It has been long known that any substance that will go into the interface and thus increase viscosity, will cause emulsification. In other words, the insoluble solid, if finely enough divided, will yield results similar to those produced by a gelatinous colloid, such as soap. Pickering was one of the first to point out that the basic sulfate precipitated in Bordeaux mixture consists of just such particles. These particles have only a slight tendency to unite with one another, and are more readily wetted by water than by oil. When the oil is added to the Bordeaux mixture and broken up by agitation, the finely divided precipitate surrounds the oil globules, thus holding them in suspension. Theoretically there seems to be no reason to expect unfavorable results with the soapless emulsions. Indeed, in instances where a weak Bordeaux is advised when the soap emulsions are to be diluted with hard water, we get, in reality, what amounts to a soapless Bordeaux-oil emulsion.

THE USE OF SOAP AS AN EMULSIFIER

Bancroft holds that if the emulsifying agent is such that it will lower the interfacial tension of the water more than that of the oil so that the film bends convex to the oil, there will be a tendency to emulsify the "oil in water," but if the absorption of the emulsifying

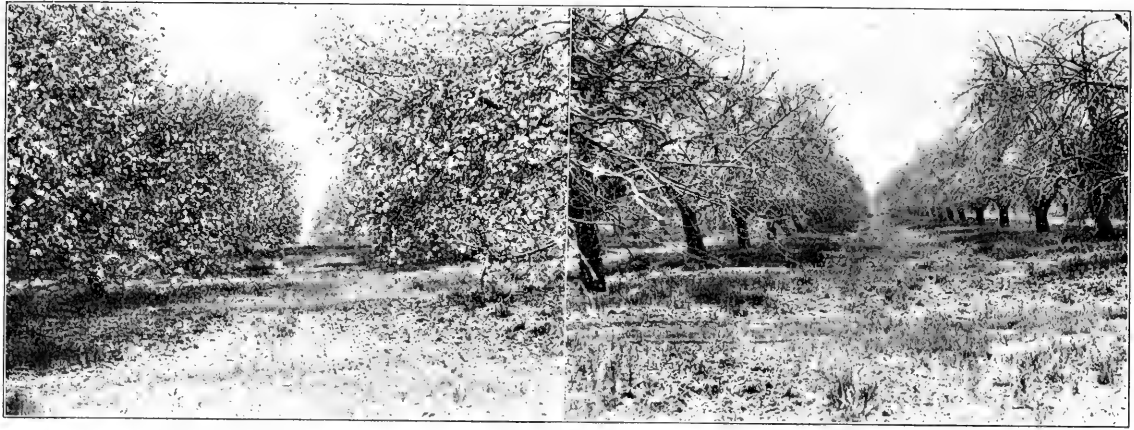

FIGURE 2

Trees on reader's right had been sprayed with lime sulfur; those on left, with oil emulsion. The pictures were taken at Olney, Ill., May 4, 1923, without moving the tripod of the camera. The lime-sulfur-sprayed trees were all killed by the San Jose scale agent brings about an opposite condition, a "water in oil" emulsion will result. Hence, to make an "oil in water" emulsion it is necessary to use a water-soluble colloid; and to make a "water in oil" emulsion an oil-soluble colloid must be used. More briefly still, to get an "oil in water" emulsion the emulsifying agent must be such that it is wetted more by water than by oil. Potash and sodium soaps are such water-soluble colloids.

The excellence of an emulsion is judged primarily by its stability, which is very dependent on its viscosity. Upon what then does the viscosity depend?

Possibly the greatest single factor affecting viscosity is the volume ratio of the oil and water, or the concentration of the oil. While it is possible to make an emulsion with potash-fish-oil soap and oil alone, or by the addition of an unusual amount of water to the oil and soap, experiment has shown that there is an optimum proportion of ingredients.

Another factor affecting viscosity is the degree to which the ingredients are mechanically agitated. Orchardists have noted that the more often the mixture is run through their pumps and the greater the pressure, the more viscous is the product. This is due to the fact that the oil is reduced to more minute globules and the extent of the oil-water surface is thus greatly increased.

A deficiency in the proportion of soap results in lower viscosity owing to the prevalence of larger oil globules, regardless of agitation. These large globules have a tendency to coalesce by breaking the film which surrounds them.

The size of the oil globules is further dependent on the temperature of the mixture when it is agitated. A cold mixture will yield an emulsion physically inferior to a hot mixture. However, field and laboratory tests have demonstrated that there is nothing to be gained by continued application of heat. Heating facilitates emulsification only by lowering the viscosity of the mixture and reducing the interfacial tension between the two phases, thus aiding mechanical agitation.

In comparative spray-tests we have often failed to take proper cognizance of the fact that an emulsion undergoes some quantitative changes during the process of manufacture. Unless these changes are taken into consideration there is apt to be an element of doubt as to the accuracy of our results. In this regard, it is well to keep in mind that a mixture may, or may not, increase in volume with emulsification.

INCREASE IN VOLUME OF BOILED EMULSIONS

In making up the large series of emulsions which was necessary for these experiments, it was noticed that there was a greater increase in volume in the case of some boiled emulsions than in others, although exactly the same proportions and length of time for boiling was allowed in all cases. In one case the volume was increased by 13%, even though the outlet hose was put into the liquid so that large amounts of air could not be mixed with the emulsion. The increase was much greater where the hose was held out of the liquid, allowing the discharge to fall through the air. In most cases, this increase in volume is not very significant after the emulsion has cooled. The grower making his own emulsion should bear this point in mind when he comes to the dilution of his product.

The data of the tables tend to prove that the amount of water and soap as well as this increase in volume are factors to be considered if final results are to be used in a comparative way.

TABLE II

1. *Formula: Oil 1 gallon, water ½ gallon, soap 2 pounds*

Emulsion	Water	Percent of oil in spray solution	Percent of dead scale
1½ gal.	100 gal.	.007	73.
3 "	100 "	.015	97.6
4½ "	100 "	.022	98.3
6 "	100 "	.030	100.

2. *Formula: Oil 1 gallon, water ¼ gallon, soap 1 pound*

Emulsion	Water	Percent of oil in spray solution	Percent of dead scale
1½ gal.	100 gal.	.010	89.
3 "	100 "	.020	98.5
4½ "	100 "	.030	99.4
6 "	100 "	.040	100.

DE-EMULSIFICATION

Sometimes an apparently good emulsion de-emulsifies, or "breaks", and the commercial orchardist generally finds that this is due to one or more of the following causes:

It is to be expected that an emulsion which contains a water phase would be injured by freezing temperatures which by breaking the external or water phase frees the oil. However, it is entirely possible to make a stock emulsion that will withstand continued zero temperature with only negligible damage. Injury is proportional to an excess amount of water in the emulsion.

A most carefully made emulsion may, after a long period, begin to de-emulsify. The air coming into contact with its surface causes evaporation of the water and results in the cracking of the film around the oil globules, and the droplets then coalesce.

The presence of acids or large amounts of lime, as in lime sulfur, leads to the breaking down of an emulsion in such way that re-agitation will not restore it.

Perhaps the most common source of de-emulsification is the presence of calcium or magnesium in the water that is used as a diluent. The presence of these salts with the oil leads to the formation of an insoluble calcium or magnesium soap, which are products of reversion and tend to form "water in oil" emulsions. The addition of Bordeaux mixture to the diluted spray solution prevents this reaction. This recommendation is based upon a statement made in the fore part of the discussion, that a colloid solution has two phases—a solid and a liquid. A fuller explanation is given in the following paragraphs.

Although emulsions can be made with even extreme amounts of water or soap, there is a practical optimum amount of each of these constituents. Judging from our experiments, the optimum amount of soap is from one to two pounds per gallon of oil, and that of water from ¼ to ½ gallon for each gallon of oil. It has been found necessary, in order to get a good emulsion, to use from 1½ to 2 pounds of soap with many of the waters used by orchardists for spraying in this state. Emulsions made with varying amounts of soap and water were tested as to their ability to kill scale. The following tables show the results.

TABLE III

Strength of oils	Amount of soap	Number of experiments	Number of scale examined	Number alive	Percent alive
2%	1 pound	2	1554	19	1.2
2%	2 pounds	2	2083	31	1.4

TABLE IV

Strength of oils	Amount of soap	Number of experiments	Number of scale examined	Number alive	Percent alive
2%	½ gallon	4	4092	77	1.8
3%	½ gallon	4	4076	28	.6
2%	¼ gallon	3	2082	50	2.4
3%	¼ gallon	4	3500	16	.4

These tables would seem to indicate that as far as kill of scale is concerned, there is little to choose between an emulsion made with either one or two pounds of soap and ¼ gallon or ½ gallon of water per gallon of oil, but laboratory experiments showed conclusively that a stock emulsion made with ¼ gallon of water to each gallon of oil was less likely to be broken down from cold, because of a lower freezing point. In addition to this, an emulsion made with ¼ gallon of water requires less space for storage. Using this amount of water in the stock emulsion, a dilution of three gallons in a hundred of water would give slightly more than a 2% solution, and for a 3% strength, four gallons to the hundred would be sufficient.

COMBINATION OF OIL EMULSION WITH OTHER MATERIALS

For practical reasons, it is desirable that a spray may be mixed with as many other spray materials as is possible. Obviously, it is highly desirable that Bordeaux mixture, a fungicide, should be one of the compatible sprays. As already indicated, any substance that will go into the interface and increase the viscosity will cause emulsification, and the basic sulfate which is precipitated when lime and copper sulfate are poured together, does exactly this thing. The small particles of the precipitate have only a slight tendency to unite with one another and are more readily wetted by the water than by the oil; hence they surround the oil globules in the spray solution, thus aiding the soap in holding them in suspension.

Pickering, in 1907, discovered that oil could be emulsified with Bordeaux mixture. Some of his work was therefore duplicated in 1922 in our laboratory, and the product tried out in the field the following year.

Since such a combination is theoretically and practically sound, an oil emulsion made by the formula, one gallon paraffin oil, 90 viscosity, one-fourth gallon of water, and two pounds of potash-fish-oil soap, was used at varying strengths with Bordeaux mixture at strengths of 3-9-50, 9-3-50, and 4-4-50. The results are shown in Table V.

TABLE V

Bordeaux	Percent of oil	Number of scales examined	Number alive	Number dead	Percent alive
3–9–50	2%	1088	20	1068	1.8
3–9–50	4%	1000	1	999	.1
3–9–50	8%	1000	0	1000	0
9–3–50	2%	1000	0	1000	0
9–3–50	4%	1000	0	1000	0
9–3–50	8%	1000	0	1000	0
4–4–50	2%	1000	5	955	.5
4–4–50	3%	1000	0	1000	0
4–4–50	4%	1000	0	1000	0
4–4–50	8%	1000	0	1000	0
Check	...	1015	669	346	65.9

This shows no decrease in the effectiveness of the lubricating oil emulsion as a scalecide when combined with Bordeaux mixture.

The emulsion was also combined with lead arsenate (basic lead) at the rate of one pound to fifty gallons of diluted emulsion. The results are shown in Table VI.

TABLE VI

Treatment	Total number of scales examined	Number alive	Number dead	Percent alive
2%	1000	9	991	.9
4%	1000	0	1000	0

COMPARISON OF BOILED EMULSIONS WITH LIME SULFUR AND VARIOUS MISCIBLE OILS

During the spring of 1923, a number of tests were made with the various spray materials listed below. As the question of thoroughness of application has often been raised in connection with control of San Jose scale, it was obvious that if our final results were to be depended on, all treated branches must have been very carefully covered. All sprays were applied with a small hand-sprayer, previously marked-off areas on the various branches being sprayed individually and from all angles, and spraying was continued until the operator was sure that the solution had covered every scale. This method eliminated the chance—always present in orchard experiments—of taking samples from a part of the tree which had been missed or only partly wet in spraying. Four to eight weeks after the sprays were applied, a number of scales, usually a thousand from each treatment, were examined under a binocular microscope to determine the percent of scale surviving. These examinations were made by at least two persons within a few days after the sample branches were cut from the tree. The scales on these trees were carefully examined in the beginning of the experiment as were also the untreated checks on the same trees at the end of the work.

TABLE VII

Treatment	Number scale examined (total)	Number alive	Number dead	Percent alive
Lime Sulfur (1–8)				
320 Baumé	1000	110	890	11
Lime Sulfur (1–4)	1000	93	907	7
Sun Oil Co.'s Emulsion 1–10	1000	0	1000	0
1–15	1000	1	999	.1
1–30	1042	182	862	17.2
Good's Mistoil				
1–10	1000	0	1000	0
1–15	1000	0	1000	0
1–30	1000	137	862	13.6
Pratt's Scalecide				
1–10	300	0	300	0
1–15	500	0	500	0
1–30	500	11	489	2.2

Table VII gives the results of applications of lime sulfur and of various miscible oils. Since these were applied in the same manner as the oil emulsions mentioned in Tables II to VI inclusive, an inspection of those tables will also give a comparison with the homemade emulsions.

TABLE VIII

Percent of oil in emulsion	Number of experiments	Number of scales examined	Number alive	Number dead	Percent alive
1	4	4558	894	3664	19.6
2	4	3637	50	3587	1.3
3	8	7576	44	7532	.5
4	8	7600	2	6598	.02
8	4	3600	0	3600	0.0
Check	...	1015	669	346	65.9

From the experiments made in 1922-23, it is apparent that in most cases, a 2% lubricating oil emulsion will give a satisfactory kill of scale if made from the proper oils and thoroughly applied. The effectiveness of the same oil at different strengths, is shown in Table IX. Judging from this record of treatment and of the examination of a fairly large number of scale coming from several experiments, it is evident that a 3% emulsion would be advisable in orchards where scale is very abundant and increasing, but that a 2% emulsion will take care of ordinary infestations when thoroughly applied.

EXPERIMENTS IN HARTLINE ORCHARDS, ANNA, ILLINOIS, WINTER OF 1923-24

After the spring of 1923, oil emulsions enjoyed a greatly increased popularity due to their cheapness as compared with other oil sprays and to their efficiency as scalecides as proved in trial tests by growers and experiments in this and other states. A large number of oils were advertised as suitable for making the stock emulsions, and insecticide companies took advantage of the general turn from lime sulfur to oil sprays and pushed the sale of their prepared oils. Cold-mixed emulsions also were attracting more attention from the growers, and inquiries began coming in for more information in regard to them. To find an answer to these questions, to gain further information, and to corroborate points brought out during the work of the two previous seasons, a series of experiments was planned for the winter of 1923-24. These were located in the apple orchards of Willis Hartline at Anna, and the sprays were applied to trees that had become badly infested. The same method of application was employed as in 1922-23, all treatments being made with a hand sprayer, and great care taken that every scale should be covered. Table IX gives the results of this work. It will be noticed that some of the fall sprays were repeated in spring. In most cases this was done to check up on fall applications which showed an appreciably higher percent of live scale than did oil emulsion made with a certain 90 viscosity paraffin oil, which we use as a standard because of the large number of tests which have been made with it. In Table IX, viscosity was ascertained by the Saybolt test. Good emulsions were obtained with all the oils used.

TABLE IX

Oils and dosage (Oils used in all cases at 2% strength unless otherwise specified)	Emulsifier and amount per gallon of oil				Date of treatment, number of scale examined, and percent living		
	Potash-fish-oil soap	Calcium caseinate	Bordeaux mixture	Iron sulfate-lime	Date of treatment	Number of scales examined	Percent of living San Jose scale 6 to 8 weeks after treatment
No. 1. Oil, 90-100 viscosity, .42% volatility	1½ #				12/24–26/23	1569	1.6
No. 9. Same oil as No. 1			4–6–50 1 gal.		"	1500	1.8
No. 23. " " " " "			6–8–50 1 gal.		1/8/24	1000	3.5
No. 30. " " " " "				4–6–50 1 gal.	"	1000	1.6
No. 31. " " " " "		4 oz.			1/29/24	1501	2.5
No. 32. " " " " "		4 oz.			"	1537	5.9
No. 35. " " " " "			4–6–50 1 gal.		"	1500	1.5
No. 49. " " " " "			(Copper sulfate 2 oz. lime 2 oz.)		1/30/24	1300	3.6
No. 54. " " " " "	¼ #				1/31/24	1500	1.6
No. 55. " " " " "	½ #				"	1500	1.
No. 56. " " " " "	1½ #				"	1500	1.
No. 62. " " " " " 3%			1–1¼–50 1 gal.		3/17–19/24	1500	0
No. 64. " " " " "				4–6–50 1 gal.	"	1500	1.5
No. 65. " " " " "		4 oz.			"	1500	.2
No. 66. " " " " " 3%		4 oz.			"	1500	.06
No. 70.* " " " " "		4 oz.			"	1500	0
No. 80. " " " " "	¼ #				"	1500	0
No. 81. " " " " "	¾ #				"	1500	0
No. 82. " " " " "	1½ #				"	1500	.06
No. 2. Oil, 98-100 viscosity, .44% volatility	1½ #				2/17–23/24	1543	3.2

* Lime sulfur (1-8) added after emulsification.

TABLE IX—Continued

Oils and dosage (Oils used in all cases at 2% strength unless otherwise specified)	Emulsifier and amount per gallon of oil				Date of treatment, number of scale examined, and percent living		
	Potash-fish-oil soap	Calcium caseinate	Bordeaux mixture	Iron sulfate-lime	Date of treatment	Number of scales examined	Percent of living San Jose scale 6 to 8 weeks after treatment
No. 10. Same oil as No. 2			4–6–50 1 gal.		2/17–23/24	1500	2.8
No. 58. “ “ “ “ “	1½#				4/14–22/24	1500	.2
No. 3. Oil, 91 viscosity, .13% volatility	1½#				12/24–26/23	1512	.4
No. 11. Same oil as No. 3			4–6–50 1 gal.		“	1300	2.9
No. 4. Oil, 177 viscosity, .04% volatility	1½#				“	1504	1.1
No. 12. Same oil as No. 4			4–6–50 1 gal.		“	1500	4.
No. 37. “ “ “ “ “	1½#				1/30/24	1500	1.7
No. 41. “ “ “ “ “			4–6–50 1 gal.		“	1500	3.3
No. 6. Oil, 108 viscosity, .28% volatility	1½#				12/24–26/23	1510	2.8
No. 14. Same oil as No. 6			4–6–50 1 gal.		“	1500	4.
No. 60. “ “ “ “ “	1½#				3/17–19/24	1500	.3
No. 7. Oil, 93 viscosity, .34% volatility	1½#				12/24–26/23	1502	2.0
No. 15. Same oil as No. 7			4–6–50 1 gal.		“	1500	4.
No. 8. Oil, 55 viscosity, 9.84% volatility	1½#				“	1506	.9
No. 16. Same oil as No. 8			4–6–50 1 gal.		“	1500	3.1
No. 17. Oil, 152 viscosity, 1.36% volatility	1½#				1/8/24	1000	.6
No. 27. Same oil as No. 17			4–6–50 1 gal.		“	1000	1.7

No. 18. Oil, 130 viscosity, 1.56% volatility	1½#				"	1000	1.7
No. 26. Same oil as No. 18			4–6–50 1 gal.		"	1000	2.3
No. 20. Oil, 147 viscosity, .77% volatility	1½#				"	1000	1.7
No. 25. Same oil as No. 20			4–6–50 1 gal.		"	1000	1.7
No. 21. Oil, 100 viscosity, .59% volatility	1½#				"	1000	.6
No. 24. Same oil as No. 21			4–6–50 1 gal.		"	1000	3.2
No. 22. Oil, 212 viscosity, 1.35% volatility	1½#				"	1000	2.5
No. 28. Same oil as No. 22			6–8–50 1 gal.		"	1000	4.4
No. 33. " " " " "		2 oz.			1/29/24	1501	.5
No. 34.* " " " " "		2 oz.			"	1500	.1
No. 36. " " " " "			4–6–50 1 gal.		1/30/24	1500	.6
No. 50. " " " " "					1/31/24	1400	2.6
No. 57. " " " " "	1½#				3/17–19/23	1100	.4
No. 63. " " " " " 3%			4–6–50 1 gal.		"	1500	.1
No. 67. " " " " "		4 oz.			"	1500	.8
No. 68. " " " " " 3%		4 oz.			"	1500	.2
No. 69.* " " " " "		4 oz.			"	1500	.5
No. 39. Oil, 100 viscosity, .33% volatility	1½#				1/30/24	1500	.9
No. 43. Same oil as No. 39			4–6–50 1 gal.		"	1500	2.1
No. 40. Oil, 189 viscosity, .50% volatility	1½#				"	1500	1.2
No. 44. Same oil as No. 40			4–6–50 1 gal.		"	1500	1.8
No. 51. Oil, 179 viscosity, .90% volatility					1/31/24	1500	1.6
No. 52. Same oil as No. 51 4%					"	1500	.4
No. 53. " " " " " 8%					"	1500	0
No. 74. " " " " " 3%					3/17–19/23	1500	.06

* Lime sulfur (1-8) added after emulsification.

TABLE IX—Concluded

Oils and dosage (Oils used in all cases at 2% strength unless otherwise specified)	Emulsifier and amount per gallon of oil				Date of treatment, number of scale examined, and percent living		
	Potash-fiish-oil soap	Calcium caseinate	Bordeaux mixture	Iron sulfate-lime	Date of treatment	Number of scales examined	Percent of living San Jose scale 6 to 8 weeks after treatment
No. 76. Same oil as No. 51					3/17–19/23	1500	.06
No. 77. " " " " " 4%					"	1500	0
No. 45. Oil, 48 viscosity, 7.72% volatility			4–6–50 1 gal.		1/30/24	1500	5.2
No. 46. Same oil as No. 45	1½#				1/31/24	1500	3.6
No. 61. " " " " "	1½#				3/17–19/23	1400	1.7
No. 71. Sherwin-Williams Freemulsion 1-50					"	1500	.6
No. 72. Same oil as No. 71 1-25					"	1500	0
No. 73. Sunoco, 1-20					3/17–19/23	1500	0
No. 75. Same oil as No. 73					"	1500	.06
No. 38. Oil, 115 viscosity, .28% volatility					1/30/24	1500	2.2

A COMPARISON OF OILS FOR OIL EMULSION

Good emulsions were made with all grades of oil used, but five of them show a somewhat too high percent of live scale in the fall tests. Comparing the scale kill with the analyses of oils, it will be found that the most effective oils fall within certain limits. After a conference with government entomologists who had been working on the control of San Jose scale with oil emulsions at Bentonville, Arkansas, and at Vincennes, Indiana, and with the Entomologist of the Purdue Agricultural Experiment Station, a joint statement was issued in the fall of 1924 to the effect that the best results had been obtained with oils within the following limits:

Specific gravity	.87 to .93 at 20° C.
Volatility	Not above 2% at 110° C. for 4 hours. (Saybolt test.)
Viscosity	90 to 250 seconds at 100° F. (Saybolt test.)

A COMPARISON OF BOILED FISH-OIL-SOAP EMULSIONS AND COLD-MIXED EMULSIONS

1. Scale Kill

Table X, summarizes all the tests made in the Hartline orchard with boiled fish-oil-soap emulsions of 2% strengths and all those with cold-mixed emulsions except where lime sulfur was combined with them. This table shows the cold-mixed emulsions to be not quite so effective as the boiled emulsions. This table, however, gives only a rough comparison of all types of cold-mixed emulsions used with certain types of boiled emulsion.

TABLE X

Type of emulsion	Number of tests made	Number of scales examined	Number of live scales	Percent alive
Boiled F. O. soap, 2%....	25	33,747	513	1.5%
Cold-mixed, 2%..........	28	37,202	996	2.7%

2. Cold-mixed Oil Emulsions

The argument in favor of cold-mixed emulsions is the ease with which they can be made. They do not require boiling, nor handling while hot, and they can usually be more cheaply made than a boiled soap emulsion. In most cases they do not have as high a wetting power as the soap emulsions, and this makes them much less effective against certain kinds of insects, such as aphids.

3. Ease of Dilution

The ease with which any spray material mixes in the tank is an important consideration. Some stock emulsions look good, but upon dilution with water, free oil, which may be injurious to plants, appears on the surface.

In the case of the cold-mixed emulsions with Bordeaux mixture as the emulsifying agent, the stock emulsion rises to the top of the spray solution, though no free oil may appear. This difficulty can be overcome by diluting the stock emulsion with a weak Bordeaux instead of water. A 1-1¼-50 Bordeaux holds it at an equilibrium. It is possible that with the agitator in a spray tank running, this difficulty would not be so serious, but the stock emulsion rises quickly, and it is not at all certain that with the agitator in the bottom of a full tank, a good mixture could be made.

4. Stability

On the whole, cold-mixed emulsions are not as stable as boiled emulsions, as shown by our experience of the past four years. The cold-mixed stock emulsions, upon standing, break down faster than the boiled emulsions, especially in cold weather. For this and other reasons, there is a greater likelihood of injury with the cold-mixed emulsions than with the boiled emulsions.

5. Compatibility with Fungicides

The boiled soap-oil emulsions will mix with Bordeaux, but not with lime sulfur. Most cold-mixed emulsions will mix with both Bordeaux and lime sulfur. While there is some precipitation in the cold-mixed emulsions with lime sulfur, yet effectiveness does not seem to be impaired, as will be seen by applications 69 and 70 in Table IX (pp. 115, 117).

6. Kinds of Cold-mixed Emulsions and Methods of Making

Bordeaux.—Cold-mixed Bordeaux-oil emulsion is made by pumping together, without heating, oil and Bordeaux mixture. Most of that used in our experiments was made with equal parts of oil and Bordeaux. Three pumpings gave a product appreciably better than that made with two. In most of our work, a 4-6-50 Bordeaux (using hydrated lime) was used.

Calcium Caseinate.—Kayso, or any form of calcium caseinate, usually makes a good emulsion. It is probably the easiest to make of any of the commonly used cold-mixed emulsions, and one of the cheapest. The formula generally used is two gallons of oil and one gallon of water in which is mixed four ounces of calcium caseinate. Calcium caseinate should be used fresh to get the best results.

Iron Sulfate-Lime.—Iron sulfate and lime can be used in place of the copper sulfate and lime of the Bordeaux mixture. In our experiments, this emulsion was made up in exactly the same way. The same difficulty of the emulsion rising to the top appeared, but was overcome by diluting with a 1-1¼-50 iron sulfate-lime mixture instead of water.

Colloidal Clays.—Certain colloidal clays—Kaolin, Fuller's earth, Bentonite, and several others—have been used successfully for making cold-mixed oil emulsions. Those made with these clays were only tested in a very limited way in the work here recorded, but very good results were obtained. Work of the entomologists of the Bureau of Entomology and in other states indicates that excellent emulsions can be made with these colloidal clays. In some respects these are superior to most other types of cold-mixed oil emulsions, and they are much cheaper than the boiled soap oil emulsion. They are made up in the form of a thin paste rather than a fluid, and this is objectionable for some uses.

VEGETABLE-OIL-SOAP EMULSIONS

In treatments Nos. 54, 55, 56, 80, 81, and 82 of Table IX (see p 115), the results of spraying with emulsions made with vegetable-oil soap as a substitute for fish-oil soap are given. They are apparently just as effective scalecides as the emulsions made with potash-fish-oil soap, and are slightly cheaper.

Summer Sprays with Oil Emulsion, 1923 and 1924

FOLIAGE TESTS, SUMMERS OF 1923 AND 1924

Oil emulsions had, of necessity, been used for a number of years on citrus trees while in foliage. During the summer of 1922, they were used on apple foliage with little or no burning in experimental work by the Bureau of Entomology in the Bentonville, Arkansas, section, and in work done by this office near Olney, Illinois. During the summer of 1923, foliage injury tests were made at Carbondale with a number of different trees, shrubs, and other plants. Apple, cherry, grape, lilac, mulberry, maple, peony, peach, pear, potato, rose, tomato, and walnut were sprayed during June on clear hot dry days, the temperatures ranging from 89° to 91° F., with 2% strengths of (1) boiled fish-oil-soap emulsion, (2) the same with Bordeaux mixture, 4-4-50, and (3) cold-mixed Bordeaux oil emulsion, and the only seen injury to plants in these tests was severe burning of the foliage on potato and tomato, and a slight blackening of a few leaves on rose and maple.

On cooler cloudy and humid days, with temperatures ranging from 80° to 83°, the following were injured.

With boiled fish-oil-soap emulsion alone

Peach	Slight to defoliation
Pear	50% of leaves specked black
Tomato	15% of leaves partly blackened
Rose	40% of leaves slightly burned
Walnut	50% of leaves peppered with black dots
Maple	2% of leaves slightly blackened

With boiled fish-oil-soap emulsion in 4-4-50 Bordeaux

Peach	Same as on p. 121
Pear	1% of leaves slightly burned
Walnut	Same as on p. 121
Maple	25% of leaves injured

With cold-mixed Bordeaux-oil emulsion

Peach	Same as on p. 121
Pear	90% of leaves burned, 15% severely, 8% killed
Tomato	10% of leaves partly blackened
Rose	50% of leaves burned
Walnut	Same as on p. 121
Maple	10% of leaves burned severely

During the summer of 1924 the following sprays were confined to apple, cherry, grape, peach, plum, potato, and tomato.

Boiled fish-oil-soap emulsion alone, 1% and 2% with paraffin oil of 90-100 viscosity.

Boiled fish-oil-soap emulsion, plus Bordeaux 4-6-50.

Boiled fish-oil-soap emulsion, plus Bordeaux 4-6-50, and arsenate of lead 2-50.

All the above repeated, using a paraffin oil of 212-220 viscosity.

Calcium caseinate cold-mixed emulsion, 1% and 2% with oil of 90-100 viscosity.

Skim milk cold-mixed emulsion, 1% and 2% with oil of 90-100 viscosity.

The injury, listed according to plants sprayed, was as follows:

Apple, Cherry, Grape	No injury by any spray under any condition of weather.
Peach	From 30% to 90% defoliation with boiled fish-oil-soap emulsion, 90 viscosity, paraffin oil at 2% strength with and without the addition of Bordeaux and arsenate of lead. This occurred both in hot dry weather, and in cooler, cloudy, humid weather. Only slight injury with 1%. Using 1% with oil of 212-220 viscosity, no defoliation was observed. No injury with the cold-mixed emulsions.
Plum	No injury.
Potato	2% strengths of everything except the milk emulsions, gave moderate to severe burning. 1% strengths produced very little burning, and usually none.

Tomato ....In most cases injured moderately to severely, both the leaves and fruit, by both 1% and 2% applications.

The apples used in these tests were Winesaps, in the nursery row.

Larger trees in the University orchard at Olney were sprayed with the regular orchard equipment in the summer of 1923 by the Horticultural Department of the University of Illinois. On apples receiving from one to three summer applications, very slight burning of the foliage was seen in all blocks, but nothing serious. Dr. B. A. Porter, using summer sprays on various varieties of apples at Vincennes, found injury serious only on Grimes Golden.

Scale Tests with Oil Emulsion, Summer of 1923

Three series of tests were made during the summer of 1923 with 2% strengths of (1) boiled-fish-oil-soap emulsion; (2) boiled fish-oil-soap emulsion, with Bordeaux; and (3) cold-mixed Bordeaux-oil emulsion. In these experiments, the leaves were all removed from the sprayed branches so that every scale could be hit; and reinfestation was prevented, as far as possible, by bands of tanglefoot around the bases of the branches. In the first two of these series, the percent of scale found alive upon examination ranged from .2% to 2.5%. In an adjoining orchard which was being sprayed with a 3% strength of oil emulsion during the time of one of the tests, 16.8% of the scale was found alive, showing the effect of the foliage in preventing thorough application, and indicating that under orchard conditions, summer applications would not be very effective. The third series of tests gave 15% of the San Jose scale alive, even where the foliage was removed so that every scale was hit.

EXPERIMENTS IN ED KELLEY ORCHARD, ANNA, ILLINOIS, WINTER OF 1924-25

During the winter of 1924-25, a series of tests was run with the object of comparing the efficiency of light and heavy oils when used in boiled and cold-mixed emulsions. All applications were made with the hand sprayer, as previously described. The fall sprays were applied December 1-9, and examined from six to eight weeks later for live scale. The spring application was made February 7, and examined six weeks later. Table XI gives the results of these sprays.

TABLE XI

Treatment (Oil emulsions, all at 2% strength)	Scale examined	Live scale	Percent alive
Paraffin oil, 90-100 viscosity .42% volatility			
Boiled fish-oil-soap emulsion	1500	7	.4
Boiled corn-oil-soap emulsion	1500	3	.2
Cold-mixed (with Bordeaux) emulsion	1500	2	.1
" (" Kayso) "	1500	14	.9
" (" egg) "	1000	33	3.3
Paraffin oil, 100 viscosity .33% volatility			
Boiled fish-oil-soap emulsion	1500	8	.5
Cold-mixed emulsion (calcium caseinate)	1500	1	.06
Paraffin oil, 212 viscosity 1.35% volatility			
Boiled fish-oil-soap emulsion	1500	1	.06
Cold-mixed (with Bordeaux) emulsion	1000	0	0
Boiled corn-oil-soap emulsion	1500	1	.06
Check, January 16	1000	293	29.3
Paraffin oil, 192 viscosity .12% volatility			
Boiled fish-oil-soap emulsion	1500	2	.1
Boiled corn-oil-soap emulsion	1500	0	0
Cold-mixed (with Bordeaux) emulsion	1500	2	.1
" (" calcium caseinate) emulsion	1500	2	.1
Cold-mixed (with egg) emulsion	1500	60	4.0
Check, February 7	1500	195	13.0
Check, March 18	1628	170	10.0
Free-mulsion 1 to 10 (Sherwin-Williams Co.)	1000	1	.1

This table would seem to indicate that there is no difference in effectivness between oils within the range of those used in these experiments. Vegetable-oil soap-emulsions in these tests show as well as those made from fish-oil soap. Cold-mixed emulsions excepting the egg emulsion appear to be as effective as the boiled emulsions. Efforts to make an egg emulsion that would mix well and would stand up over twenty-four hours were unsuccessful with the waters available.

Sherwin-Williams Free-mulsion, while it gave a satisfactory "kill", showed a considerable amount of free oil.

The Effect of Cold Winters on San Jose Scale and Scale Sprays

An examination of the foregoing tables will show considerable variation from year to year in winter mortality. The counts of live scale for the four years on untreated branches were as follows:

Year	Percent alive
1921-22	50.4 (March)
1922-23	65.9 (April)
1923-24	41.4 (March)
1924-25	29.3 (January) 13.0 (February) 10.0 (March)

It would seem entirely plausible that with the weakening effect of a cold winter on scale, the sprays would be more effective. The tables presented here seem to indicate that this is true. In the fall tests in 1923, given in Table VIII, the percent of live scale runs higher than in the spring tests (1924) given in the same table.

During this season we had a rather unusual experience in making scale counts. Previously, after applying sprays, a month had been found long enough to wait for the drying up of the scales that had been killed. Following the fall applications of this year, however, there was a period of abnormally cold weather, and on starting our counts after the usual interval, the oil-sprayed branches showed from 22 to 36 percent of the scale apparently alive. After another four weeks, branches with the same treatment showed only 1.3% to 1.8% live scale, indicating that the scales had been kept in cold storage, as it were, the continuous cold preventing their drying sufficiently to show any discoloration. The winter of 1924-25 was the most severe on the San Jose scale of any winter since 1917-18, and the record of only 10% live scale on the check branches in southern Illinois in March is remarkably low. The effect of this winter-killing is indicated by the very small percent of live scale shown in Table XI for that year, in which none of the treatments, with the exception of two very poor emulsions, gave less than 99% dead scale.

Summary and Recommendations

This report gives the results of four years experiments on the control of San Jose scale at various points in southern Illinois.

The superiority of oil sprays over lime sulfur was demonstrated, 11% of the scale remaining alive after being hit with lime sulfur, as compared with less than 2% with most of the oil sprays.

Boiled emulsion was as effective as the various miscible oils used.

Cold-mixed oil emulsions were about as effective as the boiled emulsions, but somewhat more unstable.

The most reliable type of homemade emulsions are the boiled soap-emulsions.

Vegetable-oil soap was as effective in making the boiled emulsions as fish-oil soap.

Emulsions made from oils with viscosities below 80, have not shown uniformly good kill of scale. There were apparently no differences in effectivness on San Jose scale in emulsions made from oils of 90 to 220 viscosity.

Tests with boiled potash-fish-oil-soap emulsions in summer showed very little injury to apple foliage, considerable injury to peach, and to a few other plants under some conditions. Due to the difficulty in reaching the scale when the trees are in foliage, summer sprays are not recommended except in case of very severe scale infestation.

Where oil emulsions were properly mixed and applied, no injury to trees has resulted.

On the basis of these experiments and observations, the following recommendations are made:

1. Oil emulsion is recommended as a cheap and effective spray for the control of San Jose scale. The formula for the stock emulsion found best in our experimental work is as follows:

Oil	1 gallon
Potash-fish-oil-soap	1 to 2 pounds
Water	¼ gallon

Heat to boiling, and pump twice at a pressure of 75 pounds, or more. The strength recommended is 2.4% (3 gallons in 100), or, in case of severe and increasing infestation, 4 gallons in 100 gallons of water. The best oil to use, judging by our experiments and those of investigators in Indiana and Arkansas, is a lubricating oil coming within the following limits:

Specific gravity	.87 to .93 at 20° C.
Volatility	Not above 2% at 110° C. for 4 hours.
Viscosity	90 to 250 seconds (Saybolt test) at 100° F.

2. If cold-mixed emulsions are used, they may be made according to the following formulae:—

Bordeaux, Cold-mixed

Pump together equal parts of oil and 4-4-50 Bordeaux mixture, sending the material at least three times through the pump. For a 2% strength, dilute four gallons in one hundred.

Calcium Caseinate, Cold-mixed

Pump together two gallons of oil and one gallon of water in which is dissolved four ounces of calcium caseinate. For a 2% strength, use three gallons in one hundred.

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NATURAL HISTORY SURVEY
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Vol. XVI. BULLETIN Article III.

Notes on Homoptera from Illinois, with Descriptions of New Forms, chiefly Eupteryginae

BY

W. L. McATEE

AUG. 26TH 1818

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ARTICLE III.—*Notes on Homoptera from Illinois, with Descriptions of New Forms, chiefly Eupteryginae.* BY W. L. MCATEE.

The records given herein supplement those in a previous paper (Bul. Ill. State Nat. Hist. Survey, Vol. XV, Art. II, April, 1924, pp. 39-44) along similar lines, and constitute a report on various lots of Homoptera, chiefly Eupteryginae submitted to the writer for determination. The species of the genus *Typhlocyba* are treated in a previous paper (Proc. U. S. Nat. Mus., Vol. 68, Art. 18, pp. 1-47), and those of the genus *Empoasca* are held pending revisional study.

FAMILY PSYLLIDAE

Genus CALOPHYA Loew

Calophya pallidula new species

With well-developed genal cones, contiguous at base, rather acute and outcurved at apex, this species is more closely related to *C. flavida* Schwarz than to any other species. It is of about the same size (body 1.5 mm., fore wing, 1.9 mm.), but is pale greenish yellow instead of "honey yellow" or fulvous, the wings hyaline, not fumose, and the pterostigma shorter, about ¾ the length of the cell it bounds costally, instead of ⅘ as in *C. flavida.*

Holotype and paratype (1) females, Meredosia, Illinois, May 29, 1917.

Holotype and paratype deposited in the collection of the Illinois State Natural History Survey.

FAMILY FULGORIDAE

Genus CEDUSA Fowler

C. fedusa McAtee.—Cedar Lake, Aug. 4, 1906; also Nos. 580 and 15196.

C. kedusa McAtee.—Antioch, Aug. 1, 1924, T. H. Frison.

Genus OTIOCERUS Kirby

O. wolfii Kirby.—Metropolis, Ill., Sept. 3, 1924, T. H. Frison. This species, according to its describer, has only one appendage to the antenna in the males. The male at hand has two appendages but otherwise agrees with the original description and with the identification of the species by Fitch (Trans. N. Y. State Agr. Soc. 16, 1856, p. 394) in contrasting it with his *O. amyotii.* Because of the usual imperfection of specimens the taxonomic value of these appendages is not well understood, and it seems best at present to base determination on other characters.

Otiocerus wolfii var. *nubilus* new variety

A female specimen with the mesonotum and adjacent parts of the clavi infuscate is made the holotype of this new variety. The brown vitta of tegmen is almost obsolete, and the dark marking at apex of clavus more conspicuous than usual.

Holotype, female, Metropolis, Ill., Sept. 3, 1924, T. H. Frison.

Holotype deposited in the collection of the Illinois State Natural History Survey.

FAMILY JASSIDAE

Genus ALEBRA Fieber

A. albostriella var. *pallidula* Walsh.—Urbana, June 17, 1916, July 9, 1920; Ashley, Aug. 7, 1917; Elizabeth, July 8, 1917; also Nos. 4520 and 25021. Grand Junction, Mich., July 15, 1914.

A. albostriella var. *agresta* McAtee.—Mt. Carmel, July 3, 1906; Urbana, July 16, 1916, Aug. 27, 1915; White Heath, July 5, 1916; Dubois, Aug. 8, 1917; Ashley, Aug. 7, 1917.

A. albostriella var. *bicincta* DeLong.—Dubois, Aug. 9, 1917.

A. albostriella var. *fumida* Gillette.—Urbana, July 9, 14, 1920; St. Joseph, June 27, 1915; White Heath, July 5, 1916, on *Crataegus*.

Genus DIKRANEURA Hardy

D, angustata Ball and DeLong.—Metropolis, Aug. 20, 1916; Paxton, July 30, 1916; Urbana, Sept. 8, 1916, on locust; Brownfield, Aug. 17, 1916; Dongola, May 10, 1916.

D. abnormis Walsh.—Urbana, Sept. 24, 1916.

D. fieberi Löw.—Urbana, June 2, July 29, Sept. 3, 5, 20 on hackberry, 24, 1916; Brownfield, Aug. 17, 1916; Dongola, May 10, Aug. 23, 1916; Paxton, July 30, 1916; Ingleside, July 21, 1916; White Heath, July 5, 1916; St. Joseph, Sept. 3, 1916; Clayton, Sept. 30, 1916; Plainview, May 11, 1916, on plantain; Savanna, June 12, 1917; Alto Pass, May 8, 1917; Meredosia, May 29, 1917; Dubois, May 24, 1917.

D. cruentata var. *cruentata* Gillette, red form.—Forest City, April 3, 1917; Muncie, July 4, 1919; also No. 25018.

D. cruentata var. *cruentata* Gillette, yellow form.—Dongola, May 9, 12, 1916.

D. cruentata var. *rubricata* McAtee.—Muncie, July 4, 1919; Augerville, Nov. 17, 1919.

D. maculata Gillette.—Dongola, May 10, 1917; Urbana, Sept. 2, 20, 1916, on hackberry.

Genus EUPTERYX Curtis

E. flavoscuta var. *flavoscuta* Gillette.—Savanna, June 13, 1917.

E. flavoscuta var. *clavalis* McAtee.—Oregon, June 19, 1917.

E. flavoscuta var. *nigra* Osborn.—Dubois, May 22, 1917; also No. 565, and Mineral Spring, Ind., June 24, 1916.

Genus HYMETTA McAtee

H. trifasciata var. *trifasciata* Say.—Meredosia, May 30, 1917; Savanna, June 14, 1917; Metropolis, Aug. 20, 1916; Oregon, June 21, 1917; Urbana, March 24, 1916, among leaves, Nov. 3, 1916; White Heath, April 17, 1909; Dubois, Aug. 8, 1917; Clayton, Sept. 28, 30, 1916; Hopedale, Oct. 2, 1917; Danville, March 12, 1910.

H. trifasciata var. *balteata* McAtee.—Muncie, July 4, 1919.

H. trifasciata var. *albata* McAtee.—Dongola, Aug. 23, 1916.

Genus ERYTHRONEURA Fitch

E. vulnerata var. *vulnerata* Fitch, red form.—Algonquin, April 18, 1896, May 4, 1895; White Heath, April 30, 1916; Forest City, April 3, 1917; Dongola, Aug. 22, 23, 1916; Metropolis, Aug. 20, 1916; Clayton, Sept. 30, 1916; Brownfield, Aug. 17, 1916; also Nos. 10819, 14873, 17397, 17399, 25018, 25019, and 25799

E. vulnerata var. *vulnerata* Fitch, fulvous form.—Algonquin, April 18, 1896; Dongola, May 9, 12, Aug. 22, 23, 1916; Dubois, May 22, 1917; Brownfield, Aug. 17, 1917; Metropolis, Aug. 20, 1916; Savanna, June 13, 1917; Clayton, Sept. 30, 1916.

E. vulnerata var. *decora* McAtee.—Urbana, March 24, 1916, among leaves, Sept. 6, 20, 24, 1916; Dongola, Aug. 23, 1916; Metropolis, Aug. 18, 20, 1916; St. Joseph, Sept. 3, 1916; Dubois, July 2, 1909; White Heath, April 30, 1916; Algonquin, Sept. 25, Oct. 16, 1895; also Nos. 14889, 23671, 25018, and 25019.

E. obliqua var. *obliqua* Say, red form.—White Heath, April 30, 1916; Forest City, April 3, 1917; Urbana, March 24, 1916, April 15, 1909, April 29, May 5, 1916, April 24, 1924, Sept. 2, 1916; Savoy, May 4, 1916; Muncie, July 4, 1919; Dongola, May 10, 1916; Olney, Sept. 21, 1916, on apple; also Nos. 15482 and 25048.

E. obliqua var. *obliqua* Say, yellow form.—White Heath, June 24, 1916, on oak; Dubois, May 14, 15, 1916; May 22, 1917; Dongola, May 11, 13, Aug. 22, 23, 1916; Urbana, July 7, 1915, Sept. 9, 1916; Meredosia, May 28, 1917; Olney, Sept. 21, 1916, on apple; also No. 25781.

E. obliqua var. *clavata* DeLong.—Dubois, May 22, 24, 1917.

E. obliqua var. *dorsalis* Gillette, red form.—Urbana, March 24, 1916, among leaves, April 29, 1916, April 24, 1924; Muncie, July 4, 1919; Olney, Sept. 21, 1916, on apple; Clayton, Sept. 30, 1916; Forest City, April 3, 1917; Barry, March 28, 1924; also Nos. 156, 3707, 14034, 14271, 15747, 19036, 25760, and 25837.

E. obliqua var. *dorsalis* Gillette, dusky form.—Urbana, Nov. 3, 1916. Nov. 10, 1915; Dongola, May 9, 12, Aug. 23, 1916; Meredosia, May 28, 1917; White Heath, April 30, 1916; also Nos. 10867, 15540, and 25742.

E. obliqua var. *stolata* McAtee.—No. 10591.

E. obliqua var. *parma* McAtee.—White Heath, April 30, 1916.

E. obliqua var. *noevus* Gillette, red form.—Muncie, July 4, 1919; Urbana, March 24, 1916, among leaves, April 24, 1924, April 29, 1920;

White Heath, April 30, 1916; St. Joseph, Nov. 10, 1906; also Nos. 156, 238, 266, 25048, and 25756.

E. obliqua var. *noevus* Gillette, yellow form.—Dubois, May 15, 1916; White Heath, April 30, 1916, May 7, 1909; Muncie, June 3, 1917; Dongola, May 10, 1917; Urbana, March 24, 1916, among leaves; also No. 50235.

E. obliqua var. *fumida* Gillette, red form.—Muncie, Feb. 7, 1925, June 3, 1917, July 4, 1919; White Heath, April 30, 1916; Metropolis, Aug. 20, 1916; Algonquin, Oct. 11, 1895; Urbana, April 24, 1924, April 29, 1916, Sept. 8, 1916, on locust, Nov. 13, 1915; Dongola, May 9, 13, 1916; Meredosia, May 29, 1917; Forest City, April 3, 1917; Dubois, May 14, 1916.

E. obliqua var. *fumida* Gillette, yellow form.—Urbana, June 17, Sept. 5, 9, 1916; April 24, 1924; Clayton, Sept. 30, 1916; Dongola, May 12, Aug. 23, 1916; Dubois, May 22, 25, 1917; Metropolis, Aug. 20, 1916; White Heath, April 30, 1916, Aug. 12, 1920; Savanna, June 11, 1917.

Erythroneura obliqua var. *bitincta* new variety

Like *E. obliqua* var. *obliqua* yellow form, with the anterior markings, that is of head and thorax, including those on base of scutellum, and of tegmina especially along costa, obliterated by a brownish black wash, and the tegmina from just anterior to apices of clavi apically, blackish. Upper part of face dusky yellowish, remainder of lower surface of head, and of thorax, brownish black, legs mostly stramineous, venter yellowish. Length, 3 mm.

Holotype, male, Toronto, Canada, Aug. 8, 1924, E. D. Ball.

Holotype deposited in the collection of E. D. Ball.

E. obliqua var. *eluta* McAtee.—Urbana, Aug. 3, 1916; Dongola, Aug. 22, 1916.

E. rubroscuta Gillette, red form.—Urbana, April 18, 1918, April 23, 1919, April 23, 29, July 20, 1920; Augerville, Oct. 18, 1919; Muncie, Aug. 15, 1917.

E. robroscuta Gillette, yellow form.—Urbana, April 23, 1919, April 29, 1920.

E. abolla var. *accensa* McAtee, red form.—White Heath, April 30, 1916.

E. abolla var. *accensa* McAtee, yellow form.—Urbana, April 18 1919, July 12, 1920; Dongola, May 12, 1916; Dubois, May 24, 1917.

E. abolla var. *abolla* McAtee, red form.—Muncie, July 4, 1919; Altc Pass, May 8, 1917; White Heath, April 30, 1916; Meredosia, May 30, 1917; Urbana, March 24, 1916, among leaves.

E. abolla var. *varia* McAtee, red form.—White Heath, April 30, 1916; Urbana, March 24, 1916, among leaves; Dubois, May 22, 1917; also No. 3171.

E. abolla var. *varia* McAtee, yellow form.—Metropolis, Aug. 20, 1916.

Erythroneura abolla var. *lemnisca* new variety

Like *E. abolla* var. *accensa* yellow form, except that the scutellum, and disk of pronotum and vertex are occupied by a broad dusky vitta. In the paratype, the coloration of tegmina anterior to crossveins has hardly any reddish in it (in this respect resembling var, *iconica*) but this may be due to incompletion of the coloring process. Length, 3 mm.

Holotype, female, Urbana, Ill., July 12, 1920, C. P. Alexander; paratype, Urbana, Ill., Brownfield Woods, April 29, 1920.

Holotype and paratype deposited in the collection of the Illinois State Natural History Survey.

Erythroneura mallochi McAtee

Erythroneura mallochi McAtee, W. L., Bul. Ill. State Nat. Hist. Survey, 15, Art. II, April, 1924, p. 41 [Meredosia, Ill.].

Meredosia, May 29, 1917; Dongola, May 10, 1917, May 12, 1916; Metropolis, Aug. 18, 1916; Forest City, April 3, 1917. This additional material reveals that this species has a red-marked form, the principal vittae of tegmina, the markings on head and pronotum, and even the scutellar triangles in some cases being red, usually of a bluish cast with purer red edgings.

Erythroneura repetita new species

Belongs in Group 4 of my 1920 paper (Trans. Am. Ent. Soc., 46, pp. 269-271, Aug. 26, 1920), and is nearest to *E. mallochi* McAtee in form, venation, and coloration. Ground color of vertex pale yellow, with an irregular vitta each side the median line deeper yellow; pronotum pale yellow overlaid by olive-brown except for anterior margin, a spot on each lateral margin, and three ovoid spots across disk; scutellum yellow with the basal triangles blackish, and two discal spots brownish; tegmen whitish hyaline with the base faintly dusky, a broad band from costal plaque, across corium and clavus, widening slightly toward the commissure, and apical cells except their extreme bases, a spot on costa in middle of cell 2, and apices of cells 3 and 4, dusky. Front bordered laterally by dusky stripes, and clypeus dusky basally as in *E. mallochi*. Under side of thorax, a band across base of dorsum, and apex of ovipositor, black; apex of dorsum brownish; abdomen otherwise, and legs and under side of head pale yellow. Length, 3 mm.

The holotype female was loose in one of the boxes in which the collection was received, so can be labeled only Illinois.

Holotype deposited in the collection of the Illinois State Natural History Survey.

E. aclys McAtee.—Urbana, May 1, 1920, April 24, 1924; White Heath, April 28, 30, 1916; Homer, June 17, 1917.

E. illinoiensis var. *illinoiensis* Gillette, red form.—Danville, March 12, 1910; St. Joseph, Sept. 3, 1916; White Heath, May 7, 1909; Brownfield, Aug. 18, 1916.

E. illinoiensis var. *illinoiensis* Gillette, yellow form.—Brownfield, Aug. 18, 1916.

E. illinoiensis var. *spectra* McAtee.—Dongola, May 13, 1916; Dubois, May 15, 1916.

E. morgani DeLong.—Dongola, May 13, Aug. 22, 23, 1916; Brownfield, Aug. 17, 1916; White Heath, April 30, 1916; Metropolis, Aug. 20, 1916; Meredosia, May 30, 1917.

E. hartii Gillette.—Olney, Sept. 21, 1916, on apple; White Heath, May 28, 1916, on apple; Savoy, May 4, 1916.

Erythroneura pyra McAtee

Erythroneura pyra McAtee, W. L., Proc. Biol. Soc. Wash., 37, p. 133, Dec. 29, 1924 [Berwick, Iowa].

Closely allied to *E. hartii* Gillette, and copying it in markings, except that the red markings surrounding the pale saddle-spot are confined to clavus anteriorly and extend no farther posteriorly than costal plaque, whereas in *E. hartii* they cover the corium also, and extend to the crossveins or beyond.

Inner clasper angulate inwardly, then outwardly, the angles more or less acute, the inwardly angling apical process slender and acute; process of 9th segment long, slender, bowed outwardly subapically, where it is armed below by a large aciculate process, apex also aciculate; aedeagus stout, shaft shorter than the basal cavity. Length, 3 mm.

Muncie, Ill., July 4, 1919; Urbana, Ill., July 20, 1920, C. P. Alexander. Yellow-marked forms, Urbana, Ill., April 23, 1919, April 29, May 1, 1920; in copula the latter date.

The following comparative statement about the genitalia of *E. hartii* may be made: Inner clasper rather the shape of a human lower leg, with the knee, heel, and toe more or less acute; process of 9th segment simply decurved, falcate, thinner apically as viewed from above; aedeagus slender, recurved apically, shaft much longer than the basal opening.

Erythroneura mitella new species

In venational characters this species belongs in the same group (IV of my paper on the genus, Trans. Am. Ent. Soc. 46, 1920, pp. 269-271) as *E. pyra,* but the coloration is much like that of some varieties of *E. comes* Say, as a heavily marked specimen of var. *vitifex* Fitch. Ground color of head and thorax pale yellow, of tegmina hyaline whitish. Vertex with yellowish to reddish curved lines near eyes, and forming a more or less ovate marking in middle; pronotum with an irregular Y on disk, and a heavy triangle on each anterior angle orange-red; basal triangles of scutellum yellow, outlined by red, apex red; tegmen with a broad band from costal plaque to commissure, narrowing on clavus over about the middle of which it forms an oblique marking, and a narrow band on clavus only at a point one-fourth from apex, pinkish red; a longitudinal vitta along outer margin of clavus basally is yellowish red; a triangle on costa near base of corium, orange-red and a band from posterior end of costal plaque to crossveins scarlet, a more or less inclosed oval area, and the costal border whitish. A dark spot in hind end of costal plaque, and in base of fourth apical cell.

Inner clasper somewhat enlarged and angulate subapically, the angle with a downwardly projecting short tooth, apex bifid into aciculate processes, the axial one longer; process of 9th segment, long, slender, aciculate apically, distinctly outcurved subapically, forming with its fellow a caliper-like figure; aedeagus moderately stout, swollen medially, shaft longer than the basal opening. Length, 3 mm.

Two of the females have the anterior markings yellow.

Holotype, male, White Heath, April 30, 1916; allotype, Urbana, Nov. 3, 1916; paratypes, White Heath, April 30, 1916; Dongola, May 10, 23, 1916; Dubois, Aug. 8, 1917; Alto Pass, May 7, 1917.

Holotype, allotype, and five paratypes deposited in the collection of the Illinois State Natural History Survey. Two paratypes deposited in the collection of W. L. McAtee.

E. scutelleris Gillette, red form.—Urbana, April 15, 1909, March 24, 1916, among leaves; White Heath, April 17, May 17, 1909, April 28, 30, 1916; Forest City, April 3, 1917; Dongola, Aug. 23, 1916; Muncie, July 4, 1919.

E. scutelleris Gillette, yellow form.—Dongola, Aug. 23, 1916; White Heath, May 7, 1909, April 30, 1916; Dubois, May 22, 1917; Meredosia, May 28, 1917; Urbana, Sept. 6, 19, 1916.

Erythroneura scutelleris var. *insolita* new variety

With the pronotum and scutellum chiefly dark, and with a dark dot in apex of costal plaque, and base of fourth apical cell, as customary in the species, but practically without other markings. Length, 3 mm.

Holotype, female, Muncie, July 5, 1914; allotype, Dongola, Aug. 23, 1916.

Holotype and allotype deposited in the collection of the Illinois State Natural History Survey.

E. basilaris var. *basilaris* Say, red form.—White Heath, April 15, 30, 1916; Muncie, July 4, 1919; Urbana, March 24, April 29, 1916, April 24, 1924; Sept. 8, Oct. 22, 1916; Forest City, April 3, 1917.

E. basilaris var. *basilaris* Say, yellow form.—White Heath, Oct. 10, 1915, June 11, 1916; Urbana, Sept. 3, 8, Nov. 3, 1916, April 24, 1924, July 4, 1915; Meredosia, May 28, Aug. 19, 22, 1917; Dongola, May 14, Aug. 23, 1916; May 10, 1917; Dubois, May 15, 1916, May 23, 1917.

E. maculata var. *maculata* Gillette, red form.—Dongola, May 13, Aug. 22, 23, 1916; Savoy, May 23, 26, 1916; Urbana, Sept. 21, 1916, on apple, April 15, 1908, April 23, 1919, May 1, 1920; Forest City, April 3, 1917; White Heath, May 7, 1909; St. Joseph, Nov. 10, 1906; Homer, April 1, 1909; Algonquin, Oct. 15, 22, 1895; Meredosia, Aug. 22, 1917; Muncie, July 4, 1914; also Nos. 17867, 25069, 25756, 40309, and 43384.

E. maculata var. *maculata* Gillette, yellow form.—Dongola, May 10, 12, 13, Aug. 22, 1916, May 9, 1917; Metropolis, Aug. 20, 1916; Meredosia,, May 20, 28, 1917; Dubois, Sept. 21, 1916, on apple, May 22, 1917; Alto Pass, May 8, 1917; Danville, July 30, 1917, on sycamore; Algonquin, June 8, 1907; Clayton, Sept. 30, 1916; Urbana, May 1, July 9, 1920; Homer, June 4, 1916; Oregon, June 19, 1917.

E. maculata var. *era* McAtee, red form.—Forest City, April 3, 1917, on hickory; Dubois, May 22, 1917.

E. maculata var. *bella* McAtee, red form.—Metropolis, Aug. 20, 1916, on sycamore; Dongola, May 11, 1916; Muncie, June 3, 1917, on hickory.

E. maculata var. *osborni* DeLong.—Dubois, May 22, 25, Aug. 8, 1917; Urbana, June 17, 1916.

E. maculata var. *apicalis* DeLong.—Dongola, May 10, 13, 1916, Aug. 22, 23, 1916; Urbana, May 21, 1916; Danville, July 20, 1917, on sycamore; Muncie, June 2, 1917; Dubois, 22, 23, 1917.

E. maculata var. *bigemina* McAtee.—Dongola, May 10, 13, Aug. 23, Aug. 24, on grape, 1916; Metropolis, Aug. 20, 1916; Lake Villa, June 21, 1916; Dubois, Aug. 8, 1917; Urbana, July 9, 1920; Savanna, June 12, 1917; Ashley, Aug. 7, 1916.

E. maculata var. *gemina* McAtee.—Urbana, Sept. 24, 1916; Dongola, May 12, 1916.

E. ligata var. *pupillata* McAtee.—Urbana, July 13, 14, 1920.

E. infuscata Gillette.—White Heath, April 22, 1917; Dongola, May 13, 1916.

E. vitis var. *vitis* Harris.—White Heath, April 22, 1917, April 30, 1916; Algonquin, Aug. 21, 1911; Muncie, July 4, 1919; Metropolis, Aug. 20, 1916; Meredosia, May 28, 1917; Urbana, April 24, 1924, Oct. 26, Nov. 3, 1916; Clayton, Sept. 28, 1916, on grape; St. Joseph, Sept. 3, 1916; Dubois, Aug. 8, 1917; Forest City, April 3, 1917.

E. vitis var. *corona* McAtee.—Muncie, July 4, 1919; Meredosia, May 28, 29, 1917; Metropolis, Aug. 20, 1916; White Heath, June 3, 1916; Urbana, March 24, 1916, among leaves, Aug. 27, 1916, Nov. 22, 1906; St. Joseph, Nov. 10, 1906; Brownfield, Aug. 17, 1916; White Heath, April 30, 1916; also No. 13408.

E. vitis var. *bistrata* McAtee.—Dongola, Aug. 22, 1916; White Heath, May 18, 1917.

E. vitis var. *stricta* McAtee.—Clayton, Sept. 28, on grape, Sept. 30, 1916; Forest City, April 3, 1917; Dubois, May 22, 24, 1917; White Heath, April 30, 1916; Meredosia, May 28, 29, 1917; Urbana, Aug. 4, 1916; Metropolis, Aug. 18, 1916; also Nos. 10819, 13620.

E. tricincta var. *tricincta* Fitch, red form.—Urbana, March 24, 1916, among leaves; Forest City, April 3, 1917; Muncie, Dec. 13, 1913.

E. tricincta var. *tricincta* Fitch, yellow form.—Algonquin, June 8, 11, 1907; Meredosia, May 29, 1917; Dubois, May 25, 1917; Dongola, May 10, 1916.

E. tricincta var. *calycula* McAtee, red form.—Muncie, July 4, 1919; Urbana, Nov. 22, 1906.

E. tricincta var. *calycula* McAtee, yellow form.—Dubois, May 15, 1916; Savanna, June 14, 1917; White Heath, May 7, 1909; also No. 10819.

E. tricincta var. *diva* McAtee.—Meredosia, May 28, 29, 1917; White Heath, April 30, 1916, May 18, 1917.

E. tricincta var. *integra* McAtee, red form.—Muncie, July 4, 1919; Urbana, March 24, 1916, among leaves.

E. tricincta var. *integra* McAtee, yellow form.—Dongola, May 10, 1917; Alto Pass, May 7, 1917; also No. 10819.

E. tricincta var. *cymbium* McAtee.—Dongola, May 10, 1917; Urbana, Oct. 11, 1914, April 29, 1916; White Heath, May 7, 1909; also Nos. 10819 and 14034.

E. tricincta var. *disjuncta* McAtee.—Meredosia, May 28, 1917; White Heath, May 7, 1909.

Erythroneura tricincta var. *complementa* new variety

Crossbands one and two bright red, three dusky, differing from var. *diva* McAtee in crossband one being confined to pronotum; subsidiary markings yellow. Length, 2.75 mm.

Holotype, female, Ocean Springs, Miss., Aug. 4, 1921, C. J. Drake.

Holotype deposited in the collection of W. L. McAtee.

E. comes var. *comes Say,* red form.—White Heath, April 30, 1916; also No. 25019.

E. comes var. *comes* Say, red form.—White Heath, April 30, 1916; Dongola, Aug. 24, 1916, on grape; Metropolis, Aug. 20, 1916.

E. comes var. *vitifex* Fitch, red form.—White Heath, April 30, 1916, May 7, 1909; Brownfield, Aug. 17, 18, 1916; Clayton, Sept. 30, 1916; Metropolis, Aug. 20, 1916; St. Joseph, Sept. 3, 1916, on grape; Algonquin, May 18, 1897; Clay City, Sept. 2, 1909; Forest City, April 3, 1917; Muncie, July 4, 1919; Urbana, April 24, 1924; also Nos. 25017 and 25019.

E. comes var. *vitifex* Fitch, yellow form.—St. Joseph, Sept. 3, 1916, on grape; Metropolis, Aug. 20, 1916; Clayton, Sept. 30, 1916; Meredosia, May 28, 1917; Dubois, May 22, 1917; Clay City, Aug. 17, 1911; White Heath, April 30, 1916; Brownfield, Aug. 17, 1916; Alto Pass, May 7, 1917; Dongola, Aug. 22, 23, 1916.

E. comes var. *palimpsesta* McAtee.—Several topotypes, Forest City, April 3, 1917.

E. comes var. *elegans* McAtee.—Urbana, Ill., May 5, July 3, 4, Sept. 4, 6, 1916; Aug. 25, 1924; Elizabeth, July 7, 1917; Algonquin, May 31, 1913; Muncie, July 4, 1914; Meredosia, Aug. 30, 1917; White Heath, April 30, 1916.

E. comes var. *rubra* Gillette.—Metropolis, Aug. 20, 1916; Brownfield, Aug. 18, 1916; Dongola, Aug. 23, 1916; Havana, May 1, 1912.

E. comes var. *rubrella* McAtee.—Dongola, Aug. 22, 23, 1916; Forest City, April 3, 1917; White Heath, May 7, 1906; Oregon, June 20, 1917; Meredosia, Aug. 19, 1917.

E. comes var. *reflecta* McAtee.—Forest City, April 3, 1917; Urbana, March 24, 1916, among leaves, Aug. 28, 1915; Metropolis, Aug. 18, 20, 1916; White Heath, May 7, 1909, April 27, 1917; Havana, May 1, 1912;

Dongola, May 13, 1916; Meredosia, May 28, 1917; Savanna, June 14, 1917.

Erythroneura comes var. *pontifex* new variety

Like *E. comes* var. *reflecta* McAtee (Bul. Ill. State Nat. Hist. Survey, 15, Art. II, April 1924, p. 43 [Md., Va., Ill., Ia., Kans.]), but with two black finger-shaped vittae on vertex overlying an inverted heart-shaped brownish marking; a marking somewhat similar to latter can be seen through the disk of pronotum. Length, 3 mm.

Holotype, female, Dubois, Ill., May 24, 1917.

Holotype deposited in the collection of the Illinois State Natural History Survey.

E. comes var. *delicata* McAtee, yellow form.—St. Joseph, Sept. 3, 1916, on grape.

Erythroneura comes var. *octonotata* Walsh

Having examined copious material of the genus from Illinois, which in all probability must contain some representatives of *octonotata* described by Walsh from that state, I have decided to use the name for some whitish hyaline specimens with slight orange-yellow color-markings, and a dark dot in middle of clavus, in addition to the usual ones in apex of costal plaque, apex of second apical, and base of fourth apical cell. In effect it is the variety *delicata* McAtee with a dark dot in clavus. White Heath, April 30, 1916; Brownfield, Aug. 17, 1916. Two specimens of var. *delicata* from the District of Columbia region show a faint dark spot in the clavus.

E. comes var. *accepta* McAtee, red form.—Urbana, Aug. 4, 7, 1916, on grape; St. Joseph, Sept. 3, 1916.

E. comes var. *accepta* McAtee, yellow form.—Urbana, Aug. 4, 1916, on grape; Dongola, Aug. 23, 1916.

E. comes var. *compta* McAtee, red form.—Muncie, July 4, 1914; White Heath, May 7, 1909; Brownfield, Aug. 17, 1916; Urbana, Sept. 9, 1916; Forest City, April 3, 1917.

E. comes var. *compta* McAtee, yellow form.—Urbana, Aug. 29, 1914, Aug. 4, 1916, on grape; Dongola, Aug. 23, 1916; Brownfield, Aug. 17, 1916; Clay City, Aug. 17, 1911; St. Joseph, Sept. 3, 1916, on grape.

E. comes var. *rufomaculata* McAtee.—Dongola, Aug. 23, 1916; Urbana, Sept. 6, 1916; Brownfield, Aug. 17, 1916.

E. comes var. *ziczac* Walsh, red form.—Algonquin, July 17, 1895, Aug. 20, 24, 1894, Sept. 5, 9, 1894, Oct. 18, 1895; White Heath, April 30, 1916; St. Joseph, Sept. 3, 1916, on grape.

E. comes var. *ziczac* Walsh, yellow form.—Algonquin, April 15, 1896, July 8, 1895, Aug. 28, 1894; Metropolis, Aug. 20, 1916; also No. 25799.

STATE OF ILLINOIS
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DIVISION OF THE
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STEPHEN A. FORBES, *Chief*

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A List of the Insect Types in the Collections of the Illinois State Natural History Survey and the University of Illinois

BY

THEODORE H. FRISON

AUG. 26TH 1818

PRINTED BY AUTHORITY OF THE STATE OF ILLINOIS

URBANA, ILLINOIS
February, 1927

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VOL. XVI, ART. IV.

ERRATA

Page 138, line 10 and line 14 from bottom, for *Dane* read *Dann.*
Page 139, line 5, for *Dane* read *Dann.*
Page 180, line 5 from bottom, delete *D.*
Page 198, line 19 from bottom, for *March* read *March 16, 1918.*
Page 221, line 22, for *data* read *date.*
Page 278, lines 17 and 18 from bottom in right-hand column, for *150* read *158.*
Page 285, line 24 in left-hand column, for *Franch* read *French.*

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CONTENTS

ARTICLE IV.—*A List of the Insect Types in the Collections of the Illinois State Natural History Survey and the University of Illinois.* BY THEODORE H. FRISON, Illinois State Natural History Survey.

INTRODUCTION

The ever-increasing requests by technical workers in the field of entomology for information concerning the insect types in the collections of the Illinois State Natural History Survey and the University of Illinois have led to the preparation of this paper. The reasons for such requests are readily apparent to any one acquainted with the problems and difficulties today confronting the scientific investigator in the fields of taxonomy and nomenclature. The enormous number of insects already described, comprising a total far in excess of the number of all other known kinds of animals, is augmented each year by the recognition and description of hundreds of species new to science. This multiplicity of kinds of insects has greatly increased the difficulty of their classification and brought to light many problems whose best solution rests upon a restudy of the actual type specimens—the specimens used by the author of a species in formulating the original description.

Thus it happens that at the present time the types of insects have come to possess a great practical value as well as a historical significance. A complete realization of the value of exacting type-designations and the proper labeling and preservation of the types did not come to most of the earlier entomologists. In fact, it is only within comparatively recent years that much emphasis has been placed upon exacting type-designations, disposition of types, full data concerning locality, date of capture of specimens and the many other facts now commonly added to the original description of a new species.

It was but natural, then, that when the task was undertaken of listing, locating, labeling and isolating the types in the collections here to insure their safety, no uniformity of type designations was found in the material. Various workers can be accredited for the numerous types, some described at an early date and others comparatively recently. To meet this situation the writer undertook the selection of lectotypes wherever this was deemed necessary or advisable. This procedure is in line, although not specifically covered, by that recommendation of the International Rules of Zoological Nomenclature suggesting that "only one specimen be designated and labeled as *type*". Furthermore, it makes paratypic material available for exchange and for loan to specialists, as well as eliminating certain undesirable situations that may arise from the exchanging of cotypes.

The insect collection of the Illinois State Natural History Survey contains the most complete collection of Illinois insects in existence and ranks high among the best general collections in this country. Its possession is a valuable asset to the state and an aid to all lines of research conducted by the Survey. The collection is the result of a wise policy of many years' accumulation and direct collection of insect material. For the benefit of those interested in the historical phase of the insect collection of the Illinois State Natural History Survey a short sketch of its origin and development is given. The State Entomologist's Office of Illinois was established in 1867 with Benjamin Dane Walsh as Acting State Entomologist. William LeBaron, soon after the accidental death of Walsh, was appointed to the position of State Entomologist in 1870 and held this office until 1875. Then Cyrus Thomas succeeded William LeBaron as State Entomologist and continued in office until the appointment of Stephen Alfred Forbes in 1882. The appointment of Stephen Alfred Forbes brought about, in a sense, the merger of the Office of the State Entomologist and the State Laboratory of Natural History, since he was Director of the latter institution. In 1917, the State Entomologist's Office was definitely merged by law with the State Laboratory of Natural History to form the Illinois State Natural History Survey Division of the State Department of Registration and Education, and Stephen Alfred Forbes was appointed as its Chief.

During the period of 1867 to the present time many descriptions of new species have been published in the twenty-nine reports of the State Entomologist's Office, the Bulletin of the State Laboratory of Natural History, and its successor, the Bulletin of the Illinois State Natural History Survey. Concerning these publications I quote from an introduction written for a list of exchange and available publications and published in 1924 by Stephen Alfred Forbes.

"Twenty-nine reports of the State Entomologist were published between 1868 and 1916, the first by Benjamin Dane Walsh, the second to the fifth by William LeBaron, the sixth to the eleventh by Cyrus Thomas, and the twelfth to the twenty-ninth by Stephen Alfred Forbes. Later articles of like object and character to those in these reports are published as bulletins and circulars of the State Natural History Survey.

"The State Laboratory of Natural History began publication of its Bulletin in 1876, the first number of what became Volume 1 of this series being issued as a bulletin of the Illinois Museum of Natural History. All subsequent numbers were issued as bulletins of the above Laboratory until 1917, after which the series was continued as the Bulletin of the Illinois State Natural History Survey. Volumes 1 to 12 have been published under the first of these titles, and 13 and 14, together with Articles 1-3 of Volume 15, under the second.* The State Laboratory of Natural History has also published three volumes and an atlas of final reports on

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* Now Volume 16, Article 3.

the ornithology and ichthyology of the state, all reprinted in a second edition, as were also the First, Eighteenth, and Twenty-third reports of the State Entomologist's Office."

The insect collection of the Natural History Survey now contains no material definitely known to have been collected by Benjamin Dane Walsh and only a few specimens from the LeBaron collection. Of the Thomas material, almost nothing now remains except his collection of Aphididae which was acquired in very poor condition as reported by J. J. Davis in *Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. II, 1913, pp. 97-121.* The present collection, then, consists almost entirely of specimens collected since 1883 and to Stephen Alfred Forbes and Charles H. Hart belong the main credit for its development and present importance. In addition to the material acquired by the direct collecting of members of the staff of the Survey and its forerunners, considerable material has been added by the acquisition of several private collections. The most notable of these is the first W. A. Nason collection acquired in 1908. The Survey is also the recipient of much material generously donated by specialists and amateurs and has profited through the medium of exchange.

At the conclusion of the list of types in the insect collection of the Illinois State Natural History Survey, there is added a list of the types in the insect collections belonging to the University of Illinois. These collections are available for study by members of the Survey Staff in keeping with the cooperative policy which also places the facilities and insect collection of the Survey at the service of the University. The Natural History Museum of the University of Illinois possesses the Andreas Bolter and second W. A. Nason collections of insects. Both of these collections were gifts to the University, the former in 1900 and the latter in 1920. The Bolter collection is the only one of the two which contains any types. The Department of Entomology of the University acquired the A. D. MacGillivray collection of Tenthredinoidea in 1924. This is one of the most important collections of sawflies in North America and is exceedingly rich in types. The Bolter and second Nason collections are now housed in the Natural History Museum of the University, and the A. D. MacGillivray collection is with the types of the Natural History Survey.

Some special comments are necessary concerning the contents and preparation of this article. Attention has already been directed to the selection of lectotypes to stand for single types in the case of cotypic series. The designation of lectoallotype has been given to a single specimen of the opposite sex from the lectotype of a cotypic series. The remainder of the cotypic series, after the selection of single types, have been regarded as paratypes. Where the describer of a new species has clearly indicated the selection of a type and an allotype no selections have been necessary. In cases where the describer of a new species based his description upon a unique, that specimen is considered as the type without the presence of such a statement in the literature. Where both sexes are specifically described in the original description, based in each case upon single specimens, those specimens have been considered as the type and the allotype. No transposition of original designations of type to holotype, or *vice versa,* have been made. They are listed here as given in the original description, since from the standpoint of taxonomy they are the same.

In some instances no single types have been selected from cotypic material. This is because of either the extremely poor condition of the cotypes or because the selection of the lectotype rightfully belongs to some other institution. Where it has been deemed advisable to select a lectotype of a species mounted in balsam on a slide with other specimens of the same or different species, the specimen so selected has been surrounded by a circular cut on the cover glass. A few specimens have been considered as allotypes that furnished the basis for the description of a previously undescribed or unknown sex of a species already known. This is not in conformity with the use of this term as employed by some (where the allotype must be one of the paratypes), but has the sanction of others. The International Rules of Zoological Nomenclature do not specifically cover this point.

The type series of A. A. Girault in the Survey collection require still further comment. Girault, *in litt.,* has occasionally used terms in an entirely different sense from their accepted use at the present time. In this paper his use of cotype is construed to be equivalent to paratype. Specimens listed by him in his original description, but not specifically listed by him as "type" or "cotypes", are considered as paratypes. When more than one specimen in a type series was designated as "type" by Girault, a single specimen has been selected as the lectotype and the remaining specimens as paratypes, depending as in all other cases upon the priority rights of this institution to the single type.

All type specimens listed in this paper have been labeled and isolated from the general reference collection to insure their continued preservation. It is oftentimes the case that some structural part of an insect is mounted in balsam on a slide and the remaining portion on an insect pin or a card-point mount. Note is made of this fact in the labeling of all specimens so mounted so that they are securely linked together.

The abbreviations used for citations to places of original descriptions are those commonly used in entomological publications. The references have been given in full because of the character of this article. The letter-files of the Survey have been critically searched for information regarding the precise dates of publication of the Reports of the State Entomologists. These dates, with one exception, have never been determined previously. Their significance lies in their bearing upon questions of priority as evidenced by a recent paper of P. R. Myers published in the *Proc. Ent. Soc. Wash., Vol. 26, No. 9, December, 1924, pp. 222-224.* The dates assigned to them are based upon the first definite acknowledgments of these Reports contained in our letter-files or other letters bearing upon their publication or distribution.

The abbreviation "Acc. No." refers to the Accession Catalogue of the Survey and "Hart Acc. No." to a small Accession Catalogue of the late Mr. C. A. Hart. The "Slide No." refers to the Survey collection of slides. The data pertaining to the places and dates of types, as well as full information regarding other matters of importance or interest, are given with each type, allotype, and paratype. Much of this information has never been published and in some cases even the locality of a type has not been heretofore recorded. A few errors in the literature regarding the localities of types, etc., have been corrected. Collectors' names, where known, are given in parentheses following each record. For the sake of completeness and usefulness, notes on synonymy have been added and genotype designations indicated. No new synonymy, however, is herein published. The sequence of orders and families of the Natural History Survey and the Bolter collections is arranged in a purely arbitrary manner. The family arrangement of the A. D. MacGillivray collection of Tenthredinoidea is in accord with his published classifications of 1906 and 1916. Generic and specific names in all cases are arranged alphabetically under family and order groupings.

Since most of the species of sawflies described by MacGillivray are represented by types in his collection, Mr. S. A. Rohwer has suggested the desirability of publishing a list of the species the types of which are not in the collection here, place of their description, and their present location if known. This list is published as an appendix to this article. It is probable that several species, the types of which have not been located, are in the MacGillivray collection without identifying labels or a present clue as to their identity.

The following persons have greatly aided in the preparation of this list by furnishing me with references, notes on synonymy, and other information and favors of a varied character: E. T. Cresson, Jr., L. H. Weld, F. C. Baker, C. L. Metcalf, F. H. Benjamin, H. Morrison, C. W. Johnson, J. J. Davis, R. A. Cushman, J. R. Malloch, J. M. Aldrich, A. B. Gahan, and particularly S. A. Rohwer.

TYPES IN THE COLLECTION OF THE ILLINOIS STATE NATURAL HISTORY SURVEY

ORDER ORTHOPTERA

Family TETTIGONIIDAE

Insara sinaloae Hebard
Trans. Amer. Ent. Soc., Vol. LI, December 18, 1925, p. 293.
Paratype.—♂: Venvidio, Sinaloa, Mexico, August 18, 1918 (J. A. Kusche).
Right hind leg is missing.

Montezumina sinaloae Hebard
Trans. Amer. Ent. Soc., Vol. LI, December 18, 1925, p. 297.
Paratypes.—♂: Venvidio, Sinaloa, Mexico, August 11-12 and 21, 1918 (J. A. Kusche).
Right hind leg of one male is missing.

Family GRYLLIDAE

Nemobius funeralis Hart
Ent. News, Vol. XVII, No. 5, May, 1906, p. 159.
Type.—♀: College Station, Texas, December 26, 1905 (C. A. Hart).
Now considered as a southern race of *Nemobius griseus* Walker.

Oecanthus forbesi Titus
Can. Ent., Vol. XXXV, No. 9, September, 1903, p. 260.
Type.—♂: Urbana, Illinois, September 6, 1891 (C. A. Hart). Acc. No. 17424.
According to Blatchley this is synonymous with *Oecanthus nigricornis quadripunctatus* (Beutenmüller), the latter having priority.

Family LOCUSTIDAE

Amblytropidia insignis Hebard
Trans. Amer. Ent. Soc., Vol. XLIX, November 21, 1923, p. 198.
Paratypes.—♂: Gatun, Canal Zone, Panama, July 12-15, 1916 (D. E. Harrower).

Conalcaea coyoterae Hebard
Trans. Amer. Ent. Soc., Vol. XLVIII, July 25, 1922, p. 55.
Paratypes.—♀: Prescott, Arizona, August 5 and 14, 1917 (O. C. Poling).

Cyclocercus gracilis Bruner
Biol. Centrali-Americana, Insecta-Orthoptera, Vol. II, February, 1909, p. 307.
Paratype.—♂: Tampico, Mexico, December, 1906.

Melanoplus calapooyae Hebard
Trans. Amer. Ent. Soc., Vol. XLVI, December 14, 1920, p. 385.
Paratypes.—♂ and ♀: Calapooia Mountains, Lake County, Oregon, August 11, 1909 (M. Hebard).

Melanoplus macneilli Hart
Bull. Ill. State Lab. Nat. Hist., Vol. VII, Art. VII, January, 1907, p. 261.
Lectotype.—♂: Moline, Illinois, on sand hill, September 9, 1905 (C. A. Hart and F. Shobe).
Lectoallotype.—♀: Moline, Illinois, on sand hill, September 9, 1905 (C. A. Hart and F. Shobe).
Paratypes.—♂ and ♀: Moline, Illinois, on sand hill, September 9, 1905 (C. A. Hart and F. Shobe).
According to Blatchley this species is synonymous with *Melanoplus flaviatilis* Bruner, the latter having priority.

Melanoplus microtatus Hebard
Trans. Amer. Ent. Soc., Vol. XLV, September 25, 1919, p. 285.
Paratypes.—♂ and ♀: Del Monte, Monterey County, California, September 9-10, 1910 (M. Hebard).

Melanoplus oreophilus Hebard
Trans. Amer. Ent. Soc., Vol. XLVI, December 14, 1920, p. 382.
Paratypes.—♂ and ♀: Cloud Cap Trail, Mt. Hood, Oregon, August 18-20, 1910 (M. Hebard).

Melanoplus scudderi var. texensis Hart
Ent. News, Vol. XVII, No. 5, May, 1906, p. 158.
Lectotype.—♂: College Station, Texas, December 26, 1905 (C. A. Hart).
Lectoallotype.—♀: College Station, Texas, December 26, 1905 (C. A. Hart).
Paratypes.—♂ and ♀: College Station, Texas, December 24-27, 1905 (C. A. Hart); Houston, Texas, January 6, 1906 (C. A. Hart).

Melanoplus viridipes eurycercus Hebard
Trans. Amer. Ent. Soc., Vol. XLVI, December 14, 1920, p. 392.
Paratypes.—♂ and ♀: Derrick City, McKean County, Pennsylvania, June 6, 1915 (M. Hebard).

Mesochlora unicolor Hart
Ent. News, Vol. XVII, No. 5, May, 1906, p. 157.
Lectotype.—♂: College Station, Texas, December 23, 1905 (C. A. Hart).
Lectoallotype.—♀: College Station, Texas, December 26, 1905 (C. A. Hart).
Paratypes.—♂ and ♀: College Station, Texas, December 23-27, 1905 (C. A. Hart).

Oedaleonotus phryneicus Hebard
Trans. Amer. Ent. Soc., Vol. XLV, September 25, 1919, p. 266.
Paratypes.—♂ and ♀: Del Monte, Monterey County, California, September 9-10, 1910 (M. Hebard).

Sinaloa pulchella Hebard
Trans. Amer. Ent. Soc., Vol. LI, December 18, 1925, p. 288.
Paratypes.—♂ and ♀: Venvidio, Sinaloa, Mexico, September 2, 1918 (J. A. Kusche); Villa Union, Sinaloa, Mexico, September 27, 1918 (J. A. Kusche).

Spharagemon saxatile Morse
Proc. Boston Soc. Nat. Hist., Vol. XXVI, February 21, 1894, p. 229.
Paratype.—♂: Wellesley, Massachusetts, July 29, 1892 (A. P. Morse).

Trimerotropis saxatilis McNeill
Proc. U. S. Nat. Museum, Vol. XXVIII, No. 1215, 1901, p. 440.
Lectotype.—♂: Union County, Illinois, July 23, 1884 (G. H. French).
Paratype.—♂: Union County, Illinois, July 23, 1884 (G. H. French).
Left hind leg of lectotype is missing.

Family TETRIGIDAE

Telmatettix minutus Hancock
The Tettigidae of North America, R. R. Donnelley and Sons Co., Chicago, Illinois, 1902, p. 134.
Paratype.—♂: Cordova, V. C., Mexico, I-1899.

Family BLATTIDAE

Panchlora cahita Hebard
Trans. Amer. Ent. Soc., Vol. XLVIII, January 2, 1923, p. 174.
Paratypes.—♂: Venvidio, Sinaloa, Mexico, August and August 11-12, 1918 (J. A. Kusche).

ORDER ODONATA

Family AESCHNIDAE

Gomphus lentulus Needham
Can. Ent., Vol. XXXIV, No. 10, October, 1902, p. 275.
Type.—♂: Flora, Illinois, June, 1898 (J. F. Garber).
In fair condition. Genitalia mounted on card point on separate pin.

Family LIBELLULIDAE

Somatochlora macrotona Williamson
Ent. News, Vol. XX, No. 2, February, 1909, p. 78.
Type.—♂: Duluth, Minnesota.
Allotype.—♀: Duluth, Minnesota.
Paratypes.—♂: Duluth, Minnesota.

ORDER EPHEMERIDA

Family EPHEMERIDAE

Baetis harti McDunnough
Can. Ent., Vol. LVI, No. 1, January, 1924, p. 7.
Holotype.—♂: Urbana, Illinois, July 11, 1878 (C. A. Hart). Acc. No. 24491.
Paratype.—♂: Urbana, Illinois, July 11, 1878 (C. A. Hart). Acc. No. 24491.
Baetis pallidula McDunnough
Can. Ent., Vol. LVI, No. 1, January, 1924, p. 8.
Holotype.—♂: Muncie, Illinois, Stony Creek, May 24, 1914.
Paratype.—♂: Muncie, Illinois, Stony Creek, May 24, 1914.
Campsurus primus McDunnough
Can. Ent., Vol. LVI, No. 1, January, 1924, p. 7.
Holotype.—♂: Grand Tower, Illinois, August 14, 1898 (C. A. Hart). Acc. No. 24529.
Paratype.—♂: Grand Tower, Illinois, August 14, 1898 (C. A. Hart). Acc. No. 24529.
Heptagenia integer McDunnough
Can. Ent., Vol. LVI, No. 1, January, 1924, p. 9.
Holotype.—♂: Alton, Illinois, at light, August 27, 1913 (C. A. Hart).
Paratype.—♂: Alton, Illinois, at light, August 27, 1913 (C. A. Hart); Urbana, Illinois, at light, June 14, 1887 (C. A. Hart). Acc. No. 12092.
Pseudocloeon veteris McDunnough
Can. Ent., Vol. LVI, No. 1, January, 1924, p. 8.
Holotype.—♂: Urbana, Illinois, near Salt Fork Creek, May 13, 1898 (C. A. Hart). Acc. No. 24400.
Allotype.—♀: Urbana, Illinois, near Salt Fork Creek, May 13, 1898 (C. A. Hart). Acc. No. 24400.

ORDER THYSANOPTERA

Family HETEROTHRIPIDAE

Heterothrips arisaemae Hood
Bull. Ill. State Lab. Nat. Hist., Vol. VIII, Art. II, August 22, 1908, p. 362.
Paratype.—♀: Urbana, Illinois, Brownfield Woods (Augerville), in flowers of Jack-in-the-pulpit—*(Arisaema triphyllum* Torr.*)*, May 18, 1907 (F. C. Gates). Slide No. 3265.
The genotype of *Heterothrips* Hood (Monobasic).

Family PHLOEOTHRIPIDAE

Allothrips megacephalus Hood
Bull. Ill. State Lab. Nat. Hist., Vol. VIII, Art. II, August 22, 1908, p. 373.
Paratype.—♀: Urbana, Illinois, under bark of cottonwood tree, November 19, 1907 (R. D. Glasgow). Slide No. 3266.
The genotype of *Allothrips* Hood (Monobasic).

Lissothrips muscorum Hood
Bull. Ill. State Lab. Nat. Hist., Vol. VIII, Art. II, August 22, 1908, p. 365.
Paratype.—♀: Muncie, Illinois, in moss, June 16, 1908 (J. D. Hood). Slide No. 3267.
The genotype of *Lissothrips* Hood (Monobasic).

Neothrips corticis Hood
Bull. Ill. State Lab. Nat. Hist., Vol. VIII, Art. II, August 22, 1908, p. 372.
Paratype.—♂: Urbana, Illinois, under bark of soft maple trees, January 19, 1908 (J. D. Hood). Slide No. 3268.
The genotype of *Neothrips* Hood (Monobasic).

Plectrothrips antennatus Hood
Bull. Ill. State Lab. Nat. Hist., Vol. VIII, Art. II, August 22, 1908, p. 370.
Paratype.—♂: Urbana, Illinois, on window, June 23, 1908 (J. D. Hood). Slide No. 3269.
The genotype of *Plectrothrips* Hood (Monobasic).

Trichothrips americanus Hood
Bull. Ill. State Lab. Nat. Hist., Vol. VIII, Art. II, August 22, 1908, p. 366.
Paratypes.—♂ and ♀: Urbana, Illinois, under bark of rotton maple stump, March 24, 1907 (J. D. Hood). Slide No. 3270.

Trichothrips angusticeps Hood
Bull. Ill. State Lab. Nat. Hist., Vol. VIII, Art. II, August 22, 1908, p. 367.
Paratype.—♀: Urbana, Illinois, under bark of rotton box-elder stump, April 23, 1907 (J. D. Hood). Slide No. 3271.

Trichothrips buffae Hood
Bull. Ill. State Lab. Nat. Hist., Vol. VIII, Art. II, August 22, 1908, p. 369.
Paratype.—♀: Urbana, Illinois, under bark of soft maple tree, February 22, 1908 (J. Zetek and F. C. Gates). Slide No. 3272.
This species was transferred by Hood in 1912 to the genus *Rhynchothrips* Hood.

Trichothrips longitubus Hood
Bull. Ill. State Lab. Nat. Hist., Vol. VIII, Art. II, August 22, 1908, p. 368.
Paratype.—♀: Carbondale, Illinois, sweepings, May 19, 1908 (C. A. Hart). Slide No. 3273.

Family IDOLOTHRIPIDAE

Idolothrips flavipes Hood
Bull. Ill. State Lab. Nat. Hist., Vol. VIII, Art. 2, August 22, 1908, p. 377.
Paratype.—♂: Dubois, Illinois, sifted from fallen oak leaves, April 28, 1908 (C. A. Hart and L. M. Smith). Slide No. 3274.
This species has been transferred to the genus *Gigantothrips* Zimmerman by Watson (Florida Agr. Exp. Station Tech. Bull. 168, December, 1923, p. 71).

Order HEMIPTERA

Family Gerridae

Gerris comatus Drake and Hottes
Ohio Journ. Sc., Vol. XXV, January, 1925, p. 48.
Paratype.—♂: Ames, Iowa, July 24, 1924 (C. J. Drake).

Gerris incurvatus Drake and Hottes
Proc. Biol. Soc. Wash., Vol. 38, 1925, p. 72.
Paratype.—♂: Illinois River, Hennepin, Illinois, September 13, 1912.

Gerris nebularis Drake and Hottes
Proc. Biol. Soc. Wash., Vol. 38, May 26, 1925, p. 70.
Paratypes.—♀ and ♂: Big Muddy River, Waltonville, Illinois, July 20, 1913.

Gerris notabilis Drake and Hottes
Ohio Journ. Sc., Vol. XXV, No. 1, January, 1925, p. 46.
Paratype.—♀: Pingree Park, Colorado, August 18, 1924 (C. J. Drake and F. C. Hottes).
Paramorphotype.—♀: Oaktown, Illinois, along railroad in swamp, August 15, 1905.

Gerris pingreensis Drake and Hottes
Ohio Journ. Sc., Vol. XXV, No. 1, January, 1925, p. 49.
Paratypes.—♂: Pingree Park, Colorado, August 16 and 22, 1924 (C. J. Drake and F. C. Hottes).

Family Miridae

Deraeocoris aphidiphagus Knight
Eighteenth Rep. State Ent. Minn., December 1, 1920, p. 134.
Paratypes.—♂: Augerville (Brownfield Woods, Urbana), Illinois, June 6, 1915 (J. R. Malloch); Urbana, Illinois, June 16, 1885 (C. A. Hart); Northern Illinois (A. Bolter). Acc. No. 6050.

Deraeocoris quercicola Knight
Eighteenth Rep. State Ent. Minn., December 1, 1920, p. 138.
Paratypes.—♂ and ♀: Champaign, Illinois. June 12-15. 1888 (C. A. Hart); Elizabeth, Illinois, July 6, 1917 (J. R. Malloch). Hart Acc. Nos. 322 and 328.

Plagiognathus flavicornis Knight
State Geol. Nat. Hist. Sur. Conn., Bull. 34, 1923, p. 436.
Paratypes.—♀: Sun Lake, Lake County, Illinois, bog August 9, 1906 (C. A. Hart); Cedar Lake, Lake County, Illinois, bog, August 4, 1906 (C. A. Hart).

Plagiognathus nigronitens Knight
State Geol. Nat. Hist. Sur. Conn., Bull. 34, 1923, p. 435
Paratypes.—♂: Hennepin County, Minnesota, August 12, 1919 (H. H. Knight); Little Bear Lake, Grand Junction, Michigan, July 15, 1914.

Plagiognathus politus var. flaveolus Knight
State Geol. Nat. Hist. Sur. Conn., Bull. 34, 1923, p. 434.
Paratypes.—♀: Urbana, Illinois, September 13, 1909; Algonquin, Illinois, August 30, 1894 (W. A. Nason).

Plagiognathus punctatipes var. dispar Knight
State Geol. Nat. Hist. Sur. Conn., Bull. 34, 1923, p. 451.
Paratype.—♂: Dixon, Illinois, May 31, 1914.

Family NABIDAE

Nabis elongatus Hart
Bull. Ill. State Lab. Nat. Hist., Vol. VII, Art. VII, January, 1907, p. 262.
Type.—♂: Havana, Illinois, along sandy shore of Illinois River, June 9, 1906 (C. A. Hart).
Now considered a synonym of *Nabis propinquus* Reuter. The name *elongatus* is also preoccupied.

Family REDUVIIDAE

Stenolemus spiniger McAtee and Malloch
Proc. U. S. Nat. Mus., Vol. 67, No. 2573, 1925, p. 33.
Paratype.—♀: Brownsville, Texas (Dorner).

Family TINGIDAE

Corythucha aesculi Osborn and Drake
Ohio Biol. Surv. Bull. 8, Vol. 11, No. 4, June, 1916, p. 232.
Paratype.—♀: Columbus, Ohio, May 2, 1915 (C. J. Drake).

Corythucha padi Drake
Ohio Journ. Sc., Vol. XVII, No. 6, April 16, 1917, p. 215.
Paratype.—♀: Missoula, Montana, May 20, 1916 (J. R. Parker).

Corythucha salicata Gibson
Trans. Amer. Ent. Soc., Vol. XLIV, April 14, 1918, p. 90.
Paratype.—♂: Hood River, Oregon, on willow, August 4, 1908 (J. C. Bridwell).

Merragata foveata Drake
Ohio Journ. Sc., Vol. XVII, No. 4, February 17, 1917, p. 103.
Paratype.—♀: Summit, Ohio, August 31, 1916 (C. J. Drake).

Piesma cinerea var. inornata McAtee
Bull. Brook. Ent. Soc., Vol. XIV, No. 3 (7), June, 1919, p. 87.
Paratypes.—♂ and ♀: Algonquin, Illinois, August 23-24, 1895 (W. A. Nason).

Family ANTHOCORIDAE

Lasiochilus hirtellus Drake and Harris
Proc. Biol. Soc. Wash., Vol. 39, July 30, 1926, p. 33.
Paratypes.—♂ and ♀: Brownsville, Texas, South Texan Garden, at light, June 23, 1908; Brownsville, Texas, April 11 (G. Dorner).

Family LYGAEIDAE

Geocoris frisoni Barber
Bull. Brook. Ent. Soc., Vol. XXI, Nos. 1-2, February-April, 1926, pp. 38-39.
Holotype.—♂: Havana, Illinois, Devil's Hole, August 30, 1917.
Allotype.—♀: Havana, Devil's Hole, August 15, 1907.
Paratypes.—♂ and ♀: Arenzville, Illinois, bluff sand, August 14, 1913; Bishop, Illinois, June 22, 1906, Meredosia, Illinois, sand pit, August 22, 1917, Havana, Illinois, Devil's Hole, September 11, 1910 and September 28, 1913; Havana, Illinois, Devil's Neck, June 7, 1905 (C. A. Hart).

Family ARADIDAE

Aradus implanus Parshley
Trans. Amer. Ent. Soc., Vol. XLVII, April 9, 1921, p. 45.
Paratype.—♂: Funk's Grove, Illinois, April 30, 1884 (C. A. Hart). Acc. No. 1511.

Aradus robustus var. insignis Parshley
Trans. Amer. Ent. Soc., Vol. XLVII, April 9, 1921, p. 42.
Paratype.—♀: Brownsville, Texas, under board, December 16, 1911 (C. A. Hart).

Family Coreidae

Catorhintha flava Fracker
Ann. Ent. Soc. Amer., Vol. XVI, No. 2, June, 1923, p. 171.
Holotype.—♂: Brownsville, Texas, December 9, 1910 (C. A. Hart).
Allotype.—♀: Lake Lomalta, Texas, November 27, 1910 (C. A. Hart)

Family Pentatomidae

Euschistus subimpunctatus Malloch
Bull. Ill. State Nat. Hist. Surv., Vol. XIII, Art. VII, June, 1919, p. 191.
Type.—♀: Anna, Illinois, July 22, 1883. Acc. No. 3791.
Thyanta elegans Malloch
Bull. Ill. State Nat. Hist. Surv., Vol. XIII, Art VII, June, 1919, p. 218.
Type.—♂: Loma, Texas, July 7, 1908.
Allotype.—♀: Lake Lomalta, Texas, November 27, 1910.

Family Cydnidae

Corimelaena agrella McAtee
Bull. Ill. State Nat. Hist. Surv., Vol. XIII, Art. VII, June, 1919, p. 216.
Paratypes.—♂ and ♀: Kentucky; Plummers Island, Maryland, May 18, 1913 (W. L. McAtee).
Corimelaena harti Malloch
Bull. Ill. State Nat. Hist. Surv., Vol. XIII, Art. VII, June, 1919, p. 215.
Type.—♂: Makanda, Illinois, by sweeping, June 26, 1909 (C. A. Hart).
Allotype.—♀: Makanda, Illinois, by sweeping, June 26, 1909 (C. A. Hart)
Corimelaena interrupta Malloch
Bull. Ill. State Lab. Nat. Hist., Vol. XIII, Art. VII, June, 1919, p. 214.
Type.—♂: Brownsville, Texas, November 23, 1911, swept from pastures in South Texas Garden (C. A. Hart).
Paratype.—♂: Brownsville, Texas, November 23, 1911, swept from pastures in South Texas Garden (C. A. Hart).
Corimelaena minutissima Malloch
Bull. Ill. State Nat. Hist. Surv., Vol. XIII, Art. VII, June, 1919, p. 214.
Type.—♂: Sarita, Texas, on sand hills, December 1, 1911 (C. A. Hart).
Corimelaena polita Malloch
Bull. Ill. State Nat. Hist. Surv., Vol. XIII, Art. VII, June, 1919, p. 213.
Type.—♀: Brownsville, Texas, July 10, 1908 (C .A. Hart).
Galgupha aterrima Malloch
Bull. Ill. State Nat. Hist. Surv., Vol. XIII, Art. VII, June, 1919, p. 211.
Type.—♂: Odin, Illinois, on pink sorrel, May 12, 1902 (E. G. Titus). Acc. No. 31440.
Lectoallotype.—♀: White Heath, Illinois, June 18, 1906.
Paratypes.—♂ and ♀: Havana, Illinois, along road to Devil's Hole, August 15, 1907; Dongola, Illinois, May 10, 1917; Grand Tower, Illinois, June 27, 1906; Northern Illinois; Southern Illinois; Normal, Illinois, June 14, 1882; Urbana, Illinois, June 30, 1888 (J. Martin and C. A. Hart); Cobden, Illinois, April 12, 1883; two without data. Acc. Nos. 3057, 14585 and 3198.

Order HOMOPTERA

Family Cicadidae

Tibicen semicincta Davis
Journ. N. Y. Ent. Soc., Vol. XXXIII, No. 1, March, 1925, p. 41.
Paratype.—♂: Baboquivari Mountains, Pima County, Arizona, June, 1924 (O. C. Poling).

Family Membracidae

Ceresa turbida Goding

Bull. Ill. State Lab. Nat. Hist., Vol. III, Art. XIV, January, 1894, p. 406.

Paratype.—♂: Colorado (Gillette).

Now considered as a synonym of *Ceresa basalis* Walker.

Telamona irrorata Goding

Bull. Ill. State Lab. Nat. Hist., Vol. III, Art. XIV, January, 1894, p. 418.

Cotype.—♂: Galesburg, Illinois (C. W. Stromberg).

Now listed as *Telamona dubiosa* Van Duzee, *irrorata* being preoccupied.

Family Cicadellidae

Cicadula nigrifrons Forbes

Fourteenth Rep. State Ent. Ill., September 2, 1885, p. 67.

Lectotype.—♂: Anna, Illinois, on corn, July 14, 1884 (S. A. Forbes). Acc. No. 4427.

Lectoallotype.—♀: Anna, Illinois, on corn, July 14, 1884 (S. A. Forbes). Acc. No. 4427.

Paratypes.—♂ and ♀: Anna, Illinois, on corn, July 14, 1884 (S. A. Forbes); Mt. Carmel, Illinois, on oats, May 28, 1884 (H. Garman). Acc. Nos. 4427 and 1793.

This species is now placed in the genus *Thamnotettix* Zetterstedt.

Cicadula quadrilineatus Forbes

Fourteenth Rep. State Ent. Ill., September 2, 1885, p. 68.

Lectotype.—♂: Marshall, Illinois, from wheat, May 22, 1884. Acc. No. 1871.

Lectoallotype.—♀: Marshall, Illinois, from wheat, May 22, 1884. Acc. No. 1871.

Paratypes.—♂ and ♀: Marshall, Illinois, from wheat, May 22, 1884; West Union, Illinois, on wheat, May 24, 1884. Acc. Nos. 1871 and 1888.

Lectotype, Lectoallotype and 14 paratypes mounted on card points, remainder of type series in alcohol. This species is now considered as a synonym of *Cicadula sexnotata* (Fallen), the latter having priority.

Dikraneura cockerelli Gillette

Psyche, Vol. VII, Suppl. 1, December, 1895, p. 14.

Paratypes.—♀: New Mexico (1990).

Dikraneura communis Gillette

Proc. U. S. Nat. Mus., Vol. 20, No. 1138, April 20, 1898, p. 718.

Paratype.—♂: Urbana, Illinois, May 14, 1889 (J. Marten). Acc. No. 14873.

This species is now considered as a synonym of *Dikraneura mali* (Provancher). In fair condition.

Empoa albopicta Forbes

Thirteenth Rep. State Ent. Ill., May 31, 1884, p. 181.

Lectotype.—♂: Centralia, Illinois, on apple leaves, August 6, 1883. Acc. No. 3706.

Lectoallotype.—♀: Centralia, Illinois, on apple leaves, August 6, 1883. Acc. No. 3706.

Paratypes.—♂ and ♀: Centralia, Illinois, on apple leaves, August 6, 1883. Acc. No. 3706.

Lectotype, lectoallotype and 8 paratypes mounted on card points, remainder of paratypes in alcohol. This species is now considered synonymous with *Empoasca mali* (LeBaron), the latter having priority.

Erythroneura abolla var. **lemnisca** McAtee

Bull. Ill. State Nat. Hist. Surv., Vol. XVI, Art. III, July, 1926, p. 131.

Holotype.—♀: Urbana, Illinois, Cottonwoods (University Woods), July 12, 1920 (C. P. Alexander).

Paratype.—♀: Urbana, Illinois, Brownfield Woods, April 29, 1920.

Erythroneura comes var. palimpsesta McAtee
Bull. Ill. State Nat. Hist. Surv., Vol. XV, Art. II, April, 1924, p. 43.
Holotype.—♂: Forest City, Illinois, April 3, 1917.
Allotype.—♀: Forest City, Illinois, April 3, 1917.

Erythroneura comes var. pontifex McAtee
Bull. Ill. State Nat. Hist. Surv., Vol. XVI, Art. III, July, 1926, p. 136.
Holotype.—♀: Dubois, Illinois, May 24, 1917.

Erythroneura comes var. reflecta McAtee
Bull. Ill. State Nat. Hist. Surv., Vol. XV, Art. II, April, 1924, p. 43.
Paratype.—♀: Centerville (Monticello-Mahomet), Illinois, along Sangamon River, August 16, 1914.

Erythroneura comes var. rufomaculata McAtee
Bull. Ill. State Nat. Hist. Surv., Vol. XV, Art. II, April, 1924, p. 43.
Holotype.—♀: Clay City, Illinois, August 17, 1911.
Paratype.—♀: Clay City, Illinois, August 17, 1911; Urbana, Illinois, on grape, November 23, 1914; Illinois, No. 1992.

Erythroneura ligata var. pupillata McAtee
Bull. Ill. State Nat. Hist. Surv., Vol. XV, Art. II, April, 1924, p. 42.
Holotype.—♂: Urbana, Illinois, hibernating, February 21, 1900 (H. O. Woodworth). Acc. No. 25069.
Paratype.—♂: Urbana, Illinois, on window, July 7, 1915; Urbana, Illinois, in moss and bark, March 4, 1888 (C. A. Hart). Hart Acc. No. 152.

Erythroneura lunata McAtee
Bull. Ill. State Nat. Hist. Surv., Vol. XV, Art. II, April, 1924, p. 41.
Holotype.—♂: Urbana, Illinois, on tree trunk, November 11, 1915.
Allotype.—♀: White Heath, Illinois, May 7, 1909.

Erythroneura mallochi McAtee
Bull. Ill. State Nat. Hist. Surv., Vol. XV, Art. II, April, 1924, p. 41.
Holotype.—♂: Meredosia, Illinois, May 30, 1917.

Erythroneura mitella McAtee
Bull. Ill. State Nat. Hist. Surv., Vol. XVI, Art. III, July, 1926, p. 132.
Holotype.—♂: White Heath, Illinois, April 30, 1916.
Allotype.—♀: Urbana, Illinois, November 3, 1916.
Paratypes.—♂ and ♀: White Heath, Illinois, April 30, 1916; Dongola, Illinois, May 10, 1916; Alto Pass, Illinois, May 7, 1917; DuBois, Illinois, May 23 and August 8, 1917.

Erythroneura oculata McAtee
Bull. Ill. State Nat. Hist. Surv., Vol. XV, Art. II, April, 1924, p. 39.
Holotype.—♀: Brownsville, Texas, in sweepings from weeds, November 30, 1910 (C. A. Hart).

Erythroneura repetita McAtee
Bull. Ill. State Nat. Hist. Surv., Vol. XVI, Art. III, July 1926, p. 131.
Holotype.—♀: Illinois.

Erythroneura scutelleris var. insolita McAtee
Bull. Ill. State Nat. Hist. Surv., Vol. XVI, Art. III, July, 1926, p. 133.
Holotype.—♀: Muncie, Illinois, along Stony Creek, July 5, 1914.
Allotype.—♂: Dongola, Illinois, August 23, 1916.

Erythroneura sexpunctata Malloch
Bull. Brook. Ent. Soc., Vol. XVI, No. 1, February, 1921, p. 25.
Type.—♂: Muncie, Illinois, along Salt Fork, December 13, 1913 (C. A. Hart and J. R. Malloch).
According to McAtee (Bull. Ill. Nat. Hist. Surv., Vol. XV, Art. II, p. 40, April, 1924), this is synonymous with *E. tecta* McAtee.

Gypona albimarginata Woodworth
Bull. Ill. State Lab. Nat. Hist., Vol. III, Art. II, October, 1887, p. 31.
Type.—♂: Urbana, Illinois, July 15, 1887 (C. A. Hart). Acc. No. 12915.
Now considered as a synonym of *Gypona scarlatina* var. *limbatipennis* Spangberg.

Gypona bimaculata Woodworth

Bull. Ill. State Lab. Nat. Hist., Vol. III, Art. II, October, 1887, p. 32.

Type.—♂: Urbana, Illinois, July 31, 1886 (C. A. Hart). Acc. No. 10726.

The specific name of *woodworthi* was proposed by Van Duzee because *bimaculata* was preoccupied. This species is now considered as a synonym of *Gypona scarlatina* var. *pectoralis* Spangberg.

Gypona bipunctulata Woodworth

Bull. Ill. State Lab. Nat. Hist., Vol. III, Art. II, October, 1887, p. 30.

Type.—♀: No data.

Now considered as a synonym of *Gypona melanota* Spangberg.

Gypona nigra Woodworth

Bull. Ill. State Lab. Nat. Hist., Vol. III, Art. II, October, 1887, p. 31.

Lectotype.—♂: Champaign, Illinois, on weeds, July 24, 1885. Acc. No 6814.

Paratype.—♂: Normal, Illinois, on wild plum, August, 1883; one paratype with no data. Acc. No. 3531.

Now considered as a synonym of *Gypona melanota* Spangberg.

Tettigonia similis Woodworth

Bull. Ill. State Lab. Nat. Hist., Vol. III, Art. II, October, 1887, p. 25.

Type.—♀: Bloomington, Illinois, May 9, 1884. Acc. No. 1687.

Now considered as a synonym of *Cicadella gothica* (Signoret).

Typhlocyba antigone McAtee

Proc. U. S. Nat. Mus., Vol. 68, Art. 18, June 10, 1926, p. 35.

Holotype.—♂: White Heath, Illinois, on oak, June 24, 1916.

Typhlocyba appendiculata Malloch

Can. Ent., Vol. LII, No. 4, April, 1920, p. 95.

Type.—♂: Elizabethtown, Illinois, July 8, 1917.

Allotype.—♀: Elizabethtown, Illinois, July 8, 1917.

Paratype.—♂: Urbana, Illinois, on oak, July 17, 1916 (J. R. Malloch).

Typhlocyba athene McAtee

Proc. U. S. Nat. Mus., Vol. 68, Art. 18, June 10, 1926, p. 31.

Holotype.—♂: Urbana, Illinois, on tree-trunk, June 7, 1916 (J. R. Malloch).

Typhlocyba gillettei var. **apicata** McAtee

Proc. U. S. Nat. Mus., Vol. 68, Art. 18, June 10, 1926, p. 25.

Paratypes.—♂ and ♀: Urbana, Illinois, tree-trunks and forestry, June 7, 9, 17, 1916; White Heath, Illinois, on oak, June 24, 1916; Elizabeth, Illinois, July 7, 1917.

Typhlocyba gillettei var. **casta** McAtee

Proc. U. S. Nat. Mus., Vol. 68, Art. 18, June 10, 1926, p. 26.

Paratypes.—♂ and ♀: Urbana, Illinois, tree-trunks, June 8-9, October 23, 1916, July 9, 13, 14, 1920; White Heath, Illinois, on oak, June 24, July 5, 1916; Elizabeth, Illinois, July 6, 1917; Algonquin, Illinois, June 10, 1896, October 13, 1895; Crystal Lake, Illinois, July 21, 1916; Monticello, Illinois, along Sangamon River, June 28, 1914.

Typhlocyba gillettei var. **saffrana** McAtee

Proc. U. S. Nat. Mus., Vol. 68, Art. 18, June 10, 1926, p. 26.

Paratype.—♀: White Heath, Illinois, July 5, 1916.

Typhlocyba hartii Gillette

Proc. U. S. Nat. Mus., Vol. 20, April 20, 1898, p. 754.

Paratype.—♀: Urbana, Illinois, swept from rye, May 14, 1889 (J. Marten) Acc. No. 14873.

Now placed in the genus *Erythroneura* Fitch.

Typhlocyba lancifer McAtee

Proc. U. S. Nat. Mus., Vol. 68, Art. 18, June 10, 1926, p. 19.

Paratype.—♂: Urbana, Illinois, June 4, 1916.

Typhlocyba nicarete McAtee
Proc. U. S. Nat. Mus., Vol. 68, Art. 18, June 10, 1926, p. 36.
Holotype.—♂: White Heath, Illinois, on oak, June 24, 1916.
Paratypes.—♂ and ♀: White Heath, Illinois, on oak, June 24, 1916; Urbana, Illinois, forestry, June 17, 1916.

Typhlocyba phryne McAtee
Proc. U. S. Nat. Mus., Vol. 68, Art. 18, June 10, 1926, p. 34.
Holotype.—♀: Urbana, Illinois, July 9, 1920.

Typhlocyba piscator McAtee
Proc. U. S. Nat. Mus., Vol. 68, Art. 18, June 10, 1926, p. 7.
Holotype.—♂: Elizabeth, Illinois, July 8, 1917.

Typhlocyba pomaria McAtee
Proc. U. S. Nat. Mus., Vol. 68, Art. 18, June 10, 1926, p. 29.
Paratypes.—♀: Clayton, Illinois, September 30, 1916; Urbana, Illinois, September 20, 1916; Olney, Illinois, on apple, September 21, 1916.

Typhlocyba rubriocellata Malloch
Bull. Brook. Ent. Soc. Vol. XV, Nos. 2 and 3, April-June, 1920, p. 48.
Type.—♀: Augerville Grove (Brownfield Woods), Urbana, Illinois, June 20, 1919 (J. R. Malloch).

Typhlocyba rubriocellata var. clara McAtee
Proc. U. S. Nat. Mus., Vol. 68, Art. 18, June 10, 1926, p. 21.
Holotype.—♀: Urbana, Illinois, Cottonwoods (University Woods), on *Aesculus*, July 30, 1920.

Family FULGORIDAE

Bruchomorpha bicolor Metcalf
Journ. Elisha Mitchell Sc. Soc., Vol. XXXVIII, Nos. 3 and 4, May, 1923, p. 186.
Holotype.—♂: Brownsville, Texas, palm jungle sweepings, November 21, 1911 (C. A. Hart).
Allotype.—♀: Brownsville, Texas, palm jungle sweepings, November 21, 1911 (C. A. Hart).
Paratype.—♀: Brownsville, Texas, palm jungle sweepings, November 21, 1911 (C. A. Hart).

Bruchomorpha decorata Metcalf
Journ. Elisha Mitchell Sc. Soc., Vol. XXXVIII, Nos. 3 and 4, May, 1923, p. 188.
Holotype.—♂: Brownsville, Texas, palm jungle sweepings, November 21, 1911 (C. A. Hart).
Allotype.—♀: Brownsville, Texas, palm Jungle sweepings, November 21, 1911 (C. A. Hart).
Paratype.—♀: Brownsville, Texas, palm jungle sweepings, November 21, 1911 (C. A. Hart).

Bruchomorpha vittata Metcalf
Journ. Elisha Mitchell Sc. Soc., Vol. XXXVIII, Nos. 3 and 4, May, 1923, p. 185.
Holotype.—♀: Brownsville, Texas, palm jungle sweepings, November 21, 1911 (C. A. Hart).
Paratype.—♀: Brownsville, Texas, palm jungle sweepings, November 21, 1911 (C. A. Hart).

Euklastus harti Metcalf
Journ. Elisha Mitchell Sc. Soc., Vol. XXXVIII, Nos. 3 and 4, May, 1923, p. 195.
Holotype.—♂: Grand Tower, Illinois, August 8, 1891 (C. A. Hart and Shiga). Acc. No. 17202.
The locality of this type was erroneously recorded in the original description by Z. P. Metcalf as Alto Pass, Illinois, August 13, 1891.

Herpis australis Metcalf

Journ. Elisha Mitchell Sc. Soc., Vol. XXXVIII, Nos. 3 and 4, May, 1923, p. 196.

Holotype.—♂: Brownsville, Texas, November 4 (G. Dorner).

In the original description the date is November 11. Now considered as a synonym of *Cedusa praecox* Van Duzee.

Liburnia alexanderi Metcalf

Journ. Elisha Mitchell Sc. Soc., Vol. XXXVIII, Nos. 3 and 4, May, 1923, p. 209.

Paratypes.—♂: Dongola, Illinois, meadow, August 24, 1916; Metropolis, Illinois, August 18, 1891 (C. A. Hart). Acc. No. 17232.

Original description gives Urbana, Illinois, instead of Metropolis for latter record. Now placed in the genus *Delphacodes* Fieber.

Liburnia fulvidorsum Metcalf

Journ. Elisha Mitchell Sc. Soc., Vol. XXXVIII, Nos. 3 and 4, May, 1923, p. 210.

Holotype.—♂: Brownsville, Texas, South Texas Garden, December 19, 1910 (C. A. Hart).

Paratype.—♂: Brownsville, Texas, South Texas Garden, December 19, 1910 (C. A. Hart).

Now placed in the genus *Delphacodes* Fieber. Erroneously recorded in original description as collected on December 10.

Megamelanus lautus Metcalf

Journ. Elisha Mitchell Sc. Soc., Vol. XXXVIII, Nos. 3 and 4, May, 1923, p. 200.

Holotype.—♂: Loma, Texas, sweepings, December 11, 1910 (C. A. Hart).
Allotype.—♀: Loma, Texas, sweepings, December 11, 1910 (C. A. Hart).
Paratype.—♂: Loma, Texas, sweepings, December 11, 1910 (C. A. Hart).

Microledrida flava Metcalf

Journ. Elisha Mitchell Sc. Soc., Vol. XXXVIII, Nos. 3 and 4, May, 1923, p. 183.

Holotype.—♂: Brownsville, Texas, palm jungle sweepings, November 21, 1911 (C. A. Hart).

Myndus truncatus Metcalf

Journ. Elisha Mitchell Sc. Soc., Vol. XXXVIII, Nos. 3 and 4, May, 1923, p. 184.

Holotype.—♂: Elizabeth, Illinois, July 6, 1917.

Oecleus productus Metcalf

Journ. Elisha Mitchell Sc. Soc., Vol. XXXVIII, Nos. 3 and 4, May, 1923, p. 184.

Holotype.—♂: Dongola, Illinois, August 23, 1916.
Paratype.—♂: Metropolis, Illinois, August 19, 1916.

Oliarus texanus Metcalf

Journ. Elisha Mitchell Sc. Soc., Vol. XXXVIII, Nos. 3 and 4, May, 1923, p. 181.

Holotype.—♂: Brownsville, Texas, palm jungle sweepings, November 21, 1911 (C. A. Hart).

Allotype.—♀: Brownsville, Texas, palm jungle sweepings, November 21, 1911 (C. A. Hart).

Paratypes.—♂ and ♀: Brownsville, Texas., in pasture, South Texas Garden, November 23, 1911 (C. A. Hart), December 9, 1911, sweepings (C. A. Hart).

Oliarus vittatus Metcalf

Journ. Elisha Mitchell Sc. Soc., Vol. XXXVIII, Nos. 3 and 4, May, 1923, p. 181.

Holotype.—♂: Brownsville, Texas, in pasture, South Texas Garden, November 19, 1911 (C. A. Hart).

Allotype.—♀: Brownsville, Texas, in pasture, South Texas Garden, December 8, 1911 (C. A. Hart).

Otiocerus wolfii var. nubilus McAtee
Bull. Ill. State Nat. Hist. Sur., Vol. XVI, Art. III, July, 1926, p. 128.
Type.—♀: Metropolis, Illinois, September 3, 1924 (T. H. Frison).

Pissonotus fulvus Metcalf
Journ. Elisha Mitchell Sc. Soc., Vol. XXXVIII, Nos. 3 and 4, May, 1923, p. 206.
Holotype.—♂: Paxton, Illinois, July 30, 1916.
Allotype.—♀: Paxton, Illinois, July 30, 1916.

Traxus fulvus Metcalf
Journ. Elisha Mitchell Sc. Soc., Vol. XXXVIII, Nos. 3 and 4, May, 1923, p. 189.
Allotype.—♀: Brownsville, Texas, November 21, 1910 (C. A. Hart).
Paratypes.—♀: Brownsville, Texas, sweepings from weeds, November 24, 1910 (C. A. Hart), palm jungle sweepings, November 21, 1911 (C. A. Hart), November 26, 1910 (C. A. Hart).

Family CHERMIDAE

Calophya pallidula McAtee
Bull. Ill. State Nat. Hits. Surv., Vol. XVI, Art. III, July, 1926, p. 127.
Holotype.—♀: Meredosia, Illinois, May 29, 1917.
Paratype.—♀: Meredosia, Illinois, May 29, 1917.

Trioza pyrifoliae Forbes
Fourteenth Rep. State Ent. Ill., September 2, 1885, p. 98.
Lectotype.—♂: Normal, Illinois, on pear leaves, May 7, 1884. Acc. No. 1624.
Lectoallotype.—♀: Normal, Illinois, on pear leaves, May 7, 1884. Acc. No. 1624.
Paratypes.—♀: Normal, Illinois, on pear leaves, May 7, 1884. Acc. No. 1624.

Family APHIDIDAE

Aphis cucumeris Forbes
Twelfth Rep. State Ent. Ill., November 20, 1883, p. 83.
Type.—♀: Normal, Illinois, on muskmelons, July 19, 1882 (S. A. Forbes). Slide No. 1557.
Wingless. In fair condition. Mounted in balsam.
Now considered to be synonymous with *Aphis gossypii* Glover.

Callipterus caryaefoliae Davis
Ent. News, Vol. XXI, No. 5, May, 1910, p. 198.
Lectotypic slide.—Winged viviparous females: Lake Forest, Illinois, on hickory, June 24, 1909 (J. J. Davis). Acc. No. 43266. Slide No. 1838.
In fair condition. Mounted in balsam.

Callipterus quercifolii Thomas
Eighth Rep. State Ent. Ill., 1879, p. 112.
Cotypes.—♀: Sauk City, Wisconsin, on red oak leaves, June (Bundy). Acc. No. 47317.
Several specimens in alcohol in vial. In poor condition. Stated by Davis (1913) to be synonymous with *Chaitophorus quercicola* Monell.

Callipterus ulmicola Thomas
Eighth Rep. State Ent. Ill., 1879, p. 111.
Cotypes.—♀: Sauk City, Wisconsin, on elm, June (Bundy). Acc. No. 47318.
Several specimens in alcohol in vial. In poor condition. Now considered as synonymous with *Callipterus ulmifolii* Monell (Davis, 1913).

Chaitophorus flavus Forbes

Thirteenth Rep. State Ent. Ill., May 31, 1884, p. 42.

Lectotype.—Winged ♀: Champaign, Illinois, on sorghum, July 25, 1883 (S. A. Forbes). Acc. No. 4968. Slide No. 3152.

Paratypes.—Adults and nymphs: Champaign, Illinois, on sorghum, July 25, 1883 (S. A. Forbes). Acc. No. 4968. Slides No. 3151, 3153—3156.

In poor condition. Lectotype and nineteen paratypes mounted in balsam on six slides, remainder of paratypes in alcohol in two vials. Now placed in the genus *Sipha* Passerini.

Chaitophorus negundinis Thomas

Bull. Ill. State Lab. Nat. Hist., Vol. I, No. 2, June, 1878, p. 10.

Cotypes.—Winged and wingless ♀: Peoria, Illinois, on *Negundo aceroides*, June (Miss E. A. Smith). Slide No. 2775.

In poor condition. Mounted in balsam.

Forda occidentalis Hart

Eighteenth Rep. State Ent. Ill., March 4, 1895, p. 96. (Reprint, 1920, p. 84).

Lectotype.—Wingless viviparous ♀: Champaign, Illinois, in blue-grass sod, attended by *Lasius niger*, April 28, 1894 (McElfresh). Acc. No. 19910.

Paratypes.—Wingless viviparous ♀: Urbana, Illinois, April 4, 1894 (J. Marten); Urbana, Illinois, April 10, 1894, on *Capsella bursa-pastoris*, attended by *Formica fusca gagates* (Surface). Acc. Nos. 19840 and 19807.

Lectotype in alcohol and paratypes in balsam on slide and in alcohol. In very poor condition.

Geoica squamosa Hart

Eighteenth Rep. State Ent. Ill., March 4, 1895, p. 102. (Reprint, 1920, p. 90).

Lectotype.—Wingless viviparous ♀: Champaign, Illinois, on roots of corn, October 20, 1887 (C. M. Weed). Acc. No. 14197. Slide No. 3164.

Paratypes.—♂ (?) and ♀: Normal and Champaign, Illinois, on various grasses and often associated with ants, February to November, 1883 to 1890. Acc. Nos. 1204, 1421, 2203, 3240, 3246, 4583, 5356, 5752, 6528, 7226, 7290, 8164, 10118, 10144, 10154, 10159, 10238, 10983, 12321, 12322, 12486, 12665, 12666, 12667, 12706, 14197, 14358, 16013, 17772, 19758, 19807, 19840, 19911. Slide Nos. 3161-3163, 3165-3169, 3172 and 3173.

In very poor condition. Paratypic material in various stages of development mounted in balsam on ten slides and in alcohol in vials.

Idiopterus nephrelepidis Davis

Ann. Ent. Soc. Amer., Vol. II, No. 3, September, 1909, p. 199.

Lectotypic slide.—Winged and wingless viviparous ♀: Chicago, Illinois, May 2, 1908, on sword fern in greenhouse (J. J. Davis). Acc. No. 42533. Slide No. 3117.

The genotype of *Idiopterus* Davis (Monobasic).

Megoura solani Thomas

Eighth Rep. State Ent. Ill., 1879, p. 73.

Type.—Winged ♀: Carbondale, Illinois, on tomato, May 26, 1878 (C. Thomas). Slide 2772.

In poor condition.

Pemphigus fraxinifolii Thomas

Eighth Rep. State Ent. Ill., 1879, p. 146.

Cotypes.—Winged viviparous ♀ and immature forms: Sauk City, Wisconsin, on *Fraximus quadrangulata* June (Bundy). Slide 2762.

In very poor condition. Several specimens in alcohol in a vial. Now placed in the genus *Prociphilus* Koch.

Pemphigus rubi Thomas

Eighth Rep. State Ent. Ill., 1879, p. 147.

Cotypes.—Winged ♀: Carbondale. Illinois, on raspberry, April 12, 1878 (G. H. French). Slides Nos. 2767 and 2768.

Mounted on balsam on two slides. In poor condition.

Phymatosiphum monelli Davis

Ann. Ent. Soc. Amer., Vol. II, No. 3, September, 1909, p. 197.

Lectotype slide.—Winged viviparous females and pupae: St. Louis, Missouri, on buckeye, May 15, 1908 (J. T. Monell). Acc. No. 40469. Slide No. 3119.

Paratypic slide.—Winged viviparous females: St. Louis, Missouri, on buckeye, June 30, 1908 (J. T. Monell). Acc. No. 40469. Slide No. 3120.

Mounted in balsam on two slides.

Rhizobius spicatus Hart

Eighteenth Rep. State Ent. Ill., March 4, 1895, p. 105. (Reprint, 1920, p. 92).

Cotypes.—Wingless viviparous females and nymphs: Normal, Illinois, from corn, December 5, 1883 (S. A. Forbes); Tamaroa, Illinois, on corn roots, October 5, 1893 (J. Marten); Urbana, Illinois, from corn and grass roots, April 10, 1886 (C. M. Weed) and July 20, 1886 (S. A. Forbes). Acc. Nos. 1223, 8602, 10641, 19678 and 19679.

In very poor condition. In alcohol in vials.

Rhopalosiphum tulipae Thomas

Eighth Rep. State Ent. Ill., 1879, p. 80.

Cotypes.—Winged and wingless ♀: Sauk City, Wisconsin, on *Tulipa gesneriana* (Bundy). Acc. No. 47320.

Specimens in alcohol in vial associated with specimens of *Macrosiphum tulipae* Monell. In very poor condition. Stated by Davis (1913) to be identical with *Myzus persicae* Sulzer.

Schizoneura panicola Thomas

Eighth Rep. State Ent. Ill., 1879, p. 138.

Cotypic slide.—Winged and wingless ♀: St. Louis, Missouri, from roots of *Panicum glabrum*, November 30, 1877 (H. Pergande). Slide No. 2770.

In very poor condition. Mounted in balsam.

Schizoneura pinicola Thomas

Eighth Rep. State Ent. Ill., 1879, p. 137.

Type.—Winged ♀: Carbondale, Illinois, on tender shoots of young white pines, April 20, 1878 (C. Thomas). Slide No. 2774.

In very poor condition. Mounted in balsam. Now considered as a synonym of *Mindarus abietinus* Koch.

Siphonophora acerifoliae Thomas

Bull. Ill. State Lab. Nat. Hist., Vol. 1, No. 2, June, 1878, p. 4.

Cotypes ?: Sauk City, Wisconsin, on *Acer rubrum* (Bundy). Slide 2764.

Two winged viviparous females and one immature form mounted in balsam on a slide; several additional cotypic (?) specimens in alcohol in vial. In very poor condition. Mr. Davis, in Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. II, p. 99, says that "these may be the types". Material received from Bundy is not mentioned in original description. The host record of *Acer rubrum* indicates that these specimens are probably not the type. Now placed in the genus *Drepanaphis* Del Guercio.

Siphonophora heucherae Thomas

Eighth Rep. State Ent. Ill., 1879, p. 66.

Cotypes.—Immature and winged ♀: Sauk City, Wisconsin, on *Heuchera hispida*, June (Bundy). Slide Nos. 3174 and 3175.

Two balsam slide mounts and numerous specimens in alcohol in vial. In very poor condition. Now placed in the genus *Macrosiphum* Passerini.

Siphonophora minor Forbes

Thirteenth Rep. State Ent. Ill., May 31, 1884, p. 101.

Lectotype.—Winged ♀: Normal, Illinois, on strawberry, June 19, 1883 (S. A. Forbes). Acc. No. 3397. Slide No. 3157.

Paratype.—Nymphs: Normal, Illinois, on strawberry, June 21, 1883 (S. A. Forbes). Acc. No. 3399. Slide No. 3158.

Mounted in balsam on two slides. In poor condition. Now placed in the genus *Macrosiphum* Passerini.

Tychea brevicornis Hart

Eighteenth Rep. State Ent. Ill., March 4, 1895, p. 97. (Reprint, 1920, p. 86).

Cotypes.—Wingless viviparous ♀: Normal, Illinois, on corn roots, July 28, 1884 (S. A. Forbes); Champaign, Illinois, in ants' nest in pasture, October 25, 1886 (C. M. Weed). Acc. Nos. 4583 and 10947. Slide No. 3171.

One balsam slide mount and several specimens in alcohol in two vials. Now placed in the genus *Pemphigus* Hartig. In very poor condition.

Tychea erigeronensis Thomas

Eighth Rep. State Ent. Ill., 1879, p. 168.

Cotypes ?—Immature: Champaign, Illinois, on "roots of Endive and *Erigeron canadense*" (T. J. Burrill). Slide No. 2769.

In poor condition. Mounted in balsam. Now placed in the genus *Trama* Heyden. Stated by Davis (1913) as "probably types".

Family ALEYRODIDAE

Aleurodes aceris Forbes

Fourteenth Rep. State Ent. Ill., September 2, 1885, p. 110.

Cotypes.—♀: Tamaroa, Illinois, April 10, 1884 (S. A. Forbes). Acc. No. 1368.

Remains of three cotypic adults in very poor condition preserved in alcohol. Because of the condition of these specimens no lectotype has been selected. Now known as *Aleurochiton forbesii* (Ashmead). The specific name of *forbesii* was proposed for this species by Ashmead because *aceris* was preoccupied.

Family COCCIDAE

Aspidiotus aesculi Johnson

Bull. Ill. State Lab. Nat. Hist., Vol. IV, Art. XIII, October 1896, p. 386.

Cotypes.—♂ and ♀: Stanford University, California, on *Aesculus california*, 1892 (W. G. Johnson). Acc. No. 29423.

Cotypic material on sections of small branches sealed in five glass tubes. Placed by MacGillivray in the genus *Diaspidiotus* Leonardi.

Aspidiotus comstocki Johnson

Bull. Ill. State Lab. Nat. Hist., Vol. IV, Art. XIII, October, 1896, p. 383.

Lectotypic slide.—Adult ♀: Mt. Carmel, Illinois, on leaves of *Acer saccharinum* Wang, August 2, 1895 (Dr. J. Schneck). Acc. No. 21412. Slide No. 2201.

Paratypic slides.—Immature forms and adult ♀: Mt. Carmel, Illinois, on leaves of *Acer saccharinum* Wang, April-August, 1895 (Dr. J. Schneck). Acc. Nos. 21244, 21366, 21412 and 21413. Slides 2200, 2202-2204 and 2199.

Also numerous paratypic scales on leaves in six sealed test tubes. In fair condition. MacGillivray has placed this species in the genus *Aspidiella* Leonardi.

Aspidiotus forbesi Johnson

Bull. Ill. State Lab. Nat. Hist., Vol. IV, Art. XIII, October, 1896, p. 380.

Lectotypic slide.—Adult ♀: Champaign, Illinois, on cherry trees, September 25, 1895 (W. G. Johnson). Acc. No. 21547. Slide 2163.

Lectoallotypic slide.—Adult ♂: Champaign, Illinois, on cherry trees, July 25, 1895 (W. G. Johnson). Acc. No. 21391. Slide No. 2161.

Paratypic slides.—Immature forms and adult ♀: Champaign, Illinois, on cherry trees, December, 1894, to April, 1896 (W. G. Johnson). Acc. Nos. 21056, 21342, 21360, 21472, 21547 and 29434. Slide Nos. 2160, 2162, 2164, 2173 and 2174.

Also numerous paratypic scales on sections of branches of cherry in ten sealed test tubes. In fair condition. MacGillivray (1921) has placed this species in the genus *Aspidiella* Leonardi.

Aspidiotus hartii Cockerell

Psyche, Supplement, Vol. VII, September, 1895, p. 7.

Cotypes.—♂ and ♀: Trinidad, British West Indies, Royal Botanical Garden (Hart). Acc. No. 20323.

Cotypic material on small pieces of yams sealed in five glass tubes. Placed by MacGillivray in the genus *Aspidiella* Leonardi.

Aspidiotus piceus Sanders

Ohio Naturalist, Vol. IV, No. 4, February, 1904, p. 96.

Cotypes.—♂ and ♀: Painesville, Lake County, Ohio, on *Liriodendron tulipifera*, July 7, 1903 (J. G. Sanders).

Numerous cotypic scales on pieces of bark sealed in four glass tubes. MacGillivray (1921) has placed this species in his genus *Diaspidiotus*.

Aspidiotus ulmi Johnson

Bull. Ill. State Lab. Nat. Hist., Vol. IV, Art. XIII, October, 1896, p. 388.

Lectotypic slide.—♀: Urbana, Illinois, on *Ulmus americana* Linn., September 25, 1895 (W. G. Johnson). Acc. No. 21546. Slide No. 2176.

Paratypic slide.—♀: Urbana, Illinois, on *Ulmus americana* Linn., June 6, 1895 (W. G. Johnson). Acc. No. 21359. Slide No. 2175.

Numerous paratypic scales on pieces of bark of white elm sealed in four glass tubes. Acc. No. 21261. In fair condition. MacGillivray (1921) has placed this species in his genus *Hendaspidiotus*.

Chionaspis americana Johnson

Bull. Ill. State Lab. Nat. Hist., Vol. IV, Art. XIII, October, 1896, p. 390.

Lectotypic slide.—Adult ♀: Champaign-Urbana, Illinois, April-September, 1895, on *Ulmus americana* Linn. (W. G. Johnson). Acc. No. 21536. Slide No. 2180.

Lectoallotypic slide.—Winged ♂: Champaign-Urbana, Illinois, April-September, 1895, on *Ulmus americana* Linn. (W. G. Johnson). Acc. No. 21481. Slide No. 2195.

Paratypic slides.—Adults and immature forms: Champaign-Urbana, Illinois, April-September, 1895, on *Ulmus americana* Linn. (W. G. Johnson). Acc. Nos. 21258, 21271, 21481, 21502, 21522, 21528 and 21536. Slide Nos. 2177-2179, 2180-2194 and 2196-2198.

Also numerous paratypic scales on leaves and sections of branches of elm in thirteen sealed glass tubes. In fair condition. MacGillivray (1921) has placed this species in his genus *Fundaspis*.

Chionaspis gleditsiae Sanders

Ohio Naturalist, Vol. III, No. 6, April, 1903, p. 413.

Cotypes.—♂ and ♀: Columbus, Ohio, on *Gleditsia triacanthos*, March 11, 1903 (J. G. Sanders).

Numerous cotypic scales on pieces of bark sealed in five glass tubes.

Coccus sorghiellus Forbes

Fourteenth Rep. State Ent. Ill., September 2, 1885, p. 71.

Cotypes.—Wingless ♀: Champaign, Illinois, from sorghum roots, August 4, 1884 (S. A. Forbes). Acc. No. 4667. Slide Nos. 3124 and 3125.

Two slides with cotypes mounted in balsam and one vial with several cotypes in alcohol. Because of poor condition of specimens no lectotype has been selected. Now placed in genus *Pseudococcus* Westwood.

Coccus trifolii Forbes

Fourteenth Rep. State Ent. Ill., September 2, 1885, p. 72.

Cotypes.—Wingless ♀: Normal, Illinois, on roots of white clover, May 3, 1884 (S. A. Forbes). Acc. No. 1533. Slide No. 3150.

In poor condition in vial in alcohol and one cotype mounted in balsam on slide in 1917. Because of condition of specimens no lectotype has been selected. Now placed in genus *Trionymus* Berg.

ORDER COLEOPTERA

Family CLERIDAE

Enoclerus liljebladi Wolcott
Trans. Amer. Ent. Soc., Vol. XLVIII, July 25, 1922, p. 73.
Paratype.—♂: Pentwater, Michigan, dead pine trees, July 14, 1920 (E. Liljeblad).

Family MORDELLIDAE

Mordella albosuturalis Liljeblad
Can. Ent., Vol. LIV, No. 3, March, 1922, p. 54.
Paratypes.—♂ and ♀: Callistoga, near Mt. St. Helena, California, July 14, 1918 (C. L. Hubbs).

Mordella hubbsi Liljeblad
Can. Ent., Vol. LIV, No. 3, March, 1922, p. 55.
Paratype.—♂: Switzer's Trail, St. Gabriel Mt., California, June 10, 1910 (F. Grinnell, Jr.).

Mordellistena pulchra Liljeblad
Can. Ent., Vol. XLIX, No. 1, January, 1917, p. 12, ♀.
Can. Ent., Vol. LIII, No. 8, August, 1921, p. 185, ♂.
Paratype.—♂: Edgebrook, Illinois, on flowers of *Helianthus*, September 6, 1917 (E. Liljeblad).

Family SCARABAEIDAE

Anomala kansana Hayes and McColloch
Ent. News, Vol. XXXV, No. 4, April, 1924, p. 139.
Paratype.—♂: Manhattan, Kansas.

Phyllophaga fraterna var. mississippiensis Davis
Bull. Ill. State Nat. Hist. Surv., Vol. XIII, Art. XII, August, 1920, p. 330.
Type.—♂: Agricultural College, Mississippi, April 17, 1917 (R. H. Bush).
Allotype.—♀: Agricultural College, Mississippi, on pecan, April 24, 1915.
Paratypes.—♂ and ♀: Agricultural College, Mississippi, April 2-3, 1918 (C. M. Griffin), April 14, 1917.

Phyllophaga hirticula var. comosa Davis
Bull. Ill. State Nat. Hist. Surv., Vol. XIII, Art. XII, August, 1920, p. 337.
Type.—♂: Manhattan, Kansas, at electric light, June 16-21, 1917 (J. W. McColloch).
Allotype.—♀: Manhattan, Kansas, at electric light, June 16-21, 1917 (J. W. McColloch).
Paratypes.—♂ and ♀: Manhattan, Kansas, at electric light, June 16-21, 1917 (J. W. McColloch).

Phyllophaga impar Davis
Bull. Ill. State Nat. Hist. Surv., Vol. XIII, Art. XII, August, 1920, p. 335.
Type.—♂: Southern Pines, North Carolina, April, 1910 (A. H. Manee).

Phyllophaga parvidens var. hysteropyga Davis
Bull. Ill. State Nat. Hist. Surv., Vol. XIII, Art. XII, August, 1920, p. 336.
Type.—♂: Victoria, Texas, at light, April 6-June 26 (J. D. Mitchell).

Phyllophaga pearliae Davis
Bull. Ill. State Nat. Hist. Surv., Vol. XIII, Art. XII, August, 1920, p. 332.
Type.—♂: Clarksville, Tennessee, May 15, 1918 (H. Fox).
Allotype.—♀: Clarksville, Tennessee, April 29, 1918 (H. Fox and M. Kisliuk).
Paratypes.—♂ and ♀: Clarksville, Tennessee, May 24, 1917 (H. Fox and Wyatt); Louisville, Kentucky, on honey locust, May 21, 1913 (J. J. Davis).

Phyllophaga perlonga Davis

Bull. Ill. State Nat. Hist. Surv., Vol. XIII, Art. XII, August, 1920, p. 329

Type.—♂: Agricultural College, Mississippi, at electric light, March 31, 1916 (C. C. Greer).

Allotype.—♀: Agricultural College, Mississippi, March 31, 1916 (H. M. K.).

Paratypes.—♂ and ♀: Agricultural College, Mississippi, at electric light, March 31, 1916 (C. C. Greer and H. M. K.).

Phyllophaga soror Davis

Bull. Ill. State Nat. Hist. Surv., Vol. XIII, Art. XII, August, 1920, p. 333.

Type.—♂: Raleigh, North Carolina, July 13-25, 1916 (R. W. Leiby).

Allotype.—♀: Raleigh, North Carolina, July 13-25, 1916 (R. W. Leiby).

Paratype.—♀: Raleigh, North Carolina, July 13-25, 1916 (R. W. Leiby).

Phyllophaga foxii Davis

Bull. Ill. State Nat. Hist. Surv., Vol. XIII, Art. XII, August, 1920, p. 334.

Type.—♂: Tappahannock, Virginia, from locust, April 26, 1915 (H. Fox).

Allotype.—♀: Tappahannock, Virginia, from locust, April 26, 1915 (H. Fox).

Paratype.—♀: Tappahannock, Virginia, from locust, April 26, 1915 (H. Fox).

Serica mystaca Dawson

Journ. N. Y. Ent. Soc., Vol. XXX, No. 3, September, 1922, p. 160.

Paratypes.—♂ and ♀: Carbondale, Illinois, on oak at night, May 26, 1910; Northern Illinois; Illinois.

Family CERAMBYCIDAE

Oberea ulmicola Chittenden

Bull. Ill. State Lab. Nat. Hist., Vol. VII, Art. I, February 20, 1904, p. 4.

Paratypes.—♂ and ♀: Decatur, Illinois, breeding in elms, May 26, 1902, and July 1, 1903 (E. S. G. Titus and F. M. Webster).

Eggs, larvae, pupae and some of the adults of type series are in alcohol.

Family CHRYSOMELIDAE

Donacia curticollis Knab

Proc. Ent. Soc. Wash., Vol. VII, Nos. 2 and 3, October, 1905, p. 122.

Lectotype.—♀: Fourth Lake, Lake County, Illinois, on bulrushes, August 2, 1887 (H. Garman and C. A. Hart). Acc. No. 14046.

Paratype.—♀: Fourth Lake, Lake County, Illinois, on bulrushes, August 2, 1887 (H. Garman and C. A. Hart); Fourth Lake, Lake County, Illinois, on bulrushes, August 5, 1887 (H. Garman); Normal, Illinois, September, 1880. Acc. Nos. 265, 14046 and 14057.

Family CURCULIONIDAE

Sphenophorus minimus Hart

Sixteenth Rep. State Ent. Ill., April 28, 1890, p. 65.

Lectotype.—♀: Urbana, Illinois, from driftwood, July 30, 1888 (C. A. Hart and J. Marten). Acc. No. 14585.

Lectoallotype.—♂: Urbana, Illinois, from driftwood, July 30, 1888 (C. A. Hart and J. Marten). Acc. No. 14585.

Paratype.—♂: Urbana, Illinois, from driftwood, July 30, 1888 (C. A. Hart and J. Marten). Acc. No. 14585.

ORDER LEPIDOPTERA

Family PHALONIIDAE

Hysterosia merrickana Kearfott
Can. Ent., Vol. XXXIX, No. 2, February, 1907, p. 59.
Cotypes.—♀: Algonquin, Illinois, August 4-5, 1904 (W. A. Nason).
This species has been sunk as a synonym of *Hysterosia terminana* Busck. Though labeled by Kearfott as cotypes these specimens presumably have the status of paratypes.

Family PYRALIDIDAE

Pyrausta caffreii Flint and Malloch
Bull. Ill. State Nat. Hist. Surv., Vol. XIII, Art. X, June, 1920, p. 304.
Type.—♂: Bloomington, Illinois, September 30, 1919 (J. R. Malloch).
Allotype.—♀: No data.
In very poor condition. Genitalia of types in alcohol. According to Heinrich (1921) the male is synonymous with *Loxostege similalis* Guenée and according to Barnes and Benjamin (1925) the female with *Loxostege obliteralis* Walker (authors, Walker query) (=*marculenta* G. and R.).

Family GEOMETRIDAE

Aspilates behrensaria Hulst
Ent. Amer., Vol. II, No. 11, February, 1887, p. 210.
Cotype.—♀: Soda Springs, Siskiyou, California, July 21 (J. Behrens).
In poor condition. This is now considered as synonymous with *Drepanulatrix unicalcararia* Guenée.

Biston ypsilon Forbes
Fourteenth Rep. State Ent. Ill., September 2, 1885, p. 95.
Type.—♂: Warsaw, Illinois, April 8, 1884 (S. A. Forbes). Acc. No. 4172.
Reared by Professor S. A. Forbes from a larva found feeding on apple June 26, 1883.

Coenocalpe polygrammata Hulst
Trans. Amer. Ent. Soc., Vol. XXIII, 1896, p. 288.
Cotype (?).—♀: Montana.
In fair condition. This locality is not given in original description, but specimen bears a "Type" label in the handwriting of Hulst. Now placed in genus *Perizoma* Hübner.

Diastictis floridensis Hulst
Can. Ent., Vol. XXX, No. 6, June, 1898, p. 164.
Cotype (?).—♂: Enterprise, Florida, April, 1897.
In fair condition. This specimen is labeled "Type" in the handwriting of Hulst, but this locality is not given in original description and Hulst distinctly states that he did not have the male and his generic assignment therefore doubtful. This is now considered as synonymous with *Mellilla inextricata* Walker.

Family NOCTUIDAE

Heliolonche indiana Smith
Ent. News, Vol. XIX, No. 9, November, 1908, p. 423.
Cotype.—♀: Hessville, Indiana, May 30, 1908 (E. Beer).

Pallachira hartii French
Bull. Ill. State Lab. Nat. Hist., Vol. IV, Art. II, March, 1894, p. 9.
Lectotype.—♂: Urbana, Illinois, at light, August 20, 1886 (C. A. Hart). Acc. No. 18739.

Lectoallotype.—♀: Champaign, Illinois, at light, July 27, 1886 (C. A. Hart). Acc. No. 18739.

Paratypes.—♀: Urbana, Illinois, at light, August 17, 1892 (C. A. Hart). Acc. Nos. 10712 and 10773.

In poor condition. Now placed in genus *Hormisa* Walker. *Hartii* has been synonymized as *pupillaris* Grote, which appears to be a northern form of *orciferalis* Walker.

Papaipema beeriana Bird

Can. Ent., Vol. LV, No. 5, May, 1923, p. 106.

Paratypes.—♂: Chicago, Illinois, reared from larva in *Lacinaria*, September 21, 1922 (A. K. Wyatt); Riverside, Illinois, reared from larva in *Lacinaria*, September 7, 1922 (E. Beer).

Pseudaglossa forbesi French

Bull. Ill. State Lab. Nat. Hist., Vol. IV, Art. II, March, 1894, p. 8.

Lectotype.—♀: Savanna, Illinois, July 21, 1892 (McElfresh). Acc. No. 18510

Paratype.—♀: Savanna, Illinois, July 21, 1892 (McElfresh). Acc. No. 18510.

Now placed in the genus *Camptylochila* Stephens. In fair condition.

Rhizagrotis polingi Barnes and Benjamin

Contrib. Nat. Hist. Lepidoptera, Vol. 5, June 24, 1922, p. 41.

Paratypes.—♂ and ♀: Dixieland, Imperial County, California, March 1-15, 1922 (O. C. Poling).

ORDER DIPTERA

Family TIPULIDAE

Dicranota iowa Alexander

Can. Ent., Vol. LII, No. 4, April, 1920, p. 78.

Holotype.—♀: Sioux City, Iowa, April 17, 1916 (A. W. Lindsey).

Elliptera illini Alexander

Pomona Coll. Journ. Ent. and Zool., Vol. XII, No. 4, December, 1920, p. 86.

Holotype.—♂: Makanda, Illinois, June 4, 1919 (C. P. Alexander).

In fair condition.

Limnophila imbecilla illinoiensis Alexander

Can. Ent., Vol. LII, No. 8, October, 1920, p. 226.

Holotype.—♂: Homer Park, Illinois, June 13, 1920 (T. H. Frison).

Nephrotoma sphagnicola Alexander

Can. Ent., Vol. LII, No. 5, May, 1920, p. 110.

Holotype.—♀: Antioch, Lake County, Illinois, in tamarack-sphagnum bog, June 5, 1919 (T. H. Frison).

Ormosia frisoni Alexander

Can. Ent., Vol. LII, No. 8, October, 1920, p. 224.

Holotype.—♂: Muncie, Illinois, margin of prairie cat-tail swamp, May 15, 1920 (C. P. Alexander).

Paratypes.—♂ and ♀: Muncie, Illinois, margin of prairie cat-tail swamp, May 15, 1920 (C. P. Alexander and T. H. Frison).

Tipula flavibasis Alexander

Can. Ent., Vol. L, No. 12, December, 1918, p. 414.

Paratopotype.—♂: Lawrence, Douglas County, Kansas, June 28, 1918 (C. P. Alexander).

Tipula mallochi Alexander

Pomona Coll. Journ. Ent. and Zool., Vol. XII. No. 4. 1920, p. 90.

Holotype.—♂: Alto Pass, Illinois, June 5, 1919 (C. P. Alexander).

Allotopotypes.—♀: Alto Pass, Illinois, June 5, 1919 (C. P. Alexander).

Paratypes.—♂ and ♀: Dubois, Illinois, June 3, 1919 (C. P. Alexander).

Family CHIRONOMIDAE

Bezzia albidorsata Malloch
Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 349.
Type.—♀: Algonquin, Illinois, July 12, 1895 (W. A. Nason).

Bezzia apicata Malloch
Journ. N. Y. Ent. Soc., Vol. XXII, No. 4, December, 1914, p. 284.
Type.—♂: Muncie, Illinois, along Stony Creek, May 24, 1914 (J. R. Malloch).

Bezzia cockerelli Malloch
Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 346.
Type.—♀: Modern, Colorado, May 28 (T. D. A. Cockerell).

Bezzia dentata Malloch
Journ. N. Y. Ent. Soc., Vol. XXII, No. 4, December, 1914, p. 284.
Lectotype.—♀: Monticello, Illinois, along Sangamon River, June 21, 1914 (J. R. Malloch).
Lectoallotype.—♂: Monticello, Illinois, along Sangamon River, June 28, 1914 (J. R. Malloch).
Paratypes.—♀: Monticello, Illinois, along Sangamon River, June 28, 1914 (J. R. Malloch).

Bezzia flavitarsis Malloch
Journ. N. Y. Ent. Soc., Vol. XXII, No. 4, December, 1914, p. 283.
Type.—♀: Monticello, Illinois, bank of Sangamon River, June 21, 1914 (J. R. Malloch).
Allotype.—♂: Little Bear Lake, Grand Junction, Michigan, July 15, 1914 (C. A. Hart).

Camptocladius flavens Malloch
Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 511.
Lectotype.—♂: Havana, Illinois, Chautauqua Park, along Illinois River, April 29, 1914 (C. A. Hart and J. R. Malloch).
Lectoallotype.—♀: Havana, Illinois, Chautauqua Park, along Illinois River, April 29, 1914 (C. A. Hart and J. R. Malloch).
Paratypes.—♂ and ♀: Havana, Illinois, Chautauqua Park, along Illinois River, April 29, 1914 (C. A. Hart and J. R. Malloch); St. Joseph, Illinois, along Salt Fork, May 17, 1914 (C. A. Hart and J. R. Malloch); South Haven, Michigan, shore of Lake Michigan, July 14, 1914 (C. A. Hart). Slide Nos. 3014 and 3015.
In good to poor condition. Genitalia of one male paratype and one entire female paratype mounted in balsam on slides.

Camptocladius flavibasis Malloch
Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 511.
Type.—♀: Urbana, Illinois, on window, August 23, 1914 (C. A. Hart and J. R. Malloch).

Camptocladius lasiophthalmus Malloch
Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 509.
Lectotype.—♀: Dubois, Illinois, along creek valley, April 24, 1914 (C. A. Hart and J. R. Malloch).
Paratype.—♀: Dubois, Illinois, along creek valley, April 24, 1914 (C. A. Hart and J. R. Malloch). Slide No. 3023.
Abdomen of paratype mounted in balsam on a slide.

Camptocladius subaterrimus Malloch
Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 512.
Type.—♂: Grand Tower, Illinois, along Mississippi River, April 21, 1914 (C. A. Hart and J. R. Malloch). Slide No. 3022.
Abdomen and genitalia mounted in balsam on a slide.

Camptocladius lasiops Malloch

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 508.

Lectotype.—♂: Urbana, Illinois, about garbage near house, November 29, 1913 (C. A. Hart and J. R. Malloch). Slide No. 3017.

Lectoallotype.—♀: Urbana, Illinois, about garbage near house, November 29, 1913 (C. A. Hart and J. R. Malloch).

Paratypes.—♂ and ♀: Urbana, Illinois, about garbage near house, November 29, 1913 (C. A. Hart and J. R. Malloch), in yard, September 6-7, 1914 (C. A. Hart and J. R. Malloch); March 29, 1914, October 5-6, 18, 1914, at light (C. A. Hart and J. R. Malloch). Slide Nos. 3018-3020.

Abdomen and genitalia of lectotype, one male paratype, one female paratype and heads of two paratypes (male and female) mounted in balsam on slides.

Chironomus abbreviatus Malloch

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 451.

Lectotype.—♂: Havana, Illinois, September 10, 1910. Slide No. 2522.

Paratype.—♂: Havana, Illinois, August 18, 1896 (C. A. Hart). Acc. No. 24046. Slide No. 2523.

Genitalia of both type specimens mounted in balsam on slides.

Chironomus abortivus Malloch

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 465.

Lectotype.—♂: Urbana, Illinois, at light, September 5, 1914 (C. A. Hart and J. R. Malloch). Slide No. 2553.

Lectoallotype.—♀: Urbana, Illinois, at light, September 5, 1914 (C. A. Hart and J. R. Malloch).

Paratypes.—♂ and ♀: Urbana, Illinois, at light, September 5, 1914 (C. A. Hart and J. R. Malloch); Havana, Illinois, along Illinois River, April 27-28, 1914 (C. A. Hart and J. R. Malloch); South Haven, Michigan, at light, July 15, 1914 (C. A. Hart). Slide No. 2571.

Genitalia of lectotype and one male paratype mounted in balsam on slides.

Chironomus alboviridis Malloch

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 482.

Type.—♀: Urbana, Illinois, at light, June 6, 1914 (C. A. Hart and J. R. Malloch).

Type specimen bears date label of June 6, instead of July 6 as given in original description.

Chironomus basalis Malloch

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 441.

Lectotype.—♂: Dubois, Illinois, on vegetation along bank of creek valley, April 24, 1914 (C. A. Hart and J. R. Malloch).

Lectoallotype.—♀: Dubois, Illinois, on vegetation along bank of creek valley, April 24, 1914 (C. A. Hart and J. R. Malloch).

Paratypes.—♂ and ♀: Dubois, Illinois, on vegetation along bank of creek valley, April 24, 1914 (C. A. Hart and J. R. Malloch). Slide No. 2555.

Genitalia of one male paratype mounted in balsam on a slide.

Chironomus claripennis Malloch

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 439.

Lectotype.—♂: South Haven, Michigan, along shore of Lake Michigan, at light, July 14, 1924 (C. A. Hart). Slide No. 2580.

Lectoallotype.—♀: South Haven, Michigan, along shore of Lake Michigan, at light, July 14, 1914 (C. A. Hart).

Paratypes.—♂ and ♀: South Haven, Michigan, along shore of Lake Michigan, at light, July 14-15, 1914 (C. A. Hart); Grand Tower, Illinois, on bank of Mississippi River, April 21, 1914 (C. A. Hart).

Genitalia of lectotype male mounted in balsam on a slide.

Chironomus colei Malloch

Proc. Calif. Acad. Sc. (Fourth Series), Vol. IX, August 26, 1919, p. 255.

Paratype.—♂: Forest Grove, Oregon, at light, June 3, 1918 (F. R. Cole).

Chironomus crassicaudatus Malloch

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 453.

Type.—♂: Peoria, Illinois, at light, October 22, 1914 (C. A. Hart). Slide No. 2980.

Paratype.—♂: Lake Lomalta, Texas, November 27, 1910 (C. A. Hart); Katherine, Texas, sweeping, December 3, 1911 (C. A. Hart). Slide Nos. 2516 and 2517.

Genitalia of all types mounted in balsam on slides.

Chironomus curtilamellatus Malloch

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 474.

Type.—♂: South Haven, Michigan, at light, July 15, 1914 (C. A. Hart). Slide No. 2981.

Genitalia mounted in balsam on a slide.

Chironomus digitatus Malloch

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 483.

Lectotype.—♀: Thompson's Lake, Havana, Illinois, reared from larva, May 14, 1914 (C. A. Hart and J. R. Malloch). Acc. No. 45797.

Paratypes.—♀: Havana, Illinois, flying over surface of Illinois River, May 4, 1895 (C. A. Hart). Acc. No. 13289.

Pupal exuvia, from which lectotype was reared and from which pupal description was made, is mounted in balsam on slide No. 2567. In fair condition.

Chironomus dimorphus Malloch

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 464.

Lectotype.—♂: Carbondale, Illinois, creek valley, April 23, 1914 (C. A. Hart and J. R. Malloch).

Lectoallotype.—♀: Carbondale, Illinois, creek valley, April 23, 1914 (C. A. Hart and J. R. Malloch).

Paratypes.—♂ and ♀: Carbondale, Illinois, creek valley, April 23, 1914 (C. A. Hart and J. R. Malloch); Dubois, Illinois, creek valley, April 24, 1914 (C. A. Hart and J. R. Malloch); Muncie, Illinois, along Stony Creek, May 24, 1914 (C. A. Hart and J. R. Malloch); Monticello, Illinois, along Sangamon River, June 30, 1914 (C. A. Hart and J. R. Malloch).

Genitalia of two male paratypes mounted in balsam on slides.

Chironomus dorneri Malloch

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 471.

Type.—♂: Brownsville, Texas, "3-11" (G. Dorner).

Abdomen, except basal segments, missing as stated in original description.

Chironomus fallax Johannsen

N. Y. State Museum, Bull. 86, June, 1905, p. 210. ♀

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 435. ♂ and ♀.

Allotypes.—♂: Monticello, Illinois, along Sangamon River, June 28, 1914 (C. A. Hart and J. R. Malloch); Momence, Illinois, at light, July 17, 1914 (C. A. Hart and J. R. Malloch); Centerville [White Heath], Illinois, along Sangamon River, August 16, 1914 (C. A. Hart and J. R. Malloch). Slide No. 2536.

Genitalia of one male mounted in balsam on a slide. Momence specimens collected July 17 and not July 14 as stated in original description of male. Description of male is by J. R. Malloch.

Chironomus fasciventris Malloch

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 438.

Lectotype.—♂: Dubois, Illinois, at light, April 24, 1914 (C. A. Hart and J. R. Malloch).

Lectoallotype.—♀: Dubois, Illinois, at light, April 24, 1914 (C. A. Hart and J. R. Malloch).

Paratypes.—♂ and ♀: Dubois, Illinois, at light and on vegetation along creek valley, April 24, 1914 (C. A. Hart and J. R. Malloch). Slide No. 2976.

Genitalia of one male paratype mounted in balsam on a slide.

Chironomus fulvus Johannsen.

N. Y. State Museum, Bull. 86, June, 1905, p. 224. ♀

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 478. ♂ and ♀

Allotypes.—♂: St. Joseph, Illinois, along Salt Fork, May 3, 1914 (C. A. Hart and J. R. Malloch); Muncie, Illinois, along Stony Creek, May 24, 1914 (C. A. Hart and J. R. Malloch); South Haven, Michigan, lake shore, July 14, 1914 (C. A. Hart); Cedar Lake, Indiana, July 17, 1914 (C. A. Hart); Havana, Illinois, in slough and at lights, September 20-21, 1895 (A. Hempel); Havana, Illinois, along Illinois River, May 1, 1896, and September 18, 1895 (C. A. Hart). Acc. Nos. 13705, 13709, 13711 and 13818. Slide Nos. 2570 and 2599.

Description of male is by J. R. Malloch. Genitalia of two males mounted in balsam on slides.

Chironomus fuscicornis Malloch

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 466.

Type.—♂: Havana, Illinois, on house-boat, June 15, 1914 (J. R. Malloch). Slide No. 2547.

Allotype.—♀: Havana, Illinois, on house-boat, June 15, 1914 (J. R. Malloch).

Paratypes.—♂ and ♀: Berrien Springs, Michigan, St. Joseph River, July 16, 1914 (C. A. Hart); Plummers Island, Maryland, July 6, 14, August 17, 1912 (W. L. McAtee). Slide No. 2548.

Genitalia of type and one male paratype mounted in balsam on slides.

Chironomus fusciventris Malloch

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 465.

Type.—♂: Delavan Lake, Wisconsin, September 7, 1892 (C. A. Hart). Acc. No. 18810. Slide No. 2584.

Genitalia mounted in balsam on a slide. In the original description September 9 is given, whereas date of unique type is September 7.

Chironomus griseopunctatus Malloch

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 428.

Type.—♀: Momence, Illinois, at light, July 17, 1914 (C. A. Hart). In fair condition.

Chironomus griseus Malloch

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 468.

Lectotype.—♂: South Haven, Michigan, along lake shore, July 14, 1914 (C. A. Hart). Slide No. 2579.

Paratype.—♂: South Haven, Michigan, along lake shore, July 15, 1914 (C. A. Hart).

Abdomen and genitalia of type mounted in balsam on a slide.

Chironomus harti Malloch

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 457.

Type.—♀: Urbana, Illinois, at light, September 5, 1914 (C. A. Hart and J. R. Malloch).

Chironomus illinoensis Malloch

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 471.

Lectotype.—♂: Carbondale, Illinois, creek valley, April 23, 1914 (C. A Hart and J. R. Malloch). Slide No. 2545.

Lectoallotype.—♀: Carbondale, Illinois, creek valley, April 23, 1914 (C. A. Hart and J. R. Malloch).

Paratypes.—♂ and ♀: Carbondale, Illinois, creek valley, April 23, 1914 (C. A. Hart and J. R. Malloch); Golconda, Illinois, in depot, April 19, 1914.

In good condition, except abdomen of one male paratype is missing. Genitalia of lectotype mounted in balsam on a slide.

Chironomus illinoensis var. decoloratus Malloch
Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 472.
Lectotype.—♂: Havana, Illinois, Spoon River, September 18, 1895 (C. A. Hart). Acc. No. 13705.
Paratype.—♂: Havana, Illinois, Spoon River, September 18, 1895 (C. A. Hart). Acc. No. 13705. Slide No. 2546.
One slide mount of the genitalia (all that remains) of the paratypic male. In fair condition. Date of capture is erroneously given as September 19 in original description.

Chironomus incognitus Malloch
Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 480.
Type.—♂: Muncie, Illinois, along Stony Creek, May 24, 1914 (C. A. Hart and J. R. Malloch). Slide No. 2581.
Genitalia of type mounted in balsam on a slide.

Chironomus indistinctus Malloch
Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 477.
Lectotype.—♂: St. Joseph, Illinois, along Salt Fork, May 3, 1914 (C. A. Hart and J. R. Malloch). Slide No. 2593.
Paratypes.—♂: St. Joseph, Illinois, along Salt Fork, May 3, 1914 (C. A. Hart and J. R. Malloch); Havana, Illinois, Matanzas Lake, May 2, 1914. Slide Nos. 2563-2565.
In fair to poor condition. Abdomen and genitalia of lectotype and those of three paratypes mounted in balsam on slides.

Chironomus macateei Malloch
Proc. Biol. Soc. Wash., Vol. 28, March 12, 1915, p. 45.
Paratypes.—♂ and ♀: Plummers Island, Marlyand, August 10-17, 1912, and June 28, 1914 (W. L. McAtee). Slide No. 2595.
Genitalia (all that remains) of a paratype mounted in balsam on a slide.

Chironomus neomodestus Malloch
Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 475.
Lectotype.—♂: St. Joseph, Illinois, along Salt Fork, May 3, 1914 (J. R. Malloch). Slide No. 2592.
Paratypes.—♂: St. Joseph, Illinois, along Salt Fork, May 3, 1914 (J. R. Malloch). Slide No. 2591.
Genitalia of lectotype and of one male paratype mounted in balsam on a slide.

Chironomus nigrohalteralis Malloch
Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 440.
Lectotype.—♂: Havana, Illinois, along river, April 28, 1914 (C. A. Hart and J. R. Malloch).
Lectoallotype.—♀: Havana, Illinois, along river, April 28, 1914 (C. A. Hart and J. R. Malloch).
Paratypes.—♂: Havana, Illinois, along river, April 28, 1914 (C. A. Hart and J. R. Malloch). Slide No. 2538.
Genitalia of one male paratype mounted in balsam on a slide.

Chironomus nigrovittatus Malloch
Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 456.
Lectotype.—♂: Berrien Springs, Michigan, St. Joseph River, July 16, 1914 (C. A. Hart). Slide No. 2574.
Lectoallotype.—♀: St. Joseph, Illinois, along Salt Fork, May 3, 1914 (J. R. Malloch).
Paratypes.—♂ and ♀: St. Joseph, Illinois, along Salt Fork, May 3, 1914 J. R. Malloch); South Haven, Michigan, at light, July 15, 1914 (C. A. Hart). Slide No. 2594.

The lectotype has been selected from a male listed as a paratype by Malloch. This is because the description of the species is based mainly upon a male, and no males are to be found among the St. Joseph, Illinois, specimens. In contradiction with the original description the male selected as lectotype was labeled as the type by Malloch and also the slide with its genitalia.

Chironomus nitidellus Coquillett

Proc. U. S. Nat. Mus., Vol. 23, No. 1225, March 27, 1901, p. 608. ♂

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 468. ♂ and ♀.

Allotypes.—♀: Berrien Springs, Michigan, along St. Joseph River, July 16, 1914 (C. A. Hart).

Description of the female is by J. R. Malloch.

Chironomus obscuratus Malloch

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 479.

Lectotype.—♂: Dubois, Illinois, in creek valley, April 24, 1914 (C. A Hart and J. R. Malloch). Slide No. 2552.

Lectoallotype.—♀: Dubois, Illinois, in creek valley, April 24, 1914 (C. A. Hart and J. R. Malloch).

Paratypes.—♂ and ♀: Dubois, Illinois, in creek valley, April 24, 1914 (C. A. Hart and J. R. Malloch); Lily, Illinois, along Mackinaw River, June 11, 1914 (C. A. Hart).

In fair condition. Genitalia of lectotypic male mounted in balsam on a slide.

Chironomus parvilamellatus Malloch

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 479.

Lectotype.—♂: Grand Tower, Illinois, on bank of Big Muddy River, April 22, 1914 (C. A. Hart and J. R. Malloch). Slide No. 2600.

Paratypes.—♂: Grand Tower, Illinois, on bank of Big Muddy River, April 22, 1914 (C. A. Hart and J. R. Malloch). Slide No. 2982.

Abdomen and genitalia of lectotypic male and one paratypic male mounted in balsam on slides.

Chironomus pseudoviridis Malloch

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 450.

Lectotype.—♂: Urbana, Illinois, at light, September 5, 1914 (C. A. Hart and J. R. Malloch).

Lectoallotype.—♀: Urbana, Illinois, at light, September 5, 1914 (C. A. Hart and J. R. Malloch).

Paratypes.—♂ and ♀: Urbana, Illinois, at light, September 5, 1914 (C. A. Hart and J. R. Malloch); South Haven, Michigan, lake shore, July 14, 1914 (C. A. Hart). Slide No. 2534.

Genitalia of one paratypic male mounted in balsam on a slide. Malloch in original description lists month of collection of Urbana, Illinois, specimens as August, whereas specimens were collected in September.

Chironomus quadripunctatus Malloch

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 437.

Type.—♂: Lake Delavan, Wisconsin, September 7, 1892 (C. A. Hart). Acc. No. 18810.

In fair condition.

Chironomus serus Malloch

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 481.

Lectotype.—♂: Urbana, Illinois, at light, October 2, 1914 (C. A. Hart and J. R. Malloch). Slide No. 2585.

Lectoallotype.—♀: Urbana, Illinois, on window, September 27, 1914 (C. A. Hart and J. R. Malloch).

Paratypes.—♂ and ♀: Urbana, Illinois, at light, October 2-3, 1914, on window, September 27, 1914 (C. A. Hart and J. R. Malloch); Urbana, Illinois, May 22, 1906; Havana, Illinois, at light, September 13, 1895 (C. A. Hart). Acc. No. 13572. Slide No. 2590.

Genitalia of lectotype and of one male paratype mounted in balsam on two slides.

Chironomus subaequalis Malloch

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI,, May, 1915, p. 440.

Lectotype.—♂: Muncie, Illinois, along Stony Creek, May 24, 1914 (C. A. Hart and J. R. Malloch). Slide No. 2539.

Lectoallotype.—♀: Muncie, Illinois, along Stony Creek, May 24, 1914 (C. A. Hart and J. R. Malloch).

Paratypes.—♂ and ♀: Muncie, Illinois, along Stony Creek, May 24, 1914 (C. A. Hart and J. R. Malloch).

Genitalia of lectotype mounted in balsam on a slide.

Chironomus tentans var. **pallidivittatus** Malloch

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 445.

Lectotype.—♂: Havana, Illinois, August 7, 1895 (E. B. Forbes). Acc. No. 13519.

Paratype.—♂: Havana, Illinois, August 8, 1896 (C. A. Hart and C. C. Adams). Acc. No. 24022. Slide No. 2583.

Genitalia of paratypic male mounted in balsam on a slide.

Chironomus tenuicaudatus Malloch

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 475.

Lectotype.—♂: Havana, Illinois, along river, April 28, 1914 (C. A. Hart and J. R. Malloch).

Paratypes.—♂: Havana, Illinois, along river, April 27-28, 1914 (C. A. Hart and J. R. Malloch); St. Joseph, Illinois, along Salt Fork, May 3, 1914 (C. A. Hart and J. R. Malloch); Urbana, Illinois, fair grounds, May 20, 1914 (C. A. Hart and J. R. Malloch). Slide No. 2569.

Genitalia of one male paratype mounted in balsam on a slide.

Chironomus utahensis Malloch

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 438.

Paratype.—♂: Kaysville, Utah, April 7, 1912 (E. R. Kalmbach). Slide No. 2508.

In fair condition. Genitalia mounted in balsam on a slide.

Chironomus varipennis Coquillett

Proc. U. S. Nat. Mus., Vol. 25, No. 1280, September 12, 1902, p. 94. ♂

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 427. ♂ and ♀.

Allotypes.—♀: Urbana, Illinois, in an aquarium, May 6, 1890 (C. A. Hart). Acc. No. 15661.

Description of the female is by J. R. Malloch.

Ceratopogon fusinervis Malloch

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 308.

Lectotype.—♂: Grand Tower, Illinois, along river, April 21, 1914 (C. A. Hart and J. R. Malloch).

Lectoallotype.—♀: Grand Tower, Illinois, along river, April 21, 1914 (C. A. Hart and J. R. Malloch).

Paratypes.—♂ and ♀: St. Joseph, Illinois, along Salt Fork, May 3, 1914 (C. A. Hart and J. R. Malloch); Urbana, Illinois, fair grounds, May 20, 1914 (C. A. Hart and J. R. Malloch); Havana, Illinois, Matanzas Lake, May 2, 1914 (C. A. Hart and J. R. Malloch); Monticello, Illinois, along Sangamon River, June 28, 1914 (C. A. Hart and J. R. Malloch); Dubois, Illinois, April 24, 1914 (J. R. Malloch). Slide No. 2952.

One paratypic male mounted in balsam on a slide.

Corynoneura similis Malloch

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 413.

Type.—♀: Havana, Illinois, along river, April 30, 1914 (J. R. Malloch).

Allotype.—♂: Havana, Illinois, along river, April 30, 1914 (J. R. Malloch). Slide No. 2876.

Paratype.—♀: Brownsville, Texas, South Texas Garden sweepings, November 18, 1911 (C. A. Hart).

Allotype mounted in balsam on a slide.

Cricotopus flavibasis Malloch

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 502.

Lectotype.—♂: Urbana, Illinois, at light, October 6, 1914 (C. A. Hart and J. R. Malloch). Slide No. 3054.

Allotype.—♀: Urbana, Illinois, at light, October 9, 1914 (C. A. Hart and J. R. Malloch).

Paratype.—♂: Urbana, Illinois, at light, October 5, 1914 (C. A. Hart and J. R. Malloch).

Genitalia of lectotype mounted in balsam on a slide.

Cricotopus slossonae Malloch

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 506.

Type.—♀: Algonquin, Illinois, June 4, 1894 (W. A. Nason).

Paratype.—♀: Mt. Washington, New Hampshire (Mrs. A. T. Slosson).

In fair condition.

Culicoides crepuscularis Malloch

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 303.

Type.—♂: Dubois, Illinois, April 24, 1914 (C. A. Hart and J. R. Malloch). Slide No. 2923.

Lectoallotype.—♀: Urbana, Illinois, on window, May 18, 1914 (C. A. Hart and J. R. Malloch).

Paratypes.—♂ and ♀: South Haven, Michigan, at lights, July 15, 1914 (C. A. Hart and J. R. Malloch); St. Joseph, Illinois, along Salt Fork, May 3, 1914 (C. A. Hart and J. R. Malloch).

Type male mounted in balsam on a slide.

Culicoides haematopotus Malloch

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 302.

Lectotype.—♂: Urbana, Illinois, at light, May 24, 1914 (J. R. Malloch).

Lectoallotype.—♀: Urbana, Illinois, biting hands, May 24, 1914 (J. R. Malloch).

Paratypes.—♂ and ♀: Urbana, Illinois, at light, May 24, 1914 (J. R. Malloch); Urbana, Illinois, on window, June 30, 1914 (J. R. Malloch); Muncie, Illinois, bank of Stony Creek, May 24, 1914 (J. R. Malloch). Slide No. 2924.

One paratypic male mounted in balsam.

Culicoides hierglyphicus Malloch

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 297.

Paratype.—♀: Ash Creek, Graham Mountain, Arizona, altitude 3200 feet, May 30, 1914 (E. G. Holt).

Culicoides multipunctatus Malloch

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 296.

Lectotype.—♀: Urbana, Illinois, at light, October 2, 1914 (C. A. Hart and J. R. Malloch).

Paratype.—♀: Urbana, Illinois, at light, October 3, 1914 (C. A. Hart and J. R. Malloch).

Diamesa borealis Garrett

Seventy New Diptera (Privately published), Cranbrook, British Columbia, December 31, 1925, p. 6.

Paratypes.—♂ and ♀: Cranbrook, British Columbia, May 10 and October 9 (C. Garrett).

Euforcipomyia hirtipennis Malloch

Bull. Ill. State Lab. Nat. Hist., Vol. XI, Art. IV, December, 1915, p. 313.

Lectotype.—♀: Urbana, Illinois, on window, June 30, 1915 (J. R. Malloch).

Paratype.—♀: Urbana, Illinois, on window, June 30, 1915 (J. R. Malloch).

The genotype of *Euforcipomyia* Malloch (original designation).

Euforcipomyia longitarsis Malloch
Bull. Ill. State Lab. Nat. Hist., Vol. XI, Art. IV, December, 1915, p. 314.
Type.—♀: Urbana, Illinois, on window, August 24, 1915 (J. R. Malloch).

Forcipomyia aurea Malloch
Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 318.
Lectotype.—♀: Momence, Illinois, at light, July 17, 1914 (C. A. Hart).
Lectoallotype.—♂: Momence, Illinois, at light, July 17, 1914 (C. A. Hart). Slide No. 2921.
Paratype.—♂: Centerville [White Heath], Illinois, along Sangamon River, August 17, 1914 (J. R. Malloch).
Lectoallotype mounted in balsam on a slide.

Forcipomyia elegantula Malloch
Bull. Ill. State Lab. Nat. Hist., Vol. XI, Art. IV, December, 1915, p. 311.
Lectotype.—♀: Urbana, Illinois, on window, June 28, 1915 (J. R. Malloch).
Lectoallotype.—♂: Urbana, Illinois, on window, August 13, 1915 (J. R. Malloch).
Paratype.—♀: Urbana, Illinois, on window, August 5, 1915 (J. R. Malloch).

Forcipomyia pergandei var. concolor Malloch
Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 319.
Lectotype.—♀: Grand Tower, Illinois, at light, April 22, 1914 (C. A. Hart and J. R. Malloch).
Paratypes.—♀: Grand Tower Illinois, along river, April 21, 1914 (C. A. Hart and J. R. Malloch); Urbana, Illinois, on window, July 4, 7, 1914 (C. A. Hart and J. R. Malloch).
The dates of April 21 and July 4 should have been listed in original description.

Hartomyia antennalis (Coquillett)
Proc. U. S. Nat. Mus., Vol. 23, No. 1225, March 27, 1901, p. 606. ♀
Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 343. ♂ and ♀.
Allotypes.—♂: Monticello, Illinois, along Sangamon River, June 30, 1914 (C. A. Hart and J. R. Malloch); Urbana, Illinois, fair ground, near Salt Fork, May 23, 1915 (C. A. Hart and J. R. Malloch).
The description of the male is by J. R. Malloch.

Hartomyia lutea Malloch
Bull. Brook. Ent. Soc., Vol. XIII, No. 1, February, 1918, p. 18.
Type.—♀: Elizabeth, Illinois, July 7, 1917 (J. R. Malloch).

Hartomyia pallidiventris Malloch
Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 344.
Lectotype.—♀: Urbana, Illinois, fair grounds, near Salt Fork, May 20, 1914 (J. R. Malloch).
Paratype.—♀: Lafayette, Indiana, July 25, 1914 (J. M. Aldrich).
The paratype differs from type in having the dorsum of the abdomen darkened.

Hartomyia picta (Coquillett)
Journ. N. Y. Ent. Soc., Vol. XIII, No. 2, June, 1905, p. 60. ♀
Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 341. ♂ and ♀
Allotypes.—♂: Urbana, Illinois, fair grounds, near Salt Fork, May 20, July 4, 1914 (J. R. Malloch).
The description of the allotypes is by J. R. Malloch. The genotype of *Hartomyia* Malloch (original designation).

Heteromyia aldrichi Malloch
Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 326.
Type.—♀: Moscow, Idaho (J. M. Aldrich).

Heteromyia hirta Malloch
Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 330.
Lectotype.—♀: Muncie, Illinois, along Stony Creek, May 24, 1914 (J. R. Malloch).

Lectoallotype.—♂: Muncie, Illinois, along Stony Creek, May 24, 1914 (J. R. Malloch).

Paratype.—♀: Muncie, Illinois, along Stony Creek, July 5, 1914 (J. R. Malloch).

Heteromyia opacithorax Malloch

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 329.

Type.—♀: St. Joseph, Illinois, along bank of Salt Fork, May 17, 1914 (J. R. Malloch).

Paratype.—♀: Dubois, Illinois, creek valley, April 24, 1914 (J. R. Malloch).

Heteromyia tenuicornis Malloch

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 328.

Type.—♀: Polk County, Wisconsin, July (Baker).

Johanseniella flavidula (Malloch)

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. IV, June, 1914, p. 230.

Lectotype.—♀: Havana, Illinois, Illinois River, reared from pupa, May 3, 1895 (C. A. Hart).

Lectoallotype.—♂: Havana, Illinois, Illinois River, reared from pupa, May 3, 1895 (C. A. Hart).

Paratypes.—♂ and ♀: Havana, Illinois, Illinois River, reared from pupae, May 2-25, 1895 (C. A. Hart); Algonquin, Illinois, May 11, 1894 (W. A. Nason). Slide Nos. 2940 and 2941.

One paratype mounted in balsam on two slides. Now placed in the genus *Johannsenomyia* Malloch.

Johannsenomyia aequalis Malloch

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 336.

Type.—♂: Muncie, Illinois, along Stony Creek, July 5, 1914 (J. R. Malloch).

Paratype.—♂: Centerville [White Heath], Illinois, along Sangamon River, August 16, 1914 (J. R. Malloch).

Johannsenomyia albibasis Malloch

Bull. Ill. State Lab. Nat. Hist., Vol. XI, Art. IV, December, 1915, p. 315.

Lectotype.—♀: White Heath, Illinois, along Sangamon River, May 8, 1915 (J. R. Malloch).

Lectoallotype.—♂: White Heath, Illinois, along Sangamon River, May 8, 1915 (J. R. Malloch).

Paratypes.—♂ and ♀: White Heath, Illinois, along Sangamon River, May 8, 9, 16, 30, 1915 (J. R. Malloch).

Johannsenomyia annulicornis Malloch

Ent. News, Vol. XXIX, No. 6, June, 1918, p. 230.

Type.—♀: Lake Villa, Illinois, lake shore, July 21, 1916 (C. A. Hart).

Johannsenomyia argentata (Loew)

Berl. Ent. Zeitschr., 1861, p. 310. ♀

Bull. Ill. State Lab. Nat. Hist., Vol. XI, Art. IV, December, 1915, p. 317. ♂ and ♀

Allotypes.—♂: White Heath, Illinois, May 30 and July 11, 1915 (C. A. Hart and J. R. Malloch).

The description of the male is by J. R. Malloch.

Johannsenomyia caudelli (Coquillett)

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 333.

Allotypes.—♂: Lafayette, Indiana, May 2, 1914 (J. M. Aldrich); Grand Tower, Illinois, Big Muddy River, May 5, 1914; St. Joseph, Illinois, Salt Fork, May 10, 1914; Carmi, Illinois, Little Wabash River, April 18, 1914. Acc. Nos. 45775 and 45781.

Allotypes described by J. R. Malloch for first time in key.

Johannsenomyia halteralis Malloch

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 338.

Lectotype.—♂: Monticello, Illinois, along Sangamon River, June 21, 1914 (J. R. Malloch).

Lectoallotype.—♀: Monticello, Illinois, along Sangamon River, June 21, 1914 (J. R. Malloch).

Paratypes.—♂: Monticello, Illinois, along Sangamon River, June 30, 1914 (J. R. Malloch); Muncie, Illinois, along Stony Creek, July 5, 1914 (J. R. Malloch); Lilly, Illinois, along Mackinaw River, June 11, 1914 (C. A. Hart).

Johannsenomyia macroneura Malloch

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 337.

Type.—♀: Lawrence, Kansas.

Metriocnemus annuliventris Malloch

Proc. Biol. Soc. Wash., Vol. XXVIII, March 12, 1915, p. 46.

Lectotype.—♂: Stanford University, California, March 18, 1906 (J. M. Aldrich). Slide No. 3093.

Paratype.—♂: Stanford University, California, March 18, 1906 (J. M. Aldrich).

Genitalia of lectotype mounted in balsam on a slide.

Metriocnemus brachyneura Malloch

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 498.

Type.—♂: Muncie, Illinois, along Stony Creek, May 24, 1914 (C. A. Hart and J. R. Malloch). Slide No. 3094.

Allotype.—♀: Madison, Wisconsin, at light, August 26, 1913 (A. C. Burrill).

Paratypes.—♂ and ♀: Madison, Wisconsin, at light, August 26, 1913 (A. C. Burrill). Slide Nos. 3095.

Genitalia of type and one paratypic male mounted in balsam on two slides.

Orthocladius bifasciatus Malloch

Bull. Brook. Ent. Soc., Vol. XIII, No. 2, April, 1918, p. 42.

Lectotype.—♀: Stratford, Illinois, June 22, 1917 (J. R. Malloch).

Paratypes.—♀: Stratford, Illinois, June 22, 1917 (J. R. Malloch).

Orthocladius (Dactylocladius) albidohalteralis Malloch

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 528.

Type.—♀: Monticello, Illinois, along Sangamon River, June 30, 1914 (C. A. Hart and J. R. Malloch).

Orthocladius (Dactylocladius) brevinervis Malloch

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 526.

Type.—♂: Muncie, Illinois, along Stony Creek, May 24, 1914 (C. A. Hart and J. R. Malloch). Slide No. 2989.

Paratypes.—♂: East Peoria, Illinois, along farm creek, April 10, 1912 (C. A. Hart); Havana, Illinois, mouth of Spoon River, at light, April 22, 1898 (C. A. Hart). Acc. No. 24353. Slide No. 2988.

Genitalia of type and one male paratype mounted in balsam on two slides.

Orthocladius (Dactylocladius) pleuralis Malloch

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 527.

Type.—♂: St. Joseph, Illinois, along Salt Fork, May 17, 1914 (J. R. Malloch). Slide No. 2999.

Genitalia mounted in balsam on a slide.

Orthocladius (Orthocladius) flavoscutellatus Malloch

Bull. Ill. State. Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 523.

Type.—♂: Muncie, Illinois, along Stony Creek, May 24, 1914 (C. A. Hart and J. R. Malloch). Slide No. 2991.

In poor condition. Genitalia mounted in balsam on a slide.

Orthocladius (Orthocladius) lacteipennis Malloch

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 524.

Type.—♂: South Haven, Michigan, shore of Lake Michigan, July 14, 1914 (C. A. Hart). Slide No. 2992.

Genitalia mounted in balsam on a slide.

Orthocladius (Orthocladius) nigritus Malloch

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 225.

Paratypes.—♂: Cabin John Run, Maryland, February 16, 1913 (W. D. Appel). Slide Nos. 2993 and 2994.

Portion of abdomen and genitalia of both specimens mounted in balsam on slides.

Orthocladius (Orthocladius) pilipes Malloch

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 522.

Lectotype.—♂: Urbana, Illinois, swarming about evergreens, March 21, 1889 (John Marten). Acc. No. 14781. Slide No. 2997.

Paratypes.—♂: Urbana, Illinois, swarming about evergreens, March 21, 1889 (John Marten). Acc. No. 14781. Slide Nos. 2996 and 2998.

In good to poor condition. Abdomen and genitalia of lectotype and of two paratypes mounted in balsam on three slides.

Orthocladius (Orthocladius) subparallelus Malloch

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 522.

Lectotype.—♂: Grand Tower, Illinois, along Mississippi River, April 21, 1914 (C. A. Hart and J. R. Malloch). Slide No. 3000.

Paratypes.—♂: Grand Tower, Illinois, along Mississippi River, April 21, 1914 (C. A. Hart and J. R. Malloch).

Abdomen and genitalia of lectotype mounted in balsam on a slide.

Orthocladius (Trichocladius) distinctus Malloch

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 518.

Lectotype.—♂: Havana, Illinois, Chautauqua Park, April 29, 1914 (C. A. Hart and J. R. Malloch).

Lectoallotype.—♀: Havana, Illinois, Chautauqua Park, April 29, 1914 (C. A. Hart and J. R. Malloch).

Paratypes.—♂ and ♀: Havana, Illinois, Chautauqua Park, April 29, 1914 (C. A. Hart and J. R. Malloch). Slide No. 3058.

Genitalia of one paratypic male mounted in balsam on a slide.

Orthocladius (Trichocladius) distinctus var. basalis Malloch

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 519.

Lectotype.—♂: Havana, Illinois, along shore of Illinois River, April 28, 1914 (C. A. Hart and J. R. Malloch).

Lectoallotype.—♀: Havana, Illinois, along shore of Illinois River, April 28, 1914 (C. A. Hart and J. R. Malloch).

Paratypes.—♂ and ♀: Havana, Illinois, along shore of Illinois River, April 28-30, 1914 (C. A. Hart and J. R. Malloch); Grand Tower, Illinois, along Big Muddy River, April 22, 1914 (C. A. Hart and J. R. Malloch); Muncie, Illinois, along Stony Creek, May 24, 1914 (C. A. Hart and J. R. Malloch); Rock Island, Illinois, at light, October 21, 1914 (C. A. Hart and J. R. Malloch); Peoria, Illinois, at light, October 22, 1914 (C. A. Hart and J. R. Malloch); St. Joseph, Illinois, along Salt Fork, May 3 (not May 30 as stated in original description), 1914 (C. A. Hart and J. R. Malloch). Slides Nos. 3025-3027.

Genitalia of two male paratypes, and one male and two female adult paratypes, mounted in balsam on three slides.

Orthocladius (Trichocladius) distinctus var. bicolor Malloch

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 519.

Lectotype.—♂: St. Joseph, Illinois, along Salt Fork, May 3, 1914 (J. R Malloch).

Paratype.—♂: St. Joseph, Illinois, along Salt Fork, May 3, 1914 (J. R. Malloch).

Orthocladius (Trichocladius) infuscatus Malloch
Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 517.
Type.—♂: Peoria, Illinois, at light, October 22, 1914 (C. A. Hart). Slide No. 3059.
Genitalia mounted in balsam on a slide.

Orthocladius (Trichocladius) nitidellus Malloch
Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 515.
Type.—♂: St. Joseph, Illinois, along Salt Fork, May 17, 1914 (C. A. Hart and J. R. Malloch). Slide No. 2990.
Abdomen and genitalia mounted in balsam on a slide.

Orthocladius (Trichocladius) nitidus Malloch
Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 515.
Type.—♂: Monticello, Illinois, along Sangamon River, June 28, 1914 (C. A. Hart and J. R. Malloch). Slide No. 3060.
Abdomen and genitalia mounted in balsam on a slide.

Orthocladius (Trichocladius) striatus Malloch
Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 517.
Type.—♂: Dubois, Illinois, creek valley, April 24, 1914 (C. A. Hart and J. R. Malloch). Slide No. 3061.
Abdomen and genitalia mounted in balsam on a slide.

Orthocladius (Psectrocladius) vernalis Malloch
Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 520.
Type.—♂: Dubois, Illinois, creek valley, April 24, 1914 (C. A. Hart and J. R. Malloch). Slide No. 3057.
Genitalia mounted in balsam on a slide.

Palpomyia illinoensis Malloch
Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. IV, June, 1914, p. 219.
Type.—♀: Algonquin, Illinois, May 25, 1894 (W. A. Nason).
Originally assigned specific name of *illinoisensis*, but later emended by author to *illinoensis*.

Palpomyia nebulosa Malloch
Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 322.
Type.—♀: Grand Junction, (Columbia) Michigan, Little Bear Lake, July 15, 1914 (C. A. Hart).
Paratype.—♀: Polk County, Wisconsin, July (Baker).

Parabezzia petiolata Malloch
Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 359.
Lectotype.—♂: Muncie, Illinois, along Stony Creek, July 5, 1914 (C. A. Hart and J. R. Malloch).
Paratypes.—♂: Muncie, Illinois, along Stony Creek, July 5, 1914, and May 24, 1914 (C. A. Hart and J. R. Malloch).
The genotype of *Parabezzia* Malloch (original designation).

Probezzia fulvithorax Malloch
Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 354.
Lectotype.—♀: Urbana, Illinois, at light on windows, July 7, 1914 (C. A. Hart and J. R. Malloch).
Lectoallotype.—♂: Urbana, Illinois, at light on windows, July 7, 1914 (C. A. Hart and J. R. Malloch).
Paratypes.—♀: Urbana, Illinois, at light on windows, July 7, 1914 (C. A. Hart and J. R. Malloch); Grand Junction (Columbia), Michigan, Little Bear Lake, July 15, 1914 (C. A. Hart).

Probezzia incerta Malloch
Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 358.
Lectotype.—♀: Monticello, Illinois, along Sangamon River, June 30, 1914 (J. R. Malloch).
Paratype.—♀: Monticello, Illinois, along Sangamon River, June 21, 1914 (J. R. Malloch).

Probezzia infuscata Malloch

Bull. Ill. State Lab. Nat. Hist., Vol. XI, Art. IV, December, 1915, p. 316.

Lectotype.—♀: White Heath, Illinois, along bank of Sangamon River, May 16, 1915 (J. R. Malloch).

Lectoallotype.—♂: White Heath, Illinois, along bank of Sangamon River, May 16, 1915 (J. R. Malloch).

Paratypes.—♂ and ♀: White Heath, Illinois, along bank of Sangamon River, May 9, 16 and 30, 1915 (J. R. Malloch).

Probezzia obscura Malloch

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 355.

Type.—♀: Ithaca, New York, July 15, 1901 (O. A. Johannsen).

In fair condition.

Probezzia pallida Malloch

Proc. Biol. Soc. Wash., Vol. 27, July 10, 1914, p. 138.

Type.—♀: Muncie, Illinois, along Stony Creek, May 24, 1914 (C. A. Hart and J. R. Malloch).

Allotypes.—♂: White Heath, Illinois, on bank of Sangamon River, May 16, 1915 (J. R. Malloch).

Paratypes.—♂ and ♀: Monticello, Illinois, along Sangamon River, June 21, 1914 (J. R. Malloch); White Heath, Illinois, on bank of Sangomon River, May 16, 1915 (J. R. Malloch).

Description of males first given by Malloch in Bull. Ill. State. Lab. Nat. Hist., Vol. XI, Art. IV, December, 1915, p. 318.

Protenthes claripennis Malloch

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 387.

Lectotype.—♂: South Haven, Michigan, lake shore, July 14, 1914 (C. A. Hart). Slide No. 2458.

Lectoallotype.—♀: South Haven, Michigan, lake shore, July 14, 1914 (C. A. Hart).

Paratypes.—♂ and ♀: South Haven, Michigan, lake shore, July 14, 1914 (C. A. Hart).

Genitalia of lectotype mounted in balsam on a slide.

Protenthes riparius Malloch

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 389.

Type.—♂: Havana, Illinois, Thompson's Lake, May 1, 1912. Slide No. 2484.

Allotype.—♀: Havana, Illinois, April 20, 1898 (C. A. Hart). Acc. No. 24349.

Paratypes.—♂ and ♀: Havana, Illinois, April 19, 1898 (C. A. Hart); Havana, Illinois, on house-boat, April 30, 1912. Acc. No. 24347.

Genitalia of type mounted in balsam on a slide.

Pseudochironomus richardsoni Malloch

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 500.

Lectotype.—♀: Havana, Illinois, Chautauqua Park, April 29, 1914 (C. A. Hart and J. R. Malloch).

Lectoallotype.—♀: Havana, Illinois, Chautauqua Park, April 29-May 30, 1914 (C. A. Hart and J. R. Malloch).

Paratypes.—♂ and ♀: Havana, Illinois, Chautauqua Park and Thompson's Lake, April 29-May 30, 1914 (C. A. Hart and J. R. Malloch); Mo. mence, Illinois, at light, July 17, 1914 (C. A. Hart). Slide Nos. 3048, 3049, 3051 and 3052.

The genotype of *Pseudochironomus* Malloch (original designation). Genitalia of two male paratypes, heads of three female paratypes and pupal exuviae of type specimens mounted in balsam on eight slides.

Pseudoculicoides johannseni Malloch

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 311.

Lectotype.—♂: Palo Alto, California. Slide No. 2935.

Paratypes.—♂: Palo Alto, California. Slide No. 2936.

Genitalia of lectotype and one paratype mounted in balsam on two slides.

Pseudoculicoides major Malloch

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 311.

Type.—♂: Urbana, Illinois, at light, July 2, 1914 (J. R. Malloch). Slide No. 2932.

Allotype.—♀: Ithaca, New York (O. A. Johannsen).

Genitalia of male type mounted in balsam on a slide.

Serromyia crassifemorata Malloch

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. IV, June, 1914, p. 218.

Lectotype.—♀: Mt. Carmel, Illinois, May 28, 1884 (H. Garman). Acc. No. 1789.

Paratype.—♀: Mt. Carmel, Illinois, May 28, 1884 (H. Garman). Acc. No. 1789.

Tanypus cornuticaudatus Walley

Can. Ent., Vol. LVII, No. 11, November, 1925, p. 277.

Paratypes.—♂ and ♀: Ottawa, Canada, July 26, 31, 1924 (C. H. Curran).

Tanypus decoloratus Malloch

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 370.

Lectotype.—♂: Havana, Illinois, Thompson's Lake, May 1, 1914 (J. R. Malloch). Acc. No. 45796.

Lectoallotype.—♀: Havana, Illinois, at light, September 12, 1895 (C. A. Hart). Acc. No. 13570.

Paratype.—♂: Muncie, Illinois, bank of Stony Creek, May 24, 1914 (J. R. Malloch).

Larval and pupal exuviae of lectotypic male mounted in balsam on Slide No. 2443.

Tanypus hirtipennis Loew

Berl. Ent. Zeitschr., 1866, p. 5. ♀

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 367. ♂ and ♀

Allotypes.—♂: Urbana, Illinois, May 20, 1906; Dubois, Illinois, in creek valley, April 24, 1914 (C. A. Hart and J. R. Malloch); Golconda, Illinois, April 18, 1914 (C. A. Hart and J. R. Malloch); Grand Tower, Illinois, along ditch, April 22, 1914 (C. A. Hart and J. R. Malloch). Slide Nos. 2455, 2463 and 2464.

The description of the male is by J. R. Malloch. Genitalia of three allotypes mounted in balsam on three slides.

Tanypus illinoensis Malloch

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 376.

Lectotype.—♂: Havana, Illinois, May 1, 1895 (C. A. Hart). Acc. No. 13819.

Lectoallotype.—♀: Havana, Illinois, September 27, 1895 (C. A. Hart). Acc. No. 13721.

Paratypes.—♂ and ♀: Havana, Illinois, May 1-September 27, 1895-1896 (C. A. Hart and E. B. Forbes); Lake Delavan, Wisconsin, September 5-7, 1892 (C. A. Hart); Carbondale, Illinois, April 27, 1908; Algonquin, Illinois, May 13, 1896 (W. A. Nason); Havana, Illinois, September 10, 1910. Acc. Nos. 11589, 13519, 13552, 13705, 13721, 13818, 13819, 13837, 13849, 13856, 13964, 13972, 18799, 18810, 18811, 22080, 22083, 24016, 24022 and 45782. Slide Nos. 2466 and 2468.

Apical abdominal segments and genitalia of two male paratypes mounted in balsam on two slides.

Tanypus inconspicuus Malloch

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 371.

Lectotype.—♂: Easton, Illinois, Central Ditch, May 1, 1914.

Lectoallotype.—♀: Easton, Illinois, Central Ditch, May 1, 1914.

Paratypes.—♂ and ♀: Easton, Illinois, Central Ditch, May 1, 1914. Slide No. 2469.

In good to fair condition. Apical abdominal segments and genitalia of one paratypic male mounted in balsam on a slide number 2469.

Tanypus mallochi Walley

Can. Ent., Vol. LVII, No. 11, November, 1925, p. 273.

Paratypes.—♂ and ♀: Ottawa, Canada, July 4, 1923 (C. H. Curran); Aylmer, Quebec, Canada, September 7, 1924 (C. H. Curran).

Tanypus marginellus Malloch

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 374.

Lectotype.—♂: Dubois, Illinois, in creek valley, April 24, 1914 (C. A. Hart and J. R. Malloch). Slide No. 2459.

Paratype.—♂: Dubois, Illinois, in creek valley, April 24, 1914 (C. A. Hart and J. R. Malloch).

Abdomen and genitalia of lectotype mounted in balsam on a slide.

Tanytarsus confusus Malloch

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 490.

Lectotype.—♂: Urbana, Illinois, Fair Grounds, May 20, 1914 (C. A. Hart and J. R. Malloch).

Lectoallotype.—♀: Urbana, Illinois, Fair Grounds, May 20, 1914 (C. A. Hart and J. R. Malloch).

Paratypes.—♂ and ♀: Urbana, Illinois, at light, October 2, 3, 1914 (C. A. Hart and J. R. Malloch); Havana, Illinois, along river, April 28, 1914 (C. A. Hart and J. R. Malloch); Muncie, Illinois, along Stony Creek, May 24, 1914 (C. A. Hart and J. R. Malloch); Momence, Illinois, at light, July 17, 1914 (C. A. Hart and J. R. Malloch). Slide No. 3069.

Genitalia of paratypic male mounted in balsam on a slide.

Tanytarsus dubius Malloch

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 496.

Lectotype.—♂: Havana, Illinois, Chautauqua Park, April 29, 1914 (C. A. Hart and J. R. Malloch).

Lectoallotype.—♀: Havana, Illinois, Chautauqua Park, April 29, 1914 (C. A. Hart and J. R. Malloch).

Paratypes.—♂ and ♀: Havana, Illinois, along Illinois River and at Chautauqua Park, April 28-29, 1914 (C. A. Hart and J. R. Malloch). Slide No. 3063.

Genitalia of one paratypic male mounted in balsam on a slide.

Tanytarsus flavicauda Malloch

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 493.

Lectotype.—♂: Carbondale, Illinois, along creek valley, April 23, 1914 (C. A. Hart and J. R. Malloch). Slide No. 3078.

Lectoallotype.—♀: Carbondale, Illinois, along creek valley, April 23, 1914 (C. A. Hart and J. R. Malloch).

Paratypes.—♂ and ♀: Carbondale, Illinois, along creek valley, April 23, 1914 (C. A. Hart and J. R. Malloch); Havana, Illinois, along river, April 28, 1914 (C. A. Hart and J. R. Malloch).

Paratypic females collected April 28 and not April 29 as stated in original description. Genitalia and portion of abdomen of lectotype mounted in balsam on a slide.

Tanytarsus muticus Johannsen

N. Y. State Museum, Bull. 86, June, 1905, p. 294. ♂

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 494. ♀

Allotype.—♀: Urbana, Illinois, at light, October 6, 1914 (C. A. Hart and J. R. Malloch).

Description of the female is by J. R. Malloch.

Tanytarsus neoflavellus Malloch

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 489.

Lectotype.—♂: Dubois, Illinois, April 25, 1914 (J. R. Malloch).

Paratypes.—♂: Dubois, Illinois, along creek valley and at light, April 24, 1914 (J. R. Malloch).

Female also described in original description but no specimens of this sex were found in collection.

Tanytarsus politus Malloch

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 493.

Lectotype.—♂: Easton, Illinois, along Central Dredge Ditch, May 1, 1914 (C. A. Hart and J. R. Malloch). Slide No. 3089.

Paratypes.—♂: Easton, Illinois, along Central Dredge Ditch, May 1, 1914 (C. A. Hart and J. R. Malloch).

Genitalia of lectotypic male mounted in balsam on a slide.

Tanytarsus similatus Malloch

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 494.

Lectotype.—♂: Madison Wisconsin, May 1, 1910 (J. G. Sanders). Slide No. 3084.

Allotype.—♀: Madison, Wisconsin, May 1, 1910 (J. G. Sanders).

Paratype.—♂: Madison, Wisconsin, May 1, 1910 (J. G. Sanders).

Genitalia of lectotype mounted in balsam on a slide. In fair condition.

Tanytarsus viridiventris Malloch

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, May, 1915, p. 491.

Lectotype.—♂: South Haven, Michigan, shore of Lake Michigan, July 14, 1914 (C. A. Hart).

Paratypes.—♂: South Haven, Michigan, shore of Lake Michigan, July 14, 1914 (C. A. Hart). Slide No. 3083.

Genitalia of one paratype mounted in balsam on a slide.

Family MYCETOPHILIDAE

Boletina punctus Garrett

Sixty-one New Diptera (Privately published), Cranbrook, British Columbia, February 7, 1925, p. 5.

Paratypes.—♂ and ♀: Creston, British Columbia, July 4 (C. Garrett).

Bolitophila subteresa Garrett

Sixty-one New Diptera (Privately published), Cranbrook, British Columbia, February 7, 1925, p. 7.

Paratype.—♀: Michel, British Columbia, Wilson Creek, September 9 (C. Garrett).

Macrocera distincta Garrett

Sixty-one New Diptera (Privately published), Cranbrook, British Columbia, February 7, 1925, p. 8.

Paratypes.—♂: Cranbrook, British Columbia, July 10 and 14 (C. Garrett).

Macrocera variola Garrett

Sixty-one New Diptera (Privately published), Cranbrook, British Columbia, February 7, 1925, p. 7.

Paratypes.—♂ and ♀: Cranbrook, British Columbia, September 9 (C. Garrett); Marysville, British Columbia, July 1 (C. Garrett).

Mycomya magna Garrett

Ins. Insc. Mens., Vol. XII, Nos. 4-6, April-June, 1924, p. 64.

Paratype.—♂: Fernie, British Columbia, July 24 (C. Garrett).

Mycomya vulgaris Garrett

Ins. Insc. Mens., Vol. XII, Nos. 4-6, April-June, 1924, p. 63.

Paratypes.—♂ and ♀: Fernie, British Columbia, July 23-24 (C. Garrett).

Sceptonia johannsoni Garrett

Seventy New Diptera (Privately published), Cranbrook, British Columbia, December 31, 1925, p. 15.

Paratypes.—♂ and ♀: Marysville, British Columbia, August 1 (C. Garrett).

Sciophila parvus Garrett

Sixty-one New Diptera (Privately published), Cranbrook, British Columbia, February 7, 1925, p. 10.

Paratype.—♀: Cranbrook, British Columbia, June 2, 1920 (C. Garrett).

Zygoneura fenestrata Malloch

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, June, 1914, p. 233.

Lectotype.—♂: Urbana, Illinois, on window, November 7, 1913 (C. A. Hart and J. R. Malloch).

Lectoallotype.—♀: Urbana, Illinois, on window, November 7, 1913 (C. A. Hart and J. R. Malloch). Slide No. 1841.

Paratypes.—♂ and ♀: Urbana, Illinois, on window, November 7, 13, 14, 1913 (C. A. Hart and J. R. Malloch). Slide No. 1848.

Lectoallotype and one male paratype mounted in balsam on two slides.

Zygomyia interrupta Malloch

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, June, 1914, p. 234.

Type.—♂: Urbana, Illinois, on window, November 13 1913 (J. R. Malloch).

Family ITONIDIDAE

Lasioptera muhlenbergiae Marten

Ohio Agr. Exp. Station, Tech. Ser., Vol. 1, No. 3, Art. IX, April, 1893, p. 155.

Cotypes.—♂ and ♀: Urbana, Illinois reared from fusiforn stem gall May 9-June 2, 1892 (J. Marten).

Also pupae and pupal exuviae of cotypes. Now considered as synonymous with *Asteromyia agrostis* Osten Sacken. Numerous male and especially female cotypes preserved in alcohol. In poor condition. Acc. Nos. 17979, 17980, 17981, 17999, 18011, 18041, 18122.

Family BIBIONIDAE

Forbesomyia atra Malloch

Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. VI, June, 1914, p. 235.

Type.—♀: Urbana, Illinois, on window, November 7, 1913 (C. A. Hart and J. R. Malloch).

In fair condition. The genotype of *Forbesomyia* Malloch (original designation and monobasic.)

Family SCATOPSIDAE

Aspistes harti D Malloch

Ent. News, Vol. XXXI, No. 10, December, 1920, p. 275.

Type.—♂: Havana, Illinois, Quiver Lake, May 5, 1896 (C. A. Hart). Acc. No. 13819.

Allotype.—♀: Havana, Illinois, Quiver Lake, May 5, 1896 (C. A. Hart). Acc. No. 13819.

Paratypes.—♂ and ♀: Havana, Illinois, Quiver Lake, May 20, 1894 (C. A. Hart); Meredosia, Illinois, May 28, 1917 (J. R. Malloch); Havana, Illinois, June 3, 1918 (J. R. Malloch); Oregon, Illinois, June 19, 1917 (J. R. Malloch). Acc. No. 13143.

Mr. Malloch, D when describing this species, wrote that the accession catalogue containing the data concerning some of the type specimens was missing. The fortunate recovery of the accession catalogue containing the Illinois aquatic records has enabled me to publish the data pertaining to the type, allotype and two paratypes.

Family SIMULIIDAE

Prosimulium mutatum Malloch
Bull. U. S. Bur. Ent., Tech. Ser. No. 26, 1914, p. 20.
Paratypes.—♀: Jamesburg, New Jersey, April 30, 1911; Homer, Illinois, April 25, 1909.

Simulium arcticum Malloch
Bull. U. S. Bur. Ent., Tech. Ser. No. 26, 1914, p. 37.
Paratypes.—♂: Kaslo, British Columbia, June 13 and July 4 (H. G. Dyar and R. P. Currie).

Simulium forbesi Malloch
Bull. U. S. Bur. Ent., Tech. Ser. No. 26, April 6, 1914, p. 63.
Type.—♀: Havana, Illinois, White Oak Run, June 7, 1912 (A. W. J. Pomeroy). Acc. No. 45753.
Paratypes.—♀: Havana, Illinois, Chautauqua Park, June 1, 1912 (A. W. J. Pomeroy); Havana, Illinois, White Oak Run, June 7, 1912 (A. W. J. Pomeroy). Acc. No. 45753.
Though the male is stated to be described from many specimens, no males were found in the collection labeled *forbesi* by Malloch.

Simulium johannseni Hart
Twenty-seventh Rep. State Ent. Ill., 1912, p. 32.
Lectotype.—♀: Havana, Illinois, on house boat, shore of Illinois River, April 26, 1912.
Lectoallotype.—♂: Havana, Illinois, on house boat, shore of Illinois River, April 26, 1912.
Paratypes.—♂ and ♀: Havana, Illinois, on house boat, shore of Illinois River, April 26, 1912.

Simulium parnassum Malloch
Bull. U. S. Bur. Ent., Tech. Ser. No. 26, 1914, p. 36.
Paratype.—♀: Skyland, Page County, Virginia, July 15, 1912 (H. G. Dyar).

Simulium venustoides Hart
Twenty-seventh Rep. State Ent. Ill., 1912, p. 42.
Lectotype.—♂: Algonquin, Illinois, July 8, 1896 (W. A. Nason).
Lectoallotype. ♀: Algonquin, Illinois, October 20, 1894 (W. A. Nason).
Paratypes.—♂ and ♀: Algonquin, Illinois, April, May, August, September and October, 1894-1896 (W. A. Nason).
This species is now considered as synonymous with *Simulium piscicidum* Riley.

Family BLEPHAROCERIDAE

Philorus markii Garrett
Seventy New Diptera (Privately published), Cranbrook, British Columbia, December 31, 1925, p. 5.
Paratype.—♂: Fort Steele, British Columbia, July 21 (C. Garrett).

Family STRATIOMYIIDAE

Eupachygaster henshawi Malloch
Bull. Ill. State Lab. Nat. Hist., Vol. XII, Art. III, March, 1917, p. 338.
Type.—♀: Savoy, Illinois, May 4, 1914 (J. R. Malloch). Acc. No. 46357.
Reared June 17, 1914, from larva found under bark of apple tree.

Eupachygaster punctifer Malloch
Ann. Ent. Soc. Amer., Vol. VIII, No. 4, December, 1915, p. 316.
Type.—♀: Algonquin, Illinois (W. A. Nason).

Johnsonomyia aldrichi Malloch
Ann. Ent. Soc. Amer., Vol. VIII, No. 4, December, 1915, p. 313.
Allotype.—♀: Victoria, Texas, April 9, 1914 (Bishopp No. 3266).
In fair condition. The genotype of *Johnsonomyia* Malloch (original designation and monobasic).

Nemotelus bellulus Melander
Psyche, Vol. X, October-December, 1903, p. 183.
Cotype.—♀: Galveston, Texas, June, 1900 (A. L. Melander).

Nemotelus bonnarius Johnson
Psyche. Vol. XIX, No. 1, February, 1912, p. 4.
Paratypes.—♂ and ♀: Farewell Creek, South Saskatchewan, Canada, August, 1907 (Mrs. V. A. Armstrong).

Nemotelus bruesii Melander
Psyche, Vol. X, October-December, 1903, p. 179.
Cotypes.—♂ and ♀: Austin, Texas, April 8 and 12, 1900 (A. L. Melander and C. T. Brues).

Nemotelus trinotatus Melander
Psyche, Vol. X, October-December, 1903, p. 180.
Cotypes.—♂ and ♀: Austin, Texas, May 11, 1900 (A. L. Melander and C. T. Brues).

Nemotelus wheeler Melander
Psyche, Vol. X, October-December, 1903, p. 182.
Cotype.—♀: Galveston, Texas, June, 1900 (A. L. Melander and W. M. Wheeler).

Odontomyia snowi Hart
Bull. Ill. State Lab. Nat. Hist., Vol. IV, Art. VI, December, 1896, p. 256.
Type.—♂: Champaign, Illinois, along railroad tracks, July 2, 1890 (C. A. Hart and J. Marten). Acc. No. 15784.

Oxycera albovittata Malloch
Bull. Ill. State Lab. Nat. Hist., Vol. XII, Art. III, March, 1917, p. 330.
Type.—♀: Muncie, Illinois, along Stony Creek, July 5, 1914 (J. R. Malloch).

Oxycera aldrichi Malloch
Bull. Ill. State Lab. Nat. Hist., Vol. XII, Art. III, March, 1917, p. 329.
Type.—♂: Lafayette, Indiana, June 23 (J. M. Aldrich).

Oxycera approximata Malloch
Bull. Ill. State Lab. Nat. Hist., Vol. XII, Art. III, March, 1917, p. 326.
Type.—♀: Muncie, Illinois, along Stony Creek, July 5, 1914 (J. R. Malloch).

Xylomyia pallidifemur Malloch
Bull. Ill. State Lab. Nat. Hist., Vol. XII, Art. III, March, 1917, p. 343.
Lectotype.—♂: Urbana, Illinois, in woods, June 17, 1890 (C. A. Hart). Acc. No. 15751.
Lectoallotype.—♀: Urbana, Illinois, in woods, June 1, 1890 (C. A. Hart). Acc. No. 15700.
Paratype.—♀: Urbana, Illinois, in woods, June 2, 1890 (C. A. Hart). Acc. No. 15702.

Family ASILIDAE

Laphria sicula McAtee
Ohio Journ. Sc., Vol. XIX, No. 2, December, 1918, p. 165.
Paratype.—♂: Monticello, Illinois, along Sangamon River, June 30, 1914.

Family DOLICHOPODIDAE

Chrysotus anomalus Malloch
Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. IV, June, 1914, p. 238.
Type.—♂: New Orleans, Louisiana, April 23, 1885 (S. A. Forbes). Acc. No. 5513.

Chrysotus ciliatus Malloch
Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. IV, June, 1914, p. 236.
Type.—♂: Champaign, Illinois, along side of railroad tracks, June 22, 1888 (C. A. Hart and J. Marten). Acc. No. 14504.

Chrysotus flavisetus Malloch
Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. IV, June, 1914, p. 239.
Lectotype.—♂: Champaign, Illinois, along side of railroad tracks, June 22, 1888 (C. A. Hart and J. Marten). Acc. No. 14504.
Lectoallotype.—♀: Champaign, Illinois, along side of railroad tracks, June 22, 1888 (C. A. Hart and J. Marten). Acc. No. 14504.
Paratypes.—♀: Champaign, Illinois, along side of railroad tracks, June 22, 1888 (C. A. Hart and J. Marten). Acc. No. 14504.

Chrysotus spinifer Malloch
Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. IV, June, 1914, p. 238.
Type.—♂: Algonquin, Illinois (W. A. Nason).

Hydrophorus pilitarsis Malloch
Rep. Can. Arctic Exp., 1913-18, Vol. III, Part C, July 14, 1919, p. 51c.
Cotypes.—♂ and ♀: Teller, Alaska, August 6, 1913, and July 29, 1913 (F. Johansen).
In fair condition.

Hygroceleuthus idahoensis Aldrich
Kansas Univ. Quart., Vol. 2, No. 3, January, 1894, p. 154.
Cotype.—♂: Moscow, Idaho.
Now placed in the genus *Dolichopus* Latreille.

Medeterus caerulescens Malloch
Ent. News, Vol. XXX, No. 1, January, 1919, p. 8.
Type.—♂: White Heath, Illinois, reared April 26, 1918, from larva found under bark on April 18 (J. R. Malloch).
Allotype.—♀: White Heath, Illinois, reared April 26, 1918 from larva found under bark on April 18 (J. R. Malloch).

Family EMPIDIDAE

Tachydromia harti Malloch
Can. Ent., Vol. LI, No. 11, November, 1919, p. 248.
Type.—♂: Havana, Illinois, June 5, 1918 (J. R. Malloch).
Allotype.—♀: Havana, Illinois, June 5, 1918 (J. R. Malloch).
Paratypes.—♀: Havana, Illinois, June 5, 1918 (J. R. Malloch).

Rhamphomyia conservativa Malloch
Rep. Can. Arctic Exp., 1913-1918, Vol. III, Part C, July 14, 1919, p. 48c.
Paratypes.—♂ and ♀: Bernard Harbour, Northwest Territories, Canada, July 18-19, 1915 (F. Johansen); Young Point, Northwest Territories Canada, July 18, 1916 (F. Johansen).
In poor condition.

Family PHORIDAE

Aphiochaeta aristalis Malloch
Bull. Brook. Ent. Soc., Vol. IX, No. 3, June, 1914, p. 57.
Type.—♂: Havana, Illinois, September 20, 1895 (A. Hempel). Acc. No. 13709.

Aphiochaeta bisetulata Malloch
Bull. Brook. Ent. Soc., Vol. X, No. 3, July, 1915, p. 65.
Type.—♀: Urbana, Illinois, June 14, 1914 (E. H. Swigert).

Aphiochaeta nasoni Malloch
Bull. Brook. Ent. Soc., Vol. IX, No. 3, June, 1914, p. 58.
Type.—♂: Algonquin, Illinois, November 16, 1896 (W. A. Nason).

Aphiochaeta pallidiventris Malloch
Bull. Brook. Ent. Soc., Vol. XIV, No. 2, April, 1919, p. 47.
Type.—♀: Cobden, Illinois, May 9, 1918 (J. R. Malloch).

Aphiochaeta plebeia Malloch
Bull. Brook. Ent. Soc., Vol. IX, No. 3, June, 1914, p. 59.
Type.—♂: Urbana, Illinois, reared from decaying vegetation, July 18, 1885. Acc. No. 6889.
Lectoallotype.—♀: Urbana, Illinois, reared from decaying vegetation, July 18, 1885. Acc. No. 6889.
Paratype.—♀: Urbana, Illinois, reared from decaying vegetation, July 18, 1885. Acc. No. 6889.

Aphiochaeta quadripunctata Malloch
Ent. News., Vol. XXIX, No. 4, April, 1918, p. 147.
Type.—♂: Elizabeth, Illinois, July 8, 1917.

Apocephalus pictus Malloch
Ent. News., Vol. XXIX, No. 4, April, 1918, p. 146.
Type.—♂: Havana, Illinois, August 30, 1917.

Beckerina luteola Malloch
Can. Ent., Vol. LI, November, 1919, No. 11, p. 256.
Type.—♀: Cobden, Illinois, May 9, 1918 (J. R. Malloch).

Hypocera vectabilis Brues
Ann. Hist. Nat. Mus. Hung., Vol. 11, 1913, p. 336.
Paratypes.—♂ and ♀: Abyssinia.
Male in good condition, but head of female is missing.

Phora egregia Brues
Ann. Hist. Nat. Mus. Hung., Vol. 9, 1911, p. 534.
Paratype.—♀: Fuhosho, Formosa, July (Sauter).

Platyphora flavofemorata Malloch
Bull. Ill. State Lab. Nat. Hist., Vol. XI, Art. IV, December, 1915, p. 353.
Type.—♂: White Heath, Illinois, taken *in copula* on sandy bank, August 22, 1915 (J. R. Malloch).
Allotype.—♀: White Heath, Illinois, taken *in copula* on sandy bank, August 22, 1915 (J. R. Malloch).
Type and allotype mounted on the same card point mount.

Family SYRPHIDAE

Cnemedon trochanteratus Malloch
Proc. Ent. Soc. Wash., Vol. 20, No. 5, May, 1918, p. 127.
Type.—♂: St. Joseph, Illinois, along Salt Fork, May 3, 1914.

Melanostoma pallitarsis Curran
Can. Ent., Vol. LIII, No. 4, April, 1926, p. 83.
Paratypes.—♂ and ♀: Freeport, Illinois, July 4, 1917; Cedar Lake, Lake County, Illinois, August 4, 1906; Mahomet, Illinois, April 23, 1925 (T. H. Frison).

Family CLUSIIDAE

Clusia occidentalis Malloch
Proc. Ent. Soc. Wash., Vol. 20, No. 5, January, 1918, p. 4.
Type.—♂: Washington State (T. Kincaid).
In fair condition.

Family SCATOPHAGIDAE

Amaurosoma katmaiensis Malloch
Ohio Journ. Sc., Vol. XX, No. 7, May, 1920, p. 284.
Paratype.—♀: Katmai, Alaska, June, 1917 (J. H. Hine)

Amaurosoma nuda Malloch
Bull. Brook. Ent. Soc., Vol. XVII, No. 3, June, 1922, p. 78.
Paratype.—♀: Cape Charles, Labrador, July 30, 1906.

Amaurosoma unispinosa Malloch
Ohio Journ. Sc., Vol. XX, No. 7, May, 1920, p. 285.
Paratype.—♀: Katmai, Alaska, July, 1917 (J. H. Hine).

Gimnomera atrifrons Malloch
Proc. Ent. Soc. Wash., Vol. 22, No. 1, January, 1920, p. 37.
Type.—♂: St. Anthony Park, Minnesota (O. Lugger).

Gimnomera fasciventris Malloch
Proc. Ent. Soc. Wash., Vol. 22, No. 1, January, 1920, p. 38.
Type.—♂: Meredosia, Illinois, in sand-pit, May 29, 1917 (J. R. Malloch).
Allotype.—♀: Meredosia, Illinois, in sand-pit, May 29, 1917 (J. R. Malloch).
Paratype.—♀: Meredosia, Illinois, in sand-pit, May 29, 1917 (J. R. Malloch).

Gimnomera incisurata Malloch
Proc. Ent. Soc. Wash., Vol. 22, No. 1, January, 1920, p. 37.
Type.—♂: Dubois, Illinois, May 10, 1918 (J. R. Malloch).
Allotype.—♀: Dubois, Illinois, May 10, 1918 (J. R. Malloch).
Paratypes.—♂ and ♀: Dubois, Illinois, May 10, 1918, and May 25, 1917 (J. R. Malloch).

Orthochaeta dissimilis Malloch
Psyche, Vol. XXXI, No. 5, October, 1924, p. 194.
Type.—♀: Algonquin, Illinois, June 3, 1898 (W. A. Nason).
Paratype.—♀: Urbana, Illinois, May 7, 1907.

Pseudopogonota aldrichi var. pallida Malloch
Proc. Ent. Soc. Wash., Vol. 22, No. 1, January, 1920, p. 36.
Paratypes.—♂: Craigs Mountain, Idaho (J. M. Aldrich); Marshall Pass, Colorado, July 28, 1908, elevation 10856 feet (J. M. Aldrich).

Scatophaga grisea Malloch
Proc. Ent. Soc. Wash., Vol. 22, No. 1, January, 1920, p. 34.
Type.—♂: Logan, Utah, May 20, 1914 (H. R. Hagan).
Allotype.—♀: Wells, Nevada, July 12, 1911.

Family HELOMYZIDAE

Acantholeria oediemus Garrett
Ins. Insc. Mens., Vol. IX, Nos. 7-9, July-September, 1921, p. 131.
Paratypes.—♂ and ♀: Cranbrook, British Columbia, June 6-7, July 21, August 14, October 18 (C. Garrett).

Amoebaleria fraterna var. hyalina Garrett
Sixty-one New Diptera (Privately published), Cranbrook, British Columbia, February 7, 1925, p. 4.
Paratype.—♀: Michel, British Columbia, August 1 (C. Garrett).

Amoebaleria gigas Garrett
Ins. Insc. Menstruus., Vol. IX, Nos. 7-9, July-September, 1921, p. 126.
Paratype.—♂: Cranbrook, British Columbia, May 2, 1919 (C. Garrett).
Now considered as *Amoebaleria tincta* form *pilosus* Coquillett.

Amoebaleria (Eidoamoeba) luteoala Garrett
Seventy New Diptera (Privately published), Cranbrook, British Columbia, December 31, 1925, p. 3.
Paratype.—♀: Algonquin, Illinois, November 3, 1909 (W. A. Nason).
The genotype of the subgenus *Eidoamoeba* Garrett (original designation).

Anarostomoides petersoni Malloch
Bull. Brook. Ent. Soc., Vol. XI, No. 1, February, 1916, p. 15.
Type.—♂: Urbana, Illinois, University Forestry, November 13, 1915 (A. Peterson).

Allotype.—♀: Urbana, Illinois, University Forestry, November 11, 1915 (A. Peterson).

The genotype of *Anarostomoides* Malloch (original designation and monobasic). Now placed in the genus *Crymobia* Loew.

Anorostoma coloradensis Garrett

Ins. Insc. Mens., Vol. XII, Nos. 1-3, January-March, 1924, p. 28.

Paratype.—♂: Colorado (1389).

Pseudoleria crassata Garrett

Seventy New Dipteria (Privately published). Cranbrook, British Columbia, December 31, 1925, p. 3.

Paratypes.—♂ and ♀: Havana, Illinois, Gleason's sand dune, April 30, 1914.

Pseudoleria vulgaris Garrett

Seventy New Diptera (Privately published), Cranbrook, British Columbia, December 31, 1925, p. 2.

Paratype.—♀: Cranbrook, British Columbia, May 20, 1921 (C. Garrett).

Suillia loewi Garrett

Sixty-one New Diptera (Privately published), Cranbrook, British Columbia, February 7, 1925, p. 3.

Paratypes.—♂ and ♀: Marysville, British Columbia, July 14 and August 1 (C. Garrett).

Family BORBORIDAE

Borborus scriptus Malloch

Bull. Brook. Ent. Soc., Vol. X, No. 3, July, 1915, p. 64.

Type.—♂: St. Joseph, Illinois, along Salt Fork, May 17, 1914 (J. R. Malloch).

Leptocera (Collinella) fumipennis Spuler

Ann. Ent. Soc. Amer., Vol. XVII, No. 1, March, 1924, p. 110.

Paratypes.—♂ and ♀: Algonquin, Illinois, August 1, October 5 and 27, 1895 (W. A. Nason).

Leptocera (Leptocera) hoplites Spuler

Ann. Ent. Soc. Amer., Vol. XVII, No. 1, March 1924, p. 115.

Paratype.—♂: Washougal, Washington, May 25, 1910 (A. L. Melander).

Leptocera (Scotophilella) abundans Spuler

Journ. N. Y. Ent. Soc., Vol. XXXIII, No. 3, September, 1925, p. 151.

Paratypes.—♀: Moscow Mountain, Idaho, June 17, 1918 (A. L. Melander); Moscow Mountain, Idaho, July 4, 1915 (A. L. Melander); Paradise Park, Mt. Rainier, Washington, August, 1917 (A. L. Melander).

Leptocera (Scotophilella) albifrons Spuler

Journ. N. Y. Ent. Soc., Vol. XXXIII, No. 3, September, 1925, p. 147.

Paratype.—♂: Algonquin, Illinois, April 11, 1896 (W. A. Nason).

Leptocera (Scotophilella) elegans Spuler

Journ. N. Y. Ent. Soc., Vol. XXXIII, No. 3, September, 1925, p. 149.

Paratypes.—♀: Urbana, Illinois, reared from horse manure, August 1, 1908 (J. Zetek); Champaign, Illinois, from garbage, November 6, 1908 (J. G. Sanders). Acc. Nos. 39218 and 40264.

Leptocera (Scotophilella) gracilipennis Spuler

Journ. N. Y. Ent. Soc., Vol. XXXIII, No. 2, June, 1925, p. 78.

Paratype.—♂: Algonquin, Illinois, April 11, 1896 (W. A. Nason).

Leptocera (Scotophilella) longicosta Spuler

Journ. N. Y. Ent. Soc., Vol. XXXIII, No. 3, September, 1925, p. 155.

Paratypes.—♂ and ♀: Algonquin, Illinois, November 4, 1895 and November 11, 1896 (W. A. Nason); Urbana, Illinois, in breeding cage, May 6, 1891 (J. Marten); Urbana, Illinois, reared from horse manure, August 1, 1908 (J. Zetek). Acc. Nos. 16263 and 39211.

In poor to good condition.

Leptocera (Scotophilella) ordinaria Spuler
Journ. N. Y. Ent. Soc., Vol. XXXIII, No. 3, September, 1925, p. 159.
Paratype.—♀: Muir Woods, California, August 7, 1915 (A. L. Melander).

Leptocera (Opacifrons) sciaspidis Spuler
Psyche, Vol. XXXI, Nos. 3 and 4, June-August, 1924, p. 124.
Paratypes.—♂: Mt. Constitution, Washington, July 31 (A. L. Melander).

Leptocera (Opacifrons) wheeleri Spuler
Psyche, Vol. XXXI, Nos. 3 and 4, June-August, 1924, p. 128.
Paratype.—♀: Havana, Illinois, on shore of river, December 13, 1894 (F. Smith and Hottes). Acc. No. 13135.

Leptocera (Thorocochaeta) johnsoni Spuler
Can. Ent., Vol. LVII, No. 5, May, 1925, p. 121.
Paratype.—♀: Seattle, Washington (A. L. Melander).

Family SAPROMYZIDAE

Melanomyza intermedia Malloch
Proc. Ent. Soc. Wash., Vol. 25, No. 2, February, 1925, p. 50.
Paratypes.—♂ and ♀: White Heath, Illinois, June 25-26, 1914; Summer, Illinois, August 2, 1914; Urbana, Illinois, University Woods (Cottonwood Grove), July 27, 1917; White Heath, Illinois, July 11, 1915; Odin, Illinois, in meadow, May 28, 1910.

Minettia americana Malloch
Proc. Ent. Soc. Wash., Vol. 25, No. 2, February, 1925, p. 53.
Paratype.—♂: White Heath, Illinois, May 18, 1889 (J. D. Marten). Acc. No. 14988.

Phorticoides flinti Malloch
Bull. Brook. Ent. Soc., Vol. X, No. 4, October, 1915, p. 87.
Lectotype.—♂: Urbana, Illinois, on sap from a wound on elm tree, August 30, 1915 (J. R. Malloch and W. P. Flint).
Paratype.—♂: Urbana, Illinois, on sap from a wound on elm tree, September 1, 1915 (J. R. Malloch and W. P. Flint).
The genotype of *Phorticoides* Malloch (original designation and monobasic).

Sapromyza aequalis Malloch
Proc. Biol. Soc. Wash., Vol. 27, March 20, 1914, p. 36.
Type.—♂: Algonquin, Illinois, August 8, 1895 (W. A. Nason).
Paratype?—♂: Urbana, Illinois, June 28, 1889 (C. A. Hart). Hart Acc. No. 514.

Sapromyza blaisdelli Cresson
Ent. News., Vol. XXI, No. 3, March, 1920, p. 66.
Paratype.—♀: San Francisco, California, May 27, 1908 (F. E. Blaisdell).

Sapromyza cilifera Malloch
Proc. Biol. Soc. Wash., Vol. 27, March 20, 1914, p. 33.
Type.—♂: Urbana, Illinois, swept from box-elder, May 24, 1888 (C. A. Hart). Acc. No. 14376.

Sapromyza (Sapromyzosoma) citreifrons Malloch
Can. Ent., Vol. LII, No. 6, June, 1920, p. 127.
Type.—♂: Savanna, Illinois, June 13, 1917 (J. R. Malloch).
Paratypes.—♂: Cobden, Illinois, May 9, 1918 (J. R. Malloch).

Sapromyza fratercula Malloch
Can. Ent., Vol. LII, No. 6, June, 1920, p. 128.
Paratype.—♂: Powderville, Montana, June 15, 1916 (M. Hanna).

Sapromyza fuscibasis Malloch
Can. Ent., Vol. LII, No. 6, June, 1920, p. 126.
Type.—♂: White Heath, Illinois, July 11, 1915 (J. R. Malloch).
Allotype.—♀: Summer, Illinois, August 2, 1914 (C. A. Hart).

Paratypes.—♂ and ♀: White Heath, Illinois, July 11, 1915 (J. R. Malloch); Summer, Illinois, August 2, 1914 (C. A. Hart); Dubois, Illinois, August 8, 1917 (J. R. Malloch); Urbana, Illinois, September 15, 1891 (J. Marten); St. Joseph, Illinois, June 27, 1915 (J. R. Malloch). Acc. No. 17499.

Sapromyza harti Malloch
Proc. Biol. Soc. Wash., Vol. 27, March 20, 1914, p. 32.
Lectotype.—♂: Quincy, Illinois, swept from sand bar, August 12, 1889 (C. A. Hart). Hart Acc. No. 553.
Lectoallotype.—♀: Quincy, Illinois, swept from sand bar, August 12, 1889 (C. A. Hart). Hart Acc. No. 553.
Paratypes.—♂ and ♀: Quincy, Illinois, swept from sand bar, August 12, 1889 (C. A. Hart); Quincy, Illinois, August 8, 1889 (not August 14 as stated in original description) (C. A. Hart). Hart Acc. No. 544 and 553.

Sapromyza inaequalis Malloch
Proc. Biol. Soc. Wash., Vol. 27, March 20, 1914, p. 35.
Type.—♂: Urbana, Illinois, May 9, 1911 (C. A. Hart). Acc. No. 16287.
Allotype.—♀: Urbana, Illinois, May 28, (not May 27 as given in original description), 1911 (C. A. Hart). Acc. No. 15693.

Sapromyza incerta Malloch
Proc. Biol. Soc. Wash., Vol. 27, March 20, 1914, p. 36.
Paratype.—♀: Aldridge, Illinois, August 11, 1891 (C. A. Hart and Shiga). Acc. No. 17212.

Sapromyza littoralis Malloch
Proc. Biol. Soc. Wash., Vol. 27, March 12, 1915, p. 47.
Lectotype.—♂: South Haven, Michigan, sweeping along lake shore, July 14, 1914 (C. A. Hart).
Lectoallotype.—♀: South Haven, Michigan, sweeping along lake shore, July 14, 1914 (C. A. Hart).
Paratypes.—♂ and ♀: South Haven, Michigan, sweeping along lake shore, July 14, 1914 (C. A. Hart).

Sapromyza nubilifera Malloch
Can. Ent., Vol. LII, No. 6, June, 1920, p. 126.
Type.—♂: Monticello, Illinois, along Sangamon River, June 21, 1914 (C. A. Hart and J. R. Malloch).
Allotype.—♀: Monticello, Illinois, along Sangamon River, June 28, 1914 (C. A. Hart and J. R. Malloch).
Paratypes.—♂ and ♀: Monticello, Illinois, along Sangamon River, June 21, 1914; Mahomet, Illinois, along Sangamon River, August 6, 1914; Urbana, Illinois, forestry, June 17 and 23, 1916; Urbana, Illinois, June 20, 1915 (C. A. Hart and J. R. Malloch).

Sapromyza pernotata Malloch
Can. Ent., Vol. LII, No. 6, June, 1920, p. 128.
Type.—♂: Cedar Lake (Lake County), Illinois, in tamarack bog, August 4, 1906.
Paratype.—♂: Cedar Lake (Lake County), Illinois, in tamarack bog, August 4, 1906.

Sapromyza seticauda Malloch
Proc. Biol. Soc. Wash., Vol. 27, March 20, 1914, p. 34.
Type.—♂: Havana, Illinois, July 14, 1910.

Sapromyza similata Malloch
Proc. Biol. Soc. Wash., Vol. 27, March 20, 1914, p. 30.
Type.—♀: St. Joseph, Illinois, sweepings, June 9, 1912.
Lectoallotype.—♂: Michigan.

Paratypes.—♂ and ♀: Algonquin, Illinois, June, July, September, 1895-1897. (W. A. Nason); Merchantville, New Jersey; Quincy, Illinois, swept from sand bar, August 12, 1889 (C. A. Hart); Urbana, Illinois, Pond Grove, June 13, 1889 (C. A. Hart); Normal, Illinois, swept from weeds, June 3, 1884. Acc. No. 2089. Hart Acc. Nos. 500 and 553.

Family LONCHAEIDAE

Lonchaea aberrans Malloch
Can. Ent., Vol. LII, No. 6, June, 1920, p. 131.
Type.—♀: Parker, Illinois, April 17, 1914 (C. A. Hart and J. R. Malloch).
Allotype.—♂: Algonquin, Illinois, May 4, 1895 (W. A. Nason).
Paratype.—♂: Southern Illinois (Carlinville). Collected by C. Robertson and previously determined by S. W. Williston as ,'*polita* Say".

Lonchaea nudifemorata Malloch
Proc. Biol. Soc. Wash., Vol. 27, March 20, 1914, p. 38.
Lectoallotype.—♀: Algonquin, Illinois (W. A. Nason).
Paratype.—♀: Algonquin, Illinois (W. A. Nason).

Lonchaea ruficornis Malloch
Can. Ent., Vol. LII, No. 6, June, 1920, p. 129.
Type.—♀: Savanna, Illinois, June 14, 1917 (J. R. Malloch).

Lonchaea striatifrons Malloch
Can. Ent., Vol. LII, No. 11, November, 1920, p. 246.
Paratypes.—♂: Santa Clara County, California (Baker); San Diego County, California (Harkins Collection).

Lonchaea vibrissata Malloch
Proc. Biol. Soc. Wash., Vol. 27, March 20, 1914, p. 37.
Type.—♀: Algonquin, Illinois, October 16, 1894 (W. A. Nason).
Paratype.—♀: Algonquin, Illinois, May 10, 1897 (W. A. Nason).

Lonchaea winnemanae Malloch
Proc. Biol. Soc. Wash., Vol. 27, March 20, 1914, p. 38.
Allotype.—♀: Algonquin, Illinois, May 23, 1895 (W. A. Nason).

Family ORTALIDAE

Stenomyia nasoni Cresson
Ent. News, Vol. XXIV, No. 7, July, 1913, p. 320.
Paratype.—♂: Algonquin, Illinois, June 28, 1908 (W. A. Nason).

Family SEPSIDAE

Sepsis neocynipsea Melander and Spuler
Wash. Agr. Exp. Station, Bull. 143, April, 1917, p. 28.
Paratypes.—♀: Homer, Illinois, March 1, 1909.

Sepsis signifera var. curvitibia Melander and Spuler
Wash. Agr. Exp. Station, Bull. 143, April, 1917, p. 28.
Paratypes.—♂ and ♀: Algonquin, Illinois, May 3, 1894 (W. A. Nason); Mahomet, Illinois, October 25, 1913.

Family CHLOROPIDAE

Anthracophaga distichliae Malloch
Journ. Econ. Ent. Vol. 11, No. 4, August, 1918, p. 386.
Cotype.—♀: Long Beach, California, reared from bract-covered gall on *Distichlis apicata*, July 7, 1916 (E. Bethel).

Botanobia bispina Malloch
Bull. Brook. Ent. Soc., Vol. XIII, No. 5, December, 1918, p. 109.
Type.—♂: Urbana, Illinois, *in copula*, September 20, 1916 (J. R. Malloch).
Allotype.—♀: Urbana, Illinois, in copula, September 20, 1916 (J. R. Malloch).
Type and allotype mounted upon the same card point.

Botanobia hinkleyi Malloch
Can. Ent., Vol. XLVII, No. 1, January, 1915, p. 12.
Type.—♀: Dubois, Illinois, creek valley, by sweeping evergreens, April 24, 1914 (J. R. Malloch).
Paratypes.—♀: Dubois, Illinois, creek valley, by sweeping evergreens, April 24, 1914 (J. R. Malloch).

Botanobia spiniger Malloch
Bull. Brook. Ent. Soc., Vol. XIII, No. 5, December, 1918, p. 109.
Type.—♀: Urbaña, Illinois, Augerville (Brownfield) woods, June 23, 1916 (J. R. Malloch).
Paratype.—♀: Meredosia, Illinois, August 20, 1917 (J. R. Malloch).

Chloropisca glabra var. clypeata Malloch
Can. Ent., Vol. XLVI, No. 4, April, 1914, p. 119.
Lectotype.—♀: Algonquin, Illinois, September 21, 1894 (W. A. Nason).
Lectoallotype.—♂: Urbana, Illinois, swept from *Catalpa*, June 21, 1888 (J. Marten). Acc. No. 14488.
Paratype.—♀: Urbana, Illinois, in woods, July 15, 1887 (C. A. Hart). Acc. No. 12915.
Subsequently raised to specific rank by Malloch.

Chloropisca obtusa Malloch
Can. Ent., Vol. XLVI, No. 4, April, 1914, p. 118.
Type.—♀: Champaign, Illinois, swept from grass, May 28, 1889 (J. Marten). Acc. No. 15013.
In fair condition.

Chloropisca parviceps Malloch
Proc. Ent. Soc. Wash., Vol. 17, No. 3, Sept. 18, 1915, p. 158.
Type.—♀: Monticello, Illinois, along Sangamon River, June 30, 1914 (C. A. Hart and J. R. Malloch).
Paratypes.—♀: Mahomet, Illinois, along Sangamon River, August 6, 1914 (C. A. Hart and J. R. Malloch); Centerville [White Heath], Illinois, along Sangamon River, August 16, 1914 (C. A. Hart and J. R. Malloch).

Dasyopa pleuralis Malloch
Bull. Brook. Ent. Soc., Vol. XIII, No. 1, January, 1918, p. 20.
Lectotype.—♂: Meredosia, Illinois, in sand pit, August 19, 1917 (J. R. Malloch).
Lectoallotype.—♀: Meredosia, Illinois, in sand pit, August 19, 1917 (J. R. Malloch).
Paratypes.—♂ and ♀: Meredosia, Illinois, in sand pit, August 22, 1917 (J. R. Malloch); Bluffs, Illinois, August 19, 1917 (J. R. Malloch); Dubois, Illinois, August 9, 1917 (J. R. Malloch).
The genotype of *Dasyopa* Malloch (original designation and monobasic).

Gaurax apicalis Malloch
Proc. Ent. Soc. Wash., Vol. 17, No. 3, September 18, 1915, p. 160.
Type.—♀: Mahomet, Illinois, along Sangamon River, August 6, 1914 (J. R. Malloch).

Gaurax flavidulus Malloch
Bull. Ill. State Lab. Nat. Hist., Vol. XI, Art. IV, December, 1915, p. 361.
Type.—♂: Urbana, Illinois, on cypress limb, July 4, 1915 (J. R. Malloch).

Gaurax interruptus Malloch
Bull. Ill. State Lab. Nat. Hist., Vol. XI, Art. IV, p. 363.
Type.—♀: Urbana, Illinois, on cypress tree, July 5, 1915 (J. R. Malloch).

Gaurax pallidipes Malloch
Bull. Ill. State Lab. Nat. Hist., Vol. XI, Art. IV, December, 1915, p. 362.
Type.—♂: Urbana, Illinois, on cypress tree, July 4, 1915 (J. R. Malloch).

Gaurax splendidus Malloch
Proc. Ent. Soc. Wash., Vol 17, No. 3, September 18, 1915, p. 161.
Type.—♂: White Heath, Illinois, along Sangamon River, May 30, 1915 (J. R. Malloch).

Lasiosina canadensis Aldrich
Can. Ent., Vol. L, No. 10, October, 1918, p. 337.
Paratypes.—♂ and ♀: Aweme, Manitoba, Canada, August 21, 1916 (N. Criddle); Treesbank, Manitoba, Canada, May 30, 1915.

Madiza (Siphonella) setulosa Malloch
Bull. Brook. Ent. Soc., Vol. XIII, No. 5, December, 1918, p. 110.
Type.—♀: Freeport, Illinois, July 4, 1917.
Lectoallotype.—Freeport, Illinois, July 2, 1917.
Paratypes.—♂ and ♀: Mahomet, Illinois, October 10, 1915; Urbana, Illinois, on window, June 17, 1915; Princeton, Illinois, June 24, 1915; Elizabeth, Illinois, July 7, 1917.

Meromyza flavipalpis Malloch
Can. Ent., Vol. XLVI, No. 4, April, 1914, p. 117.
Lectotype.—♂: Champaign, Illinois, along railroad, June 22, 1888 (J. Marten and C. A. Hart). Acc. No. 14504.
Paratype.—♂: Champaign, Illinois, along railroad, June 22, 1888 (J. Marten and C. A. Hart). Acc. No. 14504.
In fair condition. Gilbertson (So. Dakota Agr. Exp. Station, Bull. 217, November, 1925, p. 3) on the authority of Aldrich has sunk this species as a synonym of *Meromyza americana* Fitch.

Neogaurax fumipennis Malloch
Ent. News, Vol. XXVI, No. 2, March, 1915, p. 108.
Type.—♀: Muncie, Illinois, along Stony Creek, May 24, 1914 (E. H. Swigert).
Now placed in the genus *Pseudogaurax* Malloch.

Oscinis criddlei Aldrich
Can. Ent., Vol. L, No. 10, October, 1918, p. 341.
Paratypes.—♂ and ♀: Treesbank, Manitoba, Canada, July 23 and August 6, 1915 (N. Criddle); Aweme, Manitoba, Canada, August 1, 1916 (N. Criddle).

Oscinoides arpidia Malloch
Bull. Brook. Ent. Soc., Vol. XI, No. 4, October, 1916, p. 87.
Type.—♀: Urbana, Illinois, forestry, June 1, 1916 (J. R. Malloch).
The genotype of *Oscinoides* Malloch (original designation and monobasic).

Oscinoides arpidia var. atra Malloch
Bull. Brook. Ent. Soc., Vol. XIII, No. 1, January, 1918, p. 19.
Type.—♀: Dubois, Illinois, May 23, 1917 (J. R. Malloch).

Oscinoides arpidia var. elegans Malloch
Bull. Brook. Ent. Soc., Vol. XIII, No. 1, January, 1918, p. 19.
Type.—♂: Freeport, Illinois, July 4, 1917 (J. R. Malloch).

Oscinoides arpidia var. humeralis Malloch
Bull. Brook. Ent. Soc., Vol. XIII, No. 1, January, 1918, p. 19.
Type.—♀: Dubois, Illinois, May 22, 1917 (J. R. Malloch).

Family DROSOPHILIDAE

Amiota setigera Malloch
Bull. Brook. Ent. Soc., Vol. XIX, No. 2, April, 1924, p. 51.
Type.—♂: Savoy, Illinois, at sap on apple tree, May 23, 1916 (J. R. Malloch).

Allotype.—♀: White Heath, Illinois, August 12, 1920 (J. R. Malloch).
Paratype D.—♀: White Heath, Illinois, August 12, 1920 (J. R. Malloch). Head of paratype is missing.

Phortica minor Malloch
Ent. News, Vol. XXXII, No. 10, December, 1921, p. 312.
Type.—♂: Dubois, Illinois, June 5, 1920 (J. R. Malloch).
Paratype.—♂: Dubois, Illinois, June 3, 1919 (J. R. Malloch).

Family GEOMYZIDAE

Aphaniosoma quadrivittatum Malloch
Bull. Ill. State Lab. Nat. Hist., Vol. XI, Art. IV, December, 1915, p. 357.
Type.—♀: Urbana, Illinois, on window, June 9, 1915 (J. R. Malloch).
Paratypes.—♀: Urbana, Illinois, on window, June 15, 25, 29 and July 6, 1915 (J. R. Malloch).

Chyromya concolor Malloch
Proc. Ent. Soc. Wash., Vol. 16, No. 3, March, 1914, p. 181.
Lectotype.—♂: Monticello, Illinois, along Sangamon River, June 21, 1914 (C. A. Hart and J. R. Malloch).
Lectoallotype.—♀: Monticello, Illinois, along Sangamon River, June 21, 1914 (C. A. Hart and J. R. Malloch).
Paratypes.—♂ and ♀: Monticello, Illinois, along Sangamon River, June 28, 1914 (C. A. Hart and J. R. Malloch); Muncie, Illinois, along Stony Creek, May 24, 1914 (C. A. Hart and J. R. Malloch); Algonquin, Illinois, June 1 and 10, 1894 (W. A. Nason).

Chyromya nigrimana Malloch
Proc. Ent. Soc. Wash., Vol. 16, No. 3, March, 1914, p. 181.
Lectotype.—♂: Urbana, Illinois, fair grounds, along Salt Fork, May 20, 1914 (J. R. Malloch).
Lectoallotype.—♀: Urbana, Illinois, fair grounds, along Salt Fork, May 20, 1914 (J. R. Malloch).
Paratypes.—♂ and ♀: Urbana, Illinois, fair grounds, along Salt Fork, May 20, 1914 (J. R. Malloch); St. Joseph, Illinois, along Salt Fork, May 3 and 17, 1914 (J. R. Malloch).

Family AGROMYZIDAE

Agromyza albidohalterata Malloch
Psyche., Vol. XXIII, No. 2, April, 1916, p. 52.
Type.—♂: St. Joseph, Illinois, along Salt Fork, May 17, 1914 (C. A. Hart).

Agromyza angulicornis Malloch
Can. Ent., Vol. L, No. 3, March, 1918, p. 79.
Type.—♂: Waukegan, Illinois, on short of Lake Michigan, August 25, 1917 (J. R. Malloch).

Agromyza aprilina Malloch
Bull. Ill. State Lab. Nat. Hist., Vol. XI, Art. IV, December, 1915, p. 359
Lectotype.—♀: Urbana, Illinois, cottonwood grove, April 16, 1915 (J. R. Malloch).
Lectoallotype.—♂: Urbana, Illinois, cottonwood grove, April 16, 1915 (J. R. Malloch).
Paratypes.—♀ and ♂: Urbana, Illinois, cottonwood grove, April 16 and 20, 1915 (J. R. Malloch).

Agromyza aristata Malloch
Can. Ent., Vol. XLVII, No. 1, January, 1915, p. 13.
Type.—♀: Havana, Illinois, Gleason's Sand Dune, April 30, 1914 (C. A. Hart and J. R. Malloch).

Allotype.—♂: Havana, Illinois, along river, April 30, 1914 (C. A. Hart and J. R. Malloch).

Paratypes.—♂ and ♀: St. Joseph, Illinois, along Salt Fork, May 3, 1914 (C. A. Hart and J. R. Malloch); Golconda, Illinois, along Ohio River, April 18, 1914 (C. A. Hart and J. R. Malloch).

Agromyza assimilis Malloch

Can. Ent., Vol. L, No. 3, March, 1918, p. 80.

Type.—♂: Waukegan, Illinois, on short of Lake Michigan, August 25. 1917 (J. R. Malloch).

Agromyza citreifemorata Watt

Trans. New Zealand Inst., Vol. 54 (n. s.), December 14, 1923, p. 478.

Paratype.—♀: St. John's Hill Reserve, Wanganui, New Zealand, reared from mine in leaf of *Myoporum laetum* (M. N. Watt).

Agromyza deceptiva Malloch

Can. Ent., Vol. L, No. 3, March, 1918, p. 78.

Type.—♀: Alto Pass, Illinois, May 8, 1917 (J. R. Malloch).

Agromyza destructor Malloch

Proc. Ent. Soc. Wash., Vol. 18, No. 2, August 4, 1916, p. 93.

Lectotype.—♀: Los Banos, Philippine Islands (C. F. Baker).

Paratypes.—♀: Los Banos, Philippine Islands (C. F. Baker).

In fair condition.

Agromyza felti Malloch

Ent. News, Vol. XXV, No. 7, July 14, 1914, p. 310.

Paratypes.—♂: Hudson Falls, New York, reared from leaves of *Camptosorus rhizophyllus*, May 27, 1910.

Dr. E. P. Felt states in a letter that the type series contained fifteen specimens instead of seven as stated in original description.

Agromyza flavocentralis Watt

Trans. New Zealand Inst., Vol. 54 (n. s.), December 14, 1923, p. 474.

Paratype.—♀: Dunedin, New Zealand, Botanical gardens, reared from mine in leaf of *Veronica* (M. N. Watt).

Agromyza flavolateralis Watt

Trans. New Zealand Inst., Vol. 54 (n. s.), December 14, 1923, p. 471.

Paratype.—♂: Dunedin, New Zealand, Botanical gardens, reared from mine in leaf of *Melicytus ramiflorus* (M. N. Watt).

Agromyza flavopleura Watt

Trans. New Zealand Inst., Vol. 54 (n. s.), December 14, 1923, p. 481.

Paratype.—♂: Dunedin, New Zealand, Botanical gardens, reared from mine in leaf (M. N. Watt).

Agromyza flavopleura var. casta Watt

Trans. New Zealand Inst., Vol. 54 (n. s.), December 14, 1923, p. 482.

Paratype.—♂: Wellington, New Zealand, Botanical gardens, reared from mine in leaf of *Asplenium lucidum* (M. N. Watt).

Agromyza fumicosta Malloch

Ent. News., Vol. XXV, No. 7, July 14, 1914, p. 310.

Type.—♀: . Normal, Illinois, swept from blue grass, May 3, 1884 (S. A. Forbes). Acc. No. 1525.

Specimen is wrongly recorded in original description as collected in 1894 instead of 1884.

Agromyza gibsoni Malloch

Proc. U. S. Nat. Mus., Vol. 49, No. 2097, July 24, 1915, p. 106.

Paratypes.—♀ and ♂: Tempe, Arizona, reared from alfalfa, Webster No. 12239 (E. H. Gibson).

Agromyza indecora Malloch

Can. Ent., Vol. L, No. 4, April, 1918, p. 132.

Lectotype.—♂: White Heath, Illinois, June 24, 1916 (J. R. Malloch).

Lectoallotype.—♀: White Heath, Illinois, June 24, 1916 (J. R. Malloch).

Paratypes.—♂ and ♀: White Heath, Illinois, June 24, 1916, and June 29, 1917 (J. R. Malloch).

Agromyza infumata Malloch

Can. Ent., Vol. XLVII, No. 1, January, 1915, p. 15.

Type.—♂: Dubois, Illinois, creek valley in woods, April 24, 1914 (C. A. Hart and J. R. Malloch).

Specific name subsequently changed by Malloch (1915) to *subinfumata* because *infumata* is a primary homonym of *infumata* Strobl and Zerny. Hendel proposed the new name *fumosa* for this species in 1923, apparently overlooking the prior change by Malloch in 1915.

Agromyza nigrisquama Malloch

Psyche, Vol. XXIII, No. 2, April, 1916, p. 53.

Type.—♀: Monticello, Illinois, along bank of Sangamon River, June 28, 1914 (J. R. Malloch).

Hendel (1923) has proposed the new name of *calyptrata* for this species because *nigrisquama* Malloch is a primary homonym.

Agromyza pleuralis Malloch

Ent. News, Vol. XXV, No. 7, July 14, 1914, p. 311.

Type.—♀: Urbana, Illinois, University grounds, swept from catalpa, June 21, 1888 (J. Marten). Acc. No. 14488.

In original description the year is wrongly given as 1898 instead of 1888.

Agromyza riparia Malloch

Proc. U. S. Nat. Mus., Vol. 49, No. 2097, July 24, 1915, p. 105.

Lectotype.—♂: Urbana, Illinois, near Salt Fork, July 4, 1914 (C. A. Hart and J. R. Malloch).

Lectoallotype.—♀: Urbana, Illinois, near Salt Fork, July 4, 1914 (C. A. Hart and J. R. Malloch).

Paratypes.—♂ and ♀: Urbana, Illinois, near Salt Fork, July 4, 1914 (C. A. Hart and J. R. Malloch); Algonquin, Illinois, June 19, 1894, July 25, 1895, September 15, 1895, October 3, 1895 (W. A. Nason); St. Joseph, Illinois, along Salt Fork, May 10, 1914 (C. A. Hart and J. R. Malloch). Hendel (1923) has proposed the new name of *riparella* for this species because *riparia* Malloch is a primary homonym.

Agromyza similata Malloch

Can. Ent., Vol. L, No. 5, May, 1918, p. 178.

Type.—♂: Dubois, Illinois, May 24, 1917 (J. R. Malloch).

Agromyza subangulata Malloch

Psyche, Vol. XXIII, No. 2, April, 1916, p. 51.

Type.—♂: St. Joseph, Illinois, along Salt Fork, May 3, 1914 (C. A. Hart and J. R. Malloch).

Agromyza subvirens Malloch

Proc. U. S. Nat. Mus., Vol. 49, No. 2097, July 24, 1915, p. 105.

Lectotype.—♀: St. Joseph, Illinois, along Salt Fork, May 17, 1914 (C. A. Hart and J. R. Malloch).

Lectoallotype.—♂: St. Joseph, Illinois, along Salt Fork, May 17, 1914 (C. A. Hart and J. R. Malloch).

Paratypes.—♀: St. Joseph, Illinois, along Salt Fork, May 17, 1914 (C. A. Hart and J. R. Malloch); Algonquin, Illinois, May 17, 1894 (W. A. Nason).

Agromyza umbrina Watt

Trans. New Zealand Inst., Vol. 54 (n. s.), December 14, 1923, p. 467.

Paratypes.—♂: Dunedin, New Zealand, Botanical gardens, reared from mine in leaf of *Veronica* (M. N. Watt).

Agromyza youngi Malloch

Ent. News, Vol. XXV, No. 7, July 14, 1914, p. 312.

Paratypes.—♂: Albany, New York, reared from *Taraxacum densleonis* (D. B. Young).

Sunk as a synonym of *Agromyza nasuta* Malloch by Malloch (1924).

Leucopis americana Malloch

Bull. Ill. State Nat. Hist. Surv., Vol. XIII, Art. XIV, January 1921, p. 354.

Type.—♂: Urbana, Illinois, reared from larva found feeding on aphids on *Spirea vanhouteii*, June, 1917 (J. R. Malloch.) Acc. No. 46568.

Allotype.—♀: Urbana, Illinois, reared from larva found feeding on aphids on *Spirea vanhouteii*, June 1917 (J. R. Malloch.) Acc. No. 46568.

Paratypes.—♀: Urbana, Illinois, reared from larvae found feeding on aphids on *Spirea vanhouteii*, June 1917 (J. R. Malloch). Acc. No. 46568.

The head of one paratype is missing. Puparium from which type emerged is on card point mount.

Leucopis major Malloch

Bull. Ill. State Nat. Hist. Surv., Vol. XIII, Art. XIV, January, 1921, p. 352.

Type.—♀: St. Joseph, Illinois, along Salt Fork, May 3, 1914 (J. R. Malloch).

Paratypes.—♀: St. Joseph, Illinois, along Salt Fork, May 3, 1914 (J. R. Malloch).

In the original description the allotype is mentioned and the hypopygium figured, but the specimen was not found. An empty vial containing the label "Leucopis major Malloch Allotype" in Malloch's handwriting was found which indicates specimen was dissected and is now lost.

Leucopis minor Malloch

Bull. Ill. State Nat. Hist. Surv., Vol. XIII, Art. XIV, January, 1921, p. 354.

Type.—♂: Dubois, Illinois, August 9, 1917 (J. R. Malloch).

Leucopis orbitalis Malloch

Bull. Ill. State Nat. Hist. Surv., Vol. XIII, Art. XIV, January, 1921, p. 352.

Type.—♀ Dundee, Illinois, reared by J. R. Malloch from pine twig infested with *Kermes*, June 7, 1916 (McMillan). Acc. No. 46343.

Paratypes.—♀: Dundee, Illinois, reared by J. R. Malloch from pine twig infested with *Kermes*, June 7, 1916, (McMillan). Acc. No. 46343.

Leucopis parallela Malloch

Bull. Ill. State Nat. Hist. Surv., Vol. XIII, Art. XIV, January 1921, p. 353.

Type.—♀ Muncie, Illinois, along Stony Creek, July 5, 1914 (J. R. Malloch).

Leucopis pemphigae Malloch

Bull. Ill. State Nat. Hist. Surv., Vol. XIII, Art. XIV, January, 1921, p. 350.

Type.—♂: Carbondale, Illinois, reared July 15, 1909, from larva from Pemphigus gall collected on July 6, 1909. Acc. No. 42313.

Allotype.—♀: Carbondale, Illinois, reared July 15, 1909, from larva from Pemphigus gall collected on July 6, 1909. Acc. No. 42313.

Paratypes.—♀: Carbondale, Illinois, reared July 15 and 27, 1909, from larvae from Pemphigus gall collected on July 6, 1909. Acc. Nos. 42313 and 42344.

Two female paratypes in poor condition.

Leucopis piniperda Malloch

Bull. Ill. State Nat. Hist. Surv., Vol. XIII, Art. XIV, January, 1921, p. 351.

Type.—♂: Urbana, Illinois, in university forestry, April 29, 1916 (J. R. Malloch).

Allotype.—♀: Urbana, Illinois, on tree trunk, July 5, 1915 (J. R. Malloch).

Two legs of type are missing and allotype is in very poor condition.

Leucopomyia pulvinariae Malloch

Bull. Ill. State Nat. Hist. Surv., Vol. XIII, Art. XIV, January, 1921, p. 356.

Paratypes.—♂ and ♀: Shushan, New York, reared from larvae found feeding on the *Pulvinaria vitis* Linnaeus, July 6, 1916, No. a3076, New York State College; Chicago, Illinois, from *Pulvinaria*, Spring, 1907; Algonquin, Illinois, July 4, 1894 (W. A. Nason).

The paratype from Algonquin is in alcohol in a vial. In the original description the year of the Algonquin specimen is wrongly given as 1892 instead of 1894. The genotype of *Leucopomyia* Malloch (original designation and monobasic).

Limnoagromyza diantherae Malloch

Bull. Brook. Ent. Soc., Vol. XV, No. 5, December, 1920, p. 147.

Type.—♀ Muncie, Illinois, August 15, 1917 (T. H. Frison and J. R. Malloch).

Allotype.—♂: Lafayette, Indiana, June 11, 1915 (J. M. Aldrich).

Paratypes.—♂ and ♀: Muncie, Illinois, August 15, 1917 (T. H. Frison and J. R. Malloch); Lafayette, Indiana, June 11 and 18, 1915, and June 2, 1917 (J. M. Aldrich); Urbana, Illinois, along Salt Fork, July 11, 1898 (C. A. Hart). Acc. No. 24491.

In the original description one paratype is listed as accession number 24401. This should be accession number 24491 and recovery of missing accession catalogue permits data to be given here. The genotype of *Limnoagromyza* Malloch (original designation and monobasic).

Meoneura nigrifrons Malloch

Proc. Biol. Soc. Wash., Vol. 28, March 12, 1915, p. 47.

Type.—♂: Urbana, Illinois, on window, September 6, 1914 (J. R. Malloch).

Allotype.—♀: Urbana, Illinois, on window, September 6, 1914 (J. R. Malloch).

Neoleucopis pinicola Malloch

Bull. Ill. State Nat. Hist. Surv., Vol. XIII, Art. XIV, January 1921, p. 357.

Type.—♂: Stratford, Illinois, taken on pine tree and probably predaceous on aphids, June 22, 1917 (J. R. Malloch).

Allotype.—♀: Urbana, Illinois, on pine, May 23, 1885. Acc. No. 5690.

Paratypes.—♂: Stratford, Illinois, taken on pine trees and probably predaceous on aphids, June 22, 1917 (J. R. Malloch); Urbana, Illinois, on pine tree, July 31, 1916 (J. R. Malloch).

The genotype of *Neoleucopis* Malloch (original designation and monobasic).

Pseudodinia polita Malloch

Proc. U. S. Nat. Mus., Vol. 49, No. 2101, July 16, 1915, p. 152.

Lectotype.—♀: Centerville [White Heath], Illinois, along Sangamon River, August 16, 1914 (C. A. Hart and J. R. Malloch).

Lectoallotype.—♂: Centerville [White Heath], Illinois, along Sangamon River, August 16, 1914 (C. A. Hart and J. R. Malloch).

Paratypes.—♀: Centerville [White Heath], Illinois, along Sangamon River, August 16, 1914 (C. A. Hart and J. R. Malloch); Urbana, Illinois, August 30, 1914 (J. R. Malloch).

In the original description the date of August 17 is erroneously given instead of August 16, and September 30 should be August 30.

Family ANTHOMYIIDAE

Allognotha semivitta Malloch

Trans. Amer. Ent. Soc., Vol. XLIV, October 28, 1918, p. 282.

Type.—♂: Meredosia, Illinois, sand regions, August 19, 1917 (C. A. Hart and J. R. Malloch).

Lectoallotype.—♀: Meredosia, Illinois, sand regions, May 29, 1917 (C. A. Hart and J. R. Malloch).

Paratypes.—♂ and ♀: Meredosia, Illinois, sand regions, August 19, 1917 (C. A. Hart and J. R. Malloch); Havana, Illinois, sand regions, August 30-31, 1917 (C. A. Hart and J. R. Malloch); Northern Illinois.

Anthomyia dorsimaculata Van der Wulp
Biol. Centrali-Americana, Insecta-Diptera, Vol. II, May, 1903, p. 336.
Cotype.—♂: Omilteme, Guerrero, Mexico, 8000 feet elevation, July (H. H. Smith).
Malloch (1921) has transferred this species to the genus *Pegomyia* R.—Desvoidy.

Aricia bicolorata Malloch
Proc. Calif. Acad. Sc., Vol. IX (Fourth Ser.), No. 7, August 26, 1919, p. 253.
Paratype.—♀: Washington State (T. Kincaid).
In fair condition.

Aricia latifrontata Malloch
Trans. Amer. Ent. Soc., Vol. XLIV, October 28, 1918, p. 270.
Paratypes.—♂: Beulah, New Mexico, top of range, June 28, 1902; Bozeman, Montana, June 20, 1906.

Aricia poeciloptera Malloch
Trans. Amer. Ent. Soc., Vol. XLIV, October 28, 1918, p. 271.
Paratype.—♀: Cloudcroft, New Mexico, May 23, 1902.
Specific name subsequently changed by Malloch (1920) to *neopoeciloptera* and transferred to the genus *Helina* R.—Desvoidy.

Ariciella flavicornis Malloch
Proc. Biol. Soc. Wash., Vol. 31, June 29, 1918, p. 66.
Type.—♂: Brownsville, Texas, November 22, 1910 (C. A. Hart).
Subsequently synonymized by Malloch (1921) as *Ariciella rubripalpis* (V. D. Wulp) Malloch. The genotype of *Ariciella* Malloch (original designation and monobasic).

Bigotomyia californiensis Malloch
Trans. Amer. Ent. Soc., Vol. XLVIII, June 12, 1923, p. 236.
Paratypes.—♂ and ♀: San Antonio Canyon, Ontario, California, July 25, 1907 (J. S. Hine).

Charadrella macrosoma Van der Wulp
Biol. Centrali-Americana, Insecta-Diptera, Vol. II, May, 1903, p. 341.
Cotypes.—♂ and ♀: Northern Yucatan, Mexico (Gaumer).

Clinopera hieroglyphica Van der Wulp
Biol. Centrali-Americana, Insecta-Diptera, Vol. II, May, 1903, p. 307.
Cotype.—♂: Teapa, Tabasco, Mexico, January (H. H. Smith).
The genotype of *Clinopera* Van der Wulp (designated by Coquillett, 1910).

Coenosia aliena Malloch
Ent. News, Vol. XXXII, No. 5, May, 1921, p. 134.
Type.—♀: Gallatin County, Montana, August 23, 1917.
Date of capture is erroneously given as August 22 in original description.

Coenosia anthracina Malloch
Ent. News, Vol. XXXII, No. 5, May, 1921, p. 134.
Type.—♀: Gallatin County, Montana, elevation 5400 feet, August 15, 1912.

Coenosia cilicauda Malloch
Ent. News, Vol. XXXI, No. 4, April, 1920, p. 103.
Paratypes.—♂ and ♀: Huntley, Montana, July 23, 1917; Bozeman, Montana, Montana Experiment Station, July 7, 1917.
Subsequently transferred to the genus *Macrocoenosia* Malloch by Malloch.

Coenosia denticornis Malloch
Trans. Amer. Ent. Soc., Vol. XLVI, June 12, 1920, p. 164.
Type.—♀: Saskatchewan, Canada, Farewell Creek, July, 1907.

Coenosia femoralis Van der Wulp
Biol. Centrali-Americana, Insecta-Diptera, Vol. II, May, 1903, p. 345.
Cotype.—♀: Orizaba, Mexico, December, 1887 (H. H. Smith and F. D. Godman).

In fair condition. This species is now considered (Malloch, 1921) as a synonym of *Bithoracochaeta leucoprocta* Wied.

Coenosia fraterna Malloch

Trans. Amer. Ent. Soc., Vol. XLIV, October 28, 1918, p. 282.

Paratypes.—♀: Blitzen River, Oregon, July 6, 1906.

Coenosia frisoni Malloch

Trans. Amer. Ent. Soc., Vol. XLVI, June 12, 1920, p. 165.

Type.—♂: Urbana, Illinois, University Woods (formerly Cottonwood Grove), July 20, 1917 (J. R. Malloch).

Coenosia laricata Malloch

Trans. Amer. Ent. Soc., Vol. XLVI, June 12, 1920, p. 166.

Type.—♀: Cedar Lake, Lake County, Illinois, in a tamarack grove, August 4, 1906.

Coenosia macrocera Van der Wulp

Biol. Centrali-Americana, Insecta-Diptera, Vol. II, May, 1903, p. 344.

Cotype.—♀: Sierra de las Aguas Escondidas, Guerrero, Mexico, 9500 feet elevation, July (H. H. Smith).

Coenosia punctulata Van der Wulp

Biol. Centrali-Americana, Insecta-Diptera, Vol. II, May, 1903, p. 343.

Cotype.—♀: Omilteme, Guerrero, Mexico, 8000 feet elevation, July (H. H. Smith).

Emmesomyia apicalis Malloch

Bull. Brook. Ent. Soc., Vol. XII, No. 5, December, 1917, p. 115.

Type.—♀: Dubois, Illinois, May 23, 1917 (J. R. Malloch).

Allotype.—♂: White Heath, Illinois, June 3, 1917 (J. R. Malloch).

Paratypes.—♀: Savanna, Illinois, June 13, 1917 (J. R. Malloch); Dongola, Illinois, May 12, 1917 (J. R. Malloch).

In the original description the paratype from Savanna is erroneously recorded as collected on June 3 instead of June 13.

Emmesomyia unica Malloch

Bull. Brook. Ent. Soc., Vol. XII, No. 5, December, 1917, p. 114.

Type.—♀: Savoy, Illinois, May 23, 1916 (J. R. Malloch).

Paratypes.—♀: Algonquin, Illinois, June 12, 1897 (W. A. Nason); Homer, Illinois, Homer Park, June 17, 1917 (J. R. Malloch).

The genotype of *Emmesomyia* Malloch (original designation).

Eremomyioides fuscipes Malloch

Trans. Amer. Ent. Soc., Vol. XLVI, June 12, 1920, p. 182 .

Type.—♂ Urbana, Illinois, Augerville Woods (Brownfield Woods), March.

Allotype.—♀: Urbana, Illinois, Augerville Woods (Brownfield Woods), March 17, 1918 (T. H. Frison).

Paratypes.—♂: Urbana, Illinois, Augerville Woods (Brownfield Woods), March 5, 16-18, 1918 (T. H. Frison and J. R. Malloch); Homer, Illinois, March 21, 1909.

Date of capture of type male erroneously given as March 11 in original description.

Eremomyioides similis Malloch

Trans. Amer. Ent. Soc., Vol. XLVI, June 12, 1920, p. 183.

Type.—♀: Tuscola, Illinois, March 29, 1918 (J. R. Malloch).

Allotype.—♂: Urbana, Illinois, Cottonwood Grove (University Woods), April 16, 1915 (J. R. Malloch).

Paratypes.—♀: Tuscola, Illinois, March 29, 1918 (J. R. Malloch); Dane County, Wisconsin, April 10, 1900 (W. S. Marshall).

Eulimnophora cilifera Malloch

Trans. Amer. Ent. Soc., Vol. XLVI, June 12, 1920, p. 145.

Type.—♂: Waukegan, Illinois, August 24, 1917 (J. R. Malloch).

Allotype.—♀: Algonquin, Illinois, October 2, 1895 (W. A. Nason).

Paratypes.—♂ and ♀: Waukegan, Illinois, August 24, 1917 (J. R. Malloch); Urbana, Illinois, University forestry, October 22, 1916 (W. A. Nason); Algonquin, Illinois, September 3, 1894 (W. A. Nason).
One male paratype with no data.

Eulimnophora dorsovittata Malloch
Trans. Amer. Ent. Soc., Vol. XLVI, June 12, 1920, p. 146.
Type.—♀: Kingston, West Indies, April, 1891 (C. W. Johnson).

Fannia canadensis Malloch
Ann. Mag. Nat. Hist., Vol. XIII (Ninth Ser.), No. 76, April 1924, p. 423.
Type.—♂: Gold Rock, Ontario, Canada, Rainy River District, July 21, 1905 (H. H. Newcomb).

Fannia latifrons Malloch
Bull. Ill. State Lab. Nat. Hist., Vol. X, Art. IV, June, 1914, p. 240.
Type.—♂: Elliott, Illinois, July 10, 1906 (E. O. G. Kelley).

Fannia lasiops Malloch
Trans. Amer. Ent. Soc., Vol. XLVI, June 12, 1920, p. 169.
Type.—♂: Urbana, Illinois, Augerville (Brownfield) Woods, March 30, 1918 (J. R. Malloch).

Fannia spathiophora Malloch
Trans. Amer. Ent. Soc., Vol. XLIV, October 28, 1918, p. 294.
Type.—♀: Gold Rock, Ontario, Canada, Rainy River District, July 21, 1905 (H. H. Newcomb).
Paratype.—♀: Ontario, Canada, Gold Rock, Rainy River District, July 21, 1905 (H. H. Newcomb).

Fannia trianguligera Malloch
Trans. Amer. Ent. Soc., Vol. XLIV, October 28, 1918, p. 292.
Paratypes.—♂: Alamogordo, New Mexico, May 7, 1902.

Hebecenma affinis Malloch
Can. Ent., Vol. LIII, No. 9, September, 1921, p. 214.
Paratypes.—♂ and ♀: Mt. Greylock, Massachusetts, June 15, 1906; Bar Harbor, Maine, July 30, 1919.

Helina algonquina Malloch
Bull. Brook. Ent. Soc., Vol. XVII, No. 3, June, 1922, p. 96.
Type.—♂: Algonquin, Illinois, May 20, 1908 (W. A. Nason).

Helina bispinosa Malloch
Trans. Amer. Ent. Soc., Vol. XLVI, June 12, 1920, p. 142.
Type.—♂: Waukegan, Illinois, August 24, 1917 (J. R. Malloch).

Helina consimilata Malloch
Trans. Amer. Ent. Soc., Vol. XLVI, June 12, 1920, p. 144.
Type.—♂: New Bedford, Massachusetts (Hough).

Helina johnsoni Malloch
Trans. Amer. Ent. Soc., Vol. XLVI, June 12, 1920, p. 141.
Paratypes.—♂ and ♀: Provincetown, Massachusetts, June 29, 1891; Auburndale, Massachusetts, June 16 (C. W. Johnson).

Helina linearis Malloch
Trans. Amer. Ent. Soc., Vol. XLVI, June 12, 1920, p. 139.
Type.—♂: Bozeman, Montana, elevation 4800 feet, July 7, 1902.
Left wing is missing.

Helina mimetica Malloch
Trans. Amer. Ent. Soc., Vol. XLVI, June 12, 1920, p. 142.
Paratype.—♀: Glen House, New Hampshire, June 14, 1916.

Helina nasoni Malloch
Trans. Amer. Ent. Soc., Vol. XLVI, June 12, 1920, p. 138.
Type.—♂: Algonquin, Illinois, August 16, 1895 (W. A. Nason).

Helina nigribasis Malloch
Trans. Amer. Ent. Soc., Vol. XLVI, June 12, 1920, p. 143.
Type.—♂: Dongola, Illinois, May 12, 1917 (C. A. Hart and J. R. Malloch).

Allotype.—♀: Dongola, Illinois, May 12, 1917 (C. A. Hart and J. R. Malloch).

Paratypes.—♂ and ♀: Dongola, Illinois, May 12, 1916, May 9, 10 and 12, 1917 (C. A. Hart and J. R. Malloch); Dubois, Illinois, May 24, 1917 (C. A. Hart and J. R. Malloch); Carlinville, Illinois, May 18 (C. Robertson).

Helina nigrita Malloch

Trans. Amer. Ent. Soc., Vol. XLVI, June 12, 1920, p. 139.

Type.—♂: Monida, Montana, July 27, 1913.

Helina spinilamellata Malloch

Trans. Amer. Ent. Soc., Vol. XLVI, June 12, 1920, p. 140.

Type.—♂: Bozeman, Montana, July 17, 1916.

Helina tuberculata Malloch

Can. Ent., Vol. LI, No. 12, December, 1919, p. 277.

Type.—♂: Rigolet, Labrador, July 18, 1906.

Allotype.—♀: Alberta, Canada, Lake Louise, July 15, 1908 (C. S. Minot).

Hydrophoria collaris Van der Wulp

Biol. Centrali-Americana, Insecta-Diptera, Vol. II, May, 1903, p. 333.

Cotype.—♀ Omilteme, Guerrero, Mexico, 8000 feet elevation, July (H. H. Smith).

Malloch (1921) has transferred this species to the genus *Pegomyia* R.—Desvoidy.

Hydrophoria flavipalpis Van der Wulp

Biol. Centrali-Americana, Insecta-Diptera, Vol. II, May, 1903, p. 334.

Cotype.—♂: Sierra de las Aguas Escondidas, Guerrero, Mexico, 7000 feet elevation, July (H. H. Smith).

Malloch (1921) has transferred this species to the genus *Emmesomyia* Malloch.

Hydrophoria nigerrima Malloch

Trans. Amer. Ent. Soc., Vol. XLVI, June 12, 1920, p. 169.

Paratypes.—♂ and ♀: Mt. Rainier, Washington, on snow, 7000-9000 feet elevation, August, 1917 (A. L. Melander); Mt. Rainier, Washington, Paradise Park, August, 1917 (A. L. Melander); Mt. Rixford, California, on snow, 12000 feet elevation, August 12, 1914 (R. L. B.).

Hydrophoria polita Malloch

Trans. Amer. Ent. Soc., Vol. XLVI, June 12, 1920, p. 170.

Type.—♂: Bozeman (Copperopolis), Montana, elevation 5400 feet, July 23, 1902 (J. M. Aldrich).

Allotype.—♀ Bozeman (Copperopolis), Montana, 5400 feet elevation, July 23, 1902 (J. M. Aldrich).

Paratype.—♂: Wells, Nevada, July 12, 1911 (J. M. Aldrich).

Nothing remains of paratype but part of thorax and wings.

Hydrophoria proxima Malloch

Trans. Amer. Ent. Soc., Vol. XLVI, June 12, 1920, p. 171.

Paratype.—Princeton, Maine, July 12, 1909 (C. W. Johnson).

Hydrophoria subpellucida Malloch

Trans. Amer. Ent. Soc., Vol. XLIV, October 28, 1918, p. 296.

Paratypes.—♂ and ♀: Alamogordo, New Mexico, June 30 and May 15, 1902.

Hydrophoria transversalis Van der Wulp

Biol. Centrali-Americana, Insecta-Diptera, Vol. II, May, 1903, p. 334.

Cotypes.—♂ and ♀: Sierra de las Aguas Escondidas, Guerrero, Mexico, 7000 feet elevation, July (H. H. Smith); Omilteme, Guerrero, Mexico, 8000 feet elevation, July (H. H. Smith).

In poor condition. Stein has sunk this species as a synonym of *pictipes* Bigot and placed it in the genus *Taeniomyia* Stein. Malloch (1921) considers that this species belongs in the genus *Pegomyia* R.—Desvoidy.

Hydrophoria uniformis Malloch
Trans. Amer. Ent. Soc., Vol. XLIV, October 28, 1918, p. 297.
Type.—♂: Dubois, Illinois, May 25, 1917.
Lectoallotype.—♀ Dubois, Illinois, May 23, 1917.
Paratypes.—♂ and ♀: Urbana, Illinois, April 5-7, 1909; Savoy, Illinois, March 26, 1917.

Hydrotaea cristata Malloch
Bull. Brook. Ent. Soc., Vol. XIII, No. 4, October, 1918, p. 94.
Type.—♂: New Bedford, Massachusetts.

Hydrotaea houghi Malloch
Bull. Brook. Ent. Soc., Vol. XI, No. 5, December, 1916, p. 110.
Lectotype.—♂: Homer, Illinois, April 24, 1909.
Lectoallotype.—♀ Homer, Illinois, April 24, 1909.
Paratypes.—♂ and ♀: Claremont, New Hampshire, October 16, 1915; London, Ontario, Canada, 1896; Opelousas, Louisiana, March, 1897; Urbana, Illinois, June 20, 1888, (J. Marten); Urbana, Illinois, April 5-30, 1909; Tifton, Georgia, October 16, 1896; Algonquin, Illinois, June 10, 1895 and April 24, 1897 (W. A. Nason). Acc. No. 14488.

Hylemyia augustiventris Malloch
Trans. Amer. Ent. Soc., Vol. XLIV, October 28, 1918, p. 315.
Paratype.—♂ Cloudcroft, New Mexico, June 16, 1902.
In fair condition.

Hylemyia attenuata Malloch
Trans. Amer. Ent. Soc., XLVI, June 12, 1920, p. 188.
Type.—♂: Claremont, California (Baker).

Hylemyia bicaudata Malloch
Trans. Amer. Ent. Soc., Vol. XLVI, June 12, 1920, p. 193.
Type.—♂: Grand Tower, Illinois, along Mississippi River, April 21, 1914 (J. R. Malloch).
Paratypes.—♂: Grand Tower, Illinois, along Mississippi River, April 21, 1914 (J. R. Malloch); Algonquin, Illinois.

Hylemyia bicruciata Malloch
Trans. Amer. Ent. Soc., Vol. XLVI, June 12, 1920, p. 190.
Type.—♂: Great Caribou Island, Labrador, July 27, 1906.

Hylemyia brevitarsis Malloch
Trans. Amer. Ent. Soc., Vol. XLIV, October 28, 1918, p. 309.
Paratypes.—♂: Lagunitas Canon, Marin County, California, March 29, 1908.

Hylemyia cilifera Malloch
Trans. Amer. Ent. Soc., Vol. XLIV, October 28, 1918, p. 311.
Type.—♂: Gallatin County, Montana, June 13, 1917.

Hylemyia curvipes Malloch
Trans. Amer. Ent. Soc., Vol. XLIV, October 28, 1918, p. 316.
Type.—♂: Grand Tower, Illinois, along river, April 21, 1914.
Paratypes.—♂: Grand Tower, Illinois, Big Muddy River, April 22, 1914; Lafayette, Indiana, May 1, 1918.

Hylemyia duplicata Malloch
Trans. Amer. Ent. Soc., Vol. XLIV, October 28, 1918, p. 308.
Paratypes.—♂ and ♀: Berkeley Hills, Alameda County, California, April 20, 1908.
Hypopygium and armature of fifth abdominal segment of another paratype without data preserved in alcohol.

Hylemyia extremitata Malloch
Proc. Calif. Acad. Sc., Vol. IX, No. 11 (4th Ser.), December, 23, 1919, p. 309.
Type.—♂: Gallatin County, Montana, 5500 feet elevation, July 19, 1911.

Hylemyia gracilipes Malloch
Trans. Amer. Ent. Soc., Vol. XLVI, June 12, 1920, p. 187.
Type.—♂: Lima, Montana, July 1, 1913.
Paratypes.—♂: Lima, Montana, July 1, 1913.

Hylemyia inaequalis Malloch
Trans. Amer. Ent. Soc., Vol. XLVI, June 12, 1920, p. 190.
Type.—♂: Oregon, Illinois, June 19, 1917 (J. R. Malloch).
Paratype.—♂: Oregon, Illinois, June 20, 1917 (J. R. Malloch).

Hylemyia innocua Malloch
Trans. Amer. Ent. Soc., Vol. XLVI, June 12, 1920, p. 186.
Type.—♂: New Bedford, Massachusetts (Hough).
Allotype.—♀: New Bedford, Massachusetts (Hough).
Paratypes.—♂ and ♀: New Bedford, Massachusetts (Hough).

Hylemyia marginella Malloch
Trans. Amer. Ent. Soc., Vol. XLIV, October 28, 1918, p. 311.
Type.—♂: Tennessee Pass, Colorado, July 24, 1917 (J. M. Aldrich).
Paratype.—♂: Beulah, New Mexico, top of Las Vegas Range, June 28, 1902.
Hypopygium and fifth abdominal sternite only of another paratype male preserved in alcohol.

Hylemyia montana Malloch
Proc. Biol. Soc. Wash., Vol. 32, June 27, 1919, p. 134.
Paratypes.—♂: Denver, Colorado, July 19, 1914 (O. E. Jackson); Crow Agency, Montana, July 10, 1916 (R. Kellogg); Armstead, Montana, July 3, 1913; Bozeman, Montana, July 10 and 15, 1912.
Hypopygium and fifth abdominal sternite of one paratype preserved in alcohol.

Hylemyia normalis Malloch
Proc. Calif. Acad. Sc., Vol. IX, No. 11 (4th Ser.), December 23, 1919, p. 309.
Type.—♂: Armstead, Montana, July 3, 1913.
Paratypes.—♂: Lima, Montana, July 1, 1913; Dillon, Montana, July 5, 1913; Powderville, Montana, July 6, 1916; Musselshell, Montana, July 30, 1917.

Hylemyia occidentalis Malloch
Trans. Amer. Ent. Soc., Vol. XLVI, June 12, 1920, p. 191.
Type.—♂: Washington, April 4, 1893 (T. Kincaid).
Paratypes.—♂: Washington, April 12, 19 and 20, 1893 (T. Kincaid).

Hylemyia pedestris Malloch
Can. Ent., Vol. LI, No. 12, December, 1919, p. 274.
Paratype.—♂: Godbout, Quebec, Canada, July 25, 1918 (E. M. Walker)

Hylemyia piloseta Malloch
Trans. Amer. Ent. Soc., Vol. XLIV, October 28, 1918, p, 313.
Type.—♂: Corvallis, Oregon, April 26, 1908 (L. Hill).
Paratype.—♂: Mary's River, Oregon (Webster).
Hypopygium and armature of fifth abdominal sternite are preserved in alcohol.

Hylemyia pluvialis Malloch
Can. Ent., Vol. L, No. 9, September, 1918, p. 310.
Type.—♂: Gold Rock, Ontario, Canada, Rainy River District, July 21 (H. H. Newcomb).

Hylemyia recurva Malloch
Proc. Calif. Acad. Sc., Vol. IX, (4th Ser.), December 23, 1919, p. 308.
Paratypes.—♂: Huntington Lake, Fresno County, California, 7000 feet elevation, July 10-27, 1919 (F. C. Clark).

Hylemyia setifer Malloch
Trans. Amer. Ent. Soc., Vol. XLVI, June 12, 1920, p. 192.

Paratypes.—♂: Gallatin County, Montana, July 24, 1917; Bozeman, Montana, July 23, 1914; Tennessee Pass, Colorado, July 23, 1917 (J. M. Aldrich); Hot Springs, Montana, July 3, 1917.

Hylemyia spinilamellata Malloch

Trans. Amer. Ent. Soc., Vol. XLIV, October 12, 1918, p. 312.

Type.—♂: Silver Lake, Utah, July 10.

Lectoallotype.—♀: Beulah, New Mexico, top of Las Vegas Range, June 28, 1902.

The name of *Hylemyia spinidens* was subsequently proposed for this species by Malloch (1920) because *spinilamellata* was preoccupied. Hypopygium and armature of fifth abdominal sternite of type preserved in alcohol.

Hylemyia substriatella Malloch

Trans. Amer. Ent. Soc., Vol. XLIV, October 28, 1918, p. 309.

Type.—♂: Falls Church, Virginia, October 14, 1913 (C. T. Greene).

Hypopygium and armature of fifth abdominal segment of male preserved in alcohol.

Hylemyia tridens Malloch

Ohio Journ. Sc., Vol. XX, No. 7, May, 1920, p. 284.

Paratype.—♂: Savonoski, Naknek Lake, Alaska, August, 1919 (J. S. Hine).

Leucomelina deleta Van der Wulp

Biol. Centrali-Americana, Insecta-Diptera, Vol. II, May, 1903, p. 329.

Cotype.—♂: Omilteme, Guerrero, Mexico, 8000 feet elevation, July (H. H. Smith).

Malloch (1921) has transferred this species to the genus *Limnophora* R.—Desvoidy.

Leucomelina minuscula Van der Wulp

Biol. Centrali-Americana, Insecta-Diptera, Vol. II, May, 1903, p. 330.

Cotype.—♀: Otoyac, Vera Cruz, Mexico, April (H. H. Smith).

In poor condition. Malloch (1921) indicates but does not definitely state that this species belongs to the genus *Limnophora* R.—Desvoidy.

Limnophora angulata Malloch

Trans. Amer. Ent. Soc., Vol. XLVI, June 12, 1920, p. 151.

Paratypes.—♀: West Coast of Greenland, 1891 (Mengel and Hughes on the Peary Expedition).

Limnophora acuticornis Malloch

Trans. Amer. Ent. Soc., Vol. XLVI, June 12, 1920, p. 147.

Paratype.—♀: Swarthmore, Pennsylvania, July, 1908.

Limnophora clivicola Malloch

Trans. Amer. Ent. Soc., Vol. XLVI, June 12, 1920, p. 155.

Type.—♂: Makanda, Illinois, resting on stone, June 4, 1919 (C. P. Alexander and J. R. Malloch).

Allotype.—♀: Makanda, Illinois, resting on stone, July 5, 1919 (C. P. Alexander and J. R. Malloch).

Paratype.—♂: Makanda, Illinois, resting on stone, July 5, 1919 (C. P. Alexander and J. R. Malloch).

Limnophora extensa Malloch

Trans. Amer. Ent. Soc., Vol. XLVI, June 12, 1920, p. 150.

Paratypes.—♂ and ♀: West Coast of Greenland, 1891 (Mengel and Hughes on the Peary Expedition).

Male in poor condition.

Limnophora obsoleta Malloch

Trans. Amer. Ent. Soc., Vol. XLVI, June 12, 1920, p. 150.

Paratypes.—♂ and ♀: West Coast of Greenland, 1891 (Mengel and Hughes on the Peary Expedition).

Limnophora pearyi Malloch
Trans. Amer. Ent. Soc., Vol. XLVI, June 12, 1920, p. 151.
Paratype.—♂: West Coast of Greenland, 1891 (Mengel and Hughes on the Peary Expedition).
In fair condition.

Limnophora socia Van der Wulp
Biol. Centrali-Americana, Insecta-Diptera, Vol. II, May, 1903, p. 326.
Cotype.—♀: Omilteme, Guerrero, Mexico, 8000 feet elevation, July (H. H. Smith).
Malloch (1921) has transferred this species to the genus *Helina* R.—Desvoidy.

Limnophora tetrachaeta Malloch
Trans. Amer. Ent. Soc., Vol. XLVI, June 12, 1920, p. 153.
Type.—♂: Blitzen River, Oregon, July 6, 1906.
Paratype.—♂: Blitzen River, Oregon, July 6, 1906.
Hypopygium and fifth abdominal sternite of paratype are preserved in alcohol.

Macrophorbia houghi Malloch
Trans. Amer. Ent. Soc., Vol. XLVI, June 12, 1920, p. 173.
Type.—♀: New Bedford, Massachusetts, May 10, 1896 (Hough).
Paratype.—♂: Sherborn, Massachusetts, April 30, 1912.
The genotype of *Macrophorbia* Malloch (original designation and monobasic).

Melanochelia angulata Malloch
Can. Ent., Vol. LIII, No. 3, March, 1921, p. 63.
Lectotype.—♂: Umanak, Greenland, July 14, 1914 (M. C. Tanquary).
Lectoallotype.—♀: Umanak, Greenland, July 28, 1914 (M. C. Tanquary and W. E. Ekblaw).
Paratype.—♀: Umanak, Greenland, August 4, 1914 (M. C. Tanquary).
The data associated with these types is here published for the first time, the species being described in a key without mention of locality or date of capture.

Melanochelia imitatrix Malloch
Can. Ent., Vol. LIII, No. 3, March, 1921, p. 64.
Type.—♂: Nain, Labrador, August 18.

Muscina tripunctata Van der Wulp
Biol. Centrali-Americana, Insecta-Diptera, Vol. II, May, 1903, p. 305.
Cotype.—♂: Northern Yucatan, Mexico (Gaumer).
According to Malloch this species belongs to the genus *Neomuscina* Townsend.

Mydaea armata Malloch
Trans. Amer. Ent. Soc., Vol. XLVI, June 12, 1920, p. 135.
Type.—♀: Gallatin County, Montana, 8000 feet elevation, July 12, 1900 (E. Koch).

Mydaea brevipilosa Malloch
Trans. Amer. Ent. Soc., Vol. XLVI, June 12, 1920, p. 135.
Type.—♂: Algonquin, Illinois, July 2, 1904 (W. A. Nason).
Paratype.—♂: Savanna, Illinois, June 13, 1917 (J. R. Malloch).
The type is erroneously stated to be a female in the original description.

Mydaea concinna Van der Wulp
Biol. Centrali-Americana, Insecta-Diptera, Vol. II, May, 1903, p. 317.
Cotype.—♀: Xucumanatlan, Guerrero, Mexico, July, 7000 feet elevation H. H. Smith).
Malloch (1921) has erected the new genus *Smithomyia* for this species. The genotype of *Smithomyia* Malloch (monobasic).

Mydaea discimana Malloch
Trans. Amer. Ent. Soc., Vol. XLVI, June 12, 1920, p. 136.
Type.—♀: New Bedford, Massachusetts (Hough).

Mydaea neglecta Malloch
Trans. Amer. Ent. Soc., Vol. XLVI, June 12, 1920, p. 136.
Type.—♂: Ramsey, New Jersey, June 5, 1916.
Allotype.—♀: New Bedford, Massachusetts, August 30, 1896 (Hough).
Paratypes.—♂ and ♀: Plummer's Island, Maryland, May 10, 1916 (W. L. McAtee); Ramsey, New Jersey, June 5, 1916; North Mountain, Pennsylvania, September 1; Falls Church, Virginia, June 28, 1912 (C. T. Greene); Rowayton, Connecticut, June 16, 1909; Broad Top, Texas; New Bedford, Massachusetts, August 30, 1896 (Hough); Chester, Massachusetts, July 25, 1913.

Mydaea obscura Van der Wulp
Biol. Centrali-Americana, Insecta-Diptera, Vol. II, May, 1903, p. 317.
Cotype.—♂: Northern Yucatan, Mexico (Gaumer).
Malloch (1921) has erected the new genus *Neomusca* for this species. The genotype of *Neomusca* Malloch (monobasic).

Mydaea persimilis Malloch
Trans. Amer. Ent. Soc., Vol. XLVI, June 12, 1920, p. 134.
Type.—♀: Lake Louise, Alberta, Canada, July 15, 1908.
Erroneously recorded as collected on August 15 instead of July 15.

Neochirosia setiger Malloch
Bull. Brook. Ent. Soc., Vol. XII, No. 2, April, 1917, p. 36.
Lectotype.—♂: White Heath, Illinois, along Sangamon River, April 28, 1916 (J. R. Malloch).
Lectoallotype.—♀: White Heath, Illinois, along Sangamon River, April 28, 1916 (J. R. Malloch).
Paratype.—♀: White Heath, Illinois, along Sangamon River, April 30, 1916.
In the original description the month of capture of the type series is erroneously given as May instead of April. The genotype of *Neochirosia* Malloch (monobasic).

Neohylemyia proboscidalis Malloch
Bull. Brook. Ent. Soc., Vol. XII, No. 2, April, 1917, p. 38.
Type.—♂: Quincy, Illinois, on sand-bar along Mississippi River, August 10, 1889 (C. A. Hart). Hart Acc. No. 547.
The genotype of *Neohylemyia* Malloch (original designation and monobasic).

Pegomyia acutipennis Malloch
Trans. Amer. Ent. Soc., Vol. XLIV, October 28, 1918, p. 301.
Paratypes.—♂ and ♀: Alamogordo, New Mexico, May 2, 1902; Cloudcroft, New Mexico, May 16, 1902.

Pegomyia emmesia Malloch
Trans. Amer. Ent. Soc., Vol. XLVI, June 12, 1920, p. 179.
Type.—♂: Savanna, Illinois, June 14, 1917 (J. R. Malloch).
Allotype.—♀: Savanna, Illinois, June 11, 1917 (J. R. Malloch).
Paratypes.—♂ and ♀: Savanna, Illinois, June 13-14, 1917 (J. R. Malloch); Elizabeth, Illinois, July 7, 1917; Oregon, Illinois, June 20, 1917 (J. R. Malloch); Urbana, Illinois, July 21, 1889 (C. A. Hart). Hart Acc. No. 530.

Pegomyia fringilla Malloch
Trans. Amer. Ent. Soc., Vol. XLVI, June 12, 1920, p. 181.
Paratypes.—♂ and ♀: Urbana, Illinois, Augerville Grove (Brownfield Woods), April 18, 1919 (J. R. Malloch); Savoy, Illinois, on apple blossoms, May 4, 1916 (J. R. Malloch); Falls Church, Virginia, flying, April 27, 1915 (C. T. Greene).

Pegomyia fuscofasciata Malloch
Trans. Amer. Ent. Soc., Vol. XLVI, June 12, 1920, p. 178.
Paratype.—♂: Southbridge, Massachusetts, July 27, 1912.

Pegomyia labradorensis Malloch
Trans. Amer. Ent. Soc., Vol. XLVI, June 12, 1920, p. 176.
Type.—♂: Nain, Labrador, August, 1918.

Pegomyia littoralis Malloch
Bull. Brook. Ent. Soc., Vol. XV, No. 5, December, 1920, p. 127.
Paratypes.—♂: Bar Harbor, Maine, July 21-22, 1919 (C. W. Johnson).

Pegomyia quadrispinosa Malloch
Trans. Amer. Ent. Soc., Vol. XLVI, June 12, 1920, p. 181.
Type.—♂: Gallatin County, Montana, 9400 feet elevation, July 9, 1900 (C. Koch).
Allotype.—♀: Monida, Montana, June 27, 1913.

Pegomyia spinigerellus Malloch
Trans. Amer. Ent. Soc., Vol. XLVI, June 12, 1920, p. 178.
Type.—♂: Havana, Illinois, Gleason's sand dune, April 30, 1914 (J. R. Malloch).
Paratype.—♂: Meredosia, Illinois, sand pit, August 22, 1917 (J. R. Malloch).

Pegomyia subgrisea Malloch
Trans. Amer. Ent. Soc., Vol. XLVI, June 12, 1920, p. 180.
Type.—♂: Bozeman, Montana, June 14, 1906.
In the original description the month is erroneously given as July instead of June.

Pegomyia unguiculata Malloch
Trans. Amer. Ent. Soc., Vol. XLVI, June 12, 1920, p. 176.
Paratypes.—♂: Lake Louise, Alberta, Canada, July 15, 1908 (C. S. Minot).

Phaonia albocalyptrata Malloch
Ohio Journ. Sc., Vol. XX, No. 7, May, 1920, p. 267.
Paratype.—♂: Savonoski, Naknek Lake, Alaska, July, 1919 (J. S. Hine).

Phaonia basiseta Malloch
Trans. Amer. Ent. Soc., Vol. XLVI, June 12, 1920, p. 133.
Type.—♀: Bozeman, Montana, June 18, 1913.
Lectoallotype.—♂: Waubay, South Dakota, June 6, 1918.
Paratypes.—♂ and ♀: Waubay, South Dakota, June 6, 1918 (J. M. Aldrich).
The type is erroneously recorded as a male in the original description.

Phaonia brevispina Malloch
Trans. Amer. Ent. Soc., Vol. XLVIII, January 12, 1923, p. 269.
Type.—♂: Urbana, Illinois, on tree trunk, August 1, 1916 (J. R. Malloch).
Allotype.—♀: Urbana, Illinois, at sap exuding from tree trunk, September 5, 1915 (J. R. Malloch).

Phaonia citreibasis Malloch
Ohio Journ. Sc., Vol. XX, No. 7, May, 1920, p. 268.
Paratype.—♂: Savonoski, Naknek Lake, Alaska, July, 1919 (J. S. Hine).

Phaonia harti Malloch
Trans. Amer. Ent. Soc., Vol. XLVIII, January 12, 1923, p. 266.
Type.—♂: Urbana, Illinois, reared from larva found under bark, March-April, 1916 (J. R. Malloch). Acc. No. 46619.
Allotype.—♀: Urbana, Illinois, reared from larva found under bark, March-April, 1916 (J. R. Malloch). Acc. No. 46619.
Paratypes.—♂ and ♀: Urbana, Illinois, June 1, 1890 (C. A. Hart); Urbana, Illinois, reared from larvae found under bark, March-April, 1916 (J. R. Malloch); Great Falls, Virginia, May 2, 1917 (W. L. McAtee). Acc. Nos. 15701, 46617-46619 and 46665.

Phaonia laticornis Malloch
Trans. Amer. Ent. Soc., Vol. XLVIII, January 12, 1923, p. 279.
Type.—♂: Hampton, New Hampshire, May 20, 1907 (S. A. Shaw).
Allotype.—♀: Cedar Lake, Lake County, Illinois, bog, August 6, 1906 (C. A. Hart).
In the original description, evidently due to a typographical error, a statement regarding the locality of the type male is omitted.

Phaonia monticolla Malloch
Trans. Amer. Ent. Soc., Vol. XLIV, October 28, 1918, p. 266.
Paratype.—♂: Beulah, New Mexico, top of range, June 28, 1902.
Date of this paratype is erroneously given as June 24 in original description of species.

Phaonia nigricauda Malloch
Trans. Amer. Ent. Soc., Vol. XLIV, October 28, 1918, p. 268.
Paratypes.—♂ and ♀: Redwood Canyon, Marin County, California, May 17, 1908.

Phaonia subfusca Malloch
Trans. Amer. Ent. Soc., Vol. XLVIII, January 12, 1923, p. 273.
Type.—♂: Pulaski, Illinois, meadow, June 2, 1910 (C. A. Hart).
Allotype.—♀: Pulaski, Illinois, meadow, June 2, 1910 (C. A. Hart).
Paratypes.—♂ and ♀: Pulaski, Illinois, meadow, June 2, 1910 (C. A. Hart).
One male paratype in poor condition. The date of capture of type series is erroneously given as July 2, 1910, in the original description.

Phaonia texensis Malloch
Trans. Amer. Ent. Soc., Vol. XLVIII, January 12, 1923, p. 271.
Type.—♂: Brownsville, Texas, South Texas Garden, at sugar, November 23, 1910 (C. A. Hart).
Allotype.—♀: Brownsville, Texas, South Texas Garden, December 17, 1910 (C. A. Hart).
Paratypes.—♂: Brownsville, Texas, South Texas Garden, December 17, 1910 (C. A. Hart).

Phorbia fuscisquama Van der Wulp
Biol. Centrali-Americana, Insecta-Diptera, Vol. II, May, 1903, p. 340.
Cotype.—♂: Omilteme, Guerrero, Mexico, 8000 feet elevation, July (H. H. Smith).
Malloch (1921) has transferred this species to the genus *Phaonia* R.—Desvoidy.

Phorbia prisca Van der Wulp
Biol. Centrali-Americana, Insecta-Diptera, Vol. II, May, 1903, p. 340.
Cotype.—♀: Ciudad, Durango, Mexico, 8100 feet elevation (Forrer).

Phyllogaster littoralis Malloch
Can. Ent., Vol. XLIX, No. 7, July, 1917, p. 228.
Type.—♂: Grand Tower, Illinois, on willow, July 12, 1909.
Lectoallotype.—♀: Waukegan, Illinois, on beach, August 23, 1906.
Paratypes.—♀: South Haven, Michigan, on shore of Lake Michigan, July 14, 1914 (C. A. Hart); Algonquin, Illinois, July 10, 1895 (W. A. Nason).

Pogonomyia aldrichi Malloch
Trans. Amer. Ent. Soc., Vol. XLIV, October 28, 1918, p. 281.
Type.—♂: Moscow, Idaho, May 22, 1913 (J. M. Aldrich).

Pogonomyia aterrima Van der Wulp
Biol. Centrali-Americana, Insecta-Diptera, Vol. II, May, 1903, p. 335.
Cotype.—♀: Ciudad, Durango, Mexico, 8100 feet elevation (Forrer)

Pogonomyia flavinervis Malloch
Bull. Ill. State Lab. Nat. Hist., Vol. XL, Art. IV, December, 1915, p. 356.
Lectotype.—♂: Northern Illinois.
Lectoallotype.—♀: Algonquin, Illinois, May 24, 1895 (W. A. Nason).

Paratype.—♀: Algonquin, Illinois (W. A. Nason).

Synonymized as *Pogonomyia nitens* (Stein) by Aldrich (1918). Dr. Aldrich informs me, however, that "*flavinervis* is still the name for this species" because *nitens* is preoccupied.

Pogonomyia latifrons Malloch

Trans. Amer. Ent. Soc., Vol. XLIV, October 28, 1918, p. 281.

Type.—♀: Tennessee Pass, Colorado, July 24, 1917 (J. M. Aldrich).

Pogonomyia minor Malloch

Trans. Amer. Ent. Soc., Vol. XLIV, October 28, 1918, p. 280.

Paratypes.—♂ and ♀: Beulah, New Mexico, top of Las Vegas range, June 28, 1902; Tennessee Pass, Colorado, July 25, 1917 (J. M. Aldrich); Farewell Creek, Saskatchewan, Canada, June, 1907.

Pogonomyia similis Malloch

Trans. Amer. Ent. Soc., Vol. XLIV, October 28, 1918, p. 279.

Paratypes.—♂ and ♀: Bozeman, Montana, June 20, 1906; Beulah, New Mexico, top of Las Vegas Range, June 28, 1902; Tennessee Pass, Colorado, July 25, 1917 (J. M. Aldrich); Bozeman, Montana, 4800 feet elevation, July 7, 1902; Gallatin Mountains, Montana, 6000 feet elevation, June 1, 1914.

Pogonomyza proboscidalis Malloch

Trans. Amer. Ent. Soc., Vol. XLVI, June 12, 1920, p. 185.

Paratypes.—♂ and ♀: Delaware County, Pennsylvania, May 21, 1905; Swarthmore, Pennsylvania, June 4, 1905.

Prosalpia angustitarsus Malloch

Trans. Amer. Ent. Soc., Vol. XLVI, June 12, 1920, p. 184.

Paratypes.—♂ and ♀: Southwest Harbor, Maine, July 13, 1918 (C. W. Johnson); Machias, Maine, July 22, 1909 (C. W. Johnson).

Schoenomyza aurifrons Malloch

Trans. Amer. Ent. Soc., Vol. XLIV, October 28, 1918, p. 288.

Type.—♂: Mexico City, Mexico, July, 1897.

Schoenomyza convexifrons Malloch

Trans. Amer. Ent. Soc., Vol. XLIV, October 28, 1918, p. 287.

Paratypes.—♀ and ♂: Milbrae, San Mateo County, California, March 20, 1908.

Schoenomyza dorsalis var. partita Malloch

Trans. Amer. Ent. Soc., Vol. XLIV, October 28, 1918, p. 289.

Paratypes.—♂ and ♀: Lagunitas Canyon, Marin County, California, March 29, 1908.

Schoenomyza dorsalis var. sulfuriceps Malloch

Trans. Amer. Ent. Soc., Vol. XLIV, October 28, 1918, p. 288.

Paratypes.—♂ and ♀: Berkeley Hills, Alameda County, California, March 22, 1908; Yosemite Valley, California, May 22, 1908.

Spilogaster copiosa Van der Wulp

Biol. Centrali-Americana, Insecta-Diptera, Vol. II, May, 1903, p. 321.

Cotypes.—♂ and ♀: Omilteme, Guerrero, Mexico, 8000 feet elevation, July (H. H. Smith).

Malloch (1921) has transferred this species to the genus *Helina* R.—Desvoidy.

Spilogaster parvula Van der Wulp

Biol. Centrali-Americana, Insecta-Diptera, Vol. II, May, 1903, p. 321.

Cotype.—♀: Tepetlapa, Guerrero, Mexico, 3000 feet elevation, October (H. H. Smith).

Malloch (1921) has transferred this species to the genus *Helina* R.—Desvoidy.

Spilogaster rubripalpis Van der Wulp

Biol. Centrali-Americana, Insecta-Diptera, Vol. II, May, 1903, p. 320.

Cotype.—♀: Cuernavaca, Morelos, Mexico, June (H. H. Smith).

Malloch (1921) has transferred this species to the genus *Aricella* Malloch. *A. flavicornis* Malloch is a synonym of *rubripalpis* Van der Wulp, the latter having priority.

Spilogaster signatipennis Van der Wulp

Biol. Centrali-Americana, Insecta-Diptera, Vol. II, May, 1903, p. 322.

Cotypes.—♂ and ♀: Sierra de las Aguas Escondidas, Guerrero, Mexico, 9500 feet elevation, July (H. H. Smith); Omilteme, Guerrero, 8000 feet elevation, July (H. H. Smith).

Malloch (1921) has transferred this species to the genus *Helina* R.—Desvoidy.

Tetramerinx brevicornis Malloch

Can. Ent., Vol. XLIX, No. 7, July, 1917, p. 226.

Type.—♀: Waukegan, Illinois, on shore of Lake Michigan, August 23, 1906.

Allotype.—♂: Waukegan, Illinois, on shore of Lake Michigan, August 24, 1917 (J. R. Malloch).

Paratypes.—♂ and ♀: Waukegan, Illinois, on shore of Lake Michigan, August 23, 1906; Waukegan, Illinois, on sand on shore of Lake Michigan (J. R. Malloch).

Subsequently transferred by Malloch (1920) to the genus *Limnophora R.*—Desvoidy at the time of description of allotype.

Trichopticus conformis Malloch

Trans. Amer. Ent. Soc., Vol. XLVI, June 12, 1920, p. 157.

Paratypes.—♂: Boisdale, Cape Breton, Nova Scotia, July 18-19; Spruce Brook, Newfoundlaid, August 8-12; Youghall, New Brunswick, Canada, July 4-7, 1908 (A. Gibson).

Hypopygium and fifth abdominal sternite only of a paratype are preserved in alcohol.

Trichopticus latipennis Malloch

Trans. Amer. Ent. Soc., Vol. XLVI, June 12, 1920, p. 158.

Paratypes.—♂: North Adams, Massachusetts, June 18, 1906; Great Barrington, Massachusetts, June 16, 1915 (C. W. Johnson).

Xenocoenosia floridensis Malloch

Trans. Amer. Ent. Soc., Vol. XLVI, June 12, 1920, p. 163.

Paratypes.—♂ and ♀: St. Augustine, Florida, April 19, 1919 (C. W. Johnson).

Xenocoenosia major Malloch

Trans. Amer. Ent. Soc., Vol. XLVI, June 12, 1920, p. 163.

Paratype.—♀: St. Augustine, Florida, April 12, 1919 (C. W. Johnson).

Xenomydaea buccata Malloch

Trans. Amer. Ent. Soc., Vol. XLVI, June 12, 1920, p. 144.

Type.—♂: Monida, Montana, June 27, 1913.

Allotype.—♀ Tennessee Pass, Colorado, July 24, 1917 (J. M. Aldrich).

Family TACHINIDAE

Peleteria campestris Curran

Trans. Royal Soc. of Canada, Third Series, Vol. XIX, 1925, p. 247.

Paratype.—♂: Horseshoe Canyon, Chiricahua Mountains, Arizona, 6000 feet altitude.

Peleteria confusa Curran

Trans. Royal Soc. of Canada, Third Series, Vol. XIX, 1925, p. 253.

Paratypes.—♀: Waterbury, Connecticut, on foliage, September 26, 1914; Mt. Holyoke Gap, Massachusetts, September 17, 1914 (C. H. T. Townsend).

Peleteria townsendi Curran

Trans. Royal Soc. of Canada, Third Series, Vol. XIX, 1925, p. 252.

Paratypes.—♂ and ♀: Mexico City, Mexico (Juan Muller); Chihuahua, Mexico, at flowers of *Rudbeckia*, Mound valley, August 24, 1909 (C. H. T. Townsend).

ORDER HYMENOPTERA

Family TENTHREDINIDAE

Dolerus neostugnus MacGillivray
Bull. Brooklyn Ent. Soc., Vol. XVIII, No. 2, April, 1923, p. 55.
Paratype.—♀: Urbana, Illinois, April 12, 1898.

Euura salicicola Smith
North Amer. Ent., Vol. I, 1879, p. 41.
Cotypes.—♂ and ♀: Peoria, Illinois, bred from *Salix alba*, April 15, 1878 (E. A. Smith).

Metallus rubi Forbes
Fourteenth Rep. State Ent. Ill., September 2, 1885, p. 87.
Lectotype.—♂: Normal, Illinois, reared from mines in leaves of raspberries, August 12, 1884.
The genotype of *Metallus* Forbes (monobasic).

Nematus robiniae Forbes
Fourteenth Rep. State Ent. Ill., September 2, 1885, p. 116.
Type.—♀: Normal, Illinois, reared from larva on black locust *(Robinia pseudacacia)*, July 4, 1884. Acc. No. 4572.
This was considered by Marlatt as a synonym of *trilineata* Norton but Rohwer (1912) considers it a good species and places it in the genus *Pteronidea* Rohwer.

Tenthredo messica MacGillivray
Journ. N. Y. Ent. Soc., Vol. V, No. 3, September, 1897, p. 107.
Paratype.—♂: Olympia, Washington, June 13, 1894 (T. Kincaid).

Family ARGIDAE

Nematoneura malvacearum Cockerell
Insect Life, Vol. VII, No. 3, December, 1894, p. 252.
Paratype.—♂: Sante Fe, New Mexico, August, 1894 (T. D. A. Cockerell).
The species has been transferred to the genus *Neoptilia* Ashmead by Rohwer (1912).

Family BRACONIDAE

Adialytus maidaphidis Garman
Fourteenth Rep. State Ent. Ill., September 2, 1885, p. 31.
Lectotype.—♀: Champaign, Illinois, reared from *Aphis maidis* Fitch, November 7, 1884 (H. Garman).
Lectoallotype.—♂: Champaign, Illinois, reared from *Aphis maidis* Fitch, November 6, 1884 (H. Garman). Acc. No. 47310.
Paratypes.—♂ and ♀: Champaign, Illinois, reared from *Aphis maidis* Fitch, November 6, 1884 (H. Garman). Acc. Nos. 5357 and 47310. Slide Nos. 3145 and 3146.
Two female paratypes mounted in balsam on two slides and three female and two male paratypes in alcohol. According to Gahan this species is synonymous with *Lysiphlebius testaceipes* Cresson, the latter having priority.

Apanteles canarsiae Ashmead
Proc. Ent. Soc. Wash., Vol. 4, No. 3, March, 1897, p. 127.
Paratypes.—♂ and ♀: Normal, Illinois, bred from *Psorosina (Canarsia) hammondi* Riley, August 10-14, 1894 (W. G. Johnson). Acc. No. 20063.

Apanteles crambi Weed

Bull. Ill. State Lab. Nat. Hist., Vol. III, Art. I, August, 1887, p. 8.

Lectotype.—♀: Champaign, Illinois, bred from *Crambus zeellus* Fernald or *Crambus trisectus* Walker (=*exsiccatus* of Weed), June 19-21, 1886 (C. M. Weed). Acc. No. 10478.

Lectoallotype.—♂: Champaign, Illinois, bred from *Crambus zeellus* Fernald and *Crambus trisectus* Walker (=*exsiccatus* of Weed), July 15, 1886 (C. M. Weed). Acc. No. 10630.

Paratypes.—♂: Champaign, Illinois, bred from *Crambus zeellus* Fernald and *Crambus trisectus* Walker (=*exsiccatus* of Weed), July 15, 1886 (C. M. Weed). Acc. No. 10630.

Apanteles ornigis Weed

Bull. Ill. State Lab. Nat. Hist., Vol. III, Art. I, August, 1887, p. 6.

Lectotype.—♀: Normal, Illinois, bred from larva of *Ornix geminatella* Packard, May 3, 1886 (C. M. Weed). Acc. No. 8890.

Lectoallotype.—♂: Normal, Illinois, bred from larva of *Ornix geminatella* Packard, May 3, 1886 (C. M. Weed). Acc. No. 8890.

Paratypes.—♀: Normal, Illinois, bred from larvae of *Ornix geminatella* Packard, April 27 and May 3, 1886 (C. M. Weed). Acc. Nos. 8832 and 8890.

Apanteles orobenae Forbes

Twelfth Rep. State Ent. Ill., November 20, 1883, p. 104.

Lectotype.—♀: Anna, Union County, Illinois, bred from *Evergestis (Orobena) rimosalis* Guenée, September 15, 1882 (S. A. Forbes). Acc. No. 2851.

Lectoallotype.—♂: Anna, Union County, Illinois, bred from *Evergestis (Orobena) rinosalis* Guenée, September 15, 1882 (S. A. Forbes). Acc. No. 3129.

Paratypes.—♂ and ♀: Anna, Union County, Illinois, bred from *Evergestis (Orobena) rinosalis* Guenée, September 15, 1882 (S. A. Forbes). Acc. No. 2851. Slide Nos. 3143 and 3144.

Seventeen specimens were found labeled as types, though original description mentions but twelve. Five male and two female paratypes preserved in alcohol in two vials. Two paratypes, one male and one female, mounted in balsam on two slides.

Apanteles sarrothripae Weed

Bull. Ill. State Lab. Nat. Hist., Vol. III, Art. I, August, 1887, p. 6.

Lectotype.—♀: Normal, Illinois, bred from *Sarrothripus revayana* Scopoli (=*lintnerana* of Weed), July, 1884 (C. M. Weed). Acc. No. 2459.

Lectoallotype.—♂: Normal, Illinois, bred from *Sarrothripus revayana* Scopoli (=*lintnerana* of Weed), July, 1884 (C. M. Weed). Acc. No. 2459.

Paratype.—♀: Normal, Illinois, bred from *Sarrothripus revayana* Scopoli (=*lintnerana* of Weed), July, 1884 (C. M. Weed). Acc. No. 2459.

Bassus acrobasidis Cushman

Proc. U. S. N. M., Vol. 58, No. 2334, November 8, 1920, p. 289.

Paratype.—♂: Brownwood, Texas, reared from *Acrobasis* species, Quaintance No. 16787, July 4, 1918 (A. I. Fabis).

Clinocentrus americanus Weed

Bull. Ill. State Lab. Nat. Hist., Vol. III, Art. IV, October, 1887, p. 43.

Lectotype.—♀: Champaign, Illinois, bred from *Peronea (Teras) minuta* Robinson, June 5, 1886 (C. M. Weed). Acc. No. 10293.

Lectoallotype.—♂: Champaign, Illinois, bred from *Peronea (Teras) minuta* Robinson, June 5, 1886 (C. M. Weed). Acc. No. 10295.

Paratypes.—♀: Champaign, Illinois, bred from *Peronea (Teras) minuta* Robinson, June 5, 1886 (C. M. Weed). Acc. Nos. 10293 and 10295.

Clinocentrus niger Ashmead

Bull. Ill. State Lab. Nat. Hist., Vol. IV, Art. VII, December, 1895, p. 276

Paratypes.—♂: Havana, Illinois, taken from the surface of leaves of Lemnaceae on the shore of Quiver Lake, September 23, 1894 (C. A. Hart). Acc. No. 13068.

Placed by Gahan in the genus *Ademon* Haliday.

Microplitis hyphantriae Ashmead

Proc. Ent. Soc. Wash., Vol. 4, No. 3, March, 1897, p. 164.

Paratypes.—♀: Champaign, Illinois, reared from larvae of *Hyphantria cunea* Drury, August 12, 1885 (S. A. Forbes). Acc. No. 7209.

Microplitis mamestrae Weed

Bull. Ill. State Lab. Nat. Hist., Vol. III, Art. I, August, 1887, p. 2.

Lectotype.—♀: Normal, Illinois, reared from larva of *Ceramica (Mamestra) picta* Harris, August 23, 1884 (C. M. Weed). Acc. No. 4920.

Cocoon from which lectotype was reared is mounted on card point. Acc. No. 4922.

Protomicroplitis garmani Ashmead

Proc. U. S. Nat. Mus., Vol. 23, No. 1206, October 13, 1900, p. 132.

Paratypes.—♀: Tolono, Illinois, July 25, 1885 (C. A. Hart and Shiga); Metropolis, Illinois, August 19, 1895 (C. A. Hart and Shiga). Acc. Nos. 6783 and 17235.

Placed by Muesebeck (1922) in the genus *Microgaster* Latreille. Specific name in original description spelled *germani* but emended by Muesebeck to *garmani*.

Family Ichneumonidae

Coelinius meromyzae Forbes

Thirteenth Rep. State Ent. Ill., May 31, 1884, p. 26.

Lectotype.—♀: Cuba, Illinois, reared from *Meromyza americana* Fitch, May 15, 1883 (S. A. Forbes). Acc. No. 3314.

Lectoallotype.—♂: Cuba, Illinois, reared from *Meromyza americana* Fitch, May 15, 1883 (S. A. Forbes). Acc. No. 3314.

Paratypes.—♂ and ♀: Cuba, Illinois, reared from *Meromyza americana* Fitch, May 6-15, 1883 (S. A. Forbes). Acc. Nos. 2996, 3302, 3305, 3306 and 3314. Slide Nos. 1543-1547.

Now placed by Viereck in the genus *Coelinidea* Viereck. Most of the specimens in good condition. Anatomical features of one paratype mounted in balsam on slides.

Cremastus cookii Weed

Ent. Amer., Vol. IV, No. 8, November, 1888, p. 150.

Lectotype.—♀: Anna, Illinois, May 29-31, 1883 (C. M. Weed). Acc. No. 3238.

Lectoallotype.—♂: Anna, Illinois, June, 1883 (C. M. Weed). Acc. No. 3361.

Paratypes.—♂ and ♀: Anna, Illinois, June 6, 1884 (C. M. Weed); Urbana, Illinois, by sweeping strawberry fields or reared from *Ancylis (Phoxopteris) comptana* Froelich, July, 1885 (C. M. Weed). Acc. Nos. 2466 and 6278.

Lectotype and allotype in fair condition, paratypes in poor condition.

Cremastus cookii var. rufus Weed

Ent. Amer., Vol. IV, No. 8, November, 1888, p. 150.

Lectotype.—♂: Anna, Illinois, reared from *Ancylis (Phoxopteris) comptana* Froelich, June 6, 1884 (C. M. Weed). Acc. No. 2374.

In fair condition.

Cremastus forbesi Weed

Bull. Ill. State Lab. Nat. Hist., Vol. III, Art. III, October, 1887, p. 42.

Type.—♀: Urbana, Illinois, reared from *Peronea (Teras) minuta* Robinson, June 13, 1886 (C. M. Weed). Acc. No. 10386.

Cremastus hartii Ashmead
Bull. Ill. State Lab. Nat. Hist., Vol. IV, No. 7, December, 1896, p. 277.
Lectotype.—♀: Havana, Illinois, Quiver Lake, September 14, 1894 (C. A. Hart and Newberry). Acc. No. 13029.
Lectoallotype.—♂: Havana, Illinois, Quiver Lake, September 14, 1894 (C. A. Hart and Newberry). Acc. No. 13028b.

Glypta phoxopteridis Weed
Ent. Amer., Vol. IV, No. 8, November, 1888, p. 151.
Type.—♀: Anna, Illinois, bred from larva of *Ancylis (Phoxopteris) comptana* Froelich, July 14, 1884 (C. M. Weed). Acc. No. 4859.

Limneria (Siphonophorus) canarsiae Ashmead
Proc. Ent. Soc. Wash., Vol. 4, No. 3, March, 1897, p. 126.
Type.—♀: Normal, Illinois, bred from *Psorosina (Canarsia) hammondi* Riley, July 23, 1886 (C. M. Weed). Acc. No. 10671.
Head of type is missing.

Limneria elegans Weed
Bull. Ill. State Lab. Nat. Hist., Vol. III, Art. III, October, 1887, p. 40.
Lectotype.—♀: Urbana, Illinois, reared from *Perona (Teras) minuta* Robinson, June 12, 1886 (C. M. Weed). Acc. No. 10341.

Limneria teratis Weed
Bull. Ill. State Lab. Nat. Hist., Vol. III, Art. III, October, 1887, p. 40.
Lectotype.—♀: Urbana, Illinois, bred from *Perona (Teras) minuta* Robinson, June 9, 1886 (C. M. Weed). Acc. No. 10341.
Paratype.—♀: Urbana, Illinois, bred from *Peronea (Teras) minuta* Robinson, June 10, 1886 (C. M. Weed). Acc. No. 10355.
Abdomen and wings of paratype are missing.

Pimpla minuta Weed
Bull. Ill. State Lab. Nat. Hist., Vol. III, Art. III, October, 1887, p. 41.
Type.—♀: Urbana, Illinois, reared from *Peronea (Teras) minuta* Robinson, June 5, 1886 (C. M. Weed). Acc. No. 10295.
Only wings, thorax and two legs of type remain.

Spilocryptus canarsiae Ashmead
Proc. Ent. Soc. Wash., Vol. 4, No. 3, March, 1897, p. 124.
Lectotype.—♂: Champaign, Illinois, bred from cocoon of *Psorosina (Canarsia) hammondi* Riley, September 15, 1894 (W. G. Johnson). Acc. No. 21006.

Family SCELIONIDAE

Hoplogryon bethunei Sanders
Can. Ent., Vol. XLII, No. 1, January, 1910, p. 15.
Type.—♂: Aurora, Illinois, in a nest of *Formica subrufa*, June 15, 1909 (G. E. Sanders). Acc. No. 39771.

Phanurus tabanivorus Ashmead
Bull. Ill. State Lab. Nat. Hist., Vol. IV, Art. VII, December, 1896, p. 274.
Paratypes.—♂ and ♀: Havana, Illinois, reared from eggs of *Tabanus atratus* Fabricius, September 13, 1894 (C. A. Hart). Acc. No. 13016.

Family PLATYGASTERIDAE

Alaptus aleurodis Forbes
Fourteenth Rep. State Ent. Ill., September 2, 1885, p. 110.
Lectotype.—♀: Tamaroa, Illinois, reared from *Aleurodes* on soft maple, August 4, 1884 (S. A. Forbes). Acc. No. 5139.
Paratype.—♀: Tamaroa, Illinois, reared from *Aleurodes* on soft maple, August 4, 1884 (S. A. Forbes). Acc. No. 5139.
Generic name *Elaptus* used at time of description was a misspelling for *Alaptus*. Now considered as synonymous with *Amitus aleurodinis* Haldeman.

Platygaster hiemalis Forbes

Psyche, Vol. V, No. 144, April, 1888, p. 39.

Lectotype.—♂: Edgewood, Illinois, reared from puparia of *Phytophaga destructor* (Say) sent by Samuel Bartley, October 18, 1887 (S. A. Forbes). Acc. No. 14148.

Paratype.—♂: Edgewood, Illinois, reared from puparia of *Phytophaga destructor* (Say) sent by Samuel Bartley, October 18, 1887 (S. A. Forbes). Acc. No. 14148.

Family CYNIPIDAE

Acraspis compressus Gillette

Bull. Ill. State Lab. Nat. Hist., Vol. III, Art. XI, April, 1891, p. 197.

Type gall.—Ames, Iowa.

One of the two type specimens was originally mounted on a card point with this gall, but imago itself is now missing. Now placed by Weld (1926) in the genus *Zopheroteras* Ashmead.

Antistrophus bicolor Gillette

Bull. Ill. State Lab. Nat. Hist., Vol. III, Art. XI, April, 1891, p. 197.

Type.—♀: Normal, Illinois, July 6, 1884. Acc. No. 2584.

Accession catalogue states "Cynips from *Silphium integrifolium*" Now placed in the genus *Aylax* Hartig.

Antistrophus laciniatus Gillette

Bull. Ill. State Lab. Nat. Hist., Vol. III, Art. XI, April, 1891, p. 194.

Lectotype.—♀: Champaign, Illinois, bred from gall "on receptacle of the flowers of *Silphium laciniatum*", collected April 18, 1889 (J. Marten). Acc. No. 15073.

Lectoallotype.—♂: Champaign, Illinois, bred from gall "on receptacle of the flowers of *Silphium laciniatum*", collected April 18, 1889 (J. Marten). Acc. No. 15073.

Type gall.—Champaign, Illinois, "on receptacle of the flowers of *Silphium laciniatum*", collected April 18, 1889 (J. Marten). Acc. No. 15072.

Now placed in the genus *Aylax* Hartig.

Antistrophus minor Gillette

Bull. Ill. State Lab. Nat. Hist., Vol. III, Art. XI, April, 1891, p. 196.

Lectotype.—♀: Champaign, Illinois, bred from the stems of *Silphium laciniatum*, collected January 4, 1885. Acc. No. 5500.

Lectoallotype.—♂: Champaign, Illinois, bred from the stems of *Silphium laciniatum*, collected January 4, 1885. Acc. No. 5500.

Paratype.—♀: Champaign, Illinois, bred from the stems of *Silphium laciniatum*, collected January 4, 1885. Acc. No. 5500.

Now placed in the genus *Aylax* Hartig and assigned the specific name of *gilletti* Kieffer because *minor* Gillette is preoccupied.

Antistrophus rufus Gillette

Bull. Ill. State Lab. Nat. Hist., Vol. III, Art. XI, April, 1891, p. 195.

Lectotype.—♀: Champaign, Illinois, bred from cells in "stems of *Silphium laciniatum*", collected January 4, 1885. Acc. No. 5500.

Lectoallotype.—♂: Champaign, Illinois, bred from cells in "stems of *Silphium laciniatum*", collected January 4, 1885. Acc. No. 5500.

Paratypes.—♂ and ♀: Champaign, Illinois, bred from cells in "stems of *Silphium laciniatum*", collected January 4, 1885. Acc. No. 5500.

Type gall.—: Champaign, Illinois, in "stems of *Silphium laciniatum*", collected January 4, 1885. Acc. No. 5500.

Now placed in the genus *Aylax* Hartig.

Antistrophus silphii Gillette

Bull. Ill. State Lab. Nat. Hist., Vol. III, Art. XI, April, 1891, p. 192.

Lectotype.—♀: Champaign, Illinois, bred from galls on "*Silphium integrifolium*", collected February 6 or March 25, 1890 (Mally and J. Marten). Acc. No. 15605.
Lectoallotype.—♂: Champaign, Illinois, bred from galls on "*Silphium integrifolium*", collected February 6 or March 25, 1890 (Mally and J. Marten). Acc. No. 15605.
Paratypes.—♂ and ♀: Champaign, Illinois, bred from galls on "*Silphium integrifolium*," collected February 6 or March 25, 1890 (Mally and J. Marten). Acc. Nos. 15605 and 15665.
Type galls.—: Champaign, Illinois, galls on "*Silphium integrifolium*", collected February 6 or March 25, 1890 (Mally and J. Marten).

Aulacidea solidaginis Girault
Ent. News, Vol. XIV, No. 10, December, 1903, p. 323.
Cotypes.—♂ and ♀: Blacksburg, Virginia, reared from gall on goldenrod [*Lactuca*], June 2-8, 1903, No. 49 (A. A. Girault).
Synonymized by Beutenmüller (1910) as *Aulacidea tumida* Bassett.

Aulax bicolor Gillette
Bull. Ill. State Lab. Nat. Hist., Vol. III, Art. XI, April, 1891, p. 201.
Lectotype.—♀: Urbana, Illinois, July 9, 1885. Acc. No. 6422.
Paratype.—♀: Mt. Carmel, Illinois, taken in a wheat field, May 27, 1884. Acc. No. 1781.
In the original description Champaign is given as the locality instead of Urbana, also the year of the Mt. Carmel specimen is 1884 and not 1885.
Now placed in the genus *Aulacidea* Ashmead.

Callirhytis corallosa Weld
Proc. U. S. Nat. Mus., Vol. 59, No. 2368, June 27, 1921, p. 216.
Paratype.—♀: Ft. Sheridan, Illinois, reared from gall on *Quercus macrocarpa* Michaux or *Quercus alba* Linnaeus, October 6, 1914 (L. H. Weld).
Now considered by Weld (1922) as a synonym of *Callirhytis badia* (Bassett).

Callirhytis elliptica Weld
Proc. U. S. Nat. Mus., Vol. 59, No. 2368, June 27, 1921, p. 228.
Paratype.—Agamic ♀: Glencoe, Illinois, found ovipositing on buds of *Quercus alba* Linnaeus, May 11, 1919 (L. H. Weld).

Callirhytis ellipsoida Weld
Proc. U. S. Nat. Mus., Vol. 59, No. 2368, June 27, 1921, p. 227.
Cotypes.—Agamic ♀: Wilmette, Illinois, from galls on *Quercus bicolor* Willdenow, April 16, 1910 (L. H. Weld).

Callirhytis enigma Weld
Proc. U. S. Nat. Mus., Vol. 59, No. 2368, June 27, 1921, p. 219.
Paratypes.—♀: Winnetka, Illinois, reared from gall on *Quercus rubra* Linnaeus, October 22, 1914 (L. H. Weld); Madison Florida, cut out from gall on *Quercus catesbaei* Michaux, December 4, 1919 (L. H. Weld).

Callirhytis marginata Weld
Proc. U. S. Nat. Mus., Vol. 59, No. 2368, June 27, 1921, p. 225.
Cotype.—♀: Ft. Sheridan, Illinois, reared from gall on *Quercus coccinea* Muenchhausen, April 25, 1915 (L. H. Weld).

Callirhytis maxima Weld
Proc. U. S. Nat. Mus., Vol. 59, No. 2368, June 27, 1921, p. 217.
Cotypes.—♀: Ft. Sheridan, Illinois, reared from galls on *Quercus macrocarpa* Michaux, October 19, 1914 (L. H. Weld).

Callirhytis rubida Weld
Proc. U. S. Nat. Mus., Vol. 59, No. 2368, June 27, 1921, p. 224.
Paratype.—♀: Ravinia, Illinois, cut out from gall on one of red oaks, October 22, 1916 (L. H. Weld).

Compsodryoxenus illinoisensis Weld
Proc. U. S. Nat. Mus., Vol. 59, No. 2368, June 27, 1921, p. 234.

Paratypes.—♀: Winnetka, Illinois, cut out from galls on *Quercus macrocarpa* Michaux, October 25, 1914 (L. H. Weld); Ft. Sheridan, Illinois, cut out from galls on *Quercus macrocarpa* Michaux, October 24, 1914 (L. H. Weld).

Coptereucoila marginata Gillette
Bull. Ill. State Lab. Nat. Hist., Vol. III, Art. XI, April, 1891, p. 203.
Lectotype.—♀: Quincy, Illinois, November 14-15, 1884. Acc. No. 5437.
Paratype.—♀: Normal, Illinois, May 9, 1884. Acc. No. 1661. Now placed in the genus *Kleidotoma* Westwood.

Diastrophus scutellaris Gillette
Bull. Ill. State Lab. Nat. Hist., Vol. III, Art. XI, April, 1891, p. 191.
Type.—♀: Danville, Illinois, May 20, 1884. Acc. No. 1881.
Now placed in the genus *Gonaspis* Ashmead and considered as a variety of *potentillae* Bassett.

Disholcaspis globosa Weld
Proc. U. S. Nat. Mus., Vol. 59, No. 2368, June 27, 1921, p. 196.
Cotypes.—Agamic ♀: Ft. Sheridan, Illinois, reared from gall on *Quercus alba* Linnaeus, October, 1914 (L. H. Weld).

Disholcaspis terrestris Weld
Proc. U. S. Nat. Mus., Vol. 59, No. 2368, June 27, 1921, p. 198.
Paratypes.—Agamic ♀: Ironton, Missouri, reared from galls on *Quercus stellata* Wangenheim, December 1, 1917 (L. H. Weld).

Dryophanta lanata Gillette
Bull. Ill. State Lab. Nat. Hist., Vol. III, Art. XI, April, 1891, p. 198.
Lectotype.—♀: Ames, Iowa, Iowa Experiment Station.
Type gall.—: No data.
Now placed by Weld (1926) in the genus *Callirhytis* Foerster.

Eucoila septemspinosa Gillette
Bull. Ill. State Lab. Nat. Hist., Vol. III, Art. XI, April, 1891, p. 204.
Type.—♀: Quincy, Illinois, August 10, 1889 (C. A. Hart). Hart Acc. No. 547. Reassigned Illinois State Natural History Survey No. 25798.
Now placed in the genus *Psilodora* Foerster.

Eucoilidea rufipes Gillette
Bull. Ill. State Lab. Nat. Hist., Vol. III, Art. XI, April, 1891, p. 205.
Type.—♀: Morris, Illinois, July 19, 1883 (F. M. Webster). Acc. No. 3637.

Solenaspis singularis Ashmead
Trans. Am. Ent. Soc., Vol. XXIII, 1896, p. 183.
Paratype.—Algonquin, Illinois, July 25, 1895 (W. A. Nason).
Now placed in the genus *Xyalosema* Dalla Torre and Kieffer.

Synergus magnus Gillette
Bull. Ill. State Lab. Nat. Hist., Vol. III, Art. XI, April, 1891, p. 202.
Type.—♀: Lansing, Michigan, reared from a gall of *Amphibolips cookii* Gillette.

Synergus villosus Gillette
Bull. Ill. State Lab. Nat. Hist., Vol. III, Art. XI, April, 1891, p. 202.
Lectotype.—♀: Michigan.
The locality of "Iowa" given for this species in original description was in error.

Family CHALCIDIDAE

Ceyxia paraguayensis Girault
Zool. Jahrb., Abt. für Syst., Vol. 31, Heft 3, 1911, p. 385.
Paratype.—♂: Asuncion, Paraguay, May 4, 1905 (J. D. Anisits). Acc No. 44184.

Paraguaya pulchripennis Girault
Zool. Jahrb., Abt. für Syst., Vol. 31, Heft 3, 1911, p. 396.

Paratype.—♀: Villa Morra, Asuncion, Paraguay, November 9, 1905 (J. D. Anisits). Acc. No. 44182. Slide No. 1492.

Antenna, anterior and posterior legs only of one paratype mounted in balsam on a slide.

The genotype of *Paraguaya* Girault (original designation and monobasic).

Spilochalcis anisitsi Girault

Zool. Jahrb., Abt. für Syst., Vol. 31, Heft 3, 1911, p. 386.

Paratypes.—♀ and ♂: Paraguari, Paraguay, January 19, 1906 (J. D. Anisits). Acc. No. 44179. Slide No. 1494.

One antenna each of paratypic male and paratypic female mounted in balsam on a slide.

Tumidicoxa hyalinipennis Girault

Zool. Jahr., Abt. für Syst., Vol. 31, Heft 3, 1911, p. 381.

Paratype.—♀ Asuncion, Paraguay, April 10, 1905 (J. D. Anisits). Acc. No. 44183.

Family EURYTOMIDAE

Eurytoma paraguayensis Girault

Zool. Jahr., Abt. für Syst., Vol. 31, Heft 3, 1911, p. 390.

Paratypes.—♀: Asuncion, Paraguay, reared from an ichenumoid cocoon of a parasite of a lepidopterous larva, March 24, 1905 (J. D. Anisits). Acc. No. 44180. Slide Nos. 1438 and 1439.

Antenna and leg (all that remains) of one female paratype mounted in balsam on two slides.

Family ENCYRTIDAE

Aenasioidea latiscapus Girault

Can. Ent., Vol. XLIII, No. 5, May, 1911, p. 173.

Lectotype.—♀: Urbana, Illinois, June 25, 1908, reared from *Kermes pubescens* Bogue on oak (A. A. Girault). Acc. No. 40285.

Paratypes.—♀: Urbana, Illinois, reared from *Kermes pubescens* Bogue on oak, June 25, 1908 (A. A. Girault). Acc. No. 40285. Slide Nos. 1388 and 1874.

Four female paratypes in poor condition mounted in balsam on two slides. The genotype of *Aenasioidea* Girault (original designation and monobasic).

Anagyrus nubilipennis Girault

Psyche, Vol. XVI, No. 4, August, 1909, p. 76.

Lectotype.—♀: Carbondale, Illinois, reared from "overwintered females of *Eulecanium nigrofasciatum* (Pergande) on peach", June 9, 1908 (L. M. Smith). Acc. No. 37537.

Lectoallotype.—♂: Carbondale, Illinois, reared from "overwintered females of *Eulecanium nigrofasciatum* (Pergande) on peach", June 9, 1908 (L. M. Smith). Acc. No. 37537.

Paratypes.—♂: Carbondale, Illinois, reared from "overwintered females of *Eulecanium nigrofasciatum* (Pergande) on peach", June 9-20, 1908 (L. M. Smith). Acc. Nos. 37537, 37546 and 37550.

Aphycus stomachosus Girault

Psyche, Vol. XVI, No. 4, August, 1909, p. 77.

Lectotype.—♀: Carbondale, Illinois, reared from "overwintered females of *Eulecanium nigrofasciatum* (Pergande) on peach twigs", June 21, 1908 (L. M. Smith). Acc. No. 37559. Slide No. 1293.

Lectoallotype.—♂: Carbondale, Illinois, reared from "overwintered females of *Eulecanium nigrofasciatum* (Pergande) on peach twigs", June 20, 1908 (L. M. Smith). Acc. No. 37552. Slide No. 1300.

Paratypes.—♂ and ♀: Carbondale, Illinois, reared from 'overwintered females of *Eulecanium nigrofasciatum* (Pergande) on peach twigs", June 20-30, 1908 (L. M. Smith). Acc. Nos. 37551, 37552, 37559 and 37580. Slide Nos. 1293, 1300, 1301 and 1304.

In fair condition. Lectotype mounted in balsam on slide with paratypes, and lectoallotype on slide with five male paratypes. Remainder of paratypes mounted in balsam on two slides, except five female paratypes which are on card points.

Cristatithorax pulcher Girault

Can. Ent., Vol. XLIII, No. 5, May, 1911, p. 170.

Lectotype.—♀: Urbana, Illinois, reared from *Kermes pubescens* Bogue on oak, July 1, 1908 (A. A. Girault). Acc. No. 37590. Slide No. 1287.

Paratype.—♀: Urbana, Illinois, reared from *Kermes pubescens* Bogue on oak, July 1, 1908 (A. A. Girault). Acc. No. 37590.

Thorax, legs and abdomen of lectotype mounted on card point; head and one antenna in balsam on a slide. Antenna only of a female paratype mounted in balsam on a slide.

The genotype of *Cristatithorax* Girault (original designation and monobasic).

Microterys speciosissimus Girault

Can. Ent., Vol. XLIII, No. 5, May, 1911, p. 175.

Lectotype.—♀: Urbana, Illinois, bred from *Kermes pubescens* Bogue on oak, June 23, 1908 (A. A. Girault). Acc. No. 37561.

Paratypes.—♀: Urbana, Illinois, bred from *Kermes pubescens* Bogue on oak, June 23 and July 7, 1908 (A. A. Girault). Acc. Nos. 37561 and 37593. Slide No. 1305.

One female paratype mounted on card point has head missing. Head and antenna only of another female paratype mounted in balsam on a slide

Rhopoideus fuscus Girault

Can. Ent., Vol. XLIV, No. 1, January, 1912, p. 5.

Paratypes.—♀: Chicoutime, Quebec, Canada, July 3, 1911; St. Gabriel de Brandon, Quebec, Canada, July 3, 1911. Acc. Nos. 45080 and 45085. Slide Nos. 1471, 1500, 1501 and 1502.

The "supposed host is *Tortrix fumiferana* Clemens, but a coccid is indicated instead." Girault lists two of these specimens as "Homotypes" but they are a part of the type series and therefore are considered as paratypes. All specimens mounted in balsam on four slides.

Signiphora fasciata Girault

Proc. U. S. Nat. Mus., Vol. 45, No. 1977, May 22, 1913, p. 219.

Paratypes.—♂ and ♀: Cuantla, Morelos, Mexico, from "*Inglisia* sp. on cotton", July 1, 1897 (Koebele). Acc. No. 45088. Slide No. 1529.

In poor condition. Mounted in balsam on a slide.

Signiphora fax Girault

Proc. U. S. N. M., Vol. 45, No. 1977, May 22, 1913, p. 223.

Paratypes.—♀: San Juan, Porto Rico, parasites of *Aspidiotus* [*Mycetaspis*] *personatus* (Comstock) on Guanabana, January, 1899 (A. Busck). Acc. No. 45091. Slide No. 3262.

Mounted in balsam on a slide.

Signiphora flava Girault

Proc. U. S. Nat. Mus., Vol. 45, No. 1977, May 22, 1913, p. 213.

Paratype.—♀: Mexico, from "*Aspidiotus camelliae* Signoret on *Acacia*", December 15, 1905 (A. L. Herrara). Acc. No. 45096. Slide No. 1514.

Mounted in balsam on a slide with a male of *Signiphora aleyrodis* Ashmead.

Signiphora flavella Girault

Proc. U. S. Nat. Mus., Vol. 45, No. 1977, May 22, 1913, p. 214.

Paratype.—♀: Cuautla, Morelos, Mexico, from "*Aspidiotus* sp. on *Ciruela*", July 1, 1897 (Koebele). Acc. No. 45092. Slide No. 1510.

In poor condition. Mounted in balsam on a slide with seven females and one male of *Signiphora mexicana* Ashmead and females of *Perissopterus mexicana* Howard.

Signiphora maculata Girault

Proc. U. S. Nat. Mus., Vol. 45, No. 1977, May 22, 1913, p. 221.

Paratypes.—♀: Santiago de las Vegas, Cuba, reared from *Lepidosaphes alba* (Cockerell), June 21, 1911 (Patricio Cardin). Acc. No. 45084. Slide No. 1517.

In fair condition. Mounted in balsam on a slide.

Signiphora pulchra Girault

Proc. U. S. Nat. Mus., Vol. 45, No. 1977, May 22, 1913, p. 215.

Paratypes.—♂ and ♀: Anna, Illinois, reared from *Aspidiotus uvae* Comstock on cultivated grape, July 17, 1908 (L. M. Smith); Urbana, Illinois, reared from *Diaspis rosae*, August 15, 1895 (W. G. Johnson); Urbana, Illinois, reared from *Aspidiotus sp.* on currant and the cherry *Aspidiotus (forbesi ?)*, July 30 and August 13, 1895 (W. G. Johnson); Washington, D. C. bred from *Aspidiotus uvae* Comstock, May 15, 1911 (J. F. Zimmer). Acc. Nos. 21401, 21458, 21477, 39119 and 45083.

Mounted in balsam on five slides.

Family EUPELMIDAE

Isosoma allynii French

Can. Ent., Vol. XIV, No. 1, January, 1882, p. 9.

Cotype.—♀: Carbondale, Illinois, French Collection, July 29, 1881.

Head missing. Species now assigned to genus *Eupelmus* Dalman.

Family PTEROMALIDAE

Arthrolytus aeneoviridis Girault

Can. Ent., Vol. XLIII, No. 11, November, 1911, p. 372.

Lectotype.—♀: Ames, Iowa, August-November, 1908 (R. L. Webster). Acc. No. 40289.

Paratypes.—♂ and ♀: Ames, Iowa, August-November, 1908 (R. L. Webster). Acc. No. 40289. Slide Nos. 1392-1394.

Five female paratypes in poor condition mounted on card points. Antennae and heads of two male and three female paratypes mounted in balsam on three slides.

Catolaccus cyaneus Girault

Zool. Jahrb., Abt. für Syst., Vol. 31, Heft 3, 1911, p. 400.

Paratypes.—♀: Asuncion, Paraguay, October 10, 1905 (J. J. Anisits). Acc. No. 44181. Slide No. 1491.

Three female paratypes mounted on a single card point, and antennae and posterior leg of an additional female paratype mounted in balsam on a slide. The abdomen of one paratype on card point mount is missing.

Epipteromalus algonquinensis Ashmead

Mem. Carn. Mus., Vol. I, No. 4, 1904, p. 319.

Paratypes.—♀: Algonquin, Illinois, June 27, July 3 and 6, 1895 (W. A. Nason).

The genotype of *Epipteromalus* Ashmead (original designation and monobasic).

Muscidifurax raptor Girault and Sanders

Psyche, Vol. XVII, No. 4, August, 1910, p. 149.

Lectotype.—♀: Urbana, Illinois, reared from puparium of *Musca domestica* Linnaeus, October 24, 1908 (A. A. Girault and G. E. Sanders). Acc. No. 40250.

Lectoallotype.—♂: Urbana, Illinois, reared from puparium of *Musca domestica* Linnaeus, October 24, 1908 (A. A. Girault and G. E. Sanders). Acc. No. 40250.

Paratypes.—♂ and ♀: Urbana, Illinois, reared from puparia of *Musca domestica* Linnaeus and *Phormia regina* (Meigen), April, September, October and November, 1909 (A. A. Girault and G. E. Sanders). Acc. Nos. 20269, 39965, 40146, 40150, 40153, 40169, 40171, 40205, 40217, 40231, 40242, 40243, 40244, 40245, 40246, 40247, 40248, 40249, 40250, 40258, 40268. Slide Nos. 1377, 1397, 1398 and 1399.

The genotype of *Muscidifurax* Girault and Sanders (original designation and monobasic). The anatomical features of several paratypic females are mounted in balsam on four slides.

Nasonia brevicornis Ashmead

Mem. Carn. Mus., Vol. I, No. 4, 1904, p. 317.

Paratypes.—♀: Algonquin, Illinois, May 11 and July 3, 1895 (W. A. Nason).

This species is now placed in the genus *Mormoniella* Ashmead. The genotype of *Nasonia* Ashmead (original designation and monobasic). Isogenotypic through synonymy.

Pteromalus ? fulvipes Forbes.

Fourteenth Rep. State Ent. Ill., September 2, 1885, p. 47.

Lectotype.—♀: Robinson, Illinois, May 25, 1884. Acc. No. 2309.

Lectoallotype.—♂: Du Quoin, Illinois, August 7, 1883. Acc. No. 3806.

Paratypes.—♂ and ♀: Robinson, Illinois, June 14, 1884; Du Quoin, Illinois, August 7, 1883; Marshall, Illinois, June 25, 1884. Acc. Nos. 3806, 4357 and 4566.

This species is now placed in the genus *Nemicromelus* Girault.

Pteromalus gelechiae Webster

Twelfth Rep. State Ent. Ill., November 20, 1883, p. 151.

Lectotype.—♂: Southern Illinois, reared from a larva of *Sitotroga (Gelechia) cerealella* Olivier, 1882 (F. M. Webster). Acc. No. 3168.

Lectoallotype.—♀: Southern Illinois, reared from a larva of *Sitotroga (Gelechia) cerealella* Oliver, 1882 (F. M. Webster). Acc. No. 3168.

Paratypes.—♂ and ♀: Southern Illinois, reared from the larvae of *Sitotroga (Gelechia) cerealella* Olivier, 1882 (F. M. Webster). Acc. No. 3168. Slide Nos. 3147 and 3148.

Four paratypes are mounted in balsam on two slides, ten on card points, and the remainder in alcohol. Now considered as synonymous with *Dibrachys clisiocampae* Fitch, the latter having priority.

Pteromalus pallipes Forbes

Fourteenth Rep. Ill. State Ent., September 2, 1885, p. 46.

Lectotype.—♀: Du Quoin, Illinois, bred from puparia or larva of the Hessian fly, *Phytophaga destructor* Say, June 5, 1884. Acc. No. 2200.

Paratype.—♀: Du Quoin, Illinois, bred from puparia or larva of the Hessian fly, *Phytophaga destructor* Say, June 5, 1884. Acc. No. 2200.

The specific name of *forbesi* was assigned to this species by Dalla Torre because *pallipes* Forbes was preoccupied.

Trimeromicrus maculatus Gahan

Proc. U. S. Nat. Mus., Vol. 48, No. 2068, December 16, 1914, p. 162.

Paratype.—♀: Yuma, Arizona, reared from alfalfa seed-pod infested with *Bruchophagus funebris*, October 25, 1913 (T. D. Urbahns).

The genotype of *Trimcromicrus* Gahan (original designation and monobasic).

Tritneptis hemerocampae Girault

Psyche, Vol. XV, No. 5, October, 1908, p. 92.

Lectotype.—♀: Chicago, Illinois, reared from pupa of *Hemerocampa leucostigma* (Smith and Abbot), April 23, 1908 (A. A. Girault). Acc. No. 37512.

Lectoallotype.—♂: Chicago, Illinois, reared from pupa of *Hemerocampa leucostigma* (Smith and Abbot), April 23, 1908 (A. A. Girault). Acc. No. 37512.

Paratypes.—♀: Chicago, Illinois, reared from pupae of *Hemerocampa leucostigma* (Smith and Abbot), April 23, 1908 (A. A. Girault). Acc. No. 37512.

The genotype of *Tritneptis* Girault (original designation and monobasic).

Uriella rufipes Ashmead

Trans. Amer. Ent. Soc., Vol. XXIII, 1896, p. 222.

Paratypes.—♂ and ♀: Algonquin, Illinois, June 26, July 4 and 28, August 11 and 23, 1894 (W. A. Nason).

The genotype of *Uriella* Ashmead (original designation and monobasic). According to Kurdjumov (1913) this genus is synonymous with *Phaenacra* Thomson.

Urios vestali Girault

Journ. N. Y. Ent. Soc., Vol. XIX, No. 3, September, 1911, p. 176.

Type.—♀: Illinois, in the nest of an ant, May. Acc. No. 45066. Slide Nos. 1466-1467.

In a later publication the data for this type is given as April 1, 1911, Devil's Hole, near Havana, Illinois, in an ant's nest *(Pheidole vinelandica* Forel). In poor condition. Head and antennae mounted in balsam on two slides; abdomen, thorax and legs mounted on two card points on same pin. The genotype of *Urios* Girault (original designation and monobasic).

Zagrammosoma multilineata var. **punicea** Girault

Archiv. für Naturg., Vol. 77, Band I, Suppl. 2, 1911, p. 123.

Lectotype.—♀: Washington, D. C., reared from *Tischeria malifoliella* Clemens, August 7, 1905 (A. A. Girault). Acc. No. 44261.

Paratypes.—♀: Washington, D. C., reared from *Tischeria malifoliella* Clemens, August 7, 1905 (A. A. Girault). Acc. No. 44261.

In fair condition.

Family ELASMIDAE

Elasmus meteori Ashmead

Proc. Ent. Soc. Wash., Vol. 4, No. 3, March, 1897, p. 128.

Paratypes.—♀: Champaign, Illinois, bred from cocoons of *Meteorus vulgaris* Cresson, August 27, 1894 (W. G. Johnson); Tonti, Illinois, bred from cocoons of *Meteorus vulgaris* Cresson, September 5, 1894 (W. G. Johnson).

The head of one paratype is missing.

Family EULOPHIDAE

Aphelinus varicornis Girault

Psyche, Vol. XVI, No. 2, April, 1909, p. 29.

Lectotype.—♀: Chicago, Illinois, reared from *Schizoneura (Eriosoma) crataegi* Oestlund, November, 1908 and December 12, 1908 (J. J. Davis). Acc. No. 40284. Slide No. 1363.

Paratypes.—♀: Chicago, Illinois, reared from *Schizoneura (Eriosoma) crataegi* Oestlund, November, 1908 and December 12, 1908 (J. J. Davis). Acc. Nos. 40284 and 40291. Slide Nos. 1363, 1370 and 1387.

In fair condition. Girault in listing the types also mentions "eight females tag-mounted". I found six card point mounts of the eight mentioned in the original description, but unfortunately all the specimens of the adults originally so mounted were missing. Mounted in balsam on three slides; the lectotype being mounted on the same slide with three paratypic females. This species is now considered by Gahan (1924) as a synonym of *Aphelinus mali* Haldeman, the latter having priority.

Astichus bimaculatipennis Girault

Can. Ent. Vol. XLIV, No. 1, January, 1912, p. 8.

Type.—♀: Ames, Iowa, reared as a probable hyper-parasite of *Alceris* [*Peronea*] *minuta* Robinson, July 27, 1908 (R. L. Webster). Acc. No. 40290. Slide No. 1353.

In poor condition. Head and antennae mounted in balsam on a slide; thorax and part of appendages on a card point. Transferred by Gahan (1917) to the genus *Sympiesis* Foerster.

Coccophagus cinguliventris Girault

Psyche, Vol. XVI, No. 4, August, 1909, p. 79.

Lectotype.—♀: Carbondale, Illinois, reared from overwintered females of *Eulecanium nigrofasciatum* (Pergande), June 7, 1908 (L. M. Smith). Acc. No. 37536. Slide No. 1298.

In fair condition. Mounted in balsam on a slide.

Encarsia versicolor Girault

Psyche, Vol. XV, No. 3, June, 1908, p. 53.

Lectotype.—♀: Urbana, Illinois, reared from *Aleyrodes* [*Trialeurodes*] *vaporariorum* Westwood, March 20, 1908 (J. J. Davis). Acc. No. 37474. Slide No. 1268.

Lectoallotype.—♂: Urbana, Illinois, reared from *Aleyrodes* [*Trialeurodes*] *vaporariorum* Westwood, March 20, 1908 (J. J. Davis). Acc. No. 37474. Slide No. 1291.

Paratypes.—♂ and ♀: Urbana, Illinois, reared from *Aleyrodes* [*Trialeurodes*] *vaporariorum* Westwood, March 20, 1908 (J. J. Davis). Acc. No. 37474. Slides No. 1268 and 1269.

Mounted in balsam on three slides. Lectotype on same slide with eight female paratypes.

Mestocharis williamsoni Girault

Journ. N. Y. Ent. Soc., Vol. XIX, No. 3, September, 1911, p. 179.

Lectotype.—♀: Urbana, Illinois, reared from puparia of conopid on *Bombus americanorum* Fabricius [= *Bremus pennsylvanicus* (De Geer)], May 20, 1911. Acc. No. 45067.

Lectoallotype.—♂: Urbana, Illinois, reared from puparia of conopid on *Bombus americanorum* Fabricius [*Bremus pennsylvanicus* (De Geer)], May 20, 1911. Acc. No. 45067.

Paratypes.—♀: Urbana, Illinois, reared from puparia of conopid on *Bombus americanorum* Fabricius [*Bremus pennsylvanicus* (De Geer)], May 20, 1911. Acc. No. 45067.

Lectotype and three paratypes in fair condition, lectoallotype and two paratypes in poor condition.

Prospaltella fasciativentris Girault

Psyche, Vol. XV, No. 4, December, 1908, p. 117.

Lectotype.—♀: Urbana, Illinois, reared apparently from *Chionaspis furfura* Fitch, April 3, 1908 (A. A. Girault). Acc. No. 37481. Slide No. 1270.

Paratypes.—♀: Urbana, Illinois, reared apparently from *Chionaspis furfura* Fitch, April 3, 1908 (A. A. Girault); Urbana, Illinois, reared apparently from *Aspidiotus perniciosus* Comstock, July, 1907 (J. A. West). Acc. No. 37481. Slides No. 1296 and 1270.

In fair condition. Mounted in balsam on two slides.

Prospaltella fuscipennis Girault

Psyche, Vol. XV, No. 4, December, 1908, p. 120.

Lectotype.—♀ Marion, Illinois, reared from *Aspidiotus (Chrysomphalus) obscurus* (Comstock) on oak, August 11-13, 1908 (W. P. Flint). Acc. No. 39306. Slide No. 1271.

Paratypes.—♀: Marion, Illinois, reared from *Aspidiotus (Chrysomphalus) obscurus* (Comstock) on oak, August 11-13, 1908 (W. P. Flint). Acc. No. 39306. Slide No. 1271.

In fair condition. Mounted in balsam on one slide.

Prospaltella perspicuipennis Girault

Journ. N. Y. Ent. Soc., Vol. XVIII, No. 4, December, 1910, p. 234.

Lectotype.—♀: Centralia, Illinois, August 27, 1909 (A. A. Girault). Acc. No. 41679. Slide No. 1419.

Paratype.—♀: Centralia, Illinois, August 31, 1909 (A. A. Girault). Acc. No. 41679. Slide No. 1418.

Mounted in balsam on two slides.

Tetrastichodes hyalinipennis Girault

Zool. Jahrb., Abt. für Syst., Vol. 31, Heft 3, 1911, p. 404.

Paratypes.—♂ and ♀: Villa Morra, Asuncion, Paraguay, February 27, 1905 (J. D. Anisits). Acc. No. 44178. Slide No. 1472.

The legs, fore wing and antennae of one paratypic female mounted in balsam on a slide.

Tetrastichus caerulescens Ashmead

Proc. Ent. Soc. Wash., Vol. 4, No. 3, March, 1897, p. 130.

Type.—♀: Champaign, Illinois, bred from *Habrobracon gelechiae* Ashmead and the primary parasite of *Psorosina (Canarsia) hammondi* Riley, September 6 and 21, 1894 (W. G. Johnson). Acc. No. 21032.

Allotype.—♂: Champaign, Illinois, bred from *Habrobracon gelechiae* Ashmead and the primary parasite of *Psorosina (Canarsia) hammondi* Riley, September 6-21, 1894 (W. G. Johnson). Acc. No. 20087.

Head of allotype is missing.

Tetrastichus carinatus Forbes

Fourteenth Rep. State Ent. Ill., September 2, 1885, p. 48.

Lectotype.—♀: Anna, Illinois, bred from *Phytophaga (Cecidomyia) destructor* (Say), June 24, 1884. Acc. No. 4358.

Lectoallotype.—♂: Anna, Illinois, bred from *Phytophaga (Cecidomyia) destructor* (Say), June 24, 1884. Acc. No. 4358.

Paratypes.—♂ and ♀: Anna, Illinois, bred from *Phytophaga (Cecidomyia) destructor* (Say), June 24, 1884. Acc. No. 4358.

Paratypes in poor condition, two of them being in alcohol.

Tetrastichus johnsoni Ashmead

Trans. Amer. Ent. Soc., Vol. XXIII, 1896, p. 233.

Paratypes.—♀: Urbana, Illinois, reared from a mud wasps' nest, *Pompilus* sp., July 30, 1895 (W. G. Johnson). Acc. No. 21404.

Trichaporus aeneoviridis Girault

Can. Ent., Vol. XLIV, No. 3, March, 1912, p. 75.

Lectotype.—♀: Centralia, Illinois, supposedly reared from a larva of *Epicnaptera (Malacosoma) americana* (Harris) and apparently a primary parasite of it, May 27, 1908 (L. M. Smith and A. A. Girault). Acc. No. 37543.

Paratypes.—♀: Centralia, Illinois, supposedly reared from larvae of *Epicnaptera (Malacosoma) americana* (Harris) and apparently a primary parasite of it, May 27, 1908 (L. M. Smith and A. A. Girault). Acc. No. 37543. Slide No. 1283.

Antenna of one female paratype mounted in balsam on a slide.

Family TRICHOGRAMMATIDAE

Abbella subflava Girault

Trans. Amer. Ent. Soc., Vol. XXXVII, May 29, 1911, p. 11.

Paratypes.—♀: Centralia, Illinois, August 25, 1909 (A. A. Girault); Litchfield, Illinois, July 13, 1910 (A. A. Girault); Pullman, Washington. Acc. Nos. 41683 and 44164. Slide Nos. 1413, 1414 and 1421.

Mounted in balsam on three slides. The genotype of *Abbella* Girault (original designation).

Aphelinoidea plutella Girault

Ent. News, Vol. XXIII, No. 7, July, 1912, p. 297.

Type.—♀: Centralia, Illinois, August 26, 1909 (A. A. Girault). Acc. No. 41680. Slide No. 1415.

Mounted in balsam on a slide with the lectotype of *Aphelinoidea semifuscipennis* Girault.

Aphelinoidea semifuscipennis Girault

Trans. Amer. Ent. Soc., Vol. XXXVII, May 29, 1911, p. 4.

Lectotype.—Centralia, Illinois, August 25-26, 1909 (A. A. Girault). Acc. No. 41680. Slide No. 1415.

Paratype.—♀: Centralia, Illinois, August 25-26, 1909 (A. A. Girault). Acc. No. 41680. Slide No. 1416.

Mounted in balsam on two slides. The lectotype is mounted on the same slide with the type of *Aphelinoidea plutella* Girault.

Chaetostricha flavipes Girault

Trans. Amer. Ent. Soc., Vol. XXXVII, April 17, 1911, p. 75.

Paratype.—♀: Fort Valley, Georgia, reared, June 25, 1905. Acc. No. 44194. Slide No. 1490.

Mounted in balsam on a slide.

Japania ovi Girault

Trans. Amer. Ent. Soc., Vol. XXXVII, April 17, 1911, p. 45.

Paratype.—♀: Reared from leafhopper eggs on banyan in China. Acc. No. 44185. Slide No. 1460.

Mounted in balsam on a slide. The genotype of *Japania* Girault (original designation and monobasic).

Neotrichogramma acutiventre Girault

Trans. Amer. Ent. Soc., Vol. XXXVII, April 17, 1911, p. 40.

Cotypes.—♂ and ♀: Japan, reared from eggs of "*Chilo simplex*", March, 1910 (S. J. Kuwana). Acc. No. 44169. Slide No. 1430.

Subsequently synonymized by Girault (1911) as *Neotrichogramma (Trichogramma) japonica* (Ashmead). The genotype of *Neotrichogramma* Girault (original designation and monobasic).

Oligosita americana (Ashmead) Girault

Psyche, Vol. XVI, No. 3, October, 1909, p. 107.

Lectotype.—♀: Urbana, Illinois, reared from jassid egg deposited within the stem of *Elymus*, May 27, 1905 (R. L. Webster). Acc. No. 41078. Slide No. 1376.

Paratypes.—♀: Urbana, Illinois, reared from jassid eggs deposited within the stems of *Elymus*, May 27, 1905 (R. L. Webster). Acc. No. 41078. Slide No. 1376.

Mounted in balsam in one slide. Girault (1909) described species but assigns authorship of species to Ashmead.

Oophthora simblidis Aurivillius

Ent. Tidskr., Vol. XVIII, 1897, p. 253.

Cotypes.—♀ and ♂: Blido, Sweden, 1896. Acc. No. 44188. Slide No. 3261.

Transferred to the genus *Pentarthron* (Riley) Packard by Girault (1911). Synonymous with *Trichogramma evanescens* Westwood according to Henriksen (1918). The genotype of *Oophthora* Aurivillius (monobasic).

Pentarthron euproctidis Girault

Trans. Amer. Ent. Soc., Vol. XXXVII, April 17, 1911, p. 46.

Paratypes.—♀: Europe, bred from *Euproctis chrysorrhaea* Linnaeus, Gypsy Moth Parasite Laboratory (2006-G. M. L.). Acc. No. 44190. Slide No. 1447.

Mounted in balsam on a slide.

Pentarthron retorridum Girault

Trans. Amer. Ent. Soc., Vol. XXXVII, April 17, 1911, p. 52.

Paratypes.—♂ and ♀: Ames, Iowa, reared from the eggs of *Neleucania (Meliana) albilinea* (Hübner), September 3, 1910, Experiment 528 (T. M. M.); Ames, Iowa, reared from the eggs of *Neleucania (Meliana) albilinea* (Hübner), September, 1910, Experiment 602 (R. L. Webster); Ames, Iowa, reared from the eggs of *Neleucania (Meliana) albilinea* (Hübner), August 30, 1910, Experiment 535 (T. M. M.). Acc. No. 44186. Slide Nos. 1432, 1433 and 1445.

Mounted in balsam on three slides.

Trichogrammatoidea lutea Girault

Trans. Amer. Ent. Soc., Vol. XXXVII, May 29, 1911, p. 19.

Paratypes.—♀: Natal, Africa, reared from egg parasite of *Carpocapsa* sp., March 20, 1901 (Claude Fuller). Acc. No. 44167. Slide No. 1431.

Mounted in balsam on one slide.

Trichogrammatella tristis Girault

Archiv. für Naturg., Jahrg. 77, Band I, Suppl. 2, 1911, p. 127.

Paratypes.—♂ and ♀: Tunapunta, Trinidad, reared from eggs of *Horiola arquata*, February, 1911 (F. W. Urich). Acc. No. 44254. Slide No. 1470.

Mounted in balsam on a slide with three female paratypes of *Tumidifemur pulchrum* Girault. The genotype of *Trichogrammatella* Girault (original designation and monobasic).

Tumidiclava pulchrinotum Girault

Trans. Amer. Ent. Soc., Vol. XXXVII, May 29, 1911, p. 8.

Paratype.—♀: Urbana, Illinois, sweepings in meadow, June 8, 1910 (A. A. Girault). Acc. No. 44162. Slide No. 1454.

Mounted in balsam on a slide. The genotype of *Tumidiclava* Girault (original designation and monobasic).

Tumidifemur pulchrum Girault

Archiv. für Naturg., Jahrg. 77, Band I, Suppl. 2, 1911, p. 125.

Paratypes.—♀: Tunapunta, Trinidad, reared from eggs of *Horiola arquata*, February, 1911 (F. W. Urich). Acc. No. 44256. Slide No. 1470.

In fair condition. Mounted in balsam on a slide with three male and four female paratypes of *Trichogrammatella tristis* Girault. The genotype of *Tumidifemur* Girault (original designation and monobasic).

Uscana semifumipennis Girault

Trans. Amer. Ent. Soc., Vol. XXXVII, May 29, 1911, p. 23.

Paratypes.—♂ and ♀: Beeville, Texas—Honolulu, Hawaii, October 30, 1909 (F. Fulloway). Acc. No. 44166.

Mounted in balsam on a single slide. The genotype of *Uscana* Girault (original designation and monobasic).

Uscanella bicolor Girault

Archiv. für Naturg., Jahrg. 77, Band I, Suppl. 2, 1911, p. 129.

Paratype.—♀: Tunapunta, Trinidad, reared from egg of *Horiola arquata*, February, 1911 (F. W. Urich). Acc. No. 44255. Slide No. 1468.

The genotype of *Uscanella* Girault (original designation and monobasic).

Uscanoidea nigriventris Girault

Archiv. für Naturg., Jahrg. 77, Band I, Suppl. 2, 1911, p. 130.

Paratypes.—♂ and ♀: Paraiso, Isthmus of Panama, reared from eggs of "apparently jassids", January 20, 1911 (E. A. Schwarz). Acc. No. 44226. Slide No. 1488.

In fair condition. Mounted in balsam on a slide. The genotype of *Uscanoidea* Girault (original designation and monobasic).

Westwoodella clarimaculosa Girault

Trans. Amer. Ent. Soc., Vol. XXXVII, April 17, 1911, p. 67.

Type.—♀: Pulaski, Illinois, May 14, 1910 (C. A. Hart and A. A. Girault). Acc. No. 44193. Slide No. 1463.

Mounted in balsam on a slide. In a subsequent publication this species was considered by Girault (1911) as a color variety of *Westwoodella sanguinea* Girault.

Westwoodella comosipennis Girault

Trans. Amer. Ent. Soc., Vol. XXXVII, April 17, 1911, p. 66.

Paratype.—♀: No locality for this specimen is given. Type in United States National Museum is from "Ithaca, New York". Acc. No. 44187. Slide No. 1462.

Mounted in balsam on a slide.

Westwoodella sanguinea Girault

Trans. Amer. Ent. Soc., Vol. XXXVII, April 17, 1911, p. 58.

Type.—♀: Centralia, Illinois, August 25, 1909 (A. A. Girault). Acc. No. 41681. Slide No. 1410.

Paratypes.—♀: Urbana, Illinois, June 8, 1910 (A. A. Girault); Dalton, Illinois, June 15, 1910 (A. A. Girault). Acc. Nos. 44162 and 44244. Slide Nos. 1453 and 1454.

Mounted in balsam on three slides.

Westwoodella subfasciatipennis Girault

Trans. Amer. Ent. Soc., Vol. XXXVII, April 17, 1911, p. 63.

Allotype.—♂: Pullman, Washington, reared from green jassid egg, October 18, 1909. Acc. No. 44191. Slide No. 1450.

Mounted in balsam on a slide.

Family MYMARIDAE

Alaptus caecilii Girault

Ann. Ent. Soc. Amer., Vol. I, No. 3, September, 1908, p. 189.

Paratypes.—♂ and ♀: Los Angeles, California, reared from eggs of *Psocus*, July 21, 1888 (D. W. Coquillett). Acc. No. 37491. Slide No. 1303.

Mounted in balsam on a slide.

Alaptus eriococci Girault

Ann. Ent. Soc. Amer., Vol. I, No. 3, September, 1908, p. 191.

Paratypes.—♂ and ♀: Los Angeles, California, reared from *Eriococcus araucariae* Maskell, September 5, 1887. Acc. No. 37490. Slide No. 1302.

Mounted in balsam on one slide.

Alaptus intonsipennis Girault

Journ. N. Y. Ent. Soc., Vol. XVIII, No. 4, December, 1910, p. 244.

Lectotype.—♀: Bloomington (Hendrix), Illinois, July 22, 1910 (A. A. Girault). Acc. No. 44115. Slide No. 1417.

Paratype.—♀: Bloomington (Hendrix), Illinois, July 22, 1910 (A. A. Girault). Acc. No. 44115. Slide No. 1417.

Mounted in balsam on one slide.

Anagrus armatus var. **nigriventris** Girault

Trans. Amer. Ent. Soc., Vol. XXXVII, October 18, 1911, p. 291.

Lectotype.—♀: Centralia, Illinois, August 25, 1909 (A. A. Girault). Acc. No. 44220. Slide No. 1483.

Paratype.—♀: Centralia, Illinois, August 25, 1909 (A. A. Girault). Acc. No. 44220. Slide No. 1482.

Mounted in balsam on two slides.

Anagrus epos Girault

Trans. Amer. Ent. Soc., Vol. XXXVII, October 18, 1911, p. 292.

Lectotype.—♀: Centralia, Illinois, September 4, 1909 (A. A. Girault). Acc. No. 44222. Slide No. 1461.

Allotype.—♂: Centralia, Illinois, September 4, 1909 (A. A. Girault). Acc. No. 44222. Slide No. 1461.

Paratypes.—♀: Centralia, Illincis, September 4, 1909 (A. A. Girault); Urbana, Illinois, October 8, 1910 (A. A. Girault). Acc. Nos. 44222 and 45077. Slide Nos. 1441 and 1461.

Lectotype, lectoallotype and paratypes mounted in balsam on the same .slide and according to the label of Girault with a specimen of *Alaptus caeculii* Girault. One paratype mounted in balsam on a slide with seven females of *Camptoptera pulla* Girault.

Anagrus spiritus Girault

Ent. News, Vol. XXII, No. 5, May, 1911, p. 209.

Type.—♀: Fort Collins, Colorado, probably from egg of *Aphis pomi*, 1904 (S. A. Johnson). Acc. No. 41009. Slide No. 1400.

Allotype.—♂: Fort Collins, Colorado, probably from egg of *Aphis pomi*, 1904 (S. A. Johnson). Acc. No. 41009. Slide No. 1400.

Accession number 41009 and not 40809 as stated by Girault in original description. Mounted in balsam on one slide.

Anaphes hercules Girault

Trans. Amer. Ent. Soc., Vol. XXXVII, October 18, 1911, p. 285.

Type.—♀: Urbana, Illinois, June 8, 1910 (A. A. Girault). Acc. No. 44242. Slide No. 1504.

Mounted in balsam on a slide with one paratypic female of *Polynema consobrinus* Girault.

Anaphes nigrellus Girault

Trans. Amer. Ent. Soc., Vol. XXXVII, October 18, 1911, p. 282.

Type.—♀: Urbana, Illinois, June 26, 1909 (J. D. Hood). Acc. No. 44228. Slide No. 1520.

Mounted in balsam on a slide.

Anaphoidea pullicrura Girault

Journ. N. Y. Ent. Soc., Vol. XVIII, No. 4, December, 1910, p. 252.

Type.—♀: Centralia, Illinois, August 26, 1909 (A. A. Girault). Acc. No. 41686. Slide No. 1435.

Mounted in balsam on a slide.

Anaphoidea sordidata Girault

Journ. N. Y. Ent. Soc., Vol. XVII, No. 4, December, 1909, p. 169.

Type.—♀: Centralia, Illinois, from egg of the common weevil *Tyloderma foveolata* (Say), June 26, 1909 (A. A. Girault). Acc. No. 41651. Slide No. 1423.

Lectoallotype.—♂: Centralia, Illinois, from egg of the common weevil *Tyloderma foveolata* (Say), June 27, 1909 (A. A. Girault). Acc. No. 41651. Slide No. 1422.

Paratype.—♂: Centralia, Illinois, from egg of the common weevil *Tyloderma foveolata* (Say), July 4, 1909 (A. A. Girault). Acc. No. 41656. Slide No. 1425.

Mounted in balsam on three slides. The genotype of *Anaphoidea* Girault (original designation and monobasic).

Camptoptera pulla Girault

Ann. Ent. Soc. Amer., Vol. II, No. 1, March, 1911, p. 27.

Lectotype.—♀: Urbana, Illinois, July 15, 1908 (J. D. Hood). Acc. No. 39116. Slide No. 1307.

Mounted in balsam on a slide.

Gonatocerus fasciatus Girault

Trans. Amer. Ent. Soc., Vol. XXXVII, October 18, 1911, p. 265.

Lectotype.—♀: Arlington, Virginia, July 6. Acc. No. 44238. Slide No. 1479.

Paratype.—♀: Arlington, Virginia, July 6. Acc. No. 44238. Slide No. 1479.

In fair condition. Mounted in balsam on one slide.

Gonatocerus pygmaeus Girault

Trans. Amer. Ent. Soc., Vol. XXXVII, October 18, 1911, p. 269.

Paratype.—♀: Mississippi. Acc. No. 44249. Slide No. 1484.

In fair condition. Mounted in balsam on a slide.

Gonatocerus rivalis Girault

Trans. Amer. Ent. Soc., Vol. XXXVII, October 18, 1911, p. 257.

Paratypes.—♀: Butler, Illinois, July 21, 1910 (C. A. Hart and A. A. Girault); Pulaski, Illinois, May 14, 1910 (C. A. Hart and A. A. Girault). Acc. No. 44212. Slide Nos. 1477 and 1478.

Polynema citripes (Ashmead) Girault

Journ. N. Y. Ent. Soc., Vol. XIX, No. 1, March, 1911, p. 19.

Cotypes.—♀: Centralia, Illinois, on window, August 25, 1909 (A. A. Girault). Acc. No. 44175. Slide Nos. 1339 and 1436.

One bears data "*Cosmocoma citripes* Ash. female Type from Ind.". Description is by Girault, but Ashmead was given credit for the species. Mounted in balsam on two slides.

Polynema consobrinus Girault

Trans. Amer. Ent. Soc., Vol. XXXVII, October 18, 1911, p. 309.

Lectoallotype.—♂: Pekin, Illinois, August 14, 1883 (S. A. Forbes). Acc. No. 3816.

Paratypes.—♂ and ♀: Normal, Illinois, June 15, 1883 (S. A. Forbes); Urbana, Illinois, April 30 and June 8, 1910 (A. A. Girault); Chicago, Illinois, September 15, 1908 (J. J. Davis). Acc. Nos. 3391, 40029, 44242 and 44245. Slide Nos. 1333, 1401, 1452 and 1504.

Mounted in balsam on four slides. One of the female paratypes is mounted on a slide with paratypes of *Polynema enchenopae* Girault, and another female paratype is on a slide with the type of *Anaphes hercules* Girault.

Polynema enchenopae Girault

Journ. N. Y. Ent. Soc., Vol. XIX, No. 1, March, 1911, p. 15.

Paratypes.—♂ and ♀: Chicago, Illinois, September 15, 1908 (J. J. Davis). Acc. No. 40029. Slide No. 1401.

Mounted in balsam on a slide with one female paratype of *Polynema consobrinus* Girault.

Polynema sibylla Girault

Trans. Amer. Ent. Soc., Vol. XXXVII, October 18, 1911, p. 311.

Paratype.—♀: Algonquin, Illinois, May 10, 1896 (W. A. Nason). Acc. No. 44246. Slide No. 1348.

Mounted in balsam on a slide. The head is missing.

Polynema striaticorne Girault

Journ. N. Y. Ent. Soc., Vol. XIX, No. 1, March, 1911, p. 12.

Paratypes.—♂ and ♀: Geneva, New York, reared from membracid eggs, April 30, 1908. Acc. No. 44176. Slide No. 1437.

Mounted in balsam on one slide.

Polynema zetes Girault

Trans. Amer. Ent. Soc., Vol. XXXVII, October 18, 1911, p. 314.

Type.—♀: Urbana, Illinois, July 27, 1910 (A. A. Girault). Acc. No. 44248. Slide No. 1446.

Mounted in balsam on a slide.

Stephanodes psecas Girault

Journ. N. Y. Ent. Soc., Vol. XX, No. 1, March, 1912, p. 41.

Lectotype.—♀: Butler, Illinois, July 15, 1910 (A. A. Girault). Acc. No. 44209. Slide No. 1485.

Paratype.—♀: Urbana, Illinois, June 8, 1910 (A. A. Girault). Acc. No. 44209. Slide No. 1485.

In fair condition. Subsequently placed by Girault in the genus *Polynema* Haliday. Mounted in balsam on a slide.

Stethynium faunum Girault

Trans. Amer. Ent. Soc., Vol. XXXVII, October 18, 1911, p. 298.

Type.—♀: Bloomington (Hendrix), Illinois, June 14, 1910 (A. A. Girault). Acc. No. 44244. Slide No. 1453.

Mounted in balsam on a slide with one paratypic female of *Westwoodella sanguinea* Girault.

Stichothrix bifasciatipennis Girault

Psyche, Vol. XV, No. 4, December, 1908, p. 115.

Paratype.—♀: Washington, D. C., reared from eggs of *Anaxipha exigua* (Say), May 6, 1905 (T. Pergande). Acc. No. 37487. Slide No. 1297.

Mounted in balsam on a slide. Placed by Girault at a later date in the genus *Polynema* Haliday.

Family TIPHIIDAE

Neotiphia acuta Malloch

Bull. Ill. State Nat. Hist. Surv., Vol. XIII, Art. I, October, 1918, p. 9.

Lectotype.—♂: Texas.

Lectoallotype.—♀: Texas.

Paratypes.—♂: Texas.

The genotype of *Neotiphia* Malloch (original designation and monobasic).

Tiphia affinis Malloch

Bull. Ill. State Nat. Hist. Surv., Vol. XIII, Art. I, October, 1918, p. 19.

Lectotype.—♂: Galena, Illinois, July 8, 1917 (C. A. Hart and J. R. Malloch).

Lectoallotype.—♀: Galena, Illinois, July 8, 1917 (C. A. Hart and J. R. Malloch).

Paratypes.—♂: Galena, Illinois, July 8, 1917 (C. A. Hart and J. R. Malloch); Dubois, Illinois, August 10, 1917 (J. R. Malloch).

Head of one of the paratypes is missing.

Tiphia arida Malloch

Bull. Ill. State Nat. Hist. Surv., Vol. XIII, Art. 1, October, 1918, p. 20.

Type.—♀: Havana, Illinois, Devil's Hole, August 13, 1903 (C. A. Hart). Acc. No. 35530.

Tiphia aterrima Malloch

Bull. Ill. State Nat. Hist. Surv., Vol. XIII, Art. 1, October, 1918, p. 19.

Lectotype.—♀: Urbana, Illinois, September 6, 1891 (C. A. Hart). Acc. No. 17424.

Paratypes.—♀: Urbana, Illinois, September 6, 1891 (C. A. Hart). Acc. No. 17424.

Tiphia clypeolata Malloch

Bull. Ill. State Nat. Hist. Surv., Vol. XIII, Art. 1, October, 1918, p. 16.

Paratype.—♀: Dubois, Illinois, August 10, 1917 (J. R. Malloch).

Tiphia conformis Malloch

Bull. Ill. State Nat. Hist. Surv., Vol. XIII, Art. 1, October, 1918, p. 22.

Lectotype.—♂: Quincy, Illinois, on thistles, August 13, 1889 (C. A. Hart). Hart Acc. No. 554.

Lectoallotype.—♀: Quincy, Illinois, on thistles, August 13, 1889 (C. A. Hart). Hart Acc. No. 554.

Paratype.—♀: Brownsville, Texas, November 24, 1911 (C. A. Hart).

Lectoallotype has abdomen missing. The male has been selected as the lectotype because of the poor condition of the single female from the "Type locality" of Quincy.

Tiphia inaequalis Malloch

Bull. Ill. State Nat. Hist. Surv., Vol. XIII, Art. 1, October, 1918, p. 22.

Lectotype.—♂: Dubois, Illinois, August 9, 1917 (J. R. Malloch).
Paratypes.—♂: Dubois, Illinois, August 9, 1917 (J. R. Malloch).

Tiphia punctata var. **intermedia** Malloch

Bull. Ill. State Nat. Hist. Surv., Vol. XIII, Art. 1, October, 1918, p. 21.
Lectotype.—♀: Carlinville, Illinois (C. Robertson).

Tiphia robertsoni Malloch

Bull. Ill. State Nat. Hist. Surv., Vol. XIII, Art. 1, October, 1918, p. 23.
Lectotype.—♀: Carlinville, Illinois, August (C. Robertson).
Paratypes.—♀: Urbana, Illinois, July 23, 1891 (McElfresh and C. A. Hart); Urbana, Illinois, September 9, 1892 (Kahl); Urbana, Illinois, August 30, 1914; Muncie, Illinois, September 7, 1914; Alto Pass, Illinois, August 13, 1891 (Shiga and C. A. Hart); Falls Church, Virginia, September 6-10 (N. Banks). Acc. Nos. 17000, 17216 and 20243.

Tiphia rugulosa Malloch

Bull. Ill. State Nat. Hist. Surv., Vol. XIII, Art. 1, October, 1918, p. 15.
Lectotype.—♂: Urbana, Illinois, University Forestry, November 10, 1915 (J. R. Malloch).
Lectoallotype.—♀: Homer, Illinois, July 20, 1907 (C. A. Hart).
Paratype.—♀: Urbana, Illinois, University grounds, June 25, 1888 (J. Marten and C. A. Hart). Acc. No. 14512.

Tiphia similis Malloch

Bull. Ill. State Nat. Hist. Surv., Vol. XIII, Art. 1, October, 1918, p. 18.
Lectotype.—♂: Waukegan, Illinois, August 25, 1917 (J. R. Malloch).
Paratype.—♂: Cherry Valley, Illinois, August 17, 1883. Acc. No. 3960.

Tiphia subcarinata Malloch

Bull. Ill. State Nat. Hist. Surv., Vol. XIII, Art. 1, October, 1918, p. 15.
Paratype.—♂: Grand Junction, Michigan, July 15, 1914 (C. A. Hart).

Tiphia texensis Malloch

Bull. Ill. State Nat. Hist. Surv., Vol. XIII, Art. 1, October, 1918, p. 20.
Cotype.—♀: Dallas, Texas.

Tiphia tuberculata Malloch

Bull. Ill. State Nat. Hist. Surv., Vol. XIII, Art. 1, October, 1918, p. 14.
Lectotype.—♂: Meredosia, Illinois, by sweeping foliage of blackjack oak along margin of a sand pit, August 22, 1917, (T. H. Frison, C. A. Hart and J. R. Malloch).
Lectoallotype.—♀: Meredosia, Illinois, by sweeping foliage of black-jack oak along margin of a sand pit, August 22, 1917 (T. H. Frison, C. A. Hart and J. R. Malloch).
Paratypes.—♂ and ♀: Meredosia, Illinois, by sweeping foliage of blackjack oak along margin of a sand pit, August 22, 1917 (T. H. Frison, C. A. Hart and J. R. Malloch); Dubois, Illinois, August 8, 1917; Havana, Illinois, August 30-31, 1917; Bluffs, Illinois, August 19, 1917 (J. R. Malloch and C. A. Hart). Slide No. 3142.
Genitalia of one male paratype mounted in balsam on a slide.

Family SPHECIDAE

Ammophila argentata Hart

Bull. Ill. State Lab. Nat. Hist., Vol. VII, Art. VII, Part III, January, 1907, p. 266.
Lectotype.—♀: Topeka, Illinois, Devil's Neck, June 7, 1905 (C. A. Hart).
Paratype.—♀: Havana, Illinois, Devil's Hole, August 22, 1906 (C. A. Hart). Acc. No. 35693.
Paratype has head missing. Now placed in the genus *Sphex* Linnaeus.

Family ANDRENIDAE

Andrena (Micrandrena) amplificata Cockerell
Can. Ent., Vol. XLII, No. 11, November 11, 1910, p. 368.
Paratype.—♀: Steamboat Springs, Colorado, May 27 (T. D. A. Cockerell).

Andrena banksi Malloch
Bull. Brook, Ent. Soc., Vol. XII, No. 4, October, 1917, p. 89.
Type.—♀: Fedor, Texas, March 13, 1903 (Birkmann).
Allotype.—♂: Great Falls, Maryland, April 27 (N. Banks).
Paratypes.—♂: Maryland, near Plummer's Island, on flowers of *Prunus*, April 22, 1917 (H. L. Viereck); Great Falls, Maryland, April 27 (N. Banks).

Andrena costillensis Viereck and Cockerell
Proc. U. S. Nat. Mus., Vol. 48, No. 2064, November 28, 1914, p. 50.
Paratype.—♀: Eldora, Colorado, at flowers of *Grindelia*, August 19, 1910 (T. D. A. and W. R. Cockerell).

Andrena flexa Malloch
Bull. Brook, Ent. Soc., Vol. XII, No. 4, October, 1917, p. 92.
Type.—♂: Dubois, Illinois, on flowers of raspberry or *Crataegus*, May 15, 1916 (C. A. Hart and J. R. Malloch).
Paratypes.—♀: Dubois, Illinois, on flowers of raspberry and *Crataegus*, May 15, 1916 (C. A. Hart and J. R. Malloch); Dubois, Illinois, on flowers of raspberry and *Crataegus*, May 24, 1917 (C. A. Hart and J. R. Malloch).

Andrena lappulae Cockerell
Bull. Amer. Mus. Nat. Hist., Vol. XXII, Art. XXV, 1906, p. 437.
Paratype.—♂: Florissant, Colorado, on flowers of *Lappula floribunda*, July 19 (T. D. A. Cockerell).
Labeled by author as a cotype.

Andrena micranthrophila Cockerell
Bull. Amer. Mus. Nat. Hist., Vol. XXII, Art. XXV, 1906, p. 432.
Paratype.—♂: Colorado, east of Lake George, on flowers of *Chamaerhodos erectus*, June 18 (T. D. A. Cockerell).
Labeled by author as a cotype.

Andrena regularis Malloch
Bull. Brook. Ent. Soc., Vol. XII, No. 4, October, 1917, p. 91.
Paratype.—♂: Ithaca, New York, May 19, 1914. Slide No. 3259.
Genital structures of male paratype only mounted in balsam on a slide.

Family HALICTIDAE

Halictus euryceps Ellis
Ent. News, Vol. XXV, No. 3, March, 1914, p. 98.
Paratypes.—♀: Beulah, New Mexico, at flowers of *Polemonium*, August 25, 1899 (W. Porter) and end of August (T. D. A. Cockerell).
Labeled by author as cotypes.

Family MEGACHILIDAE

Megachile willughbiella kudiensis Cockerell
Ann. Mag. Nat. Hist., Ser. 9, Vol. XIII, No. 77, May, 1924, p. 529.
Paratype.—♀: Kudia River, Amagus, Siberia, July, 1923 (T. D. A. Cockerell).
Labeled by author as cotype.

Family COLLETIDAE

Caupolicana malvacearum Cockerell
Ann. Mag. Nat. Hist., Ser. 9, Vol. 17, No. 98, February, 1926, p. 214.
Paratype.—♂: Tingo, Peru, August 18 (T. D. A. Cockerell).

TYPES IN THE ANDREAS BOLTER COLLECTION OF INSECTS

(Natural History Museum, University of Illinois)

ORDER COLEOPTERA

Family CLERIDAE

Priocera lecontei Wolcott
Field Mus. Nat. Hist., Zool. Ser., Vol. VII, May, 1910, p. 356.
Type.—sex?: California.

ORDER LEPIDOPTERA

Family HEPIALIDAE

Hepialus confusus Hy. Edwards
Papilio, Vol. IV, Nos. 7 and 8, September, 1884, p. 122.
Type.—♀: Sitka, Alaska.
In fair condition. The specimen is labeled simply "Sitkha".

Family GLYPHIPTERYGIDAE

Thia extranea Hy. Edwards
Ent. Amer., Vol. III, No. 10, January, 1888, p. 181.
Cotype.—♂: Los Angeles, Southern California, on flowers, April, 1879 (A. J. Bolter).
The genotype of *Thia* Hy. Edwards (monobasic). Now placed in the genus *Thelethia* Dyar.

Family PYRALIDAE

Zophodia epischnioides Hulst
Can. Ent., Vol. XXXII, No. 6, June, 1900, p. 173.
Cotype.—♂: Las Vegas, New Mexico.
No locality or number of specimens in type series stated by Hulst in original description. Labeled "Type" in handwriting of Hulst.

Family GEOMETRIDAE

Diastictis speciosa Hulst
Trans. Amer. Ent. Soc., Vol. XXIII, September, 1896, p. 332.
Cotype.—♀: Hot Springs, New Mexico, 7000 feet altitude, August.
Now placed in the genus *Meris* Hulst.

Hydriomena neomexicana Hulst
Trans. Amer. Ent. Soc., Vol. XXIII, August, 1886, p. 285.

Cotype.—♀: **Colorado (Bruce).**
Now placed in the genus *Camptogramma* Stephens.

Plemyria georgii Hulst
Trans. Amer. Ent. Soc., Vol. XXIII, August, 1896, p. 280.
Cotype.—♂: Victoria, Vancouver.
Now placed in the genus *Thera* Stephens.

Selidosema albescens Hulst
Trans. Amer. Ent. Soc., Vol. XXIII, September, 1896, p. 355.
Type.—♂: Seattle, Washington.

Sympherta julia Hulst
Trans. Amer. Ent. Soc., Vol. XXIII, September, 1886, p. 338.
Cotype?—♂: Duluth, Minnesota.
Described from a number of specimens from various collectors and localities. This male is labeled "Type" in the handwriting of Hulst, but this locality is not given in the original description. This species is now considered as synonymous with *loricaria* Eversmann and placed in the genus *Dysmigia* Warren.

Family NOTODONTIDAE

Heterocampa superba Hy. Edwards
Papilio, Vol. IV. Nos. 7 & 8, September, 1884, p. 121.
Type.—♀: San Antonio, Texas.
The specimen is labeled simply "Tex.". Now considered as a synonym of *Heterocampa subrotata* Harvey.

Macrurocampa dorothea Dyar
Can. Ent., Vol. XXVIII, No. 7, July, 1896, p. 176.
Type.—♀: Las Vegas, New Mexico.
Now placed in the genus *Fentonia* Butler.

Family NOCTUIDAE

Pseudalypia crotchii var. **atrata** Hy. Edwards
Papilio, Vol. IV, Nos. 7 and 8, September, 1884, p. 121.
Type.—♀:
In fair condition. This specimen is very probably the type, since this species was described from the Bolter Collection and no type exists in the Henry Edwards Collection. Contrary to the original description, the specimen is a female and not a male as stated and it bears a locality label "San Diego, April 23, '79, S. California" instead of "Los Angeles". Now considered as a form of *Pseudalypia crotchii* Hy. Edwards.

Family ARCTIIDAE

Halisidota significans Hy. Edwards
Ent. Amer., Vol. III, No. 10, January, 1888, p. 182.
Type.—♂: Las Vegas, New Mexico.
The specimen is labeled simply "N. Mex.". Now placed in the genus *Aemilia* Kirby and considered as a subspecies of *roseata* Walker.

TYPES IN THE A. D. MACGILLIVRAY COLLECTION OF TENTHREDINOIDEA

(Department of Entomology, University of Illinois)

Family Xyelidae

Macroxyela bicolor MacGillivray
Can. Ent., Vol. XLIV, No. 10, October, 1912, p. 294.
Type.—♂: Columbus, Ohio (J. S. Hine).
Paratype.—♂: Columbus, Ohio (J. S. Hine).
Macroxyela distincta MacGillivray
Can. Ent., Vol. XLIV, No. 10, October, 1912, p. 295.
Type.—♀: Ithaca, New York, April 13, 1897 (J. C. Martin).
Allotype.—♂: Ithaca, New York, April 13, 1897 (J. O. Martin).
Paratypes.—♀: Ithaca. New York, April 28, 1897 (J. O. Martin).
Macroxyela obsoleta MacGillivray
Can. Ent., Vol. XLIV, No. 10, October, 1912, p. 294.
Type.—♀: Ithaca, New York, April 13, 1897 (J. O. Martin).
Xyela intrabilis MacGillivray
Bull. Brooklyn Ent. Soc., Vol. XVIII, No. 2, May, 1923, p. 53.
Type.—♂: Wyandanch, Long Island, New York, April 22, 1917 (F. M. Schott).

Family Pamphiliidae

Acantholyda modesta MacGillivray
Bull. Brooklyn Ent. Soc., Vol. XVIII, No. 2, May, 1923, p. 53.
Type.—♀: Wyandanch, Long Island, New York, July 4, 1917 (F. M. Schott).
Caenolyda onekama MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 8.
Type.—♀: Onekama, Michigan, on shore of Lake Michigan, July 17, 1914 (A. D. MacGillivray).
Cephaleia criddlei MacGillivray
Can. Ent., Vol. XLIV, No. 10, October, 1912, p. 296.
Type.—♀: Aweme, Manitoba, Canada, July 31, 1906 (N. Criddle).
Cephaleia dissipator MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, pp. 8-9.
Type.—♂: Guelph, Ontario, Canada, No. 839 (T. D. Jarvis).
Paratype.—♂: Guelph, Ontario, Canada, No. 839 (T. D. Jarvis).
In fair condition.
Cephaleia distincta MacGillivray
Can. Ent., Vol. XLIV, No. 10, October, 1912, p. 296.
Type.—♂: Mount Washington, New Hampshire (A. T. Slosson).
Cephaleia jenseni MacGillivray
Can. Ent., Vol. XLIV, No. 10, October, 1912, p. 297.
Type.—♀: Eagle Bend, Minnesota, July, 1909 (J. P. Jensen).
Itycorsia angulata MacGillivray
Can. Ent., Vol. XLIV, No. 10, October, 1912, p. 295.

Type.—♀: Axton, New York, June 12-22, 1901 (C. O. Houghton and A. D. MacGillivray).
Paratype.—♀: Wallingford, Connecticut, July 7, 1911 (J. K. Lewis).

Itycorsia balanata MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 18.
Type.—♀: Mary's Peak, Corvallis, Oregon (Siler).

Itycorsia balata MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 18.
Type.—♀: Mary's Peak, Corvallis, Oregon (Nelson).

Itycorsia ballista MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 19.
Type.—♀: Corvallis, Oregon, May 5, 1901.
Abdomen partially missing.

Pamphilius dentatus MacGillivray
Can. Ent., Vol. XLIV, No. 10, October, 1912, p. 297.
Type.—♀: Wilbraham, Massachusetts, June 10, 1902 (J. O. Martin).
Lectoallotype.—♂: Hamden, Connecticut, May 24, 1910, (B. H. Walden).
Paratypes.—♂ and ♀: Hamden, Connecticut, on blackberry, May 24, 1910 (B. H. Walden); Wallingford, Connecticut, June 8, 1911 (B. H. Walden).

Pamphilius fletcheri MacGillivray
Can. Ent., Vol. XLIV, No. 10, October, 1912, p. 298.
Paratype.—♀: St. John, New Brunswick, larvae on leaves of raspberry, 1899.

Pamphilius fortuitus MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 27.
Type.—♀: Olympia, Washington, July 5, 1896 (T. Kincaid).
Paratype.—♀: Olympia, Washington, July 5, 1896 (T. Kincaid).

Pamphilius persicum MacGillivray
Can. Ent., Vol. XXXIX, No. 9, September, 1907, p. 308.
Type.—♀: Yalesville, Connecticut, on peach, June 14, 1906 (B. H. Walden).
Spelling of specific name emended by MacGillivray from *persicum* to *persicus*.

Pamphilius transversa MacGillivray
Can. Ent., Vol. XLIV, No. 10, October, 1912, p. 297.
Type.—♂: Franconia, New Hampshire (A. T. Slosson).
In original description it is stated that the female is described, but the type is a male.

Pamphilius unalatus MacGillivray
Bull. Brooklyn Ent. Soc., Vol. XV, No. 4, October, 1920, p. 112.
Type.—♀: Ithaca, New York, May 20, 1919, reared (H. Yuasa, 183-1).

Family TENTHREDINIDAE

Acordulecera maculata MacGillivray
Can. Ent., Vol. XL, No. 5, May, 1908, p. 169.
Type.—♀: Slaterville—Caroline, New York, June 14, 1904.
Lectoallotype.—♂: Caroline-Harford, New York, June 15, 1904.
Paratypes.—♀ and ♂: McLean, New York, July 2-3, 1904, and Caroline—Harford, New York, June 15, 1904.
The type locality is reported as "Ithaca, N. Y." in the original description.

Acordulecera marina MacGillivray
Can. Ent., Vol. XL, No. 5, May, 1908, p. 170.
Type.—♂: Salineville, Ohio.

Acordulecera maura MacGillivray
Can. Ent., Vol. XL, No. 5, May, 1908, p. 168.
Type.—♀: North Mountain, Pennsylvania, June 2, 1897
Paratype.—♀: Ames, Iowa, June 11, 1897.

Acordulecera maxima MacGillivray
Can. Ent., Vol. XL, No. 5, May, 1908, p. 168.
Type.—♀: Ithaca, New York, May 26, 1899.

Acordulecera media MacGillivray
Can. Ent., Vol. XL, No. 5, May, 1908, p. 168.
Type.—♀: Algonquin, Illinois (W. A. Nason).

Acordulecera meleca MacGillivray
Bull. Brooklyn Ent. Soc., Vol. XVI, No. 1, February, 1921, p. 23.
Type.—♂: Ithaca, New York, bred, May 10, 1919, No. 196-2-1 (H. Yuasa).
Paratype.—♂: Ithaca, New York, bred, August 19, 1918, No. 196-2-1 (H. Yuasa).

Acordulecera mellina MacGillivray
Can. Ent., Vol. XL, No. 5, May, 1908, p. 169.
Type.—♀: Mount Washington, New Hampshire (A. T. Slosson).

Acordulecera minima MacGillivray
Can. Ent., Vol. XL, No. 5, May, 1908, p. 168.
Type.—♀: Edge Hill, Pennsylvania, May 13, 1900 (G. M. Greene).
Paratype.—♀: Ithaca, New York, June 12, 1891.

Acordulecera minuta MacGillivray
Can. Ent., Vol. XL, No. 5, May, 1908, p. 169.
Type.—♀: Ames, Iowa, June, 1897 (E. D. Ball).
Paratype.—♀: Ames, Iowa, June, 1897 (E. D. Ball).

Acordulecera mixta MacGillivray
Can. Ent., Vol. XL, No. 5, May, 1908, p. 169.
Type.—♀: Columbia, Missouri, May 19, 1905 (C. R. Crosby).
Lectoallotype.—♂: Ashbourne, Pennsylvania, May 24, 1900 (H. L. Viereck).
Paratypes.—♀ and ♂: Ithaca, New York, July 2, 1902; Salineville, Ohio; Delaware County, Pennsylvania, May 25, 1905 (Cresson); Ames, Iowa. June 23, 1896 (E. D. Ball).
The lectoallotype was labeled by MacGillivray as a paratype.

Acordulecera munda MacGillivray
Can. Ent., Vol. XL, No. 5, May, 1908, p. 169.
Type.—♀: Ithaca, New York, bred, February 26, 1898 (C. Young).
Paratype.—♀: Ithaca, New York, February 28, 1898 (C. Young).

Acordulecera musta MacGillivray
Bull. Brooklyn Ent. Soc., Vol. XVI, No. 1, February, 1921, p. 23.
Type.—♂: Ithaca, New York, bred, May 29, 1919, No. 144-5-1 (H. Yuasa).

Allantus universus MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 6.
Type.—♀: Highlands, North Carolina, September, 1906 (F. Sherman).
Paratype.—♀: Highlands, North Carolina, September, 1906 (F. Sherman).

Amauronematus vacalus MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 6.
Type.—♀: Corvallis, Oregon, May 13 (F. M. McE).

Amauronematus vacivus MacGillivray
Journ. N. Y. Ent. Soc., Vol. XXIX, No. 1, March, 1921, p. 28.
Type.—♂: Orono, Maine, August 19, 1913, Sub. 61.

Amauronematus valerius MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 6.
Type.—♂: Hood River, Oregon, August 2, 1914 (L. Childs).

Amauronematus vanus MacGillivray
Journ. N. Y. Ent. Soc., Vol. XXIX, No. 1, March, 1921, p. 27.
Type.—♀: Orono, Maine, July 26, 1913, Sub. 133.

Amauronematus venaticus MacGillivray
Journ. N. Y. Ent. Soc., Vol. XXIX, No. 1, March, 1921, p. 29.
Type.—♂: Orono, Maine, July 20, 1913, Sub. 6.

Amauronematus veneficus MacGillivray
Journ. N. Y. Ent. Soc., Vol. XXXI, No. 4,, December, 1923, p. 169.
Type.—♀: Katmai, Alaska, June, 1917 (J. S. Hine).

Amauronematus venerandus MacGillivray
Journ. N. Y. Ent. Soc., Vol. XXIX, No 1, March, 1921, p. 30.
Type.—♂: Orono, Maine, Sub. 27.

Amauronematus ventosus MacGillivray
Journ. N. Y. Ent. Soc., Vol. XXXI, No. 4, December, 1923, p. 169.
Type.—♀: Valdez, Alaska, June 4, 1919 (J. S. Hine).

Amauronematus verbosus MacGillivray
Journ. N. Y. Ent. Soc., Vol. XXIX, No. 1, March, 1921, p. 29.
Type.—♀: Orono, Maine, Sub. 162.

Amauronematus veridicus MacGillivray
Journ. N. Y. Ent. Soc., Vol. XXXI, No. 4, December, 1923, p. 170.
Type.—♀: Katmai, Alaska, July, 1917 (J. S. Hine).

Amauronematus vescus MacGillivray
Journ. N. Y. Ent. Soc., Vol. XXIX, No. 1, March, 1921, p. 30.
Type.—♀: Orono, Maine, Sub. 112.
Paratypes.—♀: Orono, Maine, Sub. 112.

Amauronematus visendus MacGillivray
Journ. N. Y. Ent. Soc., Vol. XXIX, No. 1, March, 1921, p. 28.
Type.—♀: Orono, Maine, Sub. 29.
Lectoallotype.—♂: Orono, Maine, Sub. 16.
The lectoallotype was labeled by MacGillivray as a paratype.

Aphanisus lobatus MacGillivray
Can. Ent., Vol. XL, No. 8, August, 1908, p. 295.
Type.—♀: Ormond, Florida (A. T. Slosson).
The genotype of *Aphanisus* MacGillivray (original designation).

Aphanisus muricatus MacGillivray
Can. Ent., Vol. XL, No. 8, August, 1908, p. 296.
Type.—♀: Ithaca, New York, May 3, 1895.

Aphanisus nigritus MacGillivray
Can. Ent., Vol. XL, No. 8, August, 1908, p. 296.
Type.—♀: Riverton, New Jersey, May 1, 1898 (H. L. Viereck).

Aphanisus obsitus MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 7.
Type.—♀: Moscow, Idaho (J. M. Aldrich).

Aphanisus occiduus MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 7.
Type.—♀: Juliaetta, Idaho, May 7, 1899 (J. M. Aldrich).

Aphanisus odoratus MacGillivray
Can. Ent., Vol. XL, No. 8, August, 1908, p. 296.
Type.—♀: Ithaca, New York, May 11, 1898.

Aphanisus parallelus MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 7.
Type.—♀: Colorado (C. F. Baker).

Astochus aldrichi MacGillivray
Can. Ent., Vol. XLVI, No. 4, April, 1914, p. 137.
Type.—♀: Juliaetta, Idaho (J. M. Aldrich).
Transferred by Rohwer (1918) to the genus *Laurentia* Costa.

Astochus fletcheri MacGillivray
Can. Ent., Vol. XLVI, No. 3, March, 1914, p. 108.
Type.—♀: Kaslo, British Columbia, May 28, 1906 (J. Fletcher).
The genotype of *Astochus* MacGillivray (original designation).
Transferred by Rohwer (1918) to the genus *Laurentia* Costa and synonymized as *Laurentia edwardsii* var. *ruficorna* (MacGillivray).

Blennocampa abjecta MacGillivray
Bull. Brooklyn Ent. Soc., Vol. XVI, No. 1, February, 1921. p. 22.
Type.—♀: Ithaca, New York, bred, August, 1917, No. 71-1 (H. Yuasa).

Blennocampa abnorma MacGillivray
Can. Ent., Vol. XL, No. 8, August, 1908, p. 296.
Type.—♂: Ithaca, New York, April 10, 1897.

Blennocampa absona MacGillivray
Bull. Brooklyn Ent. Soc., Vol. XVI, No. 1, February, 1921, p. 22.
Type.—♀: Orono, Maine, bred, on leaves of *Oenothera*, August 12, 1913, Sub. 186.
Lectoallotype.—♂: Orono, Maine, bred, on leaves of *Oenothera*, August 12, 1913, Sub. 186.
Paratype.—♀: Orono, Maine, bred, on leaves of *Oenothera*, August 12, 1913, Sub. 186.
The lectoallotype was labeled by MacGillivray as a paratype.

Blennocampa acuminata MacGillivray
Can. Ent., Vol. XL, No. 8, August, 1908, p. 297.
Type.—♀: Chicopee, Massachusetts, April 26, 1897 (J. O. Martin).

Blennocampa adusta MacGillivray
Can. Ent., Vol. XL, No. 8, August, 1908, p. 297.
Type.—♀: Wellesley, Massachusetts, April 21, 1891 (A. P. Morse).

Blennocampa amara MacGillivray
Can. Ent., Vol. LV, No. 7, July, 1923, p. 161.
Type.—♀: Edmonton, Alberta, Canada, May 21, 1917 (F. S. Carr).

Blennocampa angulata MacGillivray
Can. Ent., Vol. XL, No. 8, August, 1908, p. 297.
Type.—♀: Wellesley, Massachusetts, April 26, 1892 (A. P. Morse).

Blennocampa antennata MacGillivray
Can. Ent., Vol. XL, No. 8, August, 1908, p. 296.
Type.—♀: Durham, New Hampshire (W. and F.).

Blennocampa aperta MacGillivray
Can. Ent., Vol. XL, No. 8, August, 1908, p. 297.
Type.—♀: West Haven, Connecticut, April 25, 1905 (E. B. Whittlesey).

Blennocampa atrata MacGillivray
Can. Ent., Vol. XXV, No. 10, October, 1893, p. 239.
Type.—♀: Olympia, Washington, May 7, 1893 (T. Kincaid).

Blennocampa typicella MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 8.
Type.—♂: Corvallis, Oregon, March 14, 1915 (L. Childs).

Caliroa labrata MacGillivray
Can. Ent., Vol. XLI, No. 10, October, 1909, p. 360.
Type.—♂: Mountains near Claremont, California (C. F. Baker).

Caliroa lacinata MacGillivray
Can. Ent., Vol. XLI, No. 10, October, 1909, p. 357.
Type.—♀: Algonquin, Illinois, June 8, 1894 (W. A. Nason).

Caliroa lata MacGillivray
Can. Ent., Vol. XLI, No. 10, October, 1909, p. 361.
Type.—♀: Ithaca, New York, July 22, 1890.

Caliroa laudata MacGillivray
Can. Ent., Vol. XLI, No. 10, October, 1909, p. 356.
Type.—♀: Vancouver, British Columbia, June 19, 1903.

Caliroa lineata MacGillivray
Can. Ent., Vol. XLI, No. 10, October, 1909, p. 350.
Type.—♀: Columbia, Missouri, July 15, 1905 (C. R. Crosby).

Caliroa liturata MacGillivray
Can. Ent., Vol. XLI, No. 10, October, 1909, p. 349.
Lectotype.—♀: Florida (A. T. Slosson).

Paratype.—♀: Florida (A. T. Slosson).

Both species were mounted upon the same card point by MacGillivray and labeled "Type". One specimen remounted.

Caliroa lobata MacGillivray

Can. Ent., Vol. XLI, No. 10, October, 1909, p. 355.

Type.—♀: Oswego, New York, July 25, 1895 (C. S. Sheldon).

Caliroa lorata MacGillivray

Can. Ent., Vol. XLI, No. 10, October, 1909, p. 352.

Type.—♀: Mount Tom, Massachusetts, July 16, 1898 (A. P. Morse).

Caliroa loricata MacGillivray

Can. Ent., Vol. XLI, No. 10, October, 1909, p. 351.

Type.—♀: Columbia, Missouri, September 2, 1905 (C. R. Crosby).

Caliroa lunata MacGillivray

Can. Ent., Vol. XLI, No. 10, October, 1909, p. 353.

Type.—♀: Ithaca, New York, May 27, 1890.

Caliroa nortonia MacGillivray

Can. Ent., Vol. XXVI, No. 11, November, 1894, p. 324.

Type.—♂: Millersville, McLean, New York, May 30, 1890.

Transferred to the genus *Phrontosoma* MacGillivray in 1908 and the specific name emended to *nortoni*.

Ceratulus spectabilis MacGillivray

Can. Ent., Vol. XL, No. 12, December, 1908, p. 454.

Paratypes.—♀ and ♂: Dallas, Texas, bred from larvae on *Cissus incisa*, August 6—October 1, 1908, Hunter No. 1619 (E. S. Tucker).

The genotype of *Ceratulus* MacGillivray (original designation and monobasic).

Cimbex americana var. **nortoni** MacGillivray *

State Geol. Nat. Hist. Surv. Conn., Bull. 22, 1916, p. 104.

Type.—♀: Ithaca, New York, June 3, 1903.

Paratype.—♀: Ithaca, July 28, 1897.

Claremontia typica Rohwer

Can. Ent., Vol. XLI, No. 11, November, 1909, p. 397.

Cotypes.—♀ and ♂: Mountains near Claremont, California (C. F. Baker).

The genotype of *Claremontia* Rohwer (original designation and monobasic).

Cockerellonis occidentalis MacGillivray

Can. Ent., Vol. XL, No. 10, October, 1908, p. 365.

Type sex? Ruidosa Creek, New Mexico, 6,600 feet elevation, on fronds of *Pteris aquilina*, July 1 (E. O. Wooton, 8).

The sex of the type is not indicated in the original description and the abdomen of the type is missing. The genotype of *Cockerellonis* MacGillivray (original designation). Synonymized by Rohwer (1911) as *Eriocampidea arizonensis* Ashmead.

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* This variety was described without the customary statement that it was new. It is proceded by an asterisk, which according to a statement on page 15 of the same publication means that it was "originally described from Connecticut". At the orginal place of publication (p. 104) the only locality given is "Connecticut (E. [dward] N. [orton])" but reference is made to the specimen figured as figure 1 plate xii of Howard's Insect Book. The specimen figured by Howard is in the National Museum and was reared by H. G. Dyar, under his number 2D, from larvae collected at Boxbury, Mass. This specimen was probably never studied by MacGillivray nor is it probable that the specimens collected by Norton were before MacGillivray when he made his Key to the forms of *Cimbex*. It seems better, therefore, to consider the specimen from Ithaca, N. Y., which was labeled by MacGillivray as type to be the type of his variety even though it does not agree with the only locality given in the only place of publication. To do otherwise would make it impossible to have an acceptable type for the variety. S. A. ROHWER.

Craterocercus cervinus MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 9.
Type.—♀: Durham, New Hampshire, 1397 (Weed and Fiske).
Paratype.—♀: Durham, New Hampshire, 1397 (Weed and Fiske).
The paratype, labeled as such by MacGillivray, has no locality label.

Craterocercus circulus MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 9.
Type.—♀: Lake Forest, Illinois (J. G. Needham).

Craterocercus cordleyi MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 9.
Type.—♀: Corvallis, Oregon, May 6.

Craterocercus infuscatus MacGillivray
State Geol. Nat. Hist. Surv. Conn., Bull. 22, 1916, p. 106.
Type.—♀: Ithaca, New York.
Now placed in the genus *Priophorus* Dahlbom.

Dimorphopteryx desidiosus MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 10.
Type.—♀ North Fork of Swannanoa, Black Mountains, North Carolina, May.

Dimorphopteryx enucleatus MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 10.
Type.—♀: Franconia, New Hampshire (A. T. Slosson).

Dimorphopteryx ithacus MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 10.
Type.—♀: Ithaca, New York, June 28, 1898.

Dimorphopteryx morsei MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 11.
Type.—♀: Sherborn, Massachusetts, July 25, 1904 (A. P. Morse).

Dimorphopteryx oronis MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 11.
Type.—♀: Orono, Maine, July 24, 1913.

Dimorphopteryx salinus MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 11.
Type.—♀: Salineville, Ohio.

Dimorphopteryx scopulosus MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 12.
Type.—♀: Fern Rock, Pennsylvania, June 9, 1905.

Dolerus acritus MacGillivray
Can. Ent. Vol. XL, No. 4, April, 1908, p. 130.
Type.—♀: McLean, New York, May 8, 1891.

Dolerus agcistus MacGillivray
Can. Ent., Vol. XL, No. 4, April, 1908, p. 129.
Type.—♀: Lake Forest, Illinois (J. G. Needham).
Paratype.—♀: Durham, New Hampshire, 1397 (W. & F.).

Dolerus apriloides MacGillivray
Can. Ent., Vol. XL, No. 4, April, 1908, p. 126.
Type.—♀: Ithaca, New York, June 19, 1897.

Dolerus borealis MacGillivray
Can. Ent., Vol. XXV, No. 10, October, 1893, p. 238.
Type.—♀: Olympia, Washington, May 22, 1892 (T. Kincaid).

Dolerus cohaesus MacGillivray
Can. Ent., Vol. XL, No. 4, April, 1908, p. 128.
Type.—♀: Otto, New York, July 19, 1882 (J. H. Comstock).

Dolerus colosericeus MacGillivray
Can. Ent., Vol. XL, No. 4, April, 1908, p. 125.
Type.—♀: St. Anthony Park, Minnesota, May 1, 1896 (R. H. Pettit).

Dolerus conjugatus MacGillivray
Can. Ent., Vol. XL, No. 4, April, 1908, p. 128.
Type.—♀: Fulton County, New York, June 1, 1901 (C. R. Crosby).
Paratypes.—♀ and ♂: Ithaca, New York, July, 1896, and July 9, 1904; Wellesley, Massachusetts, May 27, 1891 (A. P. Morse).
No males were specifically mentioned in the original description, but male specimens labeled as paratypes by MacGillivray were found in the collection. The locality "Ithaca, New York" is not mentioned in the original description.

Dolerus dysporus MacGillivray
Can. Ent., Vol. XL, No. 4, April, 1908, p. 128.
Type.—♀: Ithaca, New York, April 26, 1896.
Paratypes.—♀: Chicopee, Massachusetts, May 4, 1902 (J. O. Martin).

Dolerus graenicheri MacGillivray
Can. Ent., Vol. XLVI, No. 3, March, 1914, p. 107.
Type.—♀: Layton Park, Milwaukee County, Wisconsin, May 1, 1901 (S. Graenicher).

Dolerus icterus MacGillivray
Can. Ent., Vol. XL, No. 4, April, 1908, p. 127.
Type.—♀: Saranac Inn, New York, June 26, 1900 (J. G. Needham).

Dolerus inspectus MacGillivray
Can. Ent., Vol. XL, No. 4, April, 1908, p. 128.
Type.—♂: Ithaca, New York, July, 1896.

Dolerus inspiratus MacGillivray
Can. Ent., Vol. XLVI, No. 3, March, 1914, p. 105.
Type.—♀: New Haven, Connecticut, May 30, 1911 (A. B. Champlain)
Paratypes.—♀: New Haven, Connecticut, May 30, 1911 (A. B. Champlain); Eagle Bend, Minnesota, July, 1905 (J. P. Jensen).

Dolerus konowi MacGillivray
Can. Ent., Vol. XLVI, No. 3, March, 1914, p. 106.
Type.—♀: Olympia, Washington, June 20, 1893 (T. Kincaid).
Lectoallotype.—♂: Olympia, Washington, April 20, 1894 (T. Kincaid).
Paratype.—♂: Olympia, Washington, July 2, 1893 (T. Kincaid).
The lectoallotype was labeled by MacGillivray as a paratype.

Dolerus lesticus MacGillivray
Can. Ent., Vol. XLVI, No. 3, March, 1914, p. 105.
Type.—♀: Durham, New Hampshire, 2435 (Weed and Fiske); Hampton, New Hampshire, May 1, 1904 (S. A. Shaw).
Lectoallotype.—♂: Durham, New Hampshire, 2435 (Weed and Fiske); Hampton, New Hampshire, May 1, 1904 (S. A. Shaw).

Dolerus luctatus MacGillivray
Can. Ent., Vol. XL, No. 4, April, 1908, p. 127.
Type.—♀: Ithaca, New York, May 28, 1895.

Dolerus minusculus MacGillivray
Can. Ent., Vol. XL, No. 4, April, 1908, p. 126.
Type.—♀: Ithaca, New York, May 31, 1891.

Dolerus monosericeus MacGillivray
Can. Ent., Vol. XL, No. 4, April, 1908, p. 126.
Type.—♀: West Springfield, Massachusetts, April 26, 1896 (J. O. Martin).
Lectoallotype.—♂: West Springfield, Massachusetts, April 26, 1896 (J. O. Martin).
The lectoallotype was labeled by MacGillivray as a paratype. Antennae of the lectoallotype are missing.

Dolerus napaeus MacGillivray
Can. Ent., Vol. LV, No. 3, March, 1923, p. 65.
Type.—♀: Corvallis, Oregon, on college campus, May 10, 1914 (G. F. Mozette and Johnson).

Dolerus narratus MacGillivray
Can. Ent., Vol. LV, No. 3, March, 1923, p. 65.
Type.—♀: Mary's Peak, Corvallis, Oregon, May 14, (A. L. Lovett).
Lectoallotype.—♂: Mary's Peak, Corvallis, Oregon, May 23, (Zwicker).
Paratype.—♂: Mary's Peak, Corvallis, Oregon, May 23 (Zwicker).
The lectoallotype was labeled by MacGillivray as a paratype.

Dolerus nasutus MacGillivray
Can. Ent., Vol. LV, No. 3, March, 1923, p. 65.
Type.—♀: Corvallis, Oregon (Laura Hill).
Lectoallotype.—♂: Corvallis, Oregon, April 20, 1908 (Laura Hill).
Paratype.—♀: Renton, Washington, May 22, 1914 (H. F. Wilson).
The lectoallotype was labeled by MacGillivray as a paratype.

Dolerus nativus MacGillivray
Ins. Insc. Mens., Vol. XI, Nos. 1-3, 1923, p. 32.
Type.—♂: Entermille, Oregon, April 29, 1917 (Baker).

Dolerus nauticus MacGillivray
Ins. Insc., Mens., Vol. XI, Nos. 1-3, 1923, p. 35.
Type.—♀: Corvallis, Oregon (W. J. Kocken).

Dolerus necessarius MacGillivray
Ins. Insc. Mens., Vol. XI, Nos. 1-3, 1923, p. 35.
Type—♀: Kings Valley, Oregon, April 5, 1916 (A. L. Lovett).
Paratypes.—♀: Kings Valley, Oregon, April 5, 1916 (A. L. Lovett).

Dolerus necosericeus MacGillivray
Univ. Ill. Bull., Vol. 20, No. 50, August 13, 1923, p. 13.
Type.—♀: Orono, Maine, July 3, 1913.

Dolerus nectareus MacGillivray
Ins. Insc. Mens., Vol. XI, Nos. 1-3, 1923, p. 33.
Type.—♂: Entermille, Oregon, April 29, 1917 (Baker).

Dolerus nefastus MacGillivray
Can. Ent., Vol. LV, No. 3, March, 1923, p. 66.
Type.—♀: Corvallis, Oregon, April 20, 1908 (Laura Hill).
Paratype.—♀: Corvallis, Oregon, April 20, 1908 (Laura Hill).

Dolerus negotiosus MacGillivray
Journ. N. Y. Ent. Soc., Vol. XXXI, No. 4, December, 1923, p. 164.
Type.—♂: Savonoski, Naknek Lake, Alaska, July, 1919 (J. S. Hine).

Dolerus nemorosus MacGillivray
Journ. N. Y. Ent. Soc., Vol. XXXI, No. 4, December, 1923, p. 164.
Type.—♀: Katmai, Alaska, June, 1917 (J. S. Hine).

Dolerus neoagcistus MacGillivray
Bull. Brooklyn Ent. Soc., Vol. XVIII, No. 2, April, 1923, p. 55.
Type.—♀: Southfields, New York, May 3, 1914 (F. M. Schott).

Dolerus neoaprilis MacGillivray
Can. Ent., Vol. XL, No. 4, April, 1908, p. 126.
Type.—♀: Nebraska (F. Rauterberger).
In fair condition.

Dolerus neocollaris MacGillivray
Can. Ent., Vol. XL, No. 4, April, 1908, p. 127.
Type.—♂: Fulton, New York, April 27, (C. R. Crosby).
Lectoallotype.—♂: Ithaca, New York, April 23, 1896.
Paratype.—♀: Ithaca, New York, April 20, 1895.
The lectoallotype was labeled by MacGillivray as a paratype.

Dolerus neosericeus MacGillivray
Can. Ent., Vol. XL, No. 4, April, 1908, p. 125.
Type.—♀: Ithaca, New York.

Dolerus neostugnus MacGillivray
Bull. Brooklyn Ent. Soc., Vol. XVIII, No. 2, April, 1923, p. 55.
Type.—♀: Urbana, Illinois, April 12, 1898.
Paratype.—♀: Urbana, Illinois, April 12, 1898.

Dolerus nepotulus MacGillivray
Can. Ent., Vol. LV, No. 3, March, 1923, p. 68.
Type.—♂: Linn County, Oregon, May 17, 1913 (Lewis).

Dolerus nervosus MacGillivray
Ins. Insc. Mens., Vol. XI, Nos. 1-3, 1923, p. 31.
Type.—♀: Colorado Lake, Oregon, May 29 (E. V. Storm).

Dolerus nescius MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 12.
Type.—♀: Kendrick, Idaho, April 14, 1900 (J. M. Aldrich).

Dolerus nicaeus MacGillivray
Can. Ent., Vol. LV, No. 3, March, 1923, p. 68.
Type.—♀: Chilliwack, Cultis Lake, British Columbia, May 31 (F. C. Ewing).

Dolerus nidulus MacGillivray
Ins. Insc. Mens., Vol. XI, Nos. 1-3, 1923, p. 31.
Type.—♀: Corvallis, Oregon, May 16, 1916 (A. M. Scott).
In poor condition.

Dolerus nimbosus MacGillivray
Ins. Insc. Mens., Vol. XI, Nos. 1-3, 1923, p. 33.
Type.—♀: Eugene, Oregon, April 9, 1896.
Lectoallotype.—♂: Eugene, Oregon, April 9, 1896.
Paratypes.—♂ and ♀: Eugene, Oregon, April 9, 1896.
The lectoallotype was labeled by MacGillivray as a paratype.

Dolerus nivatus MacGillivray
Journ. N. Y. Ent. Soc., Vol. XXXI, No. 4, December, 1923, p. 164.
Type.—♀: Katmai, Alaska, July, 1917 (J. S. Hine).

Dolerus nocivus MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 12.
Type.—♀: Ames, Iowa, May 12, 1918 (H. A. Scullen).

Dolerus nocuus MacGillivray
Ins. Insc. Mens., Vol. XI, Nos 1-3, 1923, p. 34.
Type.—♀: Mary's Peak, Oregon, May 19, 1912 (L. G. Gentner).

Dolerus nominatus MacGillivray
Ins. Insc. Mens., Vol. XI, Nos 1-3, 1923, p. 34.
Type.—♀: Oregon.
MacGillivray in the original description of this species records the locality as "Oregon". The label on the specimen reads "? Oregon".

Dolerus novellus MacGillivray
Can. Ent., Vol. LV, No. 3, March, 1923, p. 67.
Type.—♀: Mary's Peak, Corvallis, Oregon, June 3, 1920 (Hardman).
In fair condition. The abdomen, hind wings, hind legs are mounted on a card point.

Dolerus novicius MacGillivray
Can. Ent., Vol. LV, No. 3, March, 1923, p. 67.
Type.—♀: Hood River, Oregon, July 28, 1914 (Childs).

Dolerus nugatorius MacGillivray
Can. Ent., Vol. LV, No. 3, March, 1923, p. 66.
Type.—♀: Pee Dee, Oregon, July 4, 1905 (Vincent).
Lectoallotype.—♂: Mary's Peak, Corvallis, Oregon, May 14 (A. L. Lovett).
The lectoallotype was labeled by MacGillivray as a paratype.

Dolerus numerosus MacGillivray
Can. Ent., Vol. LV, No. 3, March, 1923, p. 67.
Type.—♀: Corvallis, Oregon, May 3, 1912 (H. S. Walters).
Lectoallotype.—♂: Corvallis, Oregon, May 19, 1912 (H. S. Walters).
The lectoallotype was labeled by MacGillivray as a paratype.

Dolerus nummarius MacGillivray
Can. Ent., Vol. LV, No. 7, July, 1923, p. 159.

Type.—♀: Edmonton, Alberta, Canada, June 3, 1916 (F. S. Carr).
In the original description, due to a typographical error, the last sentence is incomplete. The specimen bears a label with the statement "near *tibialis* and *nervosus*", which is likely the information MacGillivray meant to give in the incompleted sentence.

Dolerus nummatus MacGillivray
Can. Ent., Vol. LV, No. 7, July, 1923, p. 159.
Type.—♀: Edmonton, Alberta, Canada, June 2, 1917 (F. S. Carr).

Dolerus nundinus MacGillivray
Can. Ent., Vol. LV, No. 7, July, 1923, p. 159.
Type.—♂: Edmonton, Alberta, Canada, June 6, 1917 (F. S. Carr).

Dolerus nuntius MacGillivray
Can. Ent., Vol. LV, No. 7, July, 1923, p. 158.
Type.—♀: Edmonton, Alberta, Canada, May 21, 1917 (F. S. Carr).

Dolerus nutricius MacGillivray
Can. Ent., Vol. LV, No. 7, July, 1923, p. 159.
Type.—♂: Edmonton, Alberta, Canada, June, 1917 (F. S. Carr).

Dolerus nyctelius MacGillivray
Journ. N. Y. Ent. Soc., Vol. XXXI, No. 4, December, 1923, p. 163.
Type.—♂: Kodiak, Alaska, June 10, 1917 (J. S. Hine).

Dolerus parasericeus MacGillivray
Can. Ent., Vol. XL, No. 4, April, 1908, p. 125.
Type.—♀: Ithaca, New York, June 17, 1897.

Dolerus plesius MacGillivray
Can. Ent., Vol. XL, No. 4, April, 1908, p. 129.
Type.—♀: Lake Forest, Illinois (J. G. Needham).

Dolerus polysericeus MacGillivray
Can. Ent., Vol. XL, No. 4, April, 1908, p. 125.
Type.—♀: May 11, 1895, Ithaca, New York.

Dolerus refugus MacGillivray
Can. Ent., Vol. XL, No. 4, April, 1908, p. 127.
Type.—♀: Ithaca, New York, May 1, 1895 (J. H. Comstock).
In fair condition.

Dolerus simulans Rohwer
Can. Ent., Vol. XLI, No. 1, January, 1909, p. 10.
Paratype.—♀: Florissant, Colorado, July 21, 1907 (S. A. Rohwer).

Dolerus stugnus MacGillivray
Can. Ent., Vol. XL, No. 4, April, 1908, p. 129.
Type.—♀: Ithaca, New York, June 28, 1898.

Dolerus tectus MacGillivray
Can. Ent., Vol. XLVI, No. 3, March, 1914, p. 104.
Type.—♀: New Haven, Connecticut, May 4, 1904, on *Salix* (H. L. Viereck).
Paratype.—♂: New Haven, Connecticut, May 4, 1904, on *Salix* (H. L. Viereck).
The paratypic male, labeled by MacGillivray, is not as such specifically mentioned in the original description.

Emphytus gemitus MacGillivray
Journ. N. Y. Ent. Soc., Vol. XXXI, No. 4, December, 1923, p. 163.
Type.—♀: Kodiak, Alaska, June 10, 1917 (J. S. Hine).

Emphytus gillettei MacGillivray
Fifteenth Rep. Colo. Exp. Sta., 1902, p. 113.
Type.—♀: Denver, Colorado, from strawberry, May 30, 1902 (S. A. Johnson).

Emphytus halesus MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 13.

Type.—♀: Corvallis, Oregon, May 13 (Goding).
Paratype.—♀: Corvallis, College Campus, Oregon, May 21, 1913 (Denny).

Emphytus haliartus MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 14.
Type.—♀: Corvallis, College Campus, Oregon, May 29, 1917 (A. L. Lovett).

Emphytus halitus MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 14.
Type.—♂: Freeport, Illinois, July 16, 1898 (J. G. Needham).

Emphytus haustus MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 14.
Type.—♂: Grand Island, New York, June 9, 1908 (M. C. Van Duzee).

Emphytus heroicus MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 14.
Type.—♀: Hamburg, New York, June 6, 1909 (M. C. Van Duzee).

Emphytus hiatus MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 15.
Type.—♀: Ithaca, New York, May, 1911.

Emphytus hiulcus MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 15.
Type.—♀: Colorado (C. F. Baker).

Emphytus hospitus MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 15.
Type.—♀: Hampton, New Hampshire, May 20, 1904 (S. A. Shaw).

Emphytus hyacinthus MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 16.
Type.—♀: Forest Hills, Massachusetts, May 18, 1917 (A. M. Wilcox).
Allotype.—♂: Forest Hills, Massachusetts, May 18, 1917 (A. M. Wilcox).

Emphytus yuasi MacGillivray
Psyche, Vol. XXVIII, No. 2, April, 1921, p. 31.
Type.—♀: Ithaca, New York, May 28, 1919, reared (H. Yuasa, 171-1).

Empria cadurca MacGillivray
Can. Ent., Vol. LV, No. 7, July, 1923, p. 158.
Type.—♀: Edmonton, Alberta, Canada, June 2, 1917 (F. S. Carr).
Lectoallotype.—♂: Edmonton, Alberta, Canada, June 2, 1917 (F. S. Carr)
Paratype.—♂: Edmonton, Alberta, Canada, June 2, 1917 (F. S. Carr).

Empria caeca MacGillivray
Can. Ent., Vol. XLIII, No. 9, September, 1911, p. 308.
Type.—♀: Ithaca, New York.
In fair condition.

Empria caetrata MacGillivray
Can. Ent., Vol. XLIII, No. 9, September, 1911, p. 305.
Type.—♀: Ames, Iowa, April 21, 1896 (E. D. Ball).

Empria calda MacGillivray
Can. Ent., Vol. XLIII, No. 9, September, 1911, p. 307.
Type.—♀: Durham, New Hampshire, June, 1904 (J. C. Bridwell).

Empria callida MacGillivray
Can. Ent., Vol. XLIII, No. 9, September, 1911, p. 306.
Type.—♀: Ithaca, New York, June 9, 1906.

Empria callosa MacGillivray
Can. Ent., Vol. XLIII, No. 9, September, 1911, p. 305.
Type.—♀: Ithaca (Slaterville-Caroline), New York, June 14, 1904.

Empria candidula MacGillivray
Can. Ent., Vol. XLIII, No. 9, September, 1911, p. 310.
Type.—♀: Ithaca, New York, May 25, 1895.

Empria canora MacGillivray
Can. Ent., Vol. XLIII, No. 9, September, 1911, p. 310.
Type.—♀: Sherborn, Massachusetts, May 30, 1895 (A. P. Morse).

Empria capillata MacGillivray
Can. Ent., Vol. XLIII, No. 10, October, 1911, p. 341.
Type.—♀: Peck, Idaho, April 8, 1900 (J. M. Aldrich).

Empria caprina MacGillivray
Can. Ent., Vol. XLIII, No. 9, September, 1911, p. 307.
Type.—♀: Ithaca, New York, May 22, 1898.
Male also described in original description, but no male so labeled found in collection.

Empria captiosa MacGillivray
Can. Ent., Vol. XLIII, No. 9, September, 1911, p. 308.
Type.—♀: Ames, Iowa, May 6, (E. D. Ball).

Empria carbasea MacGillivray
Can. Ent., Vol. XLIII, No. 10, October, 1911, p. 341.
Type.—♀: Olympia, Washington, April 15, 1896 (T. Kincaid).

Empria cariosa MacGillivray
Can. Ent., Vol. XLIII, No. 9, September, 1911, p. 309.
Type.—♀: Slaterville-Caroline, New York, June 14, 1904.

Empria casca MacGillivray
Can. Ent., Vol. XLIII, No. 9, September, 1911, p. 310.
Type.—♂: New Haven, Connecticut, May 24, 1905 (W. E. Britton).

Empria casta MacGillivray
Can. Ent., Vol. XLIII, No. 9, September, 1911, p. 308.
Type.—♀: Salineville, Ohio.
Male also listed in original description, but no male so labeled found in collection.

Empria castigata MacGillivray
Can. Ent., Vol. XLIII, No. 9, September, 1911, p. 309.
Type.—♀: Battle Creek, Michigan (J. M. Aldrich).

Empria cata MacGillivray
Can. Ent., Vol. XLIII, No. 9, September, 1911, p. 307.
Type.—♂: Mount Washington, New Hampshire (W. F. Fisk).

Empria cauduca MacGillivray
Can. Ent., Vol. XLIII, No. 9, September, 1911, p. 309.
Type.—♀: Ithaca, New York, May 5, 1895.

Empria cauta MacGillivray
Can. Ent., Vol. XLIII, No. 9, September, 1911, p. 311.
Type.—♀: Ithaca, New York, June 17, 1897.

Empria cava MacGillivray
Can. Ent., Vol. XLIII, No. 9, September, 1911, p. 306.
Type.—♀: Lancaster, New York, May 31, 1908 (M. C. Van Duzee).

Empria cavata MacGillivray
Can. Ent., Vol. XLIII, No. 9, September, 1911, p. 305.
Type.—♀: Oswego, New York, May 27, 1896 (C. S. Sheldon).

Empria celebrata MacGillivray
Can. Ent., Vol. XLIII, No. 9, September, 1911, p. 308.
Type.—♀: Buffalo, New York, June 5, 1897 (E. P. Van Duzee).

Empria celsa MacGillivray
Can. Ent., Vol. XLIII, No. 9, September, 1911, p. 306.
Type.—♀: Ithaca, New York, May 10, 1896.

Empria cerina MacGillivray
Psyche, Vol. XXVIII, No. 2, April, 1921, p. 34.
Type.—♀: Ithaca, New York, May 26, 1919, reared (H. Yuasa, 107-5-2).
Paratype.—♂: Ithaca, New York, May 26, 1919 reared (H. Yuasa, 107-3).

The male labeled by MacGillivray as a paratype is mentioned in the original description only by number "107-3", and is therefore not selected as a lectoallotype.

Empria cetaria MacGillivray
Psyche, Vol. XXVIII, No. 2, April, 1921, p. 33.
Type.—♀: Ithaca, New York, July 14, 1918, reared (H. Yuasa, 119-1-2).
Paratype.—♀: Ithaca, New York, July 14, 1918, reared (H. Yuasa, 119 1-2).

Empria cirrha MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 16.
Type.—♀: Mary's Peak, Oregon, May 30 (Ballard).
In fair condition.

Empria cista MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 16.
Type.—♀: Corvallis, Oregon, April 18, (Peterson).

Empria cistula MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 16.
Type.—♀: Mary's River, Oregon, April 20 (Glenis).

Empria cithara MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 17.
Type.—♀: Mary's Peak, Oregon, May 19, 1912 (L. G. Gentner).

Empria columna MacGillivray
Bull. Brooklyn Ent. Soc., Vol. XVIII, No. 2, May, 1923, p. 54.
Type.—♀: Ira, Summit County, Ohio (J. S. Hine).

Empria conciliata MacGillivray
Can. Ent., Vol. XLIII, No. 10, October, 1911, p. 344.
Type.—♀: Chimney Gulch, Colorado, April 22, 1899 (E. J. Oslar).

Empria concisa MacGillivray
Can. Ent., Vol. XLIII, No. 10, October, 1911, p. 346.
Type.—♀: Pullman, Washington (C. V. Piper, No. 13).

Empria concitata MacGillivray
Can. Ent., Vol. XLIII, No. 10, October, 1911, p. 342.
Type.—♂: Olympia, Washington, May 7, 1893 (T. Kincaid).
Originally described by MacGillivray as the male of *Monostegia kincaidii* MacGillivray, but transferred to the genus *Empria* Lepeletier and given the specific name of *concitata* in 1911.

Empria concreta MacGillivray
Can. Ent., Vol. XLIII, No. 10, October, 1911, p. 344.
Type.—♀: Colorado (C. F. Baker).

Empria condensa MacGillivray
Can. Ent., Vol. XLIII, No. 10, October, 1911, p. 342.
Type.—♀: Polk County, Wisconsin, July (C. F. Baker, No. 6498).
In fair condition.

Empria condita MacGillivray
Can. Ent., Vol. XLIII, No. 10, October, 1911, p. 342.
Type.—♀: Colorado (C. F. Baker).

Empria conferta MacGillivray
Can. Ent., Vol. XLIII, No. 10, October, 1911, p. 344.
Type.—♀: Colorado (C. F. Baker).

Empria confirmata MacGillivray
Can. Ent., Vol. XLIII, No. 10, October, 1911, p. 341.
Type.—♀: Olympia, Washington, April 17, 1892, catkin of *Salix flavescens* (T. Kincaid).
Originally included by MacGillivray in the type series of *Monostegia kincaidii* MacGillivray, but transferred to the genus *Empria* Lepeletier and given the specific name of *confirmata* in 1911.

Empria contexta MacGillivray
Can. Ent., Vol. XLIII, No. 10, October, 1911, p. 345.
Type.—♀: Colorado (C. F. Baker).

Empria contorta MacGillivray
Can. Ent., Vol. XLIII, No. 10, October, 1911, p. 343.
Type.—♀: Chimney Gulch, Colorado, April 23, 1899 (E. J. Oslar).

Empria costata MacGillivray
Can. Ent., Vol. XLVI, No. 3, March, 1914, p. 103.
Type.—♀: New Haven, Connecticut, May 11, 1911 (B. H. Walden).

Empria culpata MacGillivray
Can. Ent., Vol. XLIII, No. 10, October, 1911, p. 343.
Type.—♀: Olympia, Washington, May 8, 1894 (T. Kincaid).

Empria cumulata MacGillivray
Can. Ent., Vol. XLIII, No. 10, October, 1911, p. 343.
Type.—♀: Olympia, Washington, May 23, 1892 (T. Kincaid).

Empria cuneata MacGillivray
Can. Ent., Vol. XLIII, No. 10, October, 1911, p. 345.
Type.—♀: Olympia, Washington, May 21, 1891 (T. Kincaid).

Empria cupida MacGillivray
Can. Ent., Vol. XLIII, No. 10, October, 1911, p. 346.
Type.—♀: Olympia, Washington, June 13, 1894 (T. Kincaid).

Empria curata MacGillivray
Can. Ent., Vol. XLIII, No. 10, October, 1911, p. 345.
Type.—♀: Olympia, Washington, June 17, 1894 (T. Kincaid).

Empria evecta MacGillivray
Can. Ent., Vol. XLIII, No. 9, September, 1911, p. 310.
Type.—♀: Sandy Hook, New Jersey.

Empria fragariae Rohwer
Journ. Ec. Ent., Vol. VII, No. 6, December, 1914, p. 479.
Paratypes.—♀: Storm Lake, Iowa, May 2, 1912 (R. L. Webster); Ames Iowa, April 16, 1913 (R. L. Webster).

Euura bakeri Rohwer
Can. Ent., Vol. XLII, No. 2, February, 1910, p. 51.
Paratypes.—♀ and ♂: Mountains near Claremont, California (C. F. Baker).

Euura brachycarpae Rohwer
Can. Ent., Vol. XL, No. 6, June, 1908, p. 176.
Paratypes.—♀ and ♂: Florissant, Colorado, July 7, 1907 (S. A. Rohwer).

Euura maculata MacGillivray
Can. Ent., Vol. XLVI, No. 10, October, 1914, p. 366.
Type.—♀: Columbus, Ohio, No. 169 (J. S. Hine).

Euura minuta MacGillivray
Can. Ent., Vol. XLVI, No. 10, October, 1914, p. 366.
Type.—♀: Ames, Iowa (E. D. Ball).

Euura moenia MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 17.
Type.—♀: Corvallis, Oregon, 1910.
Paratypes.—♂ and ♀: Corvallis, Oregon, 1910.
The male is not specifically mentioned in the original description but was labeled as a paratype by MacGillivray.

Hemitaxonus dediticius MacGillivray
Psyche, Vol. XXX, No. 2, April, 1923, p. 77.
Type.—♂: Corvallis, Oregon (G. F. Moznette).

Hoplocampa padusa MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 17.
Type.—♂: Corvallis, Oregon (A. L. Lovett).
Paratypes.—♂: Corvallis, Oregon (A. L. Lovett).

Hoplocampa pallipes MacGillivray
Can. Ent., Vol. XXV, No. 10, October, 1893, p. 239.
Cotype.—♀: Skokomish River, Washington, on Amelanchier, May 8, 1892 (T. Kincaid).

Hylotoma onerosa MacGillivray
Psyche, Vol. XXX, No. 2, April, 1923, p. 80.
Type.—♀: Moscow, Idaho (J. M. Aldrich).
Lectoallotype.—♂: Okanogan County, Washington, July 16, 1896 (C. W. Sutton).
Paratype.—♀: Revelstoke, British Columbia, July 14, 1912 (R. C. Osburn).
The lectoallotype was labeled by MacGillivray as a paratype.

Hylotoma sparta MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 18.
Type.—♀: Olympia, Washington, June 4, 1894 (T. Kincaid).
Lectoallotype.—♂: Corvallis, Oregon (A. L. Lovett).
Paratype.—♀: No data.
The lectoallotype was labeled by MacGillivray as a paratype.

Hylotoma spiculata MacGillivray
Can. Ent., Vol. XXXIX, No. 9, September, 1907, p. 308.
Type.—♀: Oak Creek Canyon, Arizona, 6000 feet elevation, August (F. H. Snow).
One antenna is missing.

Hypargyricus infuscatus MacGillivray
Can. Ent., Vol. XL, No. 8, August, 1908, p. 290.
Type.—♀: Ithaca, New York.
The genotype of *Hypargyricus* MacGillivray (original designation).

Hypolaepus viereckii Bradley
Can. Ent., Vol. XXXV, No. 2, February, 1903, p. 47.
Paratypes.—♀: Westville, New Jersey, September 12, 1897.

Isiodyctium *(sic)* **atratum** MacGillivray
Can. Ent., Vol. XL, No. 8, August, 1908, p. 290.
Type.—♀: Ames, Iowa, May 10, 1897 (E. D. Ball).
The generic name should have been *Isodyctium* Ashmead, which is now considered as a synonym of *Periclista* Konow.

Leucopelmonus annulatus MacGillivray
State Geol. Nat. Hist. Surv. Conn., Bull. 22, December 1, 1916, p. 83.
Type.—♀: Franconia, New Hampshire (A. T. Slosson).
The genotype of *Leucopelmonus* MacGillivray (monobasic). This species has subsequently been sunk as a synonym of *Leucopelmonus confusus* (Norton) by MacGillivray (1919).

Loderus accuratus MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 19.
Type.—♀: Orono, Maine, June 13, 1912.

Loderus acerbus MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 19.
Type.—♀: Orono, Maine, June 23, 1913.

Loderus acidus MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 20.
Type.—♀: Orono, Maine, June 12, 1913.

Loderus acriculus MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 20.
Type.—♀: Orono, Maine, August 6, 1913.
Paratype.—♀: Orono, Maine, July 7, 1913.

Loderus alticinctus MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 20.
Type.—♀: Orono, Maine, June 30, 1913.

Loderus ancisus MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 21.
Type.—♀: Orono, Maine, June 12, 1913.
Paratype.—♀: Orono, Maine, June 12, 1913.

Loderus nigra Rohwer
Can. Ent., Vol. XLII, No. 2, February, 1910, p. 49.
Cotype.—♂: Mountains near Claremont, California (C. F. Baker).

Macremphytus bicornis MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 21.
Type.—♀: Wellesley, Massachusetts, June 1, 1917 (A. M. Wilcox).

Macremphytus lovetti MacGillivray
Psyche, Vol. XXX, No. 2, April, 1923, p. 77.
Type.—♀: Rock Creek, Corvallis, Oregon, July 14, (A. L. Lovett).

Macrophya bellula MacGillivray
Bull. Brooklyn Ent. Soc., Vol. XVIII, No. 2, April, 1923, p. 55.
Type.—♀: Greenwood Lake, New Jersey, June 10, 1917 (F. M. Schott).

Macrophya bilineata MacGillivray *
State Geol. Nat. Hist. Surv. Conn., Bull. 22, 1916, p. 96.
Type.—♀: Algonquin, Illinois, May 29, 1895 (W. A. Nason).
Paratype.—♀: Algonquin, Illinois, June 12, 1894 (W. A. Nason).
Labeled by MacGillivray in collection as type and paratype.

Macrophya confusa MacGillivray
Can. Ent., Vol. XLVI, No. 4, April, 1914, p. 139.
Type.—♀: Pennsylvania, 1572 (C. F. Baker).

Macrophya fistula MacGillivray
Bull. Brooklyn Ent. Soc., Vol. XV, No. 4, October, 1920, p. 114.
Type.—♀: Ithaca, New York, bred, May 27, 1918, 59-4-1 (H. Yuasa).
Paratype.—♀: Ithaca, New York, bred, May 24, 1918, No. 59-4-1 (H. Yuasa).

Macrophya flaccida MacGillivray
Bull. Brooklyn Ent. Soc., Vol. XV, No. 4, October, 1920, p. 113.
Type.—♀: Ithaca, New York, bred, May 14, 1918, No. 11-1 (H. Yuasa).

Macrophya flicta MacGillivray
Bull. Brooklyn Ent. Soc., Vol. XV, No. 4, October, 1920, p. 114.
Type.—♀: Ithaca, New York, bred, May 13, 1919, No. 126-3-C-1 (H. Yuasa).

Macrophya magnifica MacGillivray
Can. Ent., Vol. XXV, No. 10, October, 1893, p. 240.
Type.—♀: Olympia, Washington, June 4, 1892 (T. Kincaid).
Paratype.—♀: Olympia, Washington, June 4, 1892 (T. Kincaid).
Subsequently transferred to the genus *Tenthredo* Linnaeus by MacGillivray.

Macrophya melanopleura MacGillivray
Can. Ent., Vol. XLVI, No. 4, April, 1914, p. 139.
Type.—♀: Hatch Experiment Station, Amherst, Massachusetts, July 29, 1895.

Macrophya minuta MacGillivray
Can. Ent., Vol. XXVII, No. 10, October, 1895, p. 286.
Type.—♂: Plattsburg, New York, June 8, 1894 (H. G. Dyar).

Macrophya mixta MacGillivray
Can. Ent., Vol. XXVII, No. 3, March, 1895, p. 77.
Type.—♀: Mount Washington, New Hampshire (A. T. Slosson).

Macrophya nidonea MacGillivray
Can. Ent., Vol. XXVII, No. 3, March, 1895, p. 77.
Type.—♂: Franconia, New Hampshire (A. T. Slosson).

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* These cannot be types. Type probably in collection of the Connecticut Agricultural Experiment Station and should be labeled Milldale, Connecticut, May 21, 1906, W. E. Britton. S. A. ROHWER.

Macrophya obaerata MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 21.
Type.—♀: Corvallis, Oregon (Finch).

Macrophya obnata MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 22.
Type.—♀: Mary's Peak, Corvallis, Oregon, May 14 (A. L. Lovett).

Macrophya obrussa MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 22.
Type.—♂: Mary's River, Corvallis, Oregon, May 20 (Hurst).
Paratype.—♂: Corvallis, Oregon, College campus, May 21 (Gooding).

Macrophya ornata MacGillivray
Can. Ent., Vol. XLVI, No. 4, April, 1914, p. 139.
Type.—♀: Ithaca, New York, May 29, 1896.

Macrophya pleuricinctella Rohwer
Can. Ent., Vol. XLI, No. 9, September, 1909, p. 332.
Cotypes.—♀: Stanford University, California (C. F. Baker); Claremont, California (C. F. Baker).

Macrophya pulchella alba MacGillivray
Can. Ent., Vol. XXVII, No. 10, October, 1895, p. 285.
Type.—♀: Philadelphia, Pennsylvania.
Paratype.—♂: Ithaca, New York, May 16, 1894.
No mention is specifically made of a paratypic male in the original description. Raised to specific rank by Rohwer in 1912 and this assignment followed by MacGillivray in 1916.

Macrophya punctata MacGillivray
Can. Ent., Vol. XXVII, No. 10, October, 1895, p. 285.
Type.—♀: Plattsburg, New York, June 14, 1894 (H. G. Dyar).

Macrophya truncata Rohwer
Can. Ent., Vol. XLI, No. 9, September, 1909, p. 331.
Cotypes.—♀ and ♂: Claremont, California (C. F. Baker).

Messa alsia MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 22.
Type.—♀: Ithaca, New York, May 16, 1897.

Messa alumna MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 23.
Type.—♀: Northern Illinois.

Messa amica MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 23.
Type.—♀: North Evans, New York, August 2, 1908 (M. C. Van Duzee).

Messa anita MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 23.
Type.—♀: Wisconsin.
One antenna is missing.

Messa appota MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 24.
Type.—♂: Buffalo, New York, June 27, 1908 (M. C. Van Duzee).
One antenna is missing.

Metallus bethunei MacGillivray
Can. Ent., Vol. XLVI, No. 10, October, 1914, p. 366.
Type.—♀: Jordan Harbour, Ontario, Canada, bred from leaf-mining larva on blackberry, July 5, 1910 (L. Caesar).
Lectoallotype.—♂: Saint Kits, Ontario, Canada, bred from leaf-mining larva on blackberry, August 12, 1911 (L. Caesar).
Paratypes.—♀ and ♂: Saint Kits, Ontario, Canada, bred from leaf-mining larvae on blackberry, August 12, 1911 (L. Caesar).

Metallus rohweri MacGillivray
Ann. Ent. Soc. Amer., Vol. II, No. 4, December, 1909, p. 267.
Type.—♀: Block Island, Rhode Island, August 28, 1891 (A. P. Morse).

Mogerus emarginatus MacGillivray
Can. Ent., Vol. XXVII, No. 10, October, 1895, p. 281.
Type.—♂: Boston, Massachusetts.
Now assigned to the genus *Periclista* Konow.

Monoctenus juniperinus MacGillivray
Can. Ent., Vol. XXVI, No. 11, November, 1894, p. 328.
Type.—♀: Ithaca, New York, June 9, 1894 (R. L. Junghanns).

Monophadnoides circinus MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 24.
Type.—♂: Olympia, Washington, May 3, 1897 (T. Kincaid).

Monophadnoides collaris MacGillivray
Can. Ent., Vol. XL, No. 8, August, 1908, p. 295.
Type.—♀: Ithaca, New York, June 30, 1885 (G. F. Atkinson).
Lectoallotype.—♂: Ithaca, New York, May 22, 1898.
The lectoallotype was labeled by MacGillivray as a paratype.

Monophadnoides concessus MacGillivray
Can. Ent., Vol. XL, No. 8, August, 1908, p. 294.
Type.—♀: Ithaca, New York, May 27, 1897.

Monophadnoides conductus MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 24.
Type.—♀: Santa Clara County, California, May, 1902 (Coleman).
Paratype.—♀: Santa Clara County, California, May, 1902 (Coleman).

Monophadnoides consobrinus MacGillivray
Can. Ent., Vol. XL, No. 8, August, 1908, p. 294.
Type.—♀: Durham, New Hampshire (W. and F.).

Monophadnoides consonus MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 25.
Type.—♀: Olympia, Washington, April 17, 1896 (T. Kincaid).

Monophadnoides conspersus MacGillivray
Can. Ent., Vol. XL, No. 8, August, 1908, p. 294.
Type.—♀: Ithaca, New York, May 24, 1898.

Monophadnoides conspiculata MacGillivray
Can. Ent., Vol. XL, No. 8, August, 1908, p. 293.
Type.—♀: Ithaca, New York, May.

Monophadnoides conspicuus MacGillivray
Can. Ent., Vol. XL, No. 8, August, 1908, p. 293.
Type.—♀: Mc Lean, New York, May 31, 1897.
The locality is erroneously given in the original description as "Mc Lean, Mass."

Monophadnoides constitutus MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 25.
Type.—♀: Ottawa, Quebec, Canada, May, 1912 (Germain).

Monophadnoides contortus MacGillivray
Psyche, Vol. XXX, No. 2, April, 1923, p. 78.
Type.—♀: Corvallis, Oregon, May 7 (Ballard).

Monophadnoides coracinus MacGillivray
Can. Ent., Vol. XL, No. 8, August, 1908, p. 295.
Type.—♂: Wellesley, Massachusetts, May 27, 1891 (A. P. Morse).

Monophadnoides cordatus MacGillivray
Can. Ent., Vol. XL, No. 8, August, 1908, p. 294.
Type.—♀: Illinois, 950 (W. A. Nason).

Monophadnoides corytus MacGillivray
Psyche, Vol. XXX, No. 2, April, 1923, p. 79.
Type.—♂: Corvallis, Oregon, April 13 (A. L. Lovett).

Monophadnoides costalis MacGillivray
Can. Ent., Vol. XL, No. 8, August, 1908, p. 295.
Type.—♀: Wellesley, Massachusetts, June 8, 1891 (A. P. Morse).
Most of the antennal segments are missing.

Monophadnoides crassus MacGillivray
Can. Ent., Vol. XL, No. 8, August, 1908, p. 294.
Type.—♀: Durham, New Hampshire (W. and F.).

Monophadnoides curiosus MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 25.
Type.—♀: Olympia, Washington, May 15, 1897 (T. Kincaid).
Paratype.—♀: Olympia, Washington, May 18, 1896 (T. Kincaid).

Monophadnoides kincaidi MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 26.
Type.—♀: Olympia, Washington, April 7, 1895 (T. Kincaid).

Monophadnoides shawi MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 26.
Type.—♀: Hampton, New Hampshire, May 15, 1904 (S. A. Shaw).
Lectoallotype.—♂: Hampton, New Hamphire, May 20, 1898 (S. A. Shaw).

Monophadnus aequalis MacGillivray
Can. Ent., Vol. XL, No. 8, August, 1908, p. 292.
Type.—♀: Ithaca, New York, May 3, 1896.

Monophadnus aeratus MacGillivray
Psyche, Vol. XXX, No. 2, April, 1923, p. 79.
Type.—♂: Corvallis, Oregon, April 13 (Gooding).

Monophadnus assaracus MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 26.
Type.—♂: Rock Creek, Oregon, March 19.

Monophadnus atracornus MacGillivray
Can. Ent., Vol. XXV, No. 10, October, 1893, p. 239.
Type.—♀: Olympia, Washington, April 30, 1890 (T. Kincaid).

Monophadnus bipunctatus MacGillivray
Can. Ent., Vol. XL, No. 8, August, 1908, p. 292.
Type.—♀: Ithaca, New York, May 9, 1895.

Monophadnus distinctus MacGillivray
Can. Ent., Vol. XL, No. 8, August, 1908, p. 291.
Type.—♀: Lake Forest, Illinois (J. G. Needham).

Monophadnus minutus MacGillivray
Can. Ent., Vol. XL, No. 8, August, 1908, p. 291.
Type.—♀: Milwaukee, Wisconsin, June 4, 1902 (C. E. B.).

Monophadnus planus MacGillivray
Bull. Brooklyn Ent. Soc., Vol. XVI, No. 1, February, 1921, p. 23
Type.—♂: Franconia, New Hampshire (A. T. Slosson).

Monophadnus plicatus MacGillivray
Can. Ent., Vol. XL, No. 8, August, 1908, p. 292.
Type.—♀: Ames, Iowa (E. D. Ball).
Lectoallotype.—♂: Ames, Iowa (E. D. Ball).
The lectoallotype was labeled by MacGillivray as a paratype.

Monophadnus ruscullus MacGillivray
Psyche, Vol. XXX, No. 2, April, 1923, p. 80.
Type.—♂: Mary's Peak, Corvallis, Oregon (Middlekauff).

Monophadnus transversus MacGillivray
Can. Ent., Vol. XL, No. 8, August, 1908, p. 292.
Type.—♀: Michigan.

Monostegia kincaidii MacGillivray
Can. Ent., Vol. XXV, No. 10, October, 1893, p. 239.
Type.—♀: Olympia, Washington, May 7, 1893 (T. Kincaid).

Subsequently transferred to the genus *Empria* Lepeletier. MacGillivray in 1911 considered that his description of this species in 1893 applied to a "composite of several species" and the types of *Empria confirmata* MacGillivray and *Empria concitata* MacGillivray were originally labeled as paratypes of *kincaidii* MacGillivray.

Monostegia martini MacGillivray
Can. Ent., Vol. XL, No. 10, October, 1908, p. 366.
Type.—♀: Westfield, Massachusetts, May 14, 1899 (J. O. Martin).

Neocharactus bakeri MacGillivray
Can. Ent., Vol. XL, No. 8, August, 1908, p. 293.
Type.—♂: Santa Clara County, California (C. F. Baker).
The genotype of *Neocharactus* MacGillivray (original description and monobasic).

Neopareophora martini MacGillivray
Can. Ent., Vol. XL, No. 8, August, 1908, p. 289.
Type.—♀: West Springfield, Massachusetts, May 7, 1888 (J. O. Martin).
The genotype of *Neopareophora* MacGillivray (original designation). The antennae are missing.

Neopareophora scelesta MacGillivray
Can. Ent., Vol. XL, No. 8, August, 1908, p. 289.
Type.—♀: Black Mountains, North Carolina, June (W. Beutenmüller).
Paratype.—♀: Black Mountains, North Carolina, June (W. Beutenmüller).

Neotomostethus hyalinus MacGillivray
Can. Ent., Vol. XL., No. 8, August, 1908, p. 290.
Type.—♀: Mc Lean County, New York, May 31, 1898.
The genotype of *Neotomostethus* MacGillivray (original designation and monobasic).

Pachynematus absyrtus MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 27.
Type.—♀: Mary's Peak, Corvallis, Oregon, May 23 (Zwicker).

Pachynematus academus MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 27.
Type.—♀: Corvallis, Oregon, September 26, 1906 (Farrell).

Pachynematus allegatus MacGillivray
Can. Ent., Vol. LV, No. 7, July, 1923, p. 162.
Type.—♀: Edmonton, Alberta, Canada, May 13, 1915 (F. S. Carr).

Pachynematus corticosus MacGillivray
N. Y. Sta. Mus., Bull. 47, September, 1901, p. 584.
Type.—♀: Saranac Inn, New York, sweeping, August 4, 1901.

Pachynematus rarus MacGillivray
Journ. N. Y. Ent. Soc., Vol. XXIX, No. 1, March, 1921, p. 30.
Type.—♀: Orono, Maine, August 19, 1913, Sub. 229.
Paratype.—♀: Orono, Maine, August 19, 1913, Sub. 229.

Pachynematus refractarius MacGillivray
Journ. N. Y. Ent. Soc., Vol. XXIX, No. 1, March, 1921, p. 31.
Type.—♀: Orono, Maine, September 9, 1913, Sub. 252.

Pachynematus remissus MacGillivray
Journ. N. Y. Ent. Soc., Vol. XXIX, No. 1, March, 1921, p. 32.
Type.—♀: Ithaca, New York, bred, June 9, 1918, No. 150-3 (H. Yuasa).
Paratypes.—♀: Ithaca, New York, bred, July 4-9, 1918, Nos. 150-1-1 and 150-1 (H. Yuasa).

Pachynematus repertus MacGillivray
Journ. N. Y. Ent. Soc., Vol. XXIX, No. 1, March, 1921, p. 31.
Type.—♀: Ithaca, New York, bred, July 16, 1918, No. 177-1-2 (H. Yuasa).

Pachynematus roscidus MacGillivray
Journ. N. Y. Ent. Soc., Vol. XXIX, No. 1, March, 1921, p. 31.

Type.—♀: Adirondack Mountains, New York, August 15 (C. O. Houghton).
Paratype.—♀: Orono, Maine, August 9, 1913, Sub. 227.
The antennae of the type and the abdomen of the paratype are missing.

Pachynematus rufocinctus MacGillivray
State Geol. Nat. Hist. Surv. Conn., Bull. 22, 1916, p. 117.
Type.—♀: Orange, Connecticut, May 21, 1911 (A. B. Champlain).
Lectoallotype.—♂: New Haven, Connecticut, May 15, 1911 (A. B. Champlain).
Paratype.—♀: New Haven, Connecticut, May 15, 1911 (A. B. Champlain).

Pachynematus venustus MacGillivray
Proc. Calif. Acad. Sc., Vol. XI, No. 14 (4th Series), November 2, 1921, p. 190.
Paratypes.—♀ and ♂: St. George Island, Alaska, June 30, 1920 (G. D. Hanna).

Pachynematus vernus MacGillivray
Proc. Calif. Acad. Sc., Vol. XI, No. 14 (4th Series), November 2, 1921, p. 191.
Paratypes.—♂: St. George Island, Alaska, June 30, 1920 (G. D. Hanna).

Parabates histrionicus MacGillivray
Ann. Ent. Soc. Amer., Vol. II, No. 4, December, 1909, p. 263.
Type.—♀: Olympia, Washington, July 9, 1892 (T. Kincaid).
The left pair of wings are missing. The genotype of *Parabates* MacGillivray (original designation).

Paracharactus obscuratus MacGillivray
Can. Ent., Vol. XL, No. 8, August, 1908, p. 293.
Type.—♀: West Springfield, Massachusetts (J. O. Martin).
Lectoallotype.—♂ Ithaca, New York, May 16, 1897.
The genotype of *Paracharactus* MacGillivray (monobasic and original designation). The lectoallotype was labeled by MacGillivray as a paratype.

Paracharactus obtentus MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 28.
Type.—♀: Corvallis, Oregon, May 5, 1901.

Paracharactus obversus MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 28.
Type.—♀: Corvalis, Oregon, May 10, 1912 (H. S. Walters).

Paracharactus offensus MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 28.
Type.—♀: Rock Creek, Oregon, March 19.

Pareophora aldrichi MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 28.
Type.—♀: Peck, Idaho, on Solomon's Seal, April 8, 1900 (J. M. Aldrich).
Lectoallotype.—♂: Peck, Idaho, on Solomon's Seal, April 8, 1900 (J. M. Aldrich).
Paratypes.—♀: Peck, Idaho, on Solomon's Seal, April 8, 1900 (J. M. Aldrich).

Pareophora guana MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 28.
Type.—♂: Algonquin, Illinois (W. A. Nason).

Pareophora guara MacGillivray
Bull. Brooklyn Ent. Soc., Vol. XVIII, No. 2, April, 1923, p. 54.
Type.—♀: Marion County, Arkansas, May 2, 1897 (T. M. McE.).

Periclista, confusa MacGillivray
Can. Ent., Vol. XL, No. 8, August, 1908, p. 291.
Type.—♀: Ithaca, New York, April 26, 1892.

Periclista electa MacGillivray
Psyche, Vol. XXX, No. 2, April, 1923, p. 80.
Type.—♂: Corvallis, Oregon, oak twig, April 13, 1908.
The antennae are missing.

Periclista entella MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 29.
Type.—♂: Corvallis, Oregon, campus, April 18 (Peterson).

Periclista leucostoma Rohwer
Can. Ent., Vol. XLI, No. 11, November, 1909, p. 397.
Cotypes.—♀ and ♂: Claremont, California (C. F. Baker).

Periclista occidentalis Rohwer
Can. Ent., Vol. XLI, No. 11, November, 1909, p. 398.
Cotype.—♀: Claremont, California (C. F. Baker).

Periclista patchi MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 29.
Type.—♀: Orono, Maine, July 13, 1905.

Perineura kincaidia MacGillivray
Can. Ent., Vol. XXVII, No. 1, January, 1895, p. 7.
Type.—♀: Olympia, Washington, May 28, 1893 (T. Kincaid).

Perineura turbata Rohwer
Proc. U. S. N. M., Vol. 41, October 14, 1911, p. 408.
Paratypes.—♂ and ♀: North Fork of Swannanoa River, Black Mountains, North Carolina, May (N. Banks).
This species has been subsequently sunk as a synonym of *Leucopelmonus confusus* (Norton) by MacGillivray (1919).

Phlebatrophia mathesoni MacGillivray
Can. Ent., Vol. XLI, No. 10, October, 1909, p. 345.
Type.—♀: New Glasgow, Nova Scotia, reared from larvae in leaf-mines on birch (R. Matheson).
Paratypes.—♀: New Glasgow, Nova Scotia, reared from larvae in leaf-mines on birch (R. Matheson).
The genotype of *Phlebatrophia* MacGillivray (original designation).

Phrontosoma atrum MacGillivray
Can. Ent., Vol. XL, No. 10, October, 1908, p. 367.
Type.—♂: Ames, Iowa, May 11, 1897 (E. D. Ball).
The genotype of *Phrontosoma* MacGillivray (original description).

Phrontosoma collaris MacGillivray
Can. Ent., Vol. XL, No. 10, October, 1908, p. 367.
Type.—♀: Ames, Iowa, May 11, 1897 (E. D. Ball).

Phrontosoma daeckei MacGillivray
Can. Ent., Vol. XL, No. 10, October, 1908, p. 367.
Type.—♀: Glenside, Mtg. County, Pennsylvania (E. Daecke).

Platycampus victoria MacGillivray
Can. Ent., Vol. LII, No. 3, March, 1920, p. 61.
Paratypes.—♀: Victoria, British Columbia, May 29-June 26, 1918, bred from larvae on Lombardy poplar (W. Downes). Recently sunk as a synonym of the European *Trichiocampus viminalis* Fall.

Platycampus vierecki MacGillivray
Can. Ent., Vol. LII, No. 3, March, 1920, p. 60.
Type.—♀: Cloudcroft, New Mexico, June 18, 1902 (H. L. Viereck).

Poecilostoma convexa MacGillivray
Can. Ent., Vol. XLI, No. 11, November, 1909, p. 402.
Type.—♀: New Brunswick, New Jersey (J. B. Smith).
Transferred to the genus *Empria* Lepeletier by MacGillivray in 1916.

Polybates slossonae MacGillivray
Ann. Ent. Soc. Amer., Vol. II, No. 4, December, 1909, p. 265.
Type.—♀: Franconia, New Hampshire (A. T. Slosson).
One antenna is missing. The genotype of *Polybates* MacGillivray (original designation and monobasic).

Pontania atrata MacGillivray
Rep. Can. Arctic Exped., 1913-1918, Vol. 3G, November, 1919, p. 6G.

Paratype.—♂: Herschel Island, Yukon Territory, Canada, bred from *Salix arctica*, July, 1915 (F. Johansen).

Pontania daedala MacGillivray
Journ. N. Y. Ent. Soc., Vol. XXIX, No. 1, March, 1921, p. 33.
Type.—♀: Ithaca, New York, bred, August 21, 1917, No. 7-6 (H. Yuasa).
Paratype.—♀: Ithaca, New York, bred, August 21, 1917, No. 7-6 (H. Yuasa).

Pontania decrepita MacGillivray
Journ. N. Y. Ent. Soc., Vol. XXIX, No. 1, March, 1921, p. 33.
Type.—♀: Ithaca, New York, bred, July 21, 1917, No. 35-2-5 (H. Yuasa).

Pontania dedecora MacGillivray
Journ. N. Y. Ent. Soc., Vol. XXIX, No. 1, March, 1921, p. 32.
Type.—♀: Ithaca, New York, bred, May 24, 1919, No. 185a-2.
Paratype.—♀: Ithaca, New York, bred, May 7, 1919, No. 8-51 (?)-1-1 (H. Yuasa).

Pontania demissa MacGillivray
Journ. N. Y. Ent. Soc., Vol. XXIX, No. 1, March, 1921, p. 33.
Type.—♀: Ithaca, New York, bred, May 13, 1919, No. 191-1-1 (H. Yuasa).
Paratype.—♀: Ithaca, New York, bred, May 13, 1919, No. 191-1-1 (H. Yuasa).

Pontania derosa MacGillivray
Journ. N. Y. Ent. Soc., Vol. XXIX, No. 1, March, 1921, p. 34.
Type.—♀: Ithaca, New York, bred, May 13, 1919, No. 142-1-1 (H. Yuasa).

Pontania destricta MacGillivray
Journ. N. Y. Ent. Soc., Vol. XXXI, No. 4, December, 1923, p. 168.
Type.—♀: Katmai, Alaska, June, 1917 (J. S. Hine).

Pontania devincta MacGillivray
Journ. N. Y. Ent. Soc., Vol. XXIX, No. 1, March, 1921, p. 34.
Type.—♀: Orono, Maine, August 1, 1913, Sub. 9.
Lectoallotype.—♂: Orono, Maine, Sub. 226.
The lectoallotype was labeled by MacGillivray as a paratype.

Pontania dotata MacGillivray
Journ. N. Y. Ent. Soc., Vol. XXIX, No. 1, March, 1921, p. 34.
Type.—♂: Ithaca, New York, bred, August 25, 1918, No. 8.48 (?)-1-1 (H. Yuasa).
Paratype.—♂: Ithaca, New York, bred, August 25, 1918, No. 8.48 (?)-1-1 (H. Yuasa).

Pontania lorata MacGillivray
Rep. Can. Arctic Exped., 1913-1918, Vol. 3G, November, 1919, p. 8G.
Paratype.—♂: Herschel Island, Yukon Territory, Canada, bred from galls of *Salix arctica*, July, 1915, No. 255 (F. Johansen).

Pontania subatrata MacGillivray
Proc. Calif. Acad. Sc., Vol. XI, No. 14, (4th Series), November 2, 1921, p. 189.
Paratypes.—♂: St. George Island, Alaska, June 30, 1920 (G. D. Hanna).

Pontania sublorata MacGillivray
Proc. Calif. Acad. Sc., Vol. XI, No. 14 (4th Series), November 2, 1921, p. 190.
Paratypes.—♂: St. George Island, Alaska, June 30, 1920 (G. D. Hanna).

Priophorus acericaulis MacGillivray
Can. Ent., Vol. XXXVIII, No. 9, September, 1906, p. 306.
Type.—♀: New Haven, Connecticut, May 15, 1906 (B. H. Walden).
Paratypes.—♀: New Haven, Connecticut, May 3-May 15, 1916 (B. H. Walden).
Now placed in the genus *Caulocampus* Rohwer.
The genotype of *Caulocampus* Rohwer (original designation and monobasic).

Priophorus modestius MacGillivray
Ent. News, Vol. XXXII, No. 2, February, 1921, p. 49.
Type.—♀: Orono, Maine, August 9, 1913, Sub. 109.

Priophorus moratus MacGillivray
Ent. News, Vol. XXXII, No. 2, February, 1921, p. 50.
Type.—♀: Orono, Maine, August 12, 1913, Sub. 1.
The "Sub. q." mentioned in the original description is evidently a typographical error.

Priophorus munditus MacGillivray
Ent. News, Vol. XXXII, No. 2, February, 1921, p. 50.
Type.—♀: Orono, Maine, August 9, 1913, Sub. 174.

Pristiphora ostiaria MacGillivray
Can. Ent., Vol. LII, No. 10, October, 1920, p. 236.
Type.—♀: Ithaca, New York, August 16, 1918, No. 212-1-1 (H. Yuasa).
Lectoallotype.—♂: Ithaca, New York, August 15, 1918, No. 212-1-1 (H. Yuasa).
The lectoallotype was labeled by MacGillivray as a paratype.

Profenusa collaris MacGillivray
Can. Ent., Vol. XLVI, No. 10, October, 1914, p. 364.
Type.—♀: Geneva, New York, bred from larvae mining the leaves of cherry, May 4, 1911 (P. J. Parrott).
Lectoallotype.—♂: Ithaca, New York, on *Crataegus*, May 17, 1911 (A. Rutherford).
Paratypes.—♀: Geneva, New York, bred from larvae mining the leaves of cherry, May 4, 1911 (P. J. Parrott); Ithaca, New York, on *Crataegus*, May 17, 1911 (A. Rutherford).
The genotype of *Profenusa* MacGillivray (original designation and monobasic).

Prototaxonus typicus Rohwer
Can. Ent., Vol. XLII, No. 2, February, 1910, p. 50.
Cotype.—♂: Mountains near Claremont, California (C. F. Baker).
The genotype of *Prototaxonus* Rohwer (original designation).

Pseudoselandria oxalata MacGillivray
Can. Ent., Vol. XLVI, No. 3, March, 1914, p. 104.
Type.—♀: Wisconsin (S. Graenicher).
In fair condition. The genotype of *Pseudoselandria* MacGillivray (original designation). There is also a male with the same data determined as this species in the collection, but it is not mentioned in the original description. The old type label on the female bears both "♂" and "♀" characters, indicating male specimen was received at same time as female type.

Pteronidea edessa MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 30.
Type.—♀: Sterensville, Missouri, April 12, 1911 (J. M. Enschede).
The antennae are missing.

Pteronidea edita MacGillivray
Can. Ent., Vol. LII, No. 10, October, 1920, p. 235.
Type.—♂: Ithaca, New York, bred, July 29, 1917, No. 5-1-6 (H. Yuasa).

Pteronidea edura MacGillivray
Can. Ent., Vol. LII, No. 10, October, 1920, p. 233.
Type.—♀: Ithaca, New York, bred, July 16, 1918, No. 8.45 (?) -1-1 (H. Yuasa).

Pteronidea effeta MacGillivray
Can. Ent., Vol. LII, No. 10, October, 1920, p. 234.
Type.—♀: Orono, Maine, bred, poplar, August 9, 1913, Sub. 158.

Pteronidea effrenatus MacGillivray
Journ. N. Y. Ent. Soc., Vol. XXXI, No. 4, December, 1923, p. 171.
Type.—♀: Katmai, Alaska, July, 1917 (J. S. Hine).

Pteronidea effusa MacGillivray
Can. Ent., Vol. LII, No. 10, October, 1920, p. 233.
Type.—♀: Orono, Maine, bred, July 26, 1913, Sub. 110.

Pteronidea egeria MacGillivray
Can. Ent., Vol. LV, No. 7, July, 1923, p. 161.
Type.—♀: Edmonton, Alberta, Canada, April 24, 1916 (F. S. Carr).
The antennae are missing.

Pteronidea egnatia MacGillivray
Can. Ent., Vol. LV, No. 7, July, 1923, p. 162.
Type.—♀: Edmonton, Alberta, Canada, May 19, 1917 (F. S. Carr).

Pteronidea electra MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 30.
Type.—♀: Corvallis, Oregon, May 23, 1913 (Denny).

Pteronidea elelea MacGillivray
Can. Ent., Vol. LV, No. 7, July, 1923, p. 162.
Type.—♀: Edmonton, Alberta, Canada, May 7, 1917 (F. S. Carr).

Pteronidea emerita MacGillivray
Can. Ent., Vol. LII, No. 10, October, 1920, p. 234.
Type.—♀: Orono, Maine, bred, birch, August 1, 1913, Sub. 139.
In poor condition.

Pteronidea enavata MacGillivray
Can. Ent., Vol. LII, No. 10, October, 1920, p. 236.
Type.—♀: Orono, Maine, Sub. 25.

Pteronidea equatia MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 30.
Type.—♂: Corvallis, Oregon, May 17, 1915 (D. E. Brown).

Pteronidea equina MacGillivray
Can. Ent., Vol. LII, No. 10, October, 1920, p. 235.
Type.—♀: Orono, Maine, August 1, 1913, Sub. 71.
Paratype.—♀: Orono, Maine, Sub. 71.

Pteronidea erratus MacGillivray
Journ. N. Y. Ent. Soc., Vol. XXXI, No. 4, December, 1923, p. 170.
Type.—♀: Kodiak, Alaska, June 10, 1917 (J. S. Hine).

Pteronidea erudita MacGillivray
Can. Ent., Vol. LII, No. 10, October, 1920, p. 234.
Type.—♀: Orono, Maine, bred, willow, August 12, 1913, Sub. 12.

Pteronidea evanida MacGillivray
Can. Ent., Vol. LII, No. 10, October, 1920, p. 233.
Type.—♀: Orono, Maine, bred, July 28, 1913, Sub. 119.
Lectoallotype.—♂: Orono, Maine, bred, July 26, 1913, Sub. 111.
Paratype.—♀: Orono, Maine, bred, August 1, 1913, Sub. 119.
The lectoallotype was labeled by MacGillivray as a paratype.

Pteronidea exacta MacGillivray
Can. Ent., Vol. LII, No. 10, October, 1920, p. 235.
Type.—♂: Orono, Maine, bred, Sub. 172.

Pteronidea excessus MacGillivray
Journ. N. Y. Ent. Soc., Vol. XXXI, No. 4, December, 1923, p. 170.
Type.—♀: Katmai, Alaska, July, 1917 (J. S. Hine).
Antennal segments mostly missing.

Rhadinoceraea similata MacGillivray
Can. Ent., Vol. XL, No. 8, August, 1908, p. 290.
Type.—♀: Agricultural College, Michigan, June 3, 1896.
Lectoallotype.—♂: Ithaca, New York.
The lectoallotype was labeled by MacGillivray as a paratype.

Rhogogastera respectus MacGillivray
Journ. N. Y. Ent. Soc., Vol. XXXI, No. 4, December, 1923, p. 165
Type.—♀: Katmai, Alaska, July, 1917 (J. S. Hine).

Rhogogastera respersus MacGillivray
Journ N. Y. Ent. Soc., Vol. XXXI, No. 4, December, 1923, p. 165.
Type.—♂: Katmai, Alaska, July, 1917 (J. S. Hine).

Rhogogastera ruga MacGillivray
Can. Ent., Vol. LV, No. 7, July, 1923, p. 160.
Type.—♀: Edmonton, Alberta, Alaska, May 30, 1917 (F. S. Carr).

Schizocerus johnsoni MacGillivray
Can. Ent., Vol. XLI, No. 11, November, 1909, p. 403.
Type.—♀: Riverton, New Jersey, June 27 (C. W. Johnson).

Selandria bipartita Cresson
Trans. Amer. Ent. Soc., Vol. VIII, January, 1880, p. 12.
Paratype.—♂: Texas.
Transferred to the genus *Periclista* Konow by Konow (1905). Antennae missing.

Selandria caryae Norton
Trans. Amer. Ent. Soc., Vol. IV, May, 1872, p. 83.
Allotype.—♂: No data associated with specimen.
Transferred by MacGillivray (1916) to the genus *Erythraspides* Ashmead. Antennae missing.

Selandria diluta Cresson
Trans. Amer. Ent. Soc., Vol. VIII, January, 1880, p. 12.
Paratype.—♀: Missouri.
Transferred by MacGillivray (1916) to the genus *Isodyctium* Ashmead which is now considered as a synonym of *Periclista* Konow. Right antenna missing.

Selandria floridana MacGillivray
Can. Ent., Vol. XXVII, No. 10, October, 1895, p. 281.
Type.—♂: Ormond, Florida.
MacGillivray has transferred this species to the genus *Polyselandria* MacGillivray. The genotype of *Polyselandria* MacGillivray (original designation).

Simplemphytus pacificus MacGillivray
Can. Ent., Vol. XLVI, No. 10, October, 1914, p. 363.
Type.—♀: Troutdale, Oregon, reared from larvae boring in stems of cherry, December 8, 1913 (H. F. Wilson).
Paratypes.—♀ and ♂: Troutdale, Oregon, reared from larvae boring in stems of cherry, February 27, 1914 (H. F. Wilson).
Though a male is included in the type series it is not recorded in the original description as such, and therefore it has not been selected as a lectoallotype. The genotype of *Simplemphytus* MacGillivray (original designation).

Strongylogaster pacificus MacGillivray
Can. Ent., Vol. XXV, No. 10, October, 1893, p. 241.
Cotype.—♀: Olympia, Washington, May 21, 1892 (T. Kincaid).
Cotype.—♂: Olympia, Washington, May 7, 1893 (T. Kincaid).

Strongylogaster primativus MacGillivray
Can. Ent., Vol. XXV, No. 10, October, 1893, p. 241.
Cotype.—♀: Olympia, Washington, May 18, 1892 (T. Kincaid).
In fair condition. Transferred to the genus *Tenthredopsis* Costa by MacGillivray in 1894.

Strongylogaster rufoculus MacGillivray
Can. Ent., Vol. XXVI, No. 11, November, 1894, p. 327.
Type.—♀: Ithaca, New York, June 5, 1890.
In the collection MacGillivray had transferred this to the genus *Strongylogastroidea* Ashmead.

Strongylogastroidea confusa MacGillivray
Can. Ent., Vol. XL, No. 10, October, 1908, p. 369.
Type.—♀: West Springfield, Massachusetts, June 22, 1897 (J. O. Martin).

Strongylogastroidea depressata MacGillivray
Psyche, Vol. XXVIII, No. 2, April, 1921, p. 31.
Type.—♀: Orono, Maine, reared (H. Yuasa, Sub. 39).

Strongylogastroidea potulenta MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 31.
Type.—♀: Poughkeepsie, New York, June 26 (R. L. Junghanns).
This type is stated to be a male in the original description, but it is a female.

Strongylogastroidea rufinerva MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 31.
Type.—♀: Glen to Half-way House, White Mountains, New Hampshire, July 8, 1891 (A. P. Morse).

Strongylogastroidea rufocinctana MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 31.
Type.—♀: Richmond Hill, Long Island, New York, June 1, 1903.

Strongylogastroidea rufocinctella MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 32.
Type.—♀: Hampton, New Hampshire, June 1, 1906 (S. A. Shaw).
The type is stated to be a male in the original description, but it is a female.

Stronglogastroidea rufula MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 32.
Type.—♀: Ithaca, New York, August 11, 1904.

Stronglogastroidea shermani MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 32.
Type.—♀: Hendersonville, North Carolina, June, 1907 (F. Sherman, Jr.).

Strongylogastroidea spiculatus MacGillivray
Can. Ent., Vol. XL, No. 10, October, 1908, p. 369.
Type.—♀: Ellenville, New York, June 9, 1898 (C. Young).

Strongylogastroidea unicinctella MacGillivray
Univ. Ill. Bull. Vol. XX, No. 50, August 13, 1923, p. 33.
Type.—♀: Ithaca, New York, August 10, 1904.

Taxonus borealis MacGillivray
Can. Ent., Vol. XXVII, No. 3, March, 1895, p. 78.
Type.—♀: Mount Washington, New Hampshire (A. T. Slosson).
Transferred by MacGillivray to the genus *Strongylogastroidea* Ashmead. Now considered as synonymous with *Taxonus unicinctus* Norton.

Taxonus inclinatus MacGillivray
Psyche, Vol. XXX, No. 2, April, 1923, p. 78.
Type.—♂: Corvallis, Oregon, May 13 (Hardman).

Taxonus innominatus MacGillivray
N. Y. State Mus., Bull. 47, September, 1901, p. 585.
Type.—♀: Saranac Inn, New York, August 3, 1900.

Tenthredo aequalis MacGillivray
Can. Ent., Vol. XXVII, No. 10, October, 1895, p. 284.
Type.—♀: Colorado, 1342 (C. F. Baker).

Tenthredo aldrichii MacGillivray
Can. Ent., Vol. XXXII, No. 6, June, 1900, p. 183.
Type.—♀: Juliaetta, Idaho, May 1, 1899 (J. M. Aldrich).

Tenthredo alphius MacGillivray
Can. Ent., Vol. XXXII, No. 6, June, 1900, p. 182.
Type.—♀: Olympia, Washington, July 3, 1896 (T. Kincaid).

Tenthredo atracostus MacGillivray
Can. Ent., Vol. XXXII, No. 6, June, 1900, p. 183.
Type.—♀: Craigs Mountain, Idaho (J. M. Aldrich).

Tenthredo atravenus MacGillivray
Can. Ent., Vol. XXVII, No. 10, October, 1895, p. 283.
Type.—♂: Juliaetta, Idaho (J. M. Aldrich).

Tenthredo bilineatus MacGillivray
Can. Ent., Vol. XXVII, No. 10, October, 1895, p. 282.
Type.—♀: Ithaca, New York, July 1, 1894.

Tenthredo capitatus MacGillivray
Journ. N. Y. Ent. Soc., Vol. V, No. 3, September, 1897, p. 108.
Type.—♀: Olympia, Washington, May 25, 1894 (T. Kincaid).

Tenthredo causatus MacGillivray
Can. Ent., Vol. XXXII, No. 6, June, 1900, p. 178.
Type.—♂: Ithaca, New York, June 19, 1897.

Tenthredo dubitatus MacGillivray
Journ. N. Y. Ent. Soc. Vol. V, No. 3, September, 1897, p. 103.
Type.—♂: Jay, Vermont, July 15, 1891 (A. P. Morse).
Specific name emended to *dubitata* by MacGillivray in 1916. Now considered as a color variant of *Tenthredella grandis* (Norton).

Tenthredo fernaldii MacGillivray
Can. Ent., Vol. XXXII, No. 6, June, 1900, p. 177.
Type.—♀: Amherst (Hatch Experiment Station), Massachusetts, July 8, 1895 (C. H. Fernald).
Specific name emended to *fernaldi* by MacGillivray in 1916. Now considered as a color variant of *Tenthredo* [*Allantus*] *dubia* (Norton).

Tenthredo hyalinus MacGillivray
Journ. N. Y. Ent. Soc., Vol. V, No. 3, September, 1897, p. 108.
Type.—♂: Plattsburg, New York, June 12, 1894 (H. G. Dyar).

Tenthredo junghannsii MacGillivray
Can. Ent., Vol. XXXII, No. 6, June, 1900 ,p. 179.
Type.—♀: Ithaca, New York, June 19, 1895 (R. L. Junghanns).
Paratypes.—♀: Ithaca, New York, June 19, 1895 (R. L. Junghanns).

Tenthredo lateralba MacGillivray
Journ. N. Y. Ent. Soc., Vol. V, No. 3, September, 1897, p. 108.
Type.—♀: Colorado, 1342 (C. F. Baker).

Tenthredo linipes MacGillivray
Journ. N. Y. Ent. Soc., Vol. V, No. 3, September, 1897, p. 104.
Type.—♂: Olympia, Washington, June 1, 1894 (T. Kincaid).
Paratypes.—♂: Olympia, Washington, May 16, 1897 (T. Kincaid).

Tenthredo lunatus MacGillivray
Can. Ent., Vol. XXXII, No. 6, June, 1900, p. 180.
Type.—♀: Olympia, Washington, May 10, 1894 (T. Kincaid).

Tenthredo magnatus MacGillivray
Journ. N. Y. Ent. Soc., Vol. V, No. 3, September, 1897, p. 107.
Type.—♂: Olympia, Washington, July 30, 1893 (T. Kincaid).

Tenthredo messica MacGillivray
Journ. N. Y. Ent. Soc., Vol. V, No. 3, September, 1897, p. 107.
Type.—♂: Olympia, Washington, July 2, 1893 (T. Kincaid).
Paratype.—♂: Olympia, Washington, June 13, 1894 (T. Kincaid).

Tenthredo messicaeformis Rohwer
Can. Ent., Vol. XLI, No. 5, May, 1909, p. 147.
Paratype.—♂: Top of Las Vegas Range, New Mexico, June 28, (T. D. A. Cockerell).
Antennae are missing.

Tenthredo neoslossoni MacGillivray
Can. Ent., Vol. XLVI, No. 4, April, 1914, p. 138.
Type.—♀: Franconia, New Hampshire (A. T. Slosson).
Now considered as a synonym of *Tenthredella cogitans* (Provancher).

Tenthredo nigricoxi MacGillivray
Can. Ent., Vol. XXXII, No. 6, June, 1900, p. 181.
Type.—♂: Olympia, Washington, May 9, 1894 (T. Kincaid).

Tenthredo nigrifascia MacGillivray
Can. Ent., Vol. XXXII, No. 6, June, 1900, p. 184.
Type.—♀: Olympia, Washington, May 28, 1895 (T. Kincaid).

Tenthredo nigritibialis MacGillivray
Journ. N. Y. Ent. Soc., Vol. V, No. 3, September, 1897, p. 107.
Type.—♂: Olympia, Washington, July 9, 1893 (T. Kincaid).

Tenthredo nova MacGillivray
Journ. N. Y. Ent. Soc., Vol. V, No. 3, September, 1897, p. 105.
Type.—♀: Mount Washington (A. T. Slosson).

Tenthredo obliquatus MacGillivray
Journ. N. Y. Ent. Soc., Vol. V, No. 3, September, 1897, p. 105.
Type.—♀: Olympia, Washington, July 16, 1893 (T. Kincaid).
Lectoallotype.—♂: Olympia, Washington, May 28, 1893 (T. Kincaid).
Now considered as a variety of *Tenthredella elegantula* Cresson.
The lectoallotype was labeled by MacGillivray as a paratype.

Tenthredo olivatipes MacGillivray
Can. Ent., Vol. XXXII, No. 6, June, 1900, p. 180.
Type.—♀: Olympia, Washington, July 2, 1893 (T. Kincaid).

Tenthredo pallicola MacGillivray
Can. Ent., Vol. XXVII, No. 3, March, 1895, p. 80.
Type.—♀: Mount Washington, New Hampshire (A. T. Slosson).

Tenthredo pallipectis MacGillivray
Journ. N. Y. Ent. Soc., Vol. V, No. 3, September, 1897, p. 106.
Type.—♂: Olympia, Washington, July 2, 1893 (T. Kincaid).

Tenthredo pallipunctus MacGillivray
Can. Ent., Vol. XXVII, No. 10, October, 1895, p. 282.
Type.—♀: Colorado, 782 (C. F. Baker).

Tenthredo perplexus MacGillivray
Journ. N. Y. Ent. Soc., Vol. V, No. 3, September, 1897, p. 104.
Type.—♀: Olympia, Washington, May 23, 1894 (T. Kincaid).

Tenthredo rabida MacGillivray
Journ. N. Y. Ent. Soc., Vol. XXXI, No. 2, June, 1923, p. 110.
Type.—♀: Mary's Peak, Corvallis, Oregon, July 14, (L. G. Gentner).

Tenthredo rabiosa MacGillivray
Journ. N. Y. Ent. Soc., Vol. XXXI, No. 2, June, 1923, p. 112.
Type.—♀: Philomath, Oregon, May 16 (A. L. Lovett).

Tenthredo rabula MacGillivray
Journ. N. Y. Ent. Soc., Vol. XXXI, No. 2, June, 1923, p. 112.
Type.—♂: Corvallis, Oregon (Hunter).

Tenthredo racilia MacGillivray
Journ. N. Y. Ent. Soc., Vol. XXXI, No. 2, June, 1923, p. 112.
Type.—♂: Corvallis, Oregon (L. K. Couch).

Tenthredo ralla MacGillivray
Journ. N. Y. Ent. Soc., Vol. XXXI, No. 2, June, 1923, p. 111.
Type.—♀: Mary's Peak, Corvallis, Oregon, July 14 (A. L. Lovett).
The antennae are missing.

Tenthredo redimacula MacGillivray
Can. Ent., Vol. XXVII, No. 3, March, 1895, p. 78.
Type.—♀: Mount Washington, New Hampshire (A. T. Slosson).
Paratype.—♀: Mount Washington, New Hampshire (A. T. Slosson).

Tenthredo reduvia MacGillivray
Journ. N. Y. Ent. Soc., Vol. XXXI, No. 2, June, 1923, p. 108.
Type.—♀: Corvallis, Oregon, July 1, 1905 (Foster).

Tenthredo refactaria MacGillivray
Journ. N. Y. Ent. Soc., Vol. XXXI, No. 2, June, 1923, p. 113.
Type.—♀: Union County, Oregon, June 22, 1922 (A. L. Lovett).

Tenthredo reflua MacGillivray
Journ. N. Y. Ent. Soc., Vol. XXXI, No. 2, June, 1923, p. 111.
Type.—♂: Bellfountain, Oregon, May 27, 1922 (A. L. Lovett).

Tenthredo refuga MacGillivray
Journ. N. Y. Ent. Soc., Vol. XXXI, No. 4, December, 1923, p. 167.
Type.—♀: Katmai, Alaska, July, 1917 (J. S. Hine).
Paratype.—♀: Katmai, Alaska, July, 1917 (J. S. Hine).

Tenthredo regula MacGillivray
Journ. N. Y. Ent. Soc., Vol. XXXI, No. 4, December, 1923, p. 166.
Type.—♀: Katmai, Alaska, July, 1917 (J. S. Hine).

Tenthredo reliquia MacGillivray
Journ. N. Y. Ent. Soc., Vol. XXXI, No. 4, December, 1923, p. 168.
Type.—♀: Katmai, Alaska, July, 1917 (J. S. Hine).
Paratype.—♀: Katmai, Alaska, July, 1917 (J. S. Hine).

Tenthredo remea MacGillivray
Journ. N. Y. Ent. Soc., Vol. XXXI, No. 2, June, 1923, p. 107.
Type.—♀: Corvallis, Oregon, May 16, 1914 (Finch).

Tenthredo remissa MacGillivray
Journ. N. Y. Ent. Soc., Vol. XXXI, No. 2, June, 1923, p. 114.
Type.—♂: Corvallis, Oregon, June 3, 1908.

Tenthredo remora MacGillivray
Journ. N. Y. Ent. Soc., Vol. XXXI, No. 2, June, 1923, p. 108.
Type.—♂: Corvallis, Oregon, May 24, 1912 (F. C. Shepard).
Now considered as a synonym of *Tenthredella signata* (Norton).

Tenthredo remota MacGillivray
Can. Ent., Vol. XXVII, No. 3, March, 1895, p. 81.
Type.—♀: Franconia, New Hampshire (A. T. Slosson).

Tenthredo reperta MacGillivray
Journ. N. Y. Ent. Soc., Vol. XXXI, No. 2, June, 1923, p. 115.
Type.—♀: Juliaetta, Idaho (J. M. Aldrich).
Paratype.—♀: Lewiston, Idaho (J. M. Aldrich).

Tenthredo replata MacGillivray
Journ. N. Y. Ent. Soc., Vol. XXXI, No. 2, June, 1923, p. 115.
Type.—♀: Ormsby County, Nevada, July (C. F. Baker).

Tenthredo repleta MacGillivray
Journ. N. Y. Ent. Soc., Vol. XXXI, No. 2, June, 1923, p. 111.
Type.—♀: Mary's Peak, Corvallis, Oregon, July 14, (L. G. Gentner).
Paratypes.—♀: Mary's Peak, Corvallis, Oregon, July 18, 1914 (L. G. Gentner), Rock Creek, Oregon, July 14, (A. L. Lovett).
The paratype from Rock Creek, Oregon, is not mentioned by locality in the original description. It is labeled as a paratype by MacGillivray and is undoubtedly the specimen referred to in the original description as collected by A. L. Lovett, because the other two specimens were collected by L. G. Gentner.

Tenthredo reposita MacGillivray
Journ. N. Y. Ent. Soc., Vol. XXXI, No. 2, June, 1923, p. 116.
Type.—♂: Bellfountain, Oregon, May 27, 1922 (A. L. Lovett).

Tenthredo reputina MacGillivray
Journ. N. Y. Ent. Soc., Vol. XXXI, No. 2, June, 1923, p. 114.
Type.—♂: Bellfountain, Oregon, May 27, 1922 (A. L. Lovett).
Paratypes.—♂: Bellfountain, Oregon, May 27, 1922 (A. L. Lovett).

Tenthredo reputinella MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 33.
Type.—♂: Mount Washington, New Hampshire (A. T. Slosson).

Tenthredo requieta MacGillivray
Journ. N. Y. Ent. Soc., Vol. XXXI, No. 4, December, 1923, p. 167.
Type.—♀: Katmai, Alaska, June, 1917 (J. S. Hine).

Tenthredo resegmina MacGillivray
Journ. N. Y. Ent. Soc., Vol. XXXI, No. 2, June, 1923, p. 115.
Type.—♂: Bellfountain, Oregon, May 27, 1922 (A. L. Lovett).

Tenthredo resima MacGillivray
Journ. N. Y. Ent. Soc., Vol. XXXI, No. 2, June, 1923, p. 109.
Type.—♀: Mary's River, Corvallis, Oregon, May 3 (Hardman).

Tenthredo resticula MacGillivray
Journ. N. Y. Ent. Soc., Vol. XXXI, No. 4, December, 1923, p. 168.
Type.—♀: Katmai, Alaska, July, 1917 (J. S. Hine).
Paratype.—♀: Katmai, Alaska, July, 1917 (J. S. Hine).

Tenthredo restricta MacGillivray
Journ. N. Y. Ent. Soc., Vol. XXXI, No. 2, June, 1923, p. 110.
Type.—♂: Alsea, Oregon, June 4, 1922 (A. L. Lovett).

Tenthredo resupina MacGillivray
Journ. N. Y. Ent. Soc., Vol. XXXI, No. 2, June, 1923, p. 113.
Type.—♂: Bellfountain, Oregon, May 27, 1922 (A. L. Lovett).

Tenthredo reticentia MacGillivray
Journ. N. Y. Ent. Soc., Vol. XXXI, No. 2, June, 1923, p. 114.
Type.—♀: Corvallis, Oregon, May 30, 1912 (E. O. Dalgren).
Paratypes.—♀: Alsea, Oregon (A. L. Lovett).

Tenthredo retinentia MacGillivray
Journ. N. Y. Ent. Soc., Vol. XXXI, No. 4, December, 1923, p. 166.
Type.—♀: Kodiak, Alaska, June 10, 1917 (J. S. Hine).

Tenthredo retosta MacGillivray
Journ. N. Y. Ent. Soc., Vol. XXXI, No. 2, June, 1923, p. 109.
Type.—♂: There is no locality label associated with the specimen. MacGillivray lists it as "? Corvallis, Oregon; received from A. L. Lovett."

Tenthredo retroversa MacGillivray
Journ. N. Y. Ent. Soc., Vol. XXXI, No. 4, December, 1923, p. 167.
Type.—♂: Katmai, Alaska, July, 1917 (J. S. Hine).

Tenthredo rhammisia MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 33.
Type.—♀: Sea Side, Oregon, August 15, 1914 (L. G. Gentner).

Tenthredo rima MacGillivray
Journ. N. Y. Ent. Soc., Vol. XXXI, No. 2, June, 1923, p. 110.
Type.—♂: Corvallis, Oregon, April 16, 1896.

Tenthredo ripula MacGillivray
Journ. N. Y. Ent. Soc., Vol. XXXI, No. 2, June, 1923, p. 109.
Type.—♂: Corvallis, Oregon, May 27, 1914 (R. K.).

Tenthredo rota MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 34.
Type.—♀: Colorado.

Tenthredo rotula MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 34.
Type.—♂: Potsdam, New York, June, 1899 (C. O. Houghton).

Tenthredo rubicunda MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 34.
Type.—♀: Franconia, New Hampshire (A. T. Slosson).

Tenthredo rubrica MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 35.
Type.—♀: Moscow, Idaho (J. M. Aldrich).

Tenthredo rubricosa MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 35.
Type.—♂: Algonquin, Illinois (W. A. Nason).

Tenthredo rubripes MacGillivray
Can. Ent., Vol. XXXII, No. 6, June, 1900, p. 178.
Type.—♂: Ithaca, New York, June 19, 1897 (R. L. Junghanns).
Paratype.—♂: Ithaca, New York, June 3, 1897 (R. L. Junghanns).

Tenthredo rubrisommus MacGillivray
Can. Ent., Vol. XXII, No. 6, June, 1900, p. 181.
Type.—♀: Grangeville, Idaho (J. M. Aldrich).

Tenthredo rudicula MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 35.
Type.—♀: Orono, Maine.

Tenthredo rufostigmus MacGillivray
Can. Ent., Vol. XXVII, No. 10, October, 1895, p. 283.
Type.—♂: Craig's Mountain, Idaho (J. M. Aldrich).

Tenthredo ruina MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 36.
Type.—♀: Vollmer, Idaho, May 30 (J. M. Aldrich).

Tenthredo ruinosa MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 36.
Type.—♀: Southwestern Colorado, July 23, 1899 (E. J. Oslar).

Tenthredo ruma MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 36.
Type.—♂: Jeannette, Pennsylvania (H. G. Klages).

Tenthredo rumina MacGillivray
Can. Ent., Vol. LV, No. 7, July, 1923, p. 160.
Type.—♀: Edmonton, Alberta, July 29, 1916 (F. S. Carr).
A large part of the antennae is missing.

Tenthredo rurigena MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 36.
Type.—♀: Colorado.

Tenthredo russa MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 37.
Type.—♀: Harrison, Idaho (J. M. Aldrich).

Tenthredo rustica MacGillivray
Journ. N. Y. Ent. Soc., Vol. XXXI, No. 2, June, 1923, p. 113.
Type.—♂: Union County, Oregon, June 22, 1922 (A. L. Lovett).

Tenthredo rusticana MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 37.
Type.—♀: Black Mountains, North Carolina, June (W. Beutenmüller).

Tenthredo rusticula MacGillivray
Journ. N. Y. Ent. Soc., Vol. XXXI, No. 4, December, 1923, p. 166.
Type.—♂: Katmai, Alaska, July, 1917 (J. S. Hine).

Tenthredo ruta MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 37.
Type.—♀: Pullman, Washington, May 5, 1905 (C. V. Piper).

Tenthredo rutata MacGillivray
Univ. Ill. Bull., Vol. XX, No. 50, August 13, 1923, p. 38.
Type.—♀: Culvers Lake, New Jersey, May 29.

Tenthredo rutila MacGillivray
Can. Ent., Vol. LV, No. 7, July, 1923, p. 160.
Type.—♀ Edmonton, Alberta, Canada, June, 1917 (F. S. Carr).

Tenthredo savagei MacGillivray
Can. Ent., Vol. XXXII, No. 6, June, 1900, p. 184.
Type.—♀: Juliaetta, Idaho (J. M. Aldrich).

Tenthredo secundus MacGillivray
Journ. N. Y. Ent. Soc., Vol. V, No. 3, September, 1897, p. 105.
Type.—♀: Mount Washington, New Hampshire (A. T. Slosson).
Paratype—♀: Mount Washington, New Hampshire (A. T. Slosson).

Tenthredo sicatus MacGillivray
Can. Ent., Vol. XXXII, No. 6, June, 1900, p. 179.
Type.—♂: Washington (C. V. Piper).

Tenthredo simulatus MacGillivray
Journ. N. Y. Ent. Soc., Vol. V, No. 3, September, 1897, p. 105.
Type.—♀: Winchendon, Massachusetts, July 1, 1892 (A. P. Morse).

Tenthredo slossonii MacGillivray
Can. Ent., Vol. XXXII, No. 6, June, 1900, p. 179.
Type.—♂: Franconia, New Hampshire (A. T. Slosson).
Spelling of specific name emended to *slossoni* by MacGillivray in 1916. Now considered as a synonym of *Tenthredella signata* (Norton).

Tenthredo smectica MacGillivray
Bull. Brooklyn Ent. Soc., Vol. XV, No. 4, October, 1920, p. 113.
Type.—♀: Ithaca, New York, bred, May 29, 1919, 8-11-2 (?)-2 (H. Yuasa).

Tenthredo stigmatus MacGillivray
Journ. N. Y. Ent. Soc., Vol. V, No. 3, September, 1897, p. 108.
Type.—♂: Seattle, Washington, June 4, 1895 (S. Bethel).

Tenthredo terminatus MacGillivray
Can. Ent., Vol. XXVII, No. 10, October, 1895, p. 283.
Type.—♀: Colorado, 1365 (C. F. Baker).

Tenthredo ventricus MacGillivray
Can. Ent., Vol. XXVII, No. 10, October, 1895, p. 284.
Type.—♂: Colorado, 860 (C. F. Baker).

Tenthredo yuasi MacGillivray
Bull. Brooklyn Ent. Soc., Vol. XV, No. 4, October, 1920, p. 112.
Type.—♀: Ithaca, New York, bred, May 20, 1919, 8-46-1 (H. Yuasa).

Tenthredopsis ruficorna (MacGillivray)
Can. Ent., Vol. XXV, No. 10, October, 1893, p. 242.
Type.—♀: Olympia, Washington, May 22, 1892 (T. Kincaid).
Subsequently made the genotype of *Kincaidia* MacGillivray (original designation).

Thrinax pullatus MacGillivray
Psyche, Vol. XXVIII, No. 2, April, 1921, p. 34.
Type.—♂: Ithaca, New York, May 21, 1918, reared (H. Yuasa, 20-1).

Tomostethus nortonii MacGillivray
Can. Ent., Vol. XL, No. 8, August, 1908, p. 291.
Type.—♀: Ames, Iowa (E. D. Ball).

Trichiocampus pacatus MacGillivray
Ent. News, Vol. XXXII, No. 2, February, 1921, p. 48.
Type.—♀: Ithaca, New York, bred, August 20, 1919, No. 88-1 (H. Yuasa).

Trichiocampus paetulus MacGillivray
Ent. News, Vol. XXXII, No. 2, February, 1921, p. 48.
Type.—♀: Onekama, Michigan, bred from larva on *Populus*, August, 1914 (A. D. McGillivray).

Trichiocampus palliolatus MacGillivray
Ent. News, Vol. XXXII, No. 2, February, 1921, p. 49.
Type.—♀: Ithaca, New York, bred, July 4, 1918, No. 15-4-1-1 (H. Yuasa).
Now placed in the genus *Priophorus* Dahlbom (Yuasa, 1922).

Trichiocampus patchiae MacGillivray
Ent. News, Vol. XXXII, No. 2, February, 1921, p. 48.
Type.—♀: Orono, Maine, bred, August 9, 1913, Sub. 100.
Paratype.—♀: Orono, Maine, bred, August 9, 1913, Sub. 100.

Trichiosoma confundum MacGillivray
Can. Ent., Vol. LV, No. 7, July, 1923, p. 161.
Type.—♀: Edmonton, Alberta, Canada, June 15, 1917 (F. S. Carr).

Trichiosoma confusum MacGillivray
State Geol. Nat. Hist. Surv. Conn., Bull. 22, 1916, p. 103.
Type.—♂: Saranac Inn, New York, June 17, 1900.

Lectoallotype.—♀: No data.

Paratype.—♂: Adirondack Mountains, Axton, New York, June 12-22, 1901 (A. D. MacGillivray and C. O. H.).

This species is now considered a synonym of *Trichiosoma bicolor* Norton.

Trichiosoma spicatum MacGillivray

State Geol. Nat. Hist. Surv. Conn., Bull. 22, 1916, p. 103.

Type.—♂: Mount Katahdin, Maine.

Paratypes.—♂: Mount Katahdin, Maine, and Claremont, New Hampshire.

Unitaxonus repentinus MacGillivray

Psyche, Vol. XXVIII, No. 2, April, 1921, p. 32.

Type.—♀: Ithaca, New York, July 5, 1918, reared (H. Yuasa, 129-1-2).

Allotype.—♂: Ithaca, New York, July 2, 1918, reared (H. Yuasa, 129-1-2).

Paratype.—♀: Ithaca, New York, July 1, 1918, reared (H. Yuasa, 129-1-2).

The genotype of *Unitaxonus* MacGillivray (original designation).

Unitaxonus rumicis MacGillivray

Psyche, Vol. XXVIII, No. 2, April, 1921, p. 33.

Type.—♀: Ithaca, New York, reared (H. Yuasa, 91-2-1).

FAMILY SIRICIDAE.

Urocerus indecisus MacGillivray

Can. Ent., Vol. XXV, No. 10, October, 1893, p. 243.

Type.—♂: Olympia, Washington (T. Kincaid).

Urocerus riparius MacGillivray

Can. Ent., Vol. XXV, No. 10, October, 1893, p. 244.

Type.—♂: Skokomish River, Washington, May 3, 1892 (T. Kincaid).

APPENDIX

Types of some of the species of Tenthredinoidea described by Dr. A. D. MacGillivray are in the custody of other institutions. A few types which should be in his private collection were not found. The following list gives in alphabetical sequence the names of these species, and places of original descriptions and locations of types if known.

Amauronematus aulatus MacGillivray
Rept. Can. Arctic Exp. 1913-1918, Vol. 3G, November, 1919, p. 16g.
Type in Canadian National Collection.

Amauronematus cogitatus MacGillivray
Rept. Can. Arctic Exp. 1913-1918, Vol. 3G, November, 1919, p. 15g.
Type in Canadian National Collection.

Amauronematus completus MacGillivray
Rept. Can. Arctic Exp. 1913-1918, Vol. 3G, November, 1919, p. 13g.
Type in Canadian National Collection.

Amauronematus digestus MacGillivray
Rept. Can. Arctic Exp. 1913-1918, Vol. 3G, November, 1919, p. 14g.
Type in Canadian National Collection.

Amauronematus indicatus MacGillivray
Rept. Can. Arctic Exp. 1913-1918, Vol. 3G, November, 1919, p. 14g.
Type in Canadian National Collection.

Amauronematus magnus MacGillivray
Rept. Can. Arctic Exp. 1913-1918, Vol. 3G, November, 1919, p. 17g.
Type in Canadian National Collection.

Amauronematus varianus MacGillivray
Rept. Can. Arctic Exp. 1913-1918, Vol. 3G, November, 1919, p. 16g.
Type in Canadian National Collection.

Bivena maria MacGillivray
Can. Ent. Vol. XXVI, No. 11, November, 1894, p. 327.
Location of type?

Euura abortiva MacGillivray
Rept. Can. Arctic Exp. 1913-1918, Vol. 3G, November, 1919, p. 4g.
Type in Canadian National Collection.

Euura arctica MacGillivray
Rept. Can. Arctic Exp. 1913-1918, Vol. 3G, November, 1919, p. 5g.
Type in Canadian National Collection.

Lyda olympia MacGillivray
Can. Ent., Vol. XXV, No. 10, October, 1893, p. 243.
Location of type?

Macrophya bilineata MacGillivray
State Geol. Nat. Hist. Sur. Conn., Bull. 22, 1916, p. 96.
The type can not be in the MacGillivray Collection as indicated by MacGillivray. It should be in the Collection of the Conn. Agr. Exp. Sta. See notes under this name in text.

Macrophya slossonae MacGillivray
Can. Ent., Vol. XXVII, No. 3, March, 1895, p. 78.
Location of type?

Messa atra MacGillivray
Can. Ent., Vol. XXV, No. 10, October, 1893, p. 238.
Location of type?

Pachynematus venustus MacGillivray
Proc. Calif. Acad. Sc., Vol. XI, No. 14 (4th Series), November 2, 1921, p. 190.
Type in Calif. Acad. of Sciences.

Pachynematus vernus MacGillivray
Proc. Calif. Acad. Sc., Vol. XI, No. 14 (4th Series), November 2, 1921, p. 191.
Type in Calif. Acad. of Sciences.

Parabates inspiratus MacGillivray
Ann. Ent. Soc. Amer., Vol. II, No. 4, December, 1909, p. 264.
Type in Calif. Acad. of Sciences.

Pontania delicatula MacGillivray
Rept. Can. Arctic Exp. 1913-1918, Vol. 3G, November, 1919, p. 86.
Type in Canadian National Collection.

Pontania deminuta MacGillivray
Rept. Can. Arctic Exp. 1913-1918, Vol. 3G, November, 1919, p. 9g.
Type in Canadian National Collection.

Pontania quadrifasciata MacGillivray
Rept. Can. Arctic Exp. 1913-1918, Vol. 3G, November, 1919, p. 10g.
Type in Canadian National Collection.

Pontania stipata MacGillivray
Proc. Calif. Acad. Sc., Vol. XI, No. 14 (4th Series), November 2, 1921, p. 188.
Type in Calif. Acad. of Sciences.

Pontania subatrata MacGillivray
Proc. Calif. Acad. Sc., Vol. XI, No. 14 (4th Series), November 2, 1921, p. 189.
Type in Calif. Acad. of Sciences.

Pontania sublorata MacGillivray
Proc. Calif. Acad. Sc., Vol. XI, No. 14 (4th Series), November 2, 1921, p. 190.
Type in Calif. Acad. of Sciences.

Pontania subpallida MacGillivray
Rept. Can. Arctic Exp. 1913-1918, Vol. 3G, November, 1919, p. 11g.
Type in Canadian National Collection.

Pontania sueta MacGillivray
Proc. Calif. Acad. Sc., Vol. XI, No. 14 (4th Series), November 2, 1921, p. 188.
Type in Calif. Acad. of Sciences.

Pontania trifasciata MacGillivray
Rept. Can. Arctic Exp. 1913-1918, Vol. 3G, November, 1919, p. 11g.
Type in Canadian National Collection.

Rhogogastera reliqua MacGillivray
Rept. Can. Arctic Exp. 1913-1918, Vol. 3G, November, 1919, p. 4g.
Type in Canadian National Collection.

Taxonus montanus MacGillivray
No description of this species found. Referred to by name only in Can. Ent., Vol. XL, No. 10, October, 1908, p. 366.

Tenthredo frigida MacGillivray
Can. Ent., Vol. XXVII, No. 3, March, 1895, p. 80.
Location of type?

Tenthredopsis transversa MacGillivray
Can. Ent., Vol. XXV, No. 10, October, 1893, p. 242.
Location of type?

INDEX

This index includes all scientific names referred to in this article, except those of the insect hosts or the plants from which the typic specimens were reared or collected. Order, family and generic names are in **bold face** type, valid specific and varietal names in Roman, synonymous and invalid names in *italics*. The generic name following the author's name indicates the genus under which the species is listed.

STATE OF ILLINOIS
DEPARTMENT OF REGISTRATION AND EDUCATION

DIVISION OF THE
NATURAL HISTORY SURVEY
STEPHEN A. FORBES, *Chief*

Vol. XVI. BULLETIN Articles V. & VI.

An Experimental Investigation of the Relations of the Codling Moth to Weather and Climate

By VICTOR E. SHELFORD

A Study of the Catalase Content of Codling Moth Larvae

By C. S. SPOONER

AUG. 26th 1818

PRINTED BY AUTHORITY OF THE STATE OF ILLINOIS

URBANA, ILLINOIS
March, 1927

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CONTENTS.

ARTICLE V.—*An Experimental Investigation of the Relations of the Codling Moth to Weather and Climate.* BY VICTOR E. SHELFORD.

INTRODUCTION.

The varied effects of the variable weather of current and preceding seasons on the rate of development of an insect, and hence on the time of appearance and period of continuance of each of its stages, and even on the number of generations in a year and the number of individuals in each generation, are often causes of uncertainty as to the best time to take steps for the control of an injurious species and as to the necessary intensity of control measures; and heavy losses often occur because the times chosen and the activity and thoroughness of the operation do not fit the pattern of the seasonal life history. It has hence become necessary to learn for each important insect species the facts of its life history under normal or usual conditions and the effects of unusual weather to retard or hasten its transformations and to diminish or increase its numbers.

This problem was brought to a crisis in Illinois in 1914, when an unusually hot and dry summer in combination with other favorable conditions in the southern part of the state so accelerated the development of the codling moth and so increased the number of the third generation and other late larvae, usually economically insignificant, that the most intelligent and careful apple growers suffered heavy losses, due to a lack of harmony between their standard spraying program and the larval periods of the successive generations of the codling moth. (Sprays are effective only if applied so as to have the poisons on the apples early in the larval period.) A serious study of the life history of this insect under field conditions was consequently begun, in the fall of 1914, and was continued with an elaborate equipment through the three following years. The results were published by the State Entomologist's Office* and the State Natural History Survey**, in 1916 and 1922, respectively.

These studies added materially to dependable information on this subject, but as they could deal only with such weather conditions as happened to occur in these years, their range was far too limited to warrant final conclusions concerning the effects of every kind of season likely to occur in Illinois.

The questions involved in so complex a problem called for long continued research by a climatologist provided with an ample equipment by which various kinds of weather could be artificially imitated in laboratories where the insects studied could be maintained under otherwise normal conditions. The present paper is the product of a series of such

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* Life history of the codling moth, by Stephen A. Forbes and Pressley A. Glenn, 29th Report, pp. 1-21. (1916)

** Codling moth investigations of the State Entomologist's Office, 1915-1917, by P. A. Glenn, Vol. XIV, Art. 7. (1922)

studies and experiments begun in 1917 and carried on continuously throughout the whole of each year, to and including 1922, in laboratories of the University of Illinois, equipped for the purpose in part by the Natural History Survey. While this paper is, therefore, necessarily technical and aimed especially at an improvement of apparatus and methods of climatological research, the application of conclusions to practical ends has been kept steadily in view, and a summary rehearsal of their uses to horticulture and of the methods of their application follows.

The weather in its relation to the codling moth is made up of several variable elements, each largely or completely independent of the others in its variation, and all of unequal effect on the life history of the insect and of unequal effect also upon the insect in the different stages of its development. The most powerful of these variable elements are temperature and humidity, but light, rainfall, air-movement, and rate of evaporation (the rate at which moist objects give up their moisture to the air), are too important to be ignored. By their various degrees and combinations these several elements make up a great number of kinds and gradations of weather whose effects upon insect life can be ascertained only by an experimental variation of each element separately and of various combinations of them taken together. Since they are not measurable by any single scale of magnitudes applicable to all of them—differences in heat, light, and humidity, for example, being expressed in different terms—there is no way in which their combined efficacies can be expressed in a single series of numbers except by a study of their joint effects upon the behavior, activities, and rates of development of the insect under examination.

The most convenient and practically the most important method of such a study is to experiment with artificial variations of these weather elements upon the rate of progress of an insect through its successive developmental stages, and upon the percentage of those in each of the earlier stages which survive to pass on into the next stage. The varying significance to the codling moth of different combinations of various degrees of temperature, humidity, illumination, etc., acting conjointly, may be stated in terms of the average time required under each combination for the hatching of the egg, the growth and pupation of the larva, or the transformation of the pupa to the adult insect; and the numbers thus obtained may be so tabulated that one knowing the meteorological data of a season up to a certain date may learn by reference to the table just where the insect is in the course of its development at that date, and then calculate the approximate date at which this stage of development will be completed and the insect will pass into the next stage.

As only two series of meteorological data can be carried on the same table, it has been found most convenient to construct a table of rates of development based on data of the two most potent elements, temperature and humidity, and to apply to the figures of this table any corrections which may be called for by facts concerning the other elements. Such tables and corrective data have been prepared for the codling moth, and they will be found, together with directions for their use, in PART ONE (pp. 318-327). Schemes for any necessary modification of the tabulated values are explained in PARTS TWO and THREE.

It will readily be seen that this indirect method of the application of weather data to the needs of horticulture presupposes the making and compilation of accurate and comprehensive meteorological data at numerous stations, each representing a definite district, and their continuous translation into terms of the rate of development of the insect. This is work for an expert with ample time at his command for such surveys, and inferences to be drawn as to the time and nature of practical control measures must have timely distribution by him to those concerned. Such conclusions and directions are at present formulated and distributed from time to time by the entomologists of the Natural History Survey, mainly through the farm advisers of the various counties of the state, but it is to be hoped that these farm advisers will presently become sufficiently acquainted with the method and sufficiently practiced in its application to be mainly independent in its use, subject only to the general supervision and advice of the entomologists.

It is also to be hoped that other entomologists will find themselves interested and enabled to continue investigation in this fruitful field, thus bringing to positive conclusion many matters left more or less in doubt in the present paper and attacking other problems here left untouched. To all such, it is believed that the third, especially technical, part of Dr. Shelford's discussion will have a high and indeed an indispensable value.

STEPHEN A. FORBES.

FOREWORD.

The present paper is divided into three parts for the convenience of three classes of readers:

PART ONE, for those who would apply the results of this investigation directly to the prediction of the time of appearance of the codling moth in its several stages in Illinois and in other places where weather conditions are similar, in order to set dates for spraying.

PART TWO, for those who would check the constants, climatological methods, and conclusions regarding the codling moth with data obtained in unusual years or in other climates.

PART THREE, for those who would utilize the methods here described in the investigation of the same or other organisms.

PART ONE.

PREDICTION PROCEDURE.

THE PROBLEM OF PREDICTING THE APPEARANCE OF THE CODLING MOTH

The codling moth is the most destructive insect infesting apples. Its larva, commonly called the apple-worm, eats its way into the fruit to the seeds, forming dark masses of frass, or castings, at the end of the hole and in the core. It is found wherever apples are grown throughout the world. It also attacks pears, quinces, wild haws, peaches, English walnuts, and other fruits. Its life history, appearance, and habits, together with control measures used against it, have been described by Metcalf and Flint* as follows:

> *Life History, Appearance, and Habits:* The Codling Moth passes the winter in the full-grown larval stage in a thick silken cocoon. The larvae are pinkish-white caterpillars with brown heads and are about three-fourths of an inch long. These cocoons are generally spun under loose scales of the bark on the trunks of apple trees, or other shelters about the base of the trees, or on the ground nearby. Many of the larvae winter in, or around, packing sheds. They remain dormant, and are able to withstand low temperatures. A drop in temperature to —25° F., or below, will kill many of the larvae. During the winter, birds, especially chickadees and woodpeckers, find and eat large numbers of the larvae. In the late spring the worms change inside their cocoons to a brownish pupal stage and, after a period of from two to four weeks or more, they emerge from the cocoons as grayish moths with somewhat irridescent, chocolate-brown patches on the back part or tip of the front wings. The moths have a wing expanse of from one-half to three-fourths of an inch. During the day the moths remain quiet, usually resting on the branches or trunk of the tree. The coloring of the wings is such that it blends with that of the bark, making the insect very inconspicuous. About dusk of the evening, if the temperature is above 60° F., they become active, mate, and the females lay their eggs. If the temperature is low, they remain quiet, and few eggs will be deposited. Each female usually deposits more than fifty eggs during her life time. The eggs are white, flattened, pancake-shaped, and about one-twenty-fifth of an inch in diameter. The eggs of the first generation are laid one in a place, almost entirely on the upper side of the leaves, usually a short distance from a cluster of apples. They are laid two to four weeks after the apples have bloomed, and hatch in six to twenty days depending on the temperature and, to some extent, on the rainfall. The worms feed slightly on the leaves but in a short time crawl to the young apples and chew their way into the fruit, usually entering by way of the calyx cup at the blossom end. After entering the fruit, they work their way into the core, often feeding on the seeds. Some of the infested fruits drop from the tree and the larvae complete their growth on the ground. Upon becoming full grown, they burrow to the outside of the apple and either crawl to, or down, the trunk of the tree, or drop to the ground and crawl back to the trunk or to some other object on which they spin their cocoons, and change as before to the pupa, and later to the adult stage.

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* The passage quoted is from "Destructive and Useful Insects," a text by C. L. Metcalf and W. P. Flint, which is now (1926) being used in mimeographed form (3 volumes) for instruction of classes in the University of Illinois.

In the latitude of southern Illinois, there is nearly a full first, nearly a full second, and a partial third generation of this insect in one season. In the latitude of northern Illinois, there is nearly a full first generation, a partial second, but no third generation. The emergence of the moths of the second generation extends over the entire summer, and eggs of this generation may be deposited in the north part of the United States as late as mid-August, or even the first of September. In the south, eggs may be laid as late as October.

Control Measures: While the Codling Moth, if left to itself, will infest from 20% to 95% of the apples in an orchard, it is possible to reduce the numbers of this insect so that less than 5% of the apples will be injured.

Spraying with arsenate of lead at the rate of from one to two pounds of powder to fifty* gallons of spray material is the standard remedy for the Codling Moth. It is highly important, however, that the sprays for this insect be applied at the proper time. The first and most important spray is that known as the petal-fall, or calyx, spray, which is applied when about three-fourths of the petals have fallen from the apple blossoms. The spray should not be applied when the trees are in full bloom because of the danger of poisoning honey bees. Special care should be used to hit the open calyx end of the apples and fill the calyx cup with the poison spray. Careful spraying that fills the calyx cup at this time will poison any young Codling Moth caterpillars that try to enter the apples at the blossom end for the remainder of the season. If spraying is delayed for more than a week after the petals fall, the calyx cup will have closed, and it will be impossible to force the spray into the calyx cup. A second application of spray should be made one week to ten days after the fall of the petals, and a third, three weeks after the petals fall. These sprays are all for the first generation of the Codling Moth.

The larvae of the second generation usually begin hatching from the eggs about nine weeks after the fall of the petals. However, this period is subject to considerable variation, sometimes as much as three weeks in different seasons. Owing to this fact, the time of the appearance of second and third generation larvae should be obtained in advance from the entomologist. If the notice of the time of appearance of the second generation larvae cannot be obtained in this way, the spray for the second generation should be applied nine weeks after the fall of the petals, and, in years when the Codling Moth is abundant, another spray should be given two weeks later.

* * *

In the South, a spray for third generation Codling Moths should be applied about August 15, and, during hot dry years, another spray should be given to winter varieties of apples about September 1.

Aside from spraying, there are several other measures which help in keeping down the Codling Moth. These consist of a thorough clean-up of the orchard, scraping the loose bark from old trees when the bark is scaling badly and, in cases of exceptional abundance, banding the trees during the summer. To get the best results from banding, place a strip of dark-colored building paper or tar-paper, four or five inches wide, tightly around the tree at a height of about two feet from the ground. Allow the ends to overlap slightly, fastening them with a large tack. These bands should be examined at least once a week and the Codling Moth larvae under them killed. The bands should be in place not later than June 1 in the latitude of southern Illinois, and June 15 in the latitude of northern Illinois. Experimental work in Illinois has shown that the tar-paper or building-paper bands are more attractive to the Codling Moth larvae than bands of burlap or cloth. Removing cull apples from the orchard, and a thorough clean-up of refuse and rubbish around the packing shed, will also help in keeping down the numbers of this insect.

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* If the *paste* arsenate of lead is used, double the amount.

"Two questions of special practical interest present themselves: one, the number of generations in a year; and the other, the time when the eggs of each generation hatch to give out the young worms. To these we may add a third question, as to variations in the number of generations and the times when the young larvae of each appear in different parts of the state, and in successive years of unlike weather conditions."*

Weather conditions, especially temperature, humidity, rainfall, and sunlight, have a great deal to do with the rate of development of the codling moth, with the time when the different generations make their appearance, reach their largest numbers, and disappear, and with the size and importance of the last or third generation of the year. The course of these events must be carefully and intelligently observed in order that spraying operations may be properly timed—to put the effective poisons on the apples when the larvae of each generation are to appear.

Measurement of development. Each stage in the life-cycle of an organism requires a certain period of time depending on weather conditions. The better the conditions, the shorter the time, and *vice versa,* within certain limits set by the nature of the organism. If development went on always at the same rate, the number of days or hours from the beginning to any point in the stage would be a direct measure of the amount of development which has been accomplished to that point. This is implied in such common expressions as "a year's growth" or "a day's growth," in which time alone is used as a measure of development on the assumption that the rate of growth is constant over a number of days or years. But rates of growth, or velocities of development, vary with conditions, so that it is necessary to refine this method by taking into account all factors affecting the process.

In attempting to predict the time of appearance of insect pests, to estimate the abundance of a pest or its enemies, and to arrange spraying schedules, phenologists have taken account of temperature as well as time by using "degree-days" in estimating development. They commonly get a total number of "degree-days" for a stage of development by taking for each day from the beginning to the end of the stage the number of degrees which the day's mean temperature shows above a certain assumed starting point, or "threshold", and summing the number of degrees thus obtained for all the days to the end of the stage. This "summing of effective temperatures in degree-days" is sometimes fairly useful for estimating development within certain limits of temperature. Glenn ('22) made corrections for high temperatures but not for low temperatures and for variations in humidity and other factors. This method is never very accurate, however, because medial temperatures and humidities (where the rate of development is directly proportional to temperature) are exceeded almost every day in our climate, and because development takes place at temperatures lower than the

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* Quoted from a paper "On the life history of the codling moth", by Stephen A. Forbes and Pressley A. Glenn, 29th Report of the State Entomologist of Illinois (1916).

"threshold" usually assumed. It is perhaps least successful in the spring of the year, when there is greatest need of reliable prediction in fixing spraying schedules for control of the codling moth.

The older "degree-day" method (Simpson '03) fails to give dependable results. Glenn's method is not sufficiently accurate to enable one to evaluate the effects of factors other than temperature, and hence it is most likely to fail in unusual seasons. A new method is needed, therefore, which will take into account the effects of all variations of all these factors in units of time shorter than the day. The method herein described aims to meet this need by using the amount of development accomplished in one hour as the basis of calculation.. This amount is a small fraction of the total development which makes up the stage in the life-cycle of the insect. The new unit is called the **developmental unit** and is to be defined with reference to the total development of which it is a part. It is not a "degree-hour," for it is not a measure of external conditions, but a measure of the response of the organism to those conditions. This response, moreover, is modified by other factors besides temperature; and so the *developmental unit,* taking into account all the phenomena affecting the process, is to be thought of properly as the *effect* of a "phenomena-degree-hour." (See *pheno-hour,* p. 332.)

Definition of the unit of development. The *developmental unit,* to be more specific, is the effect of one degree of mean medial variable temperature, operating for one hour in conjunction with mean medial variable humidity and with the air movement, light intensity, and other conditions normal to the habitat of the organism. In the case of insects and many other organisms whose development cannot be measured directly, this effect is best calculated in terms of the total time required to accomplish the stage of the life-cycle under consideration; for this time is shortened in direct proportion to rise of temperature within medial limits, so that the difference between the time required at a certain degree and the time required at another degree may be taken as a measure of the difference in amounts of development accomplished at those two temperatures. The *developmental unit,* for any stage in the life-cycle of the insect, is, therefore, defined as the difference in amount of development produced in one hour by a difference of one degree of mean medial variable temperature (other conditions being average), as shown by the difference in time required to complete the stage.

Developmental totals. The pupal stage of the codling moth, for example, which was considered by Glenn ('22) as requiring an average of 265 "degree-days" for complete development under normal conditions in Illinois, is here considered as normally consisting of 6,480 *developmental units* (hour units), this new total being the result of calculations based on data covering ten years of observation and experimentation, including Glenn's original data. The "degree-day" total took no adequate account

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TABLE I.

VELOCITY VALUES (NUMBERS OF DEVELOPMENTAL UNITS PER HOUR), FOR VARIOUS MEAN VALUES OF VARIABLE TEMPERATURE AND HUMIDITY, APPLICABLE TO THE CODLING MOTH PUPAE AND EGGS UNDER WEATHER CONDITIONS.

°F.	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90	92	94	96	98	100%
105	[illegible]	18.6	19.0	19.3	19.7	20.1	20.3	20.4	20.5	[illegible]	20.1	20.4	[illegible]	20.2	20.1	19.8	19.5	19.3	[illegible]	18.4	18.2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	13.0	12.1	11.3	10.5	9.8	9.1	8.2	7.4
104	[illegible]	20.0	20.4	20.9	21.2	21.4	21.5	21.6	21.7	21.8	21.8	21.7	21.6	21.5	21.4	21.2	20.9	20.4	20.3	20.0	19.5	19.0	18.4	18.1	17.4	16.8	16.0	15.1	14.1	[illegible]	11.8	10.7	10.3	9.5	[illegible]
103	[illegible]	21.4	21.9	22.5	22.8	23.2	23.4	23.5	23.7	23.7	23.5	23.5	23.4	[illegible]	22.9	22.6	[illegible]	22.0	[illegible]	21.4	21.1	[illegible]	20.2	[illegible]	19.3	18.4	18.1	17.1	16.2	[illegible]	13.9	12.8	11.8	10.5	[illegible]
102	[illegible]	23.2	23.7	24.3	24.6	24.8	25.2	25.4	25.5	25.6	25.6	25.5	[illegible]	25.0	24.8	24.6	24.4	23.9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	20.7	20.3	19.7	[illegible]	18.2	17.3	[illegible]	15.1	[illegible]	12.7	[illegible]
101	[illegible]	24.6	25.4	[illegible]	[illegible]	26.4	26.7	26.7	26.7	[illegible]	26.7	26.7	26.7	[illegible]	26.4	[illegible]	26.0	25.7	[illegible]	24.9	24.6	24.1	[illegible]	[illegible]	22.3	21.7	21.4	[illegible]	[illegible]	19.3	18.2	17.1	16.0	14.9	13.7
100	[illegible]	[illegible]	26.7	27.1	27.4	[illegible]	27.7	27.8	27.9	27.9	27.9	27.9	27.8	27.8	27.6	[illegible]	27.2	26.9	26.7	26.7	26.3	[illegible]	[illegible]	[illegible]	24.4	23.5	23.1	23.4	21.6	21.2	20.3	19.3	18.1	16.9	15.8
99	[illegible]	[illegible]	28.0	[illegible]	28.7	28.9	29.0	29.1	29.2	29.2	29.2	29.2	29.1	29.1	29.0	[illegible]	28.9	28.7	28.4	27.8	27.6	[illegible]	[illegible]	26.8	25.4	[illegible]	[illegible]	24.4	[illegible]	22.8	21.8	21.4	20.3	[illegible]	18.0
98	[illegible]	28.9	29.2	[illegible]	29.9	30.0	30.1	30.2	30.3	30.4	30.4	30.4	30.3	30.2	30.1	[illegible]	[illegible]	29.6	29.4	29.2	29.0	[illegible]	[illegible]	27.8	27.6	[illegible]	[illegible]	26.2	[illegible]	24.8	[illegible]	22.9	21.8	21.3	12.6
97	[illegible]	[illegible]	30.5	30.8	31.0	31.1	31.4	31.5	31.7	31.8	31.8	31.8	31.7	31.6	31.5	31.4	31.1	31.0	30.8	30.5	30.2	30.0	29.7	29.4	29.1	28.7	[illegible]	27.8	27.3	26.9	[illegible]	25.1	23.8	22.9	22.2
96	[illegible]	31.4	31.8	32.0	32.2	32.4	32.7	32.9	33.0	33.2	33.2	33.2	33.2	33.2	33.0	[illegible]	32.6	32.3	32.1	32.0	31.7	31.2	[illegible]	30.8	30.4	30.0	[illegible]	29.1	28.8	28.3	27.8	27.0	26.0	25.1	24.3
95	[illegible]	32.7	[illegible]	33.4	33.6	33.8	33.9	34.0	34.1	34.2	34.2	34.4	34.4	34.4	34.2	34.2	34.1	33.9	33.8	[illegible]	[illegible]	[illegible]	[illegible]	32.2	31.9	31.6	31.2	30.8	30.4	30.0	28.9	28.6	27.9	27.2	26.3
94	[illegible]	34.0	[illegible]	[illegible]	34.7	35.1	35.3	35.3	35.4	35.5	35.5	35.6	35.6	35.5	35.5	35.1	35.4	35.3	35.2	35.0	34.8	[illegible]	34.2	34.0	33.7	[illegible]	33.2	32.3	32.1	31.7	31.0	30.7	29.9	28.9	[illegible]
93	[illegible]	[illegible]	35.5	35.8	36.1	36.3	36.4	36.4	36.5	36.6	36.7	36.8	36.8	36.8	36.7	36.6	36.6	36.5	36.4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	35.1	[illegible]	34.6	34.2	34.0	33.5	33.0	32.2	31.7	[illegible]	30.7
92	[illegible]	36.4	36.8	[illegible]	37.5	37.5	37.6	37.6	37.6	37.6	37.6	37.7	37.7	37.6	37.6	37.6	37.6	37.6	37.6	37.5	37.5	[illegible]	37.2	37.0	36.8	[illegible]	36.4	35.8	35.4	35.2	34.7	34.2	33.7	33.2	32.3
91	[illegible]	37.6	37.6	37.7	37.7	37.8	37.8	37.8	37.5	37.5	37.5	37.5	37.5	[illegible]	37.7	37.5	37.5	37.5	37.5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	37.1	36.9	37.5	37.5	37.1	36.5	36.1	35.8	35.3	34.8
90	[illegible]	37.6	37.6	37.6	[illegible]	37.7	37.8	37.8	37.8	38.0	38.0	38.1	38.1	37.6	37.6	37.6	37.6	37.6	37.6	37.6	37.6	37.6	37.6	37.7	37.7	37.7	37.6	37.6	37.6	37.6	37.5	37.5	32.8	37.3	37.2
89	[illegible]	36.5	36.5	36.6	36.7	36.9	37.1	37.4	37.5	37.5	37.6	37.6	37.7	37.8	37.9	38.0	38.0	38.0	38.1	38.1	38.1	38.2	38.3	38.4	38.5	38.7	38.7	38.7	38.7	38.7	38.7	38.7	38.7	38.7	38.7
88	[illegible]	35.3	35.4	35.5	35.6	35.7	36.0	36.0	36.2	36.3	36.4	36.5	36.7	37.0	37.1	37.4	37.5	37.5	37.5	37.6	37.6	[illegible]	37.7	37.7	37.8	37.9	38.0	38.5	38.5	38.7	38.7	[illegible]	38.8	38.8	38.9
87	34.0	34.1	34.2	34.5	34.6	34.7	34.8	35.1	35.1	35.2	35.3	35.4	35.6	[illegible]	36.0	36.2	[illegible]	36.4	36.4	36.1	[illegible]	36.6	36.7	36.7	36.8	37.0	37.1	37.4	37.5	37.7	38.3	38.5	38.6	38.7	[illegible]
86	[illegible]	33.2	33.2	33.3	33.4	33.5	33.7	33.7	33.9	34.0	34.1	34.2	34.6	34.8	34.9	35.0	35.2	35.3	35.3	[illegible]	35.4	35.5	35.5	35.6	35.8	35.9	36.0	36.2	36.4	36.5	37.0	37.4	38.5	38.5	38.7
85	[illegible]	32.1	32.2	32.3	32.5	32.6	32.7	32.9	33.0	33.2	33.1	33.3	33.5	33.7	33.7	33.9	34.1	34.1	34.2	34.2	34.5	34.5	34.6	34.6	34.7	34.8	35.0	35.1	35.3	35.5	[illegible]	36.3	36.6	37.0	37.4
84	[illegible]	31.0	31.2	31.2	31.5	31.6	31.8	32.0	32.1	32.1	32.2	32.3	32.5	32.7	32.9	33.0	33.2	33.2	[illegible]	33.4	33.4	33.5	33.6	33.6	33.7	33.7	33.9	34.0	34.2	34.4	34.7	35.1	35.3	35.5	35.8
83	[illegible]	29.9	30.0	30.2	30.4	30.5	30.7	30.9	31.0	31.0	31.2	31.4	31.6	31.8	31.9	32.0	32.1	32.1	32.2	32.3	32.3	32.4	32.4	32.6	32.6	32.7	32.8	33.0	33.2	33.3	33.6	33.9	34.2	34.3	34.4
82	[illegible]	29.0	29.1	29.3	29.4	29.5	29.6	29.8	29.9	29.9	30.0	30.3	30.5	30.8	31.0	31.0	31.2	31.2	31.3	[illegible]	[illegible]	31.4	31.4	31.5	31.6	31.7	31.8	32.0	32.1	32.2	32.4	32.8	33.0	33.2	33.2
81	[illegible]	28.0	28.2	28.4	28.4	28.5	28.7	28.8	28.9	28.9	29.0	29.2	29.4	29.8	[illegible]	30.0	30.2	30.3	[illegible]	30.4	[illegible]	30.4	30.5	30.5	30.6	30.6	30.7	30.8	31.0	31.2	31.4	31.8	32.0	32.1	32.2
80	[illegible]	27.0	27.1	27.3	27.4	27.5	27.6	27.7	27.8	27.8	28.0	28.1	28.4	28.6	28.7	28.9	29.0	29.1	29.3	29.4	29.4	29.5	29.5	29.6	29.6	29.8	29.8	29.9	30.0	30.2	30.4	30.7	30.9	31.0	31.0
79	26.0	26.1	26.2	26.3	26.4	26.5	26.7	26.7	26.7	26.9	27.0	27.2	27.3	27.5	27.6	27.8	27.9	28.1	28.4	28.5	28.5	28.6	28.6	28.6	28.6	28.7	28.8	28.8	28.9	29.0	29.3	29.8	29.9	29.9	30.0
78	[illegible]	25.1	25.2	25.3	25.4	25.4	25.6	25.7	25.7	25.8	25.9	26.1	26.3	26.7	26.7	26.7	26.9	27.0	27.2	27.3	27.3	27.4	27.4	27.5	27.5	27.5	27.6	27.8	27.8	28.0	28.3	28.6	28.8	28.9	27.9
77	24.0	24.1	24.2	24.3	24.4	24.5	24.5	24.6	24.8	24.9	25.0	25.1	25.3	25.4	25.6	25.7	25.8	25.9	26.0	26.1	26.2	26.2	26.3	26.5	26.5	26.5	26.6	26.7	26.7	26.9	27.2	27.5	27.7	27.8	27.9
76	[illegible]	23.1	23.3	23.4	23.4	23.5	23.6	23.7	23.8	23.8	23.9	24.1	24.3	24.5	24.6	24.8	24.8	24.9	25.0	25.1	25.1	25.2	25.2	25.2	25.2	25.3	25.4	25.4	25.6	25.7	26.0	26.5	26.6	26.7	26.7
75	[illegible]	22.1	22.2	22.3	22.3	22.4	22.5	22.6	22.7	22.8	22.9	23.1	23.4	[illegible]	23.6	23.7	23.7	23.8	23.8	23.9	24.0	24.1	24.1	24.1	24.2	24.2	24.3	24.4	24.6	24.6	25.0	25.3	25.4	25.4	25.6
74	[illegible]	20.9	21.1	21.2	21.2	21.3	21.4	21.4	21.5	21.6	21.7	22.0	22.2	22.3	22.4	22.5	22.6	22.7	22.8	22.9	22.9	23.0	23.0	23.0	23.1	23.1	23.2	23.2	23.5	23.6	23.8	24.0	24.1	24.3	24.4
73	[illegible]	19.9	20.1	20.2	20.4	20.5	20.6	20.6	20.7	20.8	20.9	21.1	21.2	21.3	21.3	21.4	21.5	21.7	22.0	22.0	22.0	22.0	22.2	22.2	22.2	22.3	22.3	22.4	22.5	22.5	22.7	22.9	23.0	23.1	23.2
72	18.9	19.0	19.1	19.2	19.2	19.3	19.4	19.5	19.7	19.8	19.9	20.0	20.1	20.2	20.4	20.5	20.5	20.7	20.8	20.9	21.0	21.1	21.2	21.2	21.3	21.3	21.3	21.4	21.4	21.5	21.6	21.8	22.0	22.1	22.2
71	18.0	18.1	18.2	18.3	18.4	18.5	18.6	18.7	18.9	19.0	19.1	19.2	19.3	19.3	19.4	19.4	19.5	19.7	19.8	19.8	19.9	20.0	20.0	20.1	20.1	20.1	20.2	20.2	20.4	20.4	20.6	20.8	20.9	21.0	21.1
70	16.8	17.0	17.1	17.2	17.3	17.6	17.7	17.7	17.8	17.9	18.0	18.1	18.2	18.2	18.3	18.3	18.4	18.6	18.7	18.9	18.9	19.0	19.1	19.2	19.2	19.2	19.3	19.3	19.3	19.4	19.5	19.6	19.7	19.8	19.9
69	15.5	15.7	15.9	16.0	16.1	16.3	16.5	16.6	16.7	16.8	16.9	17.0	17.0	17.1	17.1	17.2	17.4	17.6	17.7	17.8	17.8	17.8	17.9	17.9	17.9	18.0	18.1	18.2	18.2	18.2	18.4	18.5	18.5	18.7	18.9
68	14.6	14.7	14.8	15.0	15.0	15.2	15.3	15.4	15.6	15.7	16.0	16.1	16.1	16.2	16.2	16.3	16.4	16.5	16.7	16.7	16.8	16.8	16.9	17.0	17.0	17.1	17.1	17.1	17.2	17.4	17.4	17.5	17.5	17.5	17.5
67	13.5	13.7	13.9	13.9	14.0	14.1	14.4	14.5	14.6	14.7	14.8	14.9	15.0	15.0	15.0	15.1	15.2	15.3	15.4	15.5	15.6	15.7	15.8	16.0	16.0	16.1	16.1	16.1	16.1	16.2	16.3	16.3	16.4	16.4	16.4
66	12.4	12.6	12.9	13.0	13.0	13.1	13.3	13.4	13.5	13.6	13.7	13.7	13.8	13.9	13.9	14.0	14.1	14.2	14.2	14.4	14.5	14.6	14.6	14.7	14.7	14.8	14.9	14.9	15.0	15.0	15.1	15.2	15.2	15.3	15.3
65	11.5	11.7	11.8	11.9	12.0	12.1	12.3	12.4	12.5	12.6	12.7	12.9	12.9	13.0	13.0	13.1	13.2	13.3	13.4	13.4	13.5	13.6	13.6	13.7	13.7	13.8	13.8	13.8	13.9	13.9	14.0	14.0	14.1	14.1	14.1
64	10.5	10.6	10.7	10.8	10.9	11.2	11.2	11.3	11.5	11.6	11.7	11.8	11.8	11.9	12.0	12.1	12.2	12.3	12.4	12.5	12.5	12.5	12.6	12.6	12.6	12.7	12.7	12.8	12.8	12.8	12.8	12.8	12.8	12.9	12.9
63	9.6	9.7	9.8	9.9	10.1	10.2	10.3	10.4	10.5	10.6	10.7	10.7	10.8	10.9	11.0	11.2	11.2	11.3	11.5	11.6	11.6	11.7	11.7	11.7	11.8	11.8	11.8	11.8	11.8	11.8	11.8	11.8	11.8	11.8	11.8
62	8.8	9.0	9.2	9.3	9.4	9.5	9.5	9.6	9.7	9.8	9.8	9.9	10.1	10.2	10.2	10.3	10.3	10.4	10.4	10.5	10.5	10.5	10.6	10.6	10.6	10.6	10.7	10.7	10.7	10.7	10.7	10.7	10.7	10.7	10.7
61	8.2	8.3	8.5	8.6	8.8	8.9	9.0	9.0	9.1	9.2	9.2	9.3	9.3	9.4	9.4	9.5	9.5	9.6	9.6	9.6	9.7	9.7	9.8	9.8	9.8	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9
60	7.6	7.7	7.8	7.9	8.0	8.1	8.2	8.3	8.4	8.5	8.6	8.6	8.8	8.8	8.8	8.9	8.9	9.0	9.0	9.1	9.1	9.2	9.2	9.2	9.3	9.3	9.3	9.3	9.3	9.3	9.3	9.3	9.3	9.2	9.2
59	6.6	6.8	7.0	7.3	7.4	7.5	7.5	7.6	7.7	7.7	7.8	7.9	8.0	8.1	8.2	8.2	8.3	8.3	8.4	8.4	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.6	8.6	8.6	8.5	8.5	8.5	8.4	8.3
58	5.9	6.1	6.2	6.4	6.4	6.5	6.7	6.8	7.0	7.1	7.3	7.3	7.4	7.5	7.5	7.5	7.5	7.6	7.6	7.7	7.7	7.7	7.8	7.8	7.8	7.8	7.8	7.8	7.9	7.9	7.9	7.8	7.8	7.7	7.6
57	5.2	5.3	5.5	5.8	5.9	6.0	6.1	6.2	6.3	6.4	6.5	6.6	6.6	6.7	6.7	6.8	6.8	6.9	7.0	7.0	7.0	7.1	7.1	7.1	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.1	7.0	6.9	6.7
56	4.5	4.7	4.9	5.1	5.2	5.3	5.4	5.5	5.6	5.8	5.9	6.0	5.9	6.1	6.1	6.2	6.2	6.3	6.3	6.4	6.4	6.5	6.5	6.5	6.6	6.6	6.7	6.7	6.7	6.6	6.6	6.5	6.4	6.3	6.0
55	3.8	4.0	4.3	4.4	4.5	4.7	4.8	4.9	5.0	5.1	5.2	5.3	5.3	5.4	5.4	5.5	5.5	5.6	5.8	5.8	5.9	5.9	6.0	6.0	6.0	6.1	6.1	6.1	6.1	6.1	6.0	6.0	5.9	5.7	5.4
54	3.3	3.4	3.6	3.9	4.0	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	5.0	5.0	5.1	5.1	5.2	5.2	5.3	5.3	5.3	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.3	5.3	5.2	4.9	4.7
53	2.7	2.8	3.0	3.2	3.2	3.4	3.5	3.6	3.9	4.0	4.1	4.2	4.3	4.3	4.3	4.4	4.5	4.5	4.6	4.6	4.7	4.8	4.8	4.8	4.9	4.9	4.9	4.9	4.9	4.8	4.7	4.6	4.5	4.3	4.1
52	2.0	2.1	2.2	2.5	2.6	2.8	2.9	3.1	3.2	3.2	3.3	3.5	3.6	3.7	3.9	3.9	4.0	4.0	4.1	4.1	4.2	4.2	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.2	4.1	4.0	3.6	3.3
51	1.3	1.4	1.5	1.7	1.9	2.0	2.1	2.4	2.5	2.6	2.8	2.9	3.0	3.1	3.2	3.2	3.3	3.4	[illegible]	3.5	3.6	3.6	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.6	3.5	3.3	3.0	2.5
50	0.8	1.0	1.1	1.2	1.3	1.5	1.6	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.6	2.7	2.8	2.8	2.9	3.0	3.0	3.1	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.1	2.9	2.6	2.2	1.9
49	0.2	0.2	0.4	0.5	0.7	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.9	2.0	2.0	2.1	2.1	2.2	2.3	2.3	2.4	2.4	2.6	2.6	2.7	2.7	2.7	2.6	2.6	2.4	2.2	2.0	1.6	1.3
48	0.0	0.0	0.0	0.0	0.1	0.2	0.4	0.5	0.6	0.8	1.0	1.1	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.8	1.9	1.9	2.0	2.0	2.1	2.1	2.1	2.0	2.0	1.9	1.7	1.5	1.1	0.7
47	......	......	......	......	0.0	0.0	0.0	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	1.0	1.1	1.2	1.3	1.4	1.4	1.5	1.5	1.6	1.6	1.6	1.6	1.6	1.5	1.4	1.2	1.0	0.5	0.1
46	......	......	......	......	......	......	......	......	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.3	0.3	0.4	0.5	0.6	0.7	0.8	1.0	1.1	1.1	1.1	1.1	1.1	1.1	1.0	0.8	0.6	0.4	0.0	0.0
45	......	......	......	......	......	......	......	......	......	......	......	......	......	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.3	0.3	0.4	0.4	0.4	0.5	0.5	0.5	0.4	0.3	0.1	0.0	......	......
44	......	......	......	......	......	......	......	......	......	......	......	......	......	......	0.0	......	......	......	......	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	......	......	......
43																				......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
42																				......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
41																				......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
40																				......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
39																				......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
38																				......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
37																				......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
36																				......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
35																				......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
34																				......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
33																				......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
32																				......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
31																				......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
30																				......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
29																				......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
28																				......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
27																				......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
26																				......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
25																				......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
24																				......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
23																				......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
22																				......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
21																				......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
20																				......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
19																				......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
18																				......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
17																				......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
16																				......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
15																				......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90	92	94	96	98	100%

DEGREES FAHRENHEIT.

PER CENT HUMIDITY.

The rate of development of the codling moth under weather conditions is here expressed in *developmental units per hour* for various mean values of temperature and humidity. (For definitions of developmental units and other terms, see pp 318 and 331.) These values are for the pupal stage but may be used also for the incubation of the egg, because the rate of development in the egg is affected by temperature and humidity to practically the same extent. For rate of development of the larva, see Table VI. For temperatures above 105° F. and humidities below 32 per cent, the rates of development may be read from Fig. 14B, p. 388, from which the values shown in this table were obtained. Note that the values read on Fig. 14B must be multiplied by 1.07 to make them true for weather conditions.

The values in this table represent rates of development for means covering *one-hour* periods for each combination of temperature and humidity. To bring the average individual through the pupal stage requires a normal total of 6480 developmental units. The normal total for incubation of the egg is 3864 developmental units. For modification of these totals, see Tables III-V.

These velocity values must not be used for mean daily temperatures and humidities. They may, however, be multiplied by 2 and thus used for two-hour periods instead of one-hour periods.

of variations in rate of development from hour to hour during the warmer and cooler parts of the day, or for variations in humidity and other factors; neither did it allow for variations in *developmental totals* in different seasons of the year. The **developmental total** as here used permits the refinement necessary for more accurate prediction.

For convenience in applying the results of this work to prediction of appearance of moths in Illinois, a table of rates of development (Table I) has been prepared, and directions for its use have been outlined. This method, which is less complicated than Glenn's "day-degree" method, can be used by the orchardist without an understanding of all the technical terms employed in the description of the experimental work or the mathematical processes by which the developmental units were derived. Knowing the temperatures and other items of weather conditions for the season, he can read the corresponding values from Table I, select the proper totals from the following tables, and calculate the time for the appearance of the larvae by simple arithmetic. Even in the hands of a novice, who follows the rules of procedure literally, this method should give more accurate results than were possible by the "degree-day" method.

NOTE: In order to apply the values given herein to the development of the insect under climatic conditions differing from those in Illinois, the developmental totals will doubtless have to be modified on the basis of experience (see methods of modification explained in PART TWO). Further experience in Illinois may make some modifications desirable here also.

PROCEDURE FOR PREDICTING THE TIME OF EMERGENCE OF MOTHS.

Spring Pupae.

a. Observe the date of the first pupation of larvae kept out of doors under conditions similar to those in the orchard.

b. On that date, or before, place a Friez hygrothermograph in a standard weather shelter under orchard conditions, taking care to have the pens read the same time for both factors recorded.*

c. From the U. S. Weather Bureau records for the nearest station, determine the total rainfall for the preceding months, Sept., Oct., Nov., Dec., and Jan. From the total of these months, select from Table III (p. 321) the correct *developmental total* for the pupal stage.

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* A thermograph and a sling psychrometer may serve instead of the hygrothermograph.

d. When the record sheet is removed from the hygrothermograph each week, tabulate on suitable sheets the degrees of temperature and percentages of relative humidity which occurred in each hour (or, if more convenient, each two-hour period) of each day of the week, assembling them by days. From Table I, where velocity values are given in numbers of developmental units per hour, take the velocity value for each of these combinations of temperature and humidity. If two-hour periods are used, multiply each velocity value by 2.

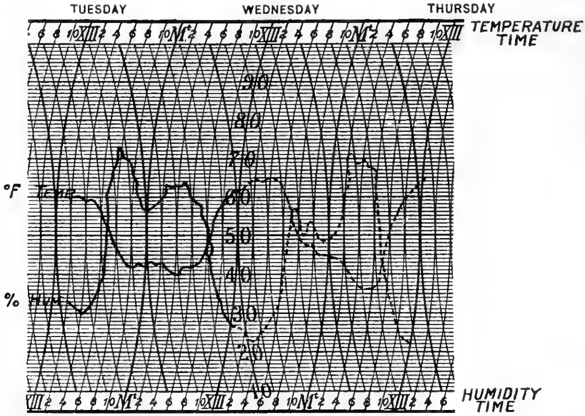

Fig. 1. Tracings of a portion of a hygrothermograph record of weather conditions at Olney, Illinois, April 13-14, 1915. The tracings in solid lines are included in Table II.

For example, refer to Fig. 1, first noting that the time of day is indicated at the top for temperature and at the bottom for humidity. The reading for 2 P. M. Apr. 13 is: temperature 60° F. and humidity 33 per cent. Referring to Table I, we find the velocity value for that combination of temperature and humidity to be 7.7 developmental units per hour, which we may use as the average rate of development for two hours. We thus get 15.4 developmental units for that two-hour period. Again, the reading for 4 P. M. is: temperature 59° and humidity 30 per cent. Another reference to Table I (and Fig. 14B) shows the corresponding velocity value to be 6.4 developmental units per hour, which may be used as the average velocity giving 12.8 developmental units for the period. The time, temperature, humidity, and velocity for all two-hour periods of the 24 hours, of which the above two readings are a part, are shown in Table II.

TABLE II. *Method of Calculating the Amount of Development of the Pupa in One Day from Hygrothermograph Records.*

Applying the values from Table I and Fig. 15 to the record for Apr. 13, 2 P. M., to Apr. 14, 12 M., 1915 at Olney, Ill., as shown in Fig. 1. (Record supplied by P. A. Glenn.)

Hour.	Temperature (° F.)	Humidity. (%)	Velocity.	Amount of Development in each two-hour period.
2. P. M	60	33	7.7	15.4
4 "	59	30	6.4	12.8
6 "	56	38	5.1	10.2
8 "	47	66	1.1	2.2
10 "	42	70	0.0	0.0
12 "	43	57	0.0	0.0
2 A. M.	42	59	0.0	0.0
4 "	40	63	0.0	0.0
6 "	42	60	0.0	0.0
8 "	47	53	0.4	0.8
10 "	58	34	6.1	12.2
12 M...	62	27	8.3	16.6

Total for the 24 hours = 70.2 developmental units.

Thus, the amount of development of the pupa for that day was 70.2 developmental units. To complete the pupal stage under normal conditions requires a total of 6480 developmental units. (Unusually light or unusually heavy rainfall in the preceding autumn requires a larger or a smaller total for the spring pupa, as shown in Table III.) Thus, if the amount of development is calculated for each day from the beginning of the pupal stage until the sum of developmental units approaches 6480

TABLE III. *Autumn Rainfall Corrections Applicable to the Developmental Total for Spring Pupae, especially first pupations and first maximum.*

(Based on a comparison of Tables VII and VIII with weather data for the periods involved.)

Inches of Rainfall. Sept.—Jan.	Ratio to Normal Total.	Developmental Total.* (hour units)
22	.97	6,300
20	.98	6,360
18	.99	6.420
16	1.00	6,480 (normal)
14	1.02	6,500
12	1.04	6,620
10	1.06	6,740

(more or less, as corrected for autumn rainfall), the end of the stage may be predicted a week or more in advance. Individual variation may permit the first moth to emerge when the sum of developmental units is 8% less than the normal total, so that this correction should be applied in prediction of first appearance.

e. If temperatures above 62° F. occur during cloudy weather or after sunset, the moths will begin laying eggs two days after emerging; if the temperatures are lower, egg-laying is delayed.

Eggs.

From the time the first moth is estimated to have begun laying eggs, proceed with the hygrothermograph records and the velocity values from Table I, as in the case of the pupa, but consider the approach of a total of 3864 developmental units as the time for hatching of the eggs.

Larvae.

From the observed or estimated date of hatching of the eggs of the first generation, in order to compute the time in the apple and in the cocoon, use the rates of development for one-hour (or two-hour) readings of temperature as given on Table V (p. 323). As the sum approaches 18,000 (more or less, depending upon rainfall, as shown on Table VI), forecast the time of pupation of the first generation.

The same procedure may be carried through the season for the later generations, using Tables I–IV for pupae and eggs and Tables V and VI for larvae. Attention must always be given to corrections for individual variation (see footnotes to Tables IV and V) and to corrections for falling temperatures, as shown in Table IV.

TABLE IV. *Falling-Temperature Corrections for Pupa and Egg.*

(Based on Tables IX and X.)

Week of Falling Temperature.	Ratio to Normal Total.	Developmental Total.*	
		Pupa. (hour units)	Egg. (hour units)
1st	.98	6,360	3,792
2d	.96	6,216	3,720
3d	.94	6,096	3,624
4th	.92	5,952	3,552

* NOTE: Individual variation permits first emergence when the accumulated number of developmental units is 8% less than the totals given here. These developmental totals represent averages for all individuals of any lot. The reverse correction of 2% per week of rising temperatures may be applied for the late-pupating individuals of the hibernated generation. See ratio of actual to standard time in Fig. 28.

TABLE V. *Rate of Development of Larva in Apple.*

(Based on recalculation of Glenn's data in comparison with results of constant temperature experiments described in PART THREE.)

Temperatures ° F.	Developmental Units per Hour.	Temperatures ° F.	Developmental Units per Hour.	Temperatures ° F.	Developmental Units per Hour.
44	0.0	64	16.5	84	33.6
45	0.5	65	17.5	85	33.5
46	1.0	66	18.5	86	33.3
47	1.5	67	19.5	87	32.9
48	2.0	68	20.5	88	32.3
49	2.6	69	21.5	89	31.4
50	3.3	70	22.5	90	30.3
51	4.0	71	23.5	91	28.7
52	4.8	72	24.5	92	27.2
53	5.7	73	25.5	93	25.7
54	6.5	74	26.5	94	24.2
55	7.5	75	27.5	95	22.7
56	8.5	76	28.5	96	21.2
57	9.5	77	29.5	97	19.7
58	10.5	78	30.5	98	18.2
59	11.5	79	31.4	99	16.7
60	12.5	80	32.4	100	15.2
61	13.5	81	33.0	101	13.7
62	14.5	82	33.3	102	12.2
63	15.5	83	33.5	103*	10.7

* Velocities for higher temperatures may be secured from Fig. 24 (p. 402). Individual variation permits the first larvae to leave the apple when the sum of developmental units is 16% less than the totals given here, which are for the average of all individuals.

TABLE VI. *Rainfall Corrections Applicable to the Developmental Total for the Larva in the Apple and Cocoon.*

Rainfall while larva is in apple. (Inches)	Developmental Total. (Hour units)
(Picked apples)	15,600
0	16,200
2	16,740
4	17,280
6	17,820
6.66	18,000*
8	18,360
10	18,900
12	19,440

* Normal used in calculation of standard (theoretical) time.

THE USE OF TEMPERATURE DATA ALONE.

a. *Maximum and minimum temperatures.* Daily maximum and minimum temperatures cannot be used to give accurate results, as the rate of development often varies too much from hour to hour.

b. *Thermograph Records.* If it is desired to use temperature alone (i. e., without data on humidity, etc.), thermograph records are necessary. For rough approximations for estimating the progress of the first generation in southern Illinois localities, use Table I as follows: Draw a straight line from T. 45°, H. 80% to T. 63°, H. 77%, continuing this line to T. 90°, H. 42%. Make a list of the velocity values lying nearest to this line and use them for their corresponding temperatures from the thermograph records for one-hour or two-hour periods. This applies to the first generation pupae and eggs. For the second and third generation pupae and eggs, draw the line from 45°, 89% to 70°, 89% and continue to 90°, 60%; and use the velocity values lying nearest to this line for their corresponding temperatures. The results by this method will not be reliable but will probably serve as well as, or better than, summing temperatures in "degree-days".

c. *Sling Psychrometer Readings at 7 A.M. and 7 P.M.* Where hygrograph records are not available, as is often the case in working over old data, it will probably give fair results to use thermograph records for hourly or bihourly temperatures if sling readings are available for humidities at 7 A. M. and 7 P. M. The values on Table I may then be read by using a celluloid triangle as a guide for getting the probable march of temperature and humidity from the 7 A. M. value to the value at the maximum temperature for the day. To make this triangle, draw a line on Table I from the temperature-humidity combination at 30° and 95%, for example (assuming that to be true for 7 A. M.), to the combination at 50° and 73% (which is the probable combination* at the time of maximum temperature on such a day in our climate); measure the angle formed by this line with a vertical line along the side of the Table; then cut the triangle to fit this angle, making it a right triangle for convenience in keeping its base parallel with lines running across the Table. Use the humidities crossed by this line drawn on the table (which line is now the hypothenuse of the triangle), with the corresponding temperatures from the thermograph sheet, up to the maximum temperature. For all clear days, read along the hypothenuse of the triangle made on the basis of the example, for all rising temperatures, beginning with the 7 A. M. combination for the day. For all falling temperatures, follow back across the Table from this maximum along a straight line to the 7 P. M. temperature-humidity combination for that day. (The triangle is not needed here.) If practicable, consider periods when it is raining as having 95 per cent humidity.

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* This probable combination was derived from data on the average daily march of temperature and humidity, obtained by an analysis of many hygrothermograph records.

AN EXAMPLE OF ESTIMATION OF SEASONAL PROGRESS.

The example below, which is designed to show the method of prediction, is based upon Glenn's observations of band collections at Olney for 1916, as shown in his Table 33.*

His observation showed that the first pupa appeared April 13, and that the maximum pupation was April 20. As the preceding autumn and winter had a total rainfall of slightly more than 20 inches, the developmental total should be 6360 (Table III), and the first moths would be expected to emerge May 13—the date on which that total was reached (using velocity values from Table I for the temperatures and humidities as shown in Glenn's hygrothermograph records April and May, 1916). The individual variation would throw it back about two days; the actual time of first emergence was May 11. The day of maximum emergence, reckoned from the date of maximum pupation, should fall on May 19, which was the date observed.

According to Isely and Ackerman, egg-laying is controlled by the temperatures after sunset, taking place in very faint light and above 62° F. In the absence of data on cloudiness and temperature immediately after sunset in May, 1916, we may take the average time as two days for the period from emergence until laying is well begun. On this basis, the first eggs should have been laid on the 14th. The actual date observed was the 14th. The normal incubation total of 3864 developmental units was reached on May 25 early in the morning. The actual time of hatching observed was May 25. (The correction of 8% for individual variation would throw some hatching back to sunset of May 24.)

Pupation should occur when a normal total of 18,000 developmental units (reckoned from the time of hatching of the eggs) is reached, if the rainfall is normal for that period. (An average of 6.66 inches was used as the normal in calculation of standard time.) It may be later or earlier, accordingly as the period in the apple comes at a time with more or less rainfall. With 10.6 inches of rainfall during this period in 1916, we should expect a maximum pupation when a total of approximately 19,060 developmental units was reached, that is, on June 30. Individual variation in larval time (16%) would permit some larvae to pupate six days earlier (June 24).

Counting from June 24, with velocity values from Table I, we get a total of 6480 developmental units on July 5. The correction for individual variation throws the probable date for first emergence of the adult moth one day earlier, or July 4. The first adult actually emerged on July 3.

The first eggs of the second generation should be laid on the 6th. That was also the date observed. A total of 3864 developmental units was reached on the 12th; the actual first larva was observed on the 12th. (The 8% correction for individual variation of the egg amounts to about half a day.)

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* These data were not used in establishing velocity values.

These first larvae of the second generation were in the apples during a period with 1.5 inches of rain, which would fix the total at 16,615 development units. This was reached on August 7. With a deduction of 4 days for individual variation, the earliest probable date for first pupation becomes August 3. The earliest actual date recorded was August 9. Reckoning from August 3, we should expect the moths to emerge on August 12, when 6480 developmental units had accumulated. With the individual-variation correction of one day, the date becomes the 11th. One adult actually appeared August 12, and others followed closely, indicating that some pupae were overlooked. Not knowing the light and temperature after sunset, we would say that some eggs should have been laid August 14, but none were actually found until the 19th; and we should expect hatching on August 20, but no larvae were observed before August 23. This indicates the need of further study of egg-laying and the recording of conditions necessary for egg-laying.

ABUNDANCE OF LATE-PUPATING LARVAE IN SPRING.

It has been supposed by some investigators that the delay in pupation on the part of some larvae in spring is due to external conditions. A large series of larvae were hibernated and the moths brought to emergence under the same condition. (For methods used, see pp. 405 ff.) The results were the same, or essentially so, for the larvae that were soaked in water and those that were merely kept in moist air. The pupations were strung out over a long period, the last emergence being 28 days after the first, at a constant temperature of 72° F. (See Fig. 25, p. 409.) The curve of emergences shown in Fig. 25 B has one main maximum which falls on the 8th day, and also a group of three small maxima centering on the 22d day (72° F.). If such a group is large, as it is likely to be when larvae hibernate in abundance, it may be responsible for damage to apples on trees sprayed to meet the early large group.

The velocity units for larvae in the apple (Table V, p. 323) may probably be used, with fair results, to estimate the time of the late pupation; because the variation in the emergence of moths is determined primarily by the time of pupation, or in other words by delay in larval development.

In the experiments the main maximum emergence came after the accumulation of 4,704 developmental units, the next maximum after an accumulation of 6,480 units, and the center of the last group after an accumulation of 12,936 units. The center of the last group of spring pupations at Olney in 1915 came after an accumulation of 16,152 units; in 1916, of 15,888; and in 1917, of 13,008. These years average 15,024 developmental units for the period. This means that the late group of pupations falls three to five weeks later than the first pupation. This marks the starting point of the pupal stage of the late group, and from this point the date of emergence of the moths may be fairly accurately determined as already indicated. Other maxima occur for pupation, but they are rather irregular. There is a corresponding one between 3,384 and 4,704 units, and one between 6,072 and 8,424 units in the different years at Olney. These units, however, were not determined on the basis of spring larvae, and the totals may need correction; factors other than temperature and humidity no doubt enter into the time of pupation. The moths from the last group of pupations should be closely watched by practical men as a guide for extra sprayings in years when hibernating larvae are abundant.*

ABUNDANCE OF HIBERNATED LARVAE AS AFFECTED BY WEATHER OF PRECEDING AUTUMN AND WINTER.

When the mean monthly temperature and rainfall in autumn and winter are mainly within the limits shown in Fig. 5A (p. 353), that is, when the autumn and early winter are "wet and not too cold," high survival and rapid development proportional to spring conditions may be expected. This statement is based chiefly upon 1914, in which the moths were very abundant. The fall and winter conditions of that year were essentially duplicated in 1925-26, with an almost 95 per cent survival, according to the observations of Mr. Flint and the Illinois field men. The diagrams in Fig. 5, however, were based on the 10 years, 1913-24. Minimum winter temperatures have not been especially considered but should be carefully checked against spring survival by field men.

The great abundance of moths in Illinois during the summer of 1926 is traceable to the large numbers of hibernated larvae and the very favorable weather conditions during May and June. Not since 1914 has there been such heavy damage to orchards over the state as in this year. Recent experience thus proves the need of more accurate methods in order to control the insect in unusual years.

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* The occurrence of darkness and temperatures above 62° F. during egg-laying periods should also be carefully considered, as these conditions have a great deal to do with the abundance of moths (Isely and Ackerman, 1923, Arkansas Agricultural Experiment Station Bulletin No. 189).

PART TWO.

A BASIS FOR THE MEASUREMENT OF DEVELOPMENT.

FORMER METHODS OF ESTIMATING PROGRESS IN LIFE-HISTORY STAGES.

Formerly investigators have relied either upon natural phenomena showing the seasonal progress of plants, *e. g.*, time of leafing, budding, or blossoming, or upon approximate accumulation of temperature as an indication of opportune times for the performance of certain agricultural operations, such as planting, spraying, and harvesting. For the greater part of a century they have assumed that temperatures above the freezing point or above the point at which a plant such as wheat starts growth, can be used directly to ascertain the amount of progress made by plants and animals at a certain date in the spring. Numerous investigators have tried temperatures above various "starting points," some using sun temperatures, others maximum temperatures or mean temperatures; and practically all have considered that the accumulated temperature, or "sum of temperatures" above a starting point, is a measure of plant or animal growth. This sum for a given period is obtained by adding together the degrees by which each day's mean temperature exceeds the assumed starting point. For many years the meteorological office of Great Britain has used 42° F. as the starting point and published the monthly accumulations above this temperature for various parts of the British Isles. A mean temperature one degree above 42° F. continuing for a day has been called a "degree-day" or a "day-degree."

Various Europeans have carried on careful critical studies employing various detailed methods of determining the total accumulated temperature necessary to bring a given plant into bloom or to ripen a crop of grain. This total, however, was found to vary so greatly for the same stage of development of the same variety of plant from season to season and from year to year that there was little or no progress in the field until the Danish physiologist Krogh ('14), while working on the effect of temperature on the development of fish eggs and of frog eggs, made the most important discovery on this subject in the present century, viz.: that development goes on slowly even at temperatures below that commonly considered as the starting point; and that, as the temperature rises, the time required to hatch an egg decreases to a minimum at a certain high point, above which the time again increases.

Glenn ('22), in his work on the codling moth, confirmed the finding of Krogh relative to high temperatures (above 90°F.). He was first to make corrections for the retarding effects of high temperatures. With his correction applied, the accumulated temperature, or "sum of temperatures," for the stages of the codling moth, varied much less from season to season than the totals for the stages of European plants referred to above. Wherever only temperature records are available, his work affords a basis for estimation.

In the present paper, Glenn's data have been worked over in conjunction with new data, and the conception of development here presented is based upon the actual behavior of the codling moth both under controlled experimental conditions and also under actual weather conditions. Only indirect use, however, is made of weather records. The results of laboratory experiments and of outdoor observations have been quite fully correlated, we believe, for the first time. The results have also been compared with the more important investigations of the last century and found to be in accord with the general results hitherto obtained.

A new method for estimating the progress of life-history stages is herein described, which affords a basis for taking humidity into account directly and other factors less directly. The factors secondarily considered are the rainfall during preceding months and the seasonal march of temperature. In the interpretation of the effects of these factors, the value of the climatic diagrams of Taylor ('14) and the observations of Huntington ('19) on man have been confirmed for the codling moth. Furthermore, the findings of Krogh relative to development taking place below the starting point, as ordinarily assumed or ascertained, have been confirmed.

Conditions Affecting the Rate of Development.

The most important growing-season factor influencing the development of animals native to moist or rainy climates, is usually temperature, for it is the most variable. It changes almost continuously throughout any twenty-four-hour period, being usually highest about 2 P. M. and lowest about 6 A. M. The duration of minimum temperature varies considerably with the length of day and night, and the duration of maximum temperature also varies; both vary with other weather conditions. The daily march of temperature (from higher to lower and from lower to higher) is irregular on stormy and cloudy or partly cloudy days.

Humidity is probably second in importance to temperature; at least, it is such a continuously accompanying variable of all temperatures and of all temperature changes that it cannot be ignored. The daily march of humidity is fully as striking as that of temperature. Usually, however, when the temperature rises, the humidity falls; and *vice versa*. The humidity accompanying any given temperature varies with the time of year, amount and frequency of precipitation, cloudiness, etc. There is no constant or dependable association between the two which can be expressed in numerical values.

Rainfall influences the rate of development of organisms in a less direct but nevertheless very important way. The amount of rainfall in autumn and winter influences the codling moth's rate of development in spring, probably also its winter survival, undoubtedly its vitality, and hence its rate of increase and success in general.

Air movement affects the organism by controlling the rate of evaporation, or withdrawal of water from the organism. Intensity of light and its color quality have an influence upon the well-being of the codling moth in some of its stages. Light intensity in combination with temperature practically controls egg-laying of the moths (Isely and Ackerman, '23).

METHODS OF MEASUREMENT OF FACTORS.

Combinations of different temperatures and the different humidities which accompany them must be considered because of the important effects of their correlated action upon rate of development. Since they vary from hour to hour, and since there is no certainty as to what humidity will accompany a given temperature, it is necessary either to take readings at close intervals or to use averages over short periods, with the periods or intervals agreeing for the two factors.

Records of average temperature and average humidity for each hour of the day are most desirable for careful experimental or observational work, but under ordinary conditions readings at two-hour intervals are sufficiently accurate for estimating the amount of progress of life-history stages. Either of these methods of reading may be applied to hygrothermograph tracings such as are shown in Fig. 1. The first three columns of Table II (p. 321) show the readings for the solid-line tracings of Fig. 1.

Daily or monthly means of rainfall, cloudiness, and percent or hours of sunshine may be taken from Weather Bureau records. These are required for showing the effects of autumn and winter rainfall and are considered in connection with mean monthly temperatures.

Rate of evaporation has been measured as cubic centimeters of water lost per day from the Livingston porous-cup atmometer.

No accurate measurements of the quality and intensity of light have as yet been made. In the experiments herein described, the diffused light of the experimental cages has been compared with total darkness, and the effect of the light of ordinary electric bulbs passed through red, blue, and green glasses has been determined. While evidence has been obtained showing that these factors have effects, it is not yet possible to apply the results to weather conditions because of the lack of accurate measurement both in the experiments and in nature and because of the impossibility of making tenable comparisons.*

DEFINITIONS OF TERMS.

In order to define terms with which to express the effects of all these phenomena of weather and climate upon the rate of development of an organism, we must regard certain conditions as standard and compare all changes in the rate of its development with its behavior under the standard. Obviously, the conditions normal to the habitat of the species should be taken as standard,* and the most important factor in those conditions should be considered first. We may begin, therefore, with temperature, using the range of temperature within which the codling moth

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* Experiments with photo-electric cells given promise of some aid in the approach to the problem of the effects of varying light.

* The ideal standard is described in PART THREE, p. 359.

develops most rapidly, rather than a degree arbitrarily assumed as a "starting point" for development.

This optimum range of temperature can be determined for any stage in the life-cycle only by a series of preliminary experiments performed at intervals of a few degrees throughout the whole range of temperatures under which the insect is known to thrive. The results of constant-temperature and variable-temperature experiments whose means are comparable, covering this whole range (with variations in humidity, etc., carefully controlled so as to accompany variations in temperature in a manner closely approximating that characteristic of average weather conditions in the optimum climate for the stage)—the results of such experiments, when properly correlated, should give the necessary basis for defining standard conditions. Under these standard conditions, the time required to complete the stage may be taken as a basis for comparing the rate of development at any temperature.

That range of temperature within which the time to complete the stage is shortened in exact proportion to the rise of temperature is designated as the *medial range;* that is, within the medial range, the increase in the rate of development bears a fixed ratio to the number of degrees which the temperature rises. For the codling-moth larva in an apple, we find that the medial range is approximately from 55° to 75° F., and that for all other stages, including the hibernated larva, the medial range is approximately from 65° to 85° F. *Medial humidities* are those which usually accompany these medial temperatures in normal weather.

Under such standard conditions a given individual may be considered to accomplish a certain amount of development within one hour, this amount being as standard as the conditions which define it. This reaction of the organism to all these environmental phenomena operating for one hour is to be considered as consisting of a certain number of **developmental units,** each of which is a small part of the total development making up the stage of the life-cycle. As the rate of development in any given case is dependent primarily, though not entirely, upon the number of degrees of temperature above the actual threshold of development (whatever that may be),* the *unit* of development may be determined, under standard conditions, from the difference between the rate at one temperature and that at another temperature one degree† higher; and this unit is to be defined with reference to all these conditioning factors, each factor being expressed in the terms in which it is commonly measured.

The **developmental unit** is, therefore, the difference between the amount of development taking place in one hour at a given degree of mean medial variable temperature and the amount of development taking place in one hour at a temperature one degree higher, with

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[*] The actual threshold is not a fixed temperature but varies with other conditions.

[†] The Fahrenheit scale is used in this paper. The Centigrade scale, which is preferable for several reasons, is used in a book on Experimental Animal Ecology, now in course of preparation, to be published in 1927 by Williams and Wilkins Company, Baltimore, Md.

the humidity, air movement, light intensity, and other conditions normal to the habitat of the organism in that stage of its life-history. In other words, the **developmental unit** is the effect produced in one hour by one degree of medial temperature in conjunction with all other phenomena characterizing the standard conditions described above. This *phenomena-degree-hour* may be designated as one **pheno-hour.**

While relative velocity of development has heretofore been expressed as the arithmetical reciprocal of the time required to complete a stage in the life-cycle, this new method permits a definition of absolute velocity as the number of developmental units per hour.

The **threshold** of development is the intensity, or quantity, of any factor immediately *above* which development begins to be measurable. For example, the temperature threshold is that degree of temperature just above which development begins to be perceptible in amount. It is not a fixed point but varies, within certain limits, with the humidity and other weather factors and with the generation and the individual. For the larvae in the apple, it varies from 43° to 48° F.; for the pupa and egg, from 44° to 49° F.; and for the hibernated larva, from 43° to 50° F.

The **developmental total** for any stage is the sum of developmental units for that stage. It is calculated by simply adding together all the developmental units for every hour from the observed (or calculated) beginning of the stage to the observed (or calculated) end of it, using velocity values such as those shown in Table I for hourly combinations of recorded temperature and humidity. More briefly, a developmental total is obtained directly by summing the hourly velocity values for the known weather conditions throughout the stage. Similarly, a developmental total for a whole life-cycle may be obtained. *Developmental totals are not constants* but vary with the rainfall of the season and the preceding season, with other weather factors, with the generation, and with the individual. The average, or *normal,* developmental total for any lot of individuals or for any generation under any set of conditions, is, however, useful in the interpretation of data and in the prediction of appearance.

Standard time for a stage is the number of hours (or days) calculated from the normal developmental total for average organisms under standard conditions. Because of the practical difficulties involved, only temperature and humidity are taken into account in the calculation of standard time in this paper. The term **substitution-quotient** is here used to designate one-twenty-fourth of the number of pheno-hours calculated for a stage by the temperature-substitution method as described in PART THREE (pp. 387-393). When correctly calculated, the substitution-quotient is numerically equal to one-twenty-fourth of the normal developmental total for the stage; and it is used only in establishing standards of development and velocity values.

The **velocity values** (numbers of developmental units per hour for different combinations of temperature, humidity, etc., as shown in Table I) are here regarded as **fixed** and **standard** for average organisms in each stage. This is more convenient, mathematically, than to regard the developmental total as fixed. These standard velocity values were derived from data on moths under observation at Olney in 1915 and 1916; at Olney, Urbana, and Plainview in 1917; and at Urbana in 1918, 1919, and 1920. The methods by which these values were derived are too involved for brief description here (see PART THREE), and they need not be completely understood by readers who are interested primarily in the use of velocity values and in the modification of developmental totals for purposes of estimating progress of life-histories.

As has been noted, the direct use of weather data in spray calendars, etc., though of some value, has failed to give results of sufficient accuracy in all years and seasons. In the most successful recent attempt at the direct use of temperature, namely, that of Glenn ('22), the temperatures as occurring were extensively corrected to conform to the behavior of the codling moth. If the last century of phenological observation and "temperature summing" has proved anything, it is that direct application of weather data is largely a failure. This failure is further emphasized by a growing tendency to use plants as indicators. (McLean, '17; Clements, '24—Bibliography.) The researches herein described have shown conclusively that in the case of the codling moth, estimation of progress in development, of abundance, and of fecundity must be based primarily upon the physiological characters and responses of the species. Weather data cannot be used directly. Temperatures summed above the empirical or imaginary "threshold" selected by ordinary methods do not give correct results because they have different accelerative values under different conditions and because temperatures below it are actually effective. Also, high temperatures, above or near 90° F., have a much smaller accelerating effect than they have been expected to show by most investigators excepting Glenn ('22). In this paper all attempts at direct use of weather data are abandoned, the chief reliance is put upon *velocity of development of the codling-moth in its several stages.*

Graphic Representation of Velocity.

The meaning of velocity is well illustrated by reference to rate of movement, or speed of travel, of a machine or animal or man. In all matters of speed of travel, the *reciprocal* of the *time* required to cover a fixed distance is used to represent *relative velocity,* or rate of travel. For example, in the case of a tractor pulling a load 12 miles at various speeds, the relative velocity is obtained from the time as follows:

Time to go 12 mi.	2 hr.	3 hr.	4 hr.	5 hr.	6 hr.	8 hr.	10 hr.	12 hr.
Reciprocals of time	.50	.33⅓	.25	.20	.16⅔	.12½	.10	.08⅓
Miles per hour (12 x reciprocals)..	6.0	4.0	3.0	2.4	2.0	1.5	1.2	1.0

The reciprocal multiplied by the total miles gives velocity in miles per hour. The reciprocals of the time to complete any unit of work are thus a convenient expression of relative velocity.

The activity of cold-blooded animals, such as insects and millipeds, in a general way varies directly with temperature just as development does. Also, rate of progression may be used as an index of physiological activity, and something of the laws governing rate of development may be ascertained from a study of progression.

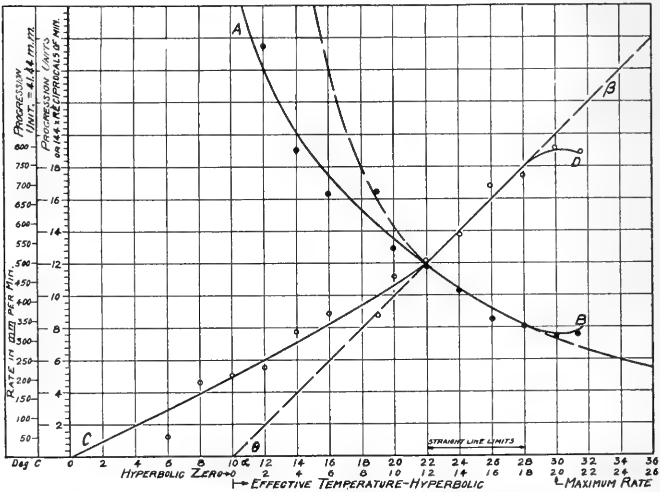

Fig. 2. Rate of creeping of a diplopod at various temperatures, shown in millimeters per minute and in progression units (41.44 mm) per minute. Note how the velocity curve CD departs from a straight line above 28° C. and below 22° C.; and how the time-temperature curve AB differs from an equilateral hyperbola. (Date from Crozier '24.)

Fig. 2 shows a curve for the velocity of progression, or rate of creeping, of a milliped, plotted from the experimental data of Crozier ('24). For velocities of progression of 500—750 mm. per minute (temperatures 22°—28° C.), a milliped in an experiment conducted at a temperature one degree higher than 22° adds 41.44 mm. to the distance traveled in one minute. Likewise, an animal in an experiment at two degrees higher than

22° travels 82.88 mm. farther per minute, and so on up to 28°, where a change takes place. The *unit of progression* is 41.44 mm., based upon the effect of one degree Centigrade within the range of medial temperatures, which are marked by the straight-line limits of the velocity curve CD. This same unit is the basis of determining the points at which the effect of one degree higher or lower temperature upon the rate of progression is greater or less than 41.44 mm. in one minute. The *alpha* value (hyperbolic zero) for the data of Crozier is approximately 10° C., a fact of very little actual significance except in the determining of the constant product of the temperature above *alpha* and the time for a definite total distance. This total distance is here assumed to be 5967.3 mm. The portion of the time-temperature curve AB between 22° and 28° C. is a portion of an equilateral hyperbola. The time is that required to travel 5967.3 mm. at the temperatures plotted. An inspection of the curve will show that the mathematical product of time (as plotted) and temperature above 10° C. (as plotted) is 144, and that for each point plotted the reciprocal of the time units multiplied by 144 equals the number of progression units. These relationships are characteristic of the equilateral hyperbola.

The total distance was here arbitrarily taken as 144 × 41.44 mm. units, or 5967.3 mm. (calculated). If another distance were chosen, the velocity for each temperature would be the same, because the milliped would travel at the same rate, but the number of progression units would differ. The same principle holds good in respect to the different stages of development of an organism. The amount of metabolism required in each stage is comparable to distance to be traveled, while the rate of development remains basically of the same order of magnitude not only for the different stages of the same insect but probably also for all the various insects and, indeed, perhaps for all cold-blooded animals.*

The next step in the way of experiments with the milliped would be the use of *variable* temperatures from 20° to 28° C. Such variability would probably increase the rate of progression slightly for a mean of the varying temperatures as compared with the constant ones, but this difference will be ignored in the absence of data from variable-temperature experiments in this case. For the present purpose, we may assume that the rate of progression as plotted for a certain degree of constant temperature would hold good for the same degree of mean variable temperature; accordingly, we may construct a table of "effective temperature" above 10° C. as the "starting point" (using some of the nomenclature of those writers who have summed temperatures), by assuming a different

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* Evidence of the metabolic basis for the developmental unit is reviewed in PART THREE, p. 361.

mean temperature for each minute of a ten-minute schedule and reading the mean velocity for each minute from the curve in Fig. 2, as follows:

Time.	Actual Temperature. (above 0°C.)	"Effective Temperature". (above 10°C.)	Mean Velocity (Progression units per minute)
1st min.	20	10	10.8
2d min.	30	20	19.0
3d min.	14	4	7.0
4th min.	10.5	0.6	5.2
5th min.	4	(—6) omitted	2.0
6th min.	2	(—8) omitted	0.8
7th min.	12	2	6.0
8th min.	13	3	5.4
9th min.	16	6	8.2
10th min.	25	15	15.0
10 min.	146.5 above 0°C.	60.5 "effective degrees"	79.4 progression units travelled.

Thus, with an accumulation of 60.5° of "effective temperature," a total distance of 79.4 progression units, or 3290.33 mm., was traveled in those 10 minutes of variable temperature; but a comparison of column 3 and column 4 shows clearly that the "effective temperature" is *not* a correct index of the rate of travel or of the distance traveled above 28° C. or below 22° C. (i. e., outside the straight-line limits). Only in the 10th min., with the temperature at 25° C. (i. e., within the straight-line limits) does the "effective temperature" properly indicate the rate of travel.

The development of the codling moth in its several stages, and in fact, the behavior of nearly all other organisms hitherto investigated* with respect to different temperatures, is similar to the activity of the milliped. In a developing organism, however, the processes involved in growth, transformation of parts, etc., do not go on at the same rate at different times within the same stage, and thus only fractions of a whole process are usable as developmental units. Various results of the stimulation of organisms by temperature do bear a definite ratio to the temperature within the straight-line limits of the velocity curve, although not outside those limits.

Further evidence of the nature of development is found in the fact that the total carbon-dioxide given off by an organism such as the pupa of the meal worm is a constant for individuals of the same weight. This total bears a fixed ratio to the sum of the daily amounts of development of the pupa, but not to the "effective degrees" summed above a definite beginning (an imaginary "threshold," which is the hyperbolic zero) ex-

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* Shapley ('20) has a curve for progression of ants which appears to be exceptional in that it turns upward at high temperatures.

cept between approximately 18° and 29° C. The total carbon dioxide is, moreover, the *same* at the high temperatures where the sum of the "effective degrees" is *too great*. The sum of developmental units for constant temperatures is easily derived for the straight-line portion of the velocity curve, as it is simply the product of time units and constant-temperature units. This product has a fixed value under a given set of conditions and has been known as the "thermal constant." The mean of temperatures varying within the straight-line limits of the velocity curve but not going outside these limits (approximately 18° and 29° C. for the meal-worm pupa) also gives a constant product when multiplied by the time. This product is smaller than the time-temperature product obtained within the same range for constant-temperature conditions, because development proceeds faster under variable-temperature conditions. In very carefully controlled experiments on animals, the product is remarkably constant for any one set of conditions. (Krogh '14a and '14b.)

ORDER OF EXPERIMENTATION.

In the determination of velocities for any stage of an organism, the first procedure is to run a series of preliminary experiments with constant-temperatures at five-degree intervals from 45° to 100° F., beginning with 100% humidity at 45° F. and lowering the humidity about 6% with each five degrees rise in temperature. Such experiments would show, for example, in the case of the codling-moth pupa, that the straight-line limits are from a little below 65° to a little above 85°. These should be followed by: (1) a series of experiments under constant temperatures at five-degree intervals from 45° F. to 100° F. with 95%, 85%, 75%, 65%, 55%, 45%, 35% relative humidity; and (2) a series of variable-temperature experiments with daily variations ranging from 65° F. to 85° F. with the following humidities at 65° F.: 100%, 90%, 80%, 70%, and 60%,—and one experiment out of doors. This would make 90 experiments, and for the desired results the material should be uniform, and all experiments should be started on the same day. This would require a minimum of 3,000 individuals; 9,000 would be preferable; and this series of experiments should be repeated with each generation for each of three seasons.

Experimentation on this huge scale could not be done with the facilities available for the work here reported. Moreover, when this work was undertaken, there was no basis in experience showing that such a procedure would be necessary. As a result, the variation in the different stocks caused irregularities in the data, which necessitated much additional calculation. However, our experience indicates that the developmental totals, the thresholds, and the velocity values are different for each humidity, and that the developmental totals differ most.

INTERPRETATION OF EXPERIMENTAL DATA.

It has proved more convenient to establish fixed velocity values for average stocks under average weather conditions than to establish a fixed developmental total. This was done by determining the average developmental total and using it as a standard. For the constant-temperature experiments within the straight-line limits, the average total was 6,936 developmental units for the pupa, and for the variable-temperature experiments it was smaller, approximately 6,480 (average by two methods). This variable-temperature total, 6,480, was used as a normal in adjusting the velocity values *outside the straight-line limits,* because ordinary weather conditions are variable with respect to temperature, etc., and result in more rapid development. This normal total for the pupal stage was verified by elaborate calculations covering all of Glenn's Olney data. Similarly, normal totals were established and verified for the other stages.

The developmental totals used herein are not comparable to the sums of "effective day-degrees" commonly used in direct applications of weather data, for developmental units are not temperature units but are numerical expressions of the response of the organism to temperature and all other conditions, a response which is usually growth or an internal change leading to transformation from one stage to another in the life-cycle. These developmental totals, being based on the **pheno-hour,** are in accord with the concepts of phenology which take into account both weather and the responses of organisms.

CALCULATION OF STANDARD TIME.

In order to compare the results obtained by this method with those obtained by the old method of summing "effective temperatures", it is convenient to express the conditions of development in terms of the **substitution-quotient,** which is approximately equal to the number of "degree-days" summed for medial temperatures. (See PART THREE, p 391 ff. This practice has been followed in Tables VII-XI, in which all of Glenn's Olney data and his Urbana data on pupae are recalculated in terms of standard velocity values. These data were used in the calculation of standard time for each stage, as follows:

Starting with the date of the observed beginning of each stage in each generation in each year, as recorded by Glenn, velocity values (Table I) were set down for the mean temperatures and humidities for all two-hour periods as shown in his hygrothermograph records for the several years covered by his work; the numbers of developmental units (velocity values multiplied by 2, because two-hour periods were being used) were then summed to normal totals, and dates were thus obtained on which the several stages in each generation should have been completed if these velocity values and developmental totals were normally fulfilled. In order to calculate the theoretical time for each individual or group of individuals behaving alike, the sums of developmental units for each day from the beginning of a stage to the actual date of its completion were then averaged, and this daily mean was in each case divided into the normal developmental total, so as to give a number of days approximating the standard time for the stage. This calculated number of days in each case was then compared to the actual number of days recorded for the stage in question. (For more detailed discussion of these methods of calculation, see PART THREE, pp. 381-400.)

a. Pupae.

Standard time for the pupal stage was calculated on a basis of 6,480 as the normal developmental total, this total being divided by the mean daily number of developmental units for the actual period of the stage as recorded by Glenn. For convenience, since most of the data were expressed in days, this calculation was generally done by dividing one-twenty-fourth of the daily mean into 270, which is one-twenty-fourth of 6,480.

The results in detail for a part of the 1915 pupae, with means for groups of 30 individuals, are shown in Table VII; and the results by 30-individual means for all the pupae of 1915–1917 are shown in Table VIII and Fig. 3. The detailed data on the first-generation pupae shown in Table VII are similar, in general, to those on the pupae of all generations; the differences are of a minor character and will be considered later.

The accuracy of this method of measurement of development, as well as the validity of these standard velocity values, is indicated by the fact that the actual time for all the Olney data averaged only 0.1% over the calculated time. The deviation was —0.6% for 1915, —1.4% for 1916, and 2.1% for 1917.* These deviations from calculated time are the averages of the 30-individual groups for the whole of each year. Averaging the means of the three generations for each year gives the following deviations: 1915, —1.5%; 1916, —2.8%; 1917, —1.8%; total average deviation, —2%.

The Urbana data on pupae showed the following ratios of actual to calculated time: 1917, all generations, 99%; 1918, first generation, 119%. The average ratio is 103.6%; with the 1918 set omitted, it is 99.8%. The ratios for individuals vary from 91% to 119.0%. The actual time for the latter part of the first generation shows the largest positive deviation from standard time; it is about standard in the beginning and increases to the end of the generation. The actual time for the second generation is at first shorter than the standard; it then increases and finally falls off again; while that for the third generation is short throughout. This type of deviation is apparently characteristic, though it is due in some measure to factors other than temperature and humidity (see Fig. 28), which are discussed in Part III.

b. Adult Moths.

Isely and Ackerman ('23) ascribed the abundance of codling moths in a given season partly to favorable conditions of light and temperature during the oviposition period. They found that a temperature of 62° F.

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* This 1917 time is high because of a lack of a large part of the data for the second generation. The loss of one hygrothermograph sheet necessitated large omissions at a period when the actual time is usually less than the calculated time.

TABLE VII. *Showing the actual and calculated time from pupation to emergence of moths of the first generation at Olney, Illinois, 1915, based on the original records of P. A. Glenn.*

No. of individuals.	Observed Dates.		Calculated Date for Emergence.	Developmental Total divided by 24.	Mean Daily Velocity divided by 24.	Calculated Time Days.	Actual Time Days.	Ratio of Actual to Calculated Time. %.	Substitution Quotient.	"Degree-days" above 52° F. by Glenn's Method.
	Pupation.	Emergence.								
1	4/13	5/3	5/3 A. M.	273.6	13.7	19.7	20	......	275.8	261
1	4/16	5/2	5/4 A. M.	243.4	15.2	17.8	16	......	*249.1*	232
3	4/16	5/3	5/4 A. M.	258.7	15.2	17.8	17	......	265.7	247
1	4/16	5/6	5/4 A. M.	285.5	14.3	18.8	20	......	*279.2*	268
3	4/17	5/3	5/6 P. M.	247.4	15.5	17.4	16	......	*262.4*	237
2	4/17	5/6	5/6 P. M.	274.1	14.4	18.7	19	......	*269.4*	258
2	4/17	5/7	5/6 P. M.	285.8	14.3	18.8	20	......	*275.0*	269
1	4/19	5/6	5/8 P. M.	255.2	15.0	18.0	17	......	*255.8*	240
2	4/19	5/8	5/8 P. M.	274.2	14.4	18.7	19	......	285.9	257
1	4/19	5/14	5/8 P. M.	350.0	14.0	19.3	25	......	354.2	328
1	4/20	5/10	5/10 M.	270.0	13.5	20.0	20	......	272.4	257
1	4/20	5/12	5/10 M.	293.9	13.4	20.2	22	......	*270.0*	278
1	4/20	5/13	5/10 M.	311.6	13.5	20.0	23	......	*283.0*	295
3	4/21	5/11	5/11 P. M.	264.7	13.2	20.5	20	......	*270.0*	250
2	4/21	5/12	5/11 P. M.	278.3	13.3	20.3	21	......	283.2	263
3	4/22	5/12	5/12 P. M.	265.6	13.3	20.3	20	......	270.0	251
1	4/22	5/13	5/12 P. M.	288.5	13.7	19.7	21	......	*283.0*	268
1	4/23	5/12	5/13 P. M.	249.4	13.1	20.6	19	......	252.0	235
Mean (30 individuals)				271.8	......	19.3	19.1	101.1	271.4	257
1	4/23	5/13	5/13 P. M.	267.0	13.3	20.3	20	......	270.0	252
6	4/23	5/14	5/13 P. M.	290.0	13.8	19.6	21	......	283.0	275
1	4/24	5/13	5/14 P. M.	246.3	12.9	20.2	19	......	*254.0*	232
1	4/24	5/14	5/14 P. M.	269.2	13.5	20.0	20	......	*268.0*	254
5	4/24	5/15	5/14 P. M.	292.1	13.9	19.4	21	......	293.6	276
1	4/24	5/16	5/14 P. M.	316.3	14.4	18.8	22	......	*312.0*	301
2	4/25	5/15	5/15 A. M.	272.7	13.6	19.9	20	......	*268.0*	257
4	4/25	5/16	5/15 A. M.	296.9	14.1	19.1	21	......	*294*	281
7	4/26	5/16	5/16 A. M.	265.4	13.3	20.3	20	......	280.0	260
2	4/26	5/20	5/16 A. M.	299.8	12.5	21.6	24	......	288.0	276
Mean (30 individuals)				285.3		19.8	20.8	105.0	283.9	269

Column 4 gives the date on which the developmental total reached 6480 (equivalent to 270 substitution-quotient), on a basis of velocity values shown in Table I, assuming that pupation occurred at noon of the day recorded. Column 5 gives the total which was reached on the actual date of emergence, reduced to the same basis. Column 6 gives the mean number of developmental units per day, reckoned from velocity values in Table I, for the actual period of pupal life as recorded. Column 7 gives the theoretical time, in view of the recorded conditions of temperature and humidity, calculated by dividing the mean daily velocity into 6480 as the normal developmental total. This eliminates individual variation. The substitution totals shown in the last column were obtained by the temperature-substitution method explained on p. 393; interpolations are shown in italics.

Table VIII. *Showing the actual and calculated time from pupation to emergence for all of Glenn's Olney data, 1915-1917, summing velocity values from Table I to a normal total of 6480 (equivalent to 270 substitution-quotient) and averaging the results by groups of 30 individuals.*

Compare the first two items of this table with the means of 30 individuals shown in Table VII. The mean ratio of actual to calculated time for each generation is given here to aid in determining the effects of factors other than temperature and humidity.

Date of Pupation.	Date of Emergence.	Calculated Time.	Actual Time.	Ratio of Actual to Calculated Time. %	Developmental Total divided by 24.	Substitution-quotient.
Hibernated Generation 1915						
4/13	5/12	19.1	19.3	101.1	271.8	271.4
4/23*	5/20	19.8	20.8	105.0	285.3	283.9
4/26	5/24	22.2	24.2	109.0	295.8	290.0
4/30	5/30	22.1	23.5	106.3	289.9	284.8
5/9	6/9	20.2	21.7	107.4	293.6	288.5
			Mean	105.8		
First Generation 1915						
6/19	7/10	14.3	13.0	91.0	236.7	254.7
6/27	7/10	14.5	13.6	93.8	254.7	270.5
6/28	7/13	14.5	13.1	90.4	244.3	261.6
6/29	7/16	13.8	13.5	97.8	263.5	280.8
7/1	7/15	12.7	13.0	102.3	275.8	275.1
7/4	7/17	11.7	10.9	93.1	252.3	253.7
7/6	7/18	10.9	10.9	100.0	268.4	264.3
7/7	7/20	9.9	9.9	100.0	271.8	264.8
7/10	7/22	9.8	10.1	103.0	276.2	271.3
7/13	7/25	10.6	10.4	98.1	266.4	275.0
7/14	7/27	10.9	10.5	96.3	258.6	258.0
7/16	8/2	11.4	11.1	97.3	262.3	277.0
7/21	8/5	10.3	9.7	94.1	252.5	256.0
7/26	8/7	11.1	11.2	100.9	270.3	257.7
7/28	8/16	11.9	12.0	100.9	272.8	266.3
			Mean	97.3		
Second Generation 1915						
8/7	8/31	14.8	13.7	92.5	250.3	249.3
Hibernated Generation 1916						
4/13	5/15	29.3	28.7	98.0	265.6	263.8
4/16	5/15	27.9	27.7	99.3	269.2	267.5
4/17	5/15	27.3	26.9	98.6	265.7	262 2
4/19*	5/18	27.1	26.7	97.9	267.0	270.0
4/19*	5/19	28.3	27.6	97.6	262.7	265.5
4/20*	5/19	28.9	28.9	100.0	270.4	272.2
4/21	5/20	27.2	27.1	99.6	269.2	269.2
4/24	5/21	24.6	24.9	101.1	273.5	267.1
4/28	5/22	22.2	22.2	100.0	270.3	270.3
4/30	5/23.	20.8	20.9	100.4	272.4	268.2
5/5	5/26	18.1	18.5	102.1	276.9	268.2
5/7	5/27	17.5	18.4	105.0	284.8	269.7
5/9	5/29	17.1	17.7	103.5	281.3	268.7
5/11	6/1	16.4	17.8	108.4	293.9	272.3
5/15	6/7	15.1	16.4	108.8	292.9	278.2
5/24	6/17	16.2	17.2	106.1	287.5	274.0
			Mean	101.7		

* Maximum.

TABLE VIII—Continued.

Date of Pupation.	Date of Emergence.	Calculated Time.	Actual Time.	Ratio of Actual to Calculated Time. %	Developmental Total divided by 24.	Substitution-quotient.
First Generation 1916						
6/20	7/10	10.7	10.3	97.4	260.3	271.1
7/1	7/14	10.8	9.9	91.6	248.0	276.0
7/4	7/15	10.9	9.9	90.7	244.8	260.1
7/5	7/16	10 5	10.2	98.0	261.6	270.8
7/6	7/17	10.0	10.0	100.0	268.6	266.6
7/8	7/18	9.8	9.6	98.0	263.9	267.4
7/9	7/23	9.6	10.0	104.2	279.6	278.5
7/10	7/18	9.5	9.7	102.0	274.6	269.1
7/11	7/21	9.5	9.2	96.9	261.9	262.4
7/11	7/21	9.6	9.2	95.8	257.0	258.0
7/12	7/22	9.6	9.4	98.0	261.0	264.7
7/13	7/21	9.6	9.7	101.1	273.6	271.1
7/14	7/23	9.6	9.1	94.8	255.2	254.8
7/15	7/24	9.7	8.9	91.8	248.3	252.8
7/15	7/24	9.7	10.0	103.0	278.6	276.1
7/16	7/26	9.8	9.4	96.0	259.2	265.0
7/16	7/26	9.9	9.7	98.0	264.8	270.6
7/17	7/26	9.9	9.9	100.0	269.1	278.3
7/18	7/28	9.9	9.4	95.0	256.5	268.2
7/18	7/30	9.9	10.0	101.0	273.6	284.1
7/19	7/30	9.8	9.8	100.0	270.9	277.9
7/21	8/1	9.5	9.4	99.0	267.2	268.6
7/23	8/2	9.4	9.2	98.0	265.8	264.8
7/24	8/3	9.4	9.2	98.0	265.0	271.9
7/25	8/5	9.3	9.4	101.0	274.5	274.2
7/27	8/6	9.2	9.4	102.1	276.6	268.2
7/27	8/7	9.1	9.8	107.5	289.0	295.3
7/29	8/8	9.2	9.4	98.0	277.3	273.2
7/30	8/9	9.2	9.2	100.0	269.3	268.3
7/31	8/10	9.2	9.1	98.9	267.6	273.0
8/2	8/12	9.1	9.1	100.0	273.2	263.1
8/3	8/16	9.5	9.5	100.0	270.8	277.7
8/6	8/18	10.3	10.1	98.2	264.7	264.4
8/7	8/18	10.4	10.2	98.2	263.5	261.0
8/10	8/21	10.3	9.8	96.1	255.4	259.0
8/10	8/22	10.3	10.2	99.1	265.3	262.2
8/12	8/24	10.6	10.1	95.4	255.6	263.0
8/14	8/24	10.5	10.0	95.3	254.9	263.0
8/14	8/24	10.5	10.3	98.2	263.2	258.4
8/15	8/25	10.4	10.0	96.2	258.3	266.1
8/16	8/26	10.6	9.6	90.6	244.8	250.1
8/16	8/28	10.9	10.6	97.4	262.0	264.6
8/16	8/28	11.0	10.1	91.9	245.2	249.0
8/17	8/29	11.5	11.1	96.5	258.6	255.9
8/17	8/30	12.3	11.5	96.7	251.0	250.4
8/18	8/31	13.3	12.1	91.0	243.8	252.6
8/19	9/2	13.5	13.2	97.8	262.5	271.0
8/19	9/4	14.4	13.4	93.2	251.5	259.3
8/21	9/4	14.8	13.9	94.0	254.7	262.0
8/23	9/7	14.1	13.0	92.2	249.4	255.7
8/26	9/11	13.6	12.7	94.4	251.4	260.0
			Mean	97.6		
Second Generation 1916						
8/28	9/12	12.6	11.6	92.2	246.8	245.8

TABLE VIII—Concluded.

Date of Pupation.	Date of Emergence.	Calculated Time.	Actual Time.	Ratio of Actual to Calculated Time. %	Developmental Total divided by 24.	Substitution-quotient.
Hibernated Generation 1917						
4/12	5/19	36.5	37.0	101.4	273.8	269.8
4/12	5/19	34.3	36.2	105.5	285.2	267.1
4/15	5/20	33.1	34.4	103.9	282.9	262.8
4/16	5/21	32.3	34.1	105.6	287.5	281.2
4/17	5/20	32.6	33.0	101.2	275.5	275.2
4/17	5/20	32.5	33.0	101.5	276.6	273.9
4/17	5/19	32.6	32.8	100.6	272.9	272.9
4/18	5/20	33.4	32.0	95.8	257.7	268.8
4/18	5/21	32.6	33.0	101.2	274.9	271.7
4/18	5/21	32.5	33.0	101.5	275.5	271.9
4/18	5/21	32.5	33.0	101.5	275.5	271.9
4/19	5/21	33.8	33.0	97.6	267.7	262.0
4/19	5/21	33.7	32.0	94.9	256.7	259.0
4/19	5/22	33.6	32.1	95.5	258.1	260.0
4/19	5/24	33.2	33.7	101.5	274.2	272.8
4/19	5/24	33.7	35.0	103.8	281.1	283.5
4/19	5/25	33.6	35.2	104.8	282.8	285.4
4/19	5/25	33.4	36.0	107.8	291.3	295.3
4/19*	5/21	33.9	34.4	101.4	274.4	277.0
4/20*	5/24	34.6	34.0	98.3	264.8	272.0
4/20*	5/24	34.6	34.4	99.4	268.9	275.0
4/20	5/25	34.6	35.0	101.1	275.1	280.0
4/20	5/25	34.6	35.0	101.1	275.1	280.0
4/20	5/26	34.4	35.4	102.9	280.6	283.7
4/20	5/29	34.2	36.0	105.5	286.9	288.0
4/22	5/27	34.0	33.9	99.5	270.7	274.3
4/22	5/29	32.9	35.1	106.7	289.5	283.9
4/23	5/27	34.6	33.9	98.0	267.5	263.0
4/23	5/27	34.8	34.0	97.7	273.9	268.6
4/23	5/29	34.1	34.5	101.1	284.3	284.7
4/23	5/27	34.1	34.5	101.1	274.9	273.5
4/24	5/30	34.6	35.0	101.1	277.5	273.4
4/24	5/31	34.2	36.2	105.8	295.1	288.4
4/24	5/30	34.1	34.8	102.0	277.8	278.8
4/25	5/28	33.5	34.9	104.1	284.3	281.5
4/26	5/24	32.6	34.9	107.0	291.7	286.2
4/27	6/1	31.2	31.9	102.2	279.9	276.6
4/30	6/1	28.4	31.1	109.5	287.0	282.9
5/3	6/3	25.6	27.0	105.4	286.1	251.2
5/10	6/5	20.8	22.3	107.2	290.3	283.2
5/16	6/7	18.6	20.4	109.6	296.7	302.9
5/18	6/9	18.5	20.2	109.2	295.2	296.9
5/20	6/20	17.3	18.9	109.2	287.3	303.1
			Mean	102.6		
Partial First Generation 1917						
6/27	7/12	12.1	10.8	89.2	239.1	253.8
7/2	7/15	12.1	11.9	98.3	221.4	242.6
			Mean	93.8		

* Maximum.

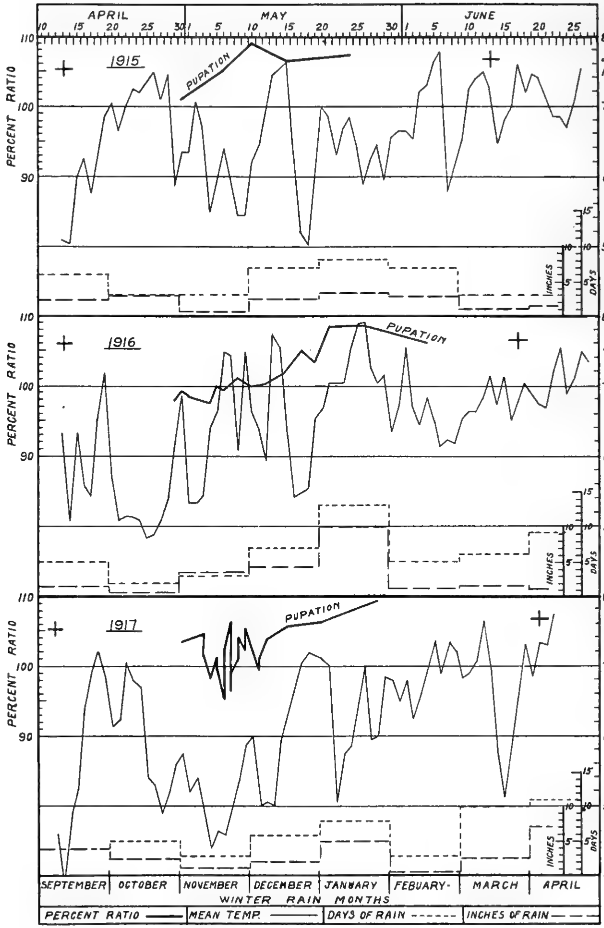

Fig. 3. Graphic summary of data in Table VIII.
(See explanatory note on opposite page.)

TABLE IX. *Showing the calculated and actual time for incubation of eggs from first generation moths at Olney, Ill., (1915).*

For detailed explanations see Table VII.

No. of Eggs.	Dates.	Developmental total divided by 24.	Mean Daily velocity divided by 24.	Calculated time.	Actual Time.	Ratio of Actual to calculated time. (per cent.)
3	5/5 —5/17	159.9	13.3	12.0	12	....
6	5/5 —5/20	175.1	11.7	13.7	15	....
10	5/5 —5/17	159.9	13.3	12.0	12	....
27	5/5 —5/20	175.1	11.7	13.7	15	....
2	5/6 —5/21	185.7	12.4	12.9	15	....
12	5/7 —5/21	173.9	12.4	12.9	14	....
Mean for 60	....	*171.9*	....	*13.1*	*14.1*	107.6
15	5/8 —5/21	166.5	12.8	12.5	13	....
2	5/8 —5/22	182.0	13.0	12.3	14	....
2	5/8 —5/23	193.4	12.9	12.4	15	....
13	5/9 —5/21	160.9	13.4	11.9	12	....
3	5/9 —5/22	176.5	13.6	11.8	13	....
6	5/10—5/21	155.3	14.1	11.3	11	....
1	5/10—5/22	170.8	14.2	11.3	12	....
5	5/11—5/22	160.3	14.6	11.0	11	....
5	5/21—6/2	153.0	12.9	12.6	12	....
Mean for 60	....	*164.8*	....	*12.0*	*12.4*	103.3
87	5/21—6/3	168.6	13.0	12.3	13	....
Mean for 60	....	*168.6*	....	*12.3*	*13.0*	105.7
1	5/21—6/5	189.1	13.5	11.9	14	....
25	5/22—6/3	153.1	12.7	12.6	12	....
19	5/22—6/4	173.6	13.4	12.0	13	....
Mean for 60	....	*163.7*	....	*12.3*	*12.6*	102.4

Fig. 3. Length of the pupal stage of first-generation codling moths in 1915, 1916, and 1917 at Olney, expressed in per cent of standard average time for the stage (scales at the left). The data are plotted for groups of 30 individuals on dates midway between the first pupation and the last emergence of each group. The cross at the left indicates the date of pupation of the first individual of the first group in each year, and the cross at the right indicates the date of emergence of the last individual of the last group. The mean temperature for each day for the whole period covered in each year is plotted according to the Fahrenheit scales at the right, for comparison with pupation graphs. The inches of rainfall and number of rainy days for each month from the preceding September to and including April are plotted below, with names of months at the bottom of the figure.

TABLE X. *Showing actual and calculated time for incubation of eggs of all generations of moths recorded by Glenn at Olney, 1915-1917, on a basis of 160 as the normal substitution-quotient.*

Dates.	Time for Incubation.		Ratio of Actual to Calculated time. %	Substitution-quotient.
	Calculated.	Actual.		
First Generation 1915				
5/5 —5/21	13.1	14.1	107.6	171.9
5/8 —6/2	12.0	12.4	103.3	164.8
5/21—6/3	12.3	13.0	105.7	168.6
5/21—6/4	12.3	12.6	102.4	163.7
5/23—6/5	11.8	12.3	104.2	167.8
5/23—6/6	10.9	11.9	109.2	212.2
5/27—6/10	9.6	9.0	93.7	152.6
6/1 —6/11	9.2	9.3	101.1	161.1
6/3 —6/11	8.9	8.4	94.4	150.2
6/3 —6/12	8.6	9.0	104.6	167.8
6/3 —6/12	8.5	9.1	107.0	168.6
6/4 —6/13	8.4	8.3	98.8	158.3
6/5 —6/14	8.4	8.2	97.7	157.0
6/5 —6/20	8.0	8.5	106.2	170.7
6/14—6/23	7.7	7.7	100.0	159.2
6/16—6/27	7.9	8.0	101.2	163.3
		Mean	*102.3*	
Second Generation 1915				
7/2 —7/13	9.1	9.0	98.9	157.7
7/7 —7/15	7.0	6.7	95.7	153.0
7/9 —7/24	6.2	6.5	104.9	170.5
7/17—7/29	6.9	7.3	105.8	165.8
7/24—7/30	6.4	6.0	93.8	149.1
7/24—7/31	6.0	6.0	100.0	159.8
7/28—8/3	5.6	5.4	96.5	154.1
7/28—8/6	6.4	6.6	103.1	166.1
7/30—8/8	7.3	7.1	97.3	157.2
7/31—8/21	7.8	7.8	100.0	160.4
8/13—9/2	11.1	10.0	90.1	143.0
8/22—9/4*	11.6	11.2	87.9	152.9
*48 eggs				
		Mean	97.8	
Third Generation 1915				
8/22—9/10	11.5	10.6	92.2	148.7
9/13—9/19*	5.6	6.0	.....	.....
*20 eggs				
		Mean	92.2	

The results are averaged for groups of 60 eggs unless otherwise indicated. The mean ratio of actual to calculated time for each generation is given here to aid in determining the effects of factors other than temperature and humidity.

TABLE X—Concluded.

Dates.	Time for Incubation.		Ratio of Actual to Calculated time. %	Substitution quotient.
	Calculated.	Actual.		
First Generation 1916				
5/14—5/26	9.7	9.2	94.9	151.6
5/19—5/27	7.8	8.0	102.6	165.2
5/20—5/27	7.4	7.1	96.0	154.0
5/20—5/28	7.1	6.5	91.5	147.0
5/21—5/28	7.1	6.9	97.2	154.6
5/22—5/29	7.1	7.0	98.6	156.6
5/22—5/30	7.1	7.0	98.6	156.6
5/23—5/30	7.2	7.1	98.6	157.5
5/23—5/31	7.4	7.2	97.3	155.3
5/24—6/2	7.7	7.6	98.7	157.5
5/25—6/7	9.8	9.3	94.9	160.4
5/30—6/12	9.9	10.5	106.1	170.6
6/7 —6/20	9.9	9.5	96.0	153.1
6/12—6/26	9.4	9.7	103.1	166.3
		Mean	98.2	
Second Generation 1916				
7/6 —7/20	5.6	5.5	98.2	155.5
7/15—7/21	5.5	5.5	100.0	158.7
7/15—7/24	5.9	5.9	100.0	160.1
7/18—7/24	6.0	6.0	100.0	158.2
7/18—7/25	6.2	6.0	96.8	156.0
7/19—7/27	6.0	6.3	105.0	166.9
7/20—7/29	5.7	6.2	108.7	172.4
7/24—7/30	5.5	5.7	103.6	165.3
7/25—8/3	5.4	5.3	98.1	155.8
7/28—8/4	5.5	5.7	103.6	164.5
7/29—8/17	6.1	5.9	96.7	151.4
8/10—8/18	6.6	7.0	106.0	168.4
8/11—8/18	6.7	7.0	104.5	167.9
8/11—8/21	6.6	6.7	101.5	163.6
		Mean	101.6	
Third Generation 1916				
8/17—8/24	6.2	6.3	101.6	164.2
8/26—9/4	9.3	9.0	96.8	156.2
8/26—9/12	7.5	7.5	100.0	159.0
9/5 —9/14*	7.6	7.2	94.8	150.2
*39 eggs				
		Mean	98.4	
First Generation 1917				
5/20—6/5	12.6	10.8	93.7	149.5
5/26—6/7	10.8	10.8	100.0	161.2
5/26—6/8	9.5	9.4	98.9	158.5
5/30—6/12	8.8	8.4	95.5	151.3
6/4 —6/16	9.4	8.7	92.6	148.7
6/7 —6/19	10.4	10.1	97.1	154.9
6/8 —6/21	10.7	9.9	92.5	149.2
		Mean	95.7	

TABLE XI. *Comparison of actual and calculated time for larvae in apples and in cocoons, in groups of ten individuals, for all generations of 1915-1917 as recorded by Glenn.*

Observed Date of Hatching of first individual.	Time in apple.			Time in cocoon.			Observed date of last pupation.	Entire Larval Period.		
	Calculated days.	Actual days.	Ratio A. to C. %.	Calculated days.	Actual days.	Ratio A. to C. %.		Calculated days.	Actual days.	Ratio A. to C. %.
1st Gen. 1915										
6/ 3—	27.9	28.7	102.8	4.1	4.8	117.1	7/12	32.01	33.4	104.3
6/ 4—	27.8	29.1	104.6	5.4	4.6	85.2	7/18	32.1	32.8	102.2
6/11—	28.4	27.6	97.2	4.1	4.1	100.0	7/20	32.0	31.0	96.9
6/11—	28.1	29.2	103.9	3.9	4.5	115.4	7/22	31.6	33.3	105.4
Means	......	......	102.1	......	......	104.4	......	......	......	102.2
2nd Gen. 1915										
7/11—	24.6	25.0	101.6	4.6	4.4	95.7	8/17	28.8	29.4	102.1
1st Gen. 1916										
5/27—	30.4	33.0	108.5	3.7	2.8	75.67	7/4	34.4	35.8	104.1
5/27—	30.2	32.0	105.9	3.3	3.3	100.0	7/8	33.9	35.5	104.7
5/ 3—	29.2	33.7	111.5	3.8	3.6	94.7	7/11	33.3	35.4	106.3
6/ 2—	28.1	34.7	123.5	3.3	3.3	100.0	7/17	32.7	38.5	117.7
6/22— (6 individuals)	25.3	22.9	90.5	3.0	3.7	123.3	7/19	28.8	26.8	93.1
Means	......	......	108.0	......	......	98.7	......	......	......	105.2
2nd Gen. 1916										
7/12—	23.4	22.2	94.9	4.1	3.7	90.2	8/18	27.7	25.9	93.5
7/20—	24.0	21.9	91.3	3.8	3.7	97.4	8/18	28.0	25.7	91.8
7/20—	23.9	23.0	96.2	4.3	4.4	102.3	8/18	28.4	27.4	96.5
7/21—	24.1	20.7	85.9	4.4	4.2	95.5	8/19	28.0	24.4	87.1
7/23—	24.1	21.3	88.4	3.4	3.8	111.8	8/20	27.8	25.1	90.3
7/25—	24.1	21.3	88.4	3.7	4.1	110.8	8/26	27.8	27.2	97.8
7/27—	23.8	21.9	92.0	3.8	4.3	113.2	8/27	28.4	26.2	92.3
7/28— (5 individuals)	23.5	22.0	93.6	4.4	4.7	106.8	9/3	27.3	25.9	94.9
Means	......	......	91.3	......	......	103.5	......	......	......	93.0
1st Gen. 1917										
6/ 4—	28.7	25.8	89.9	4.2	4.7	111.9	7/11	32.9	30.5	92.7
6/ 9—	28.7	25.5	88.9	4.0	4.5	112.5	7/12	32.7	30.0	91.7
6/ 9—	28.5	24.9	87.4	4.8	4.0	83.3	7/12	32.3	28.1	86.9
6/12—	27.9	27.3	97.8	4.4	3.6	81.8	7/20	32.2	30.7	95.3
6/16—	26.7	21.6	80.9	2.6	3.2	123.1	7/16	30.8	24.8	80.5
6/16—	26.4	23.5	89.0	5.2	4.5	86.5	7/19	30.4	27.6	90.8
6/16—	26.4	26.3	99.6	......	4.5	......	7/19	......	31.1	......
Means	......	......	90.5	......	......	99.8	......	......	......	89.7
Means of all	......	......	98.7	......	......	100.4	......	......	......	98.4

On a basis of 750 as the normal substitution-quotient for the whole larval life (650 for the time in the apple and 100 for that in the cocoon). The mean ratio of actual to calculated time for each generation is given here to aid in the determination of the effects of factors other than temperature and humidity. For detailed explanations of the methods of calculation, see Tables V and VII and pp. 401-405.

after sunset was necessary for oviposition and that the maximum number of eggs laid was on the second, third, and fourth days after emergence. In prediction work, therefore, at least two days should be allowed for the time from emergence to egg laying, as very few eggs are laid the first day.

c. Incubation of Eggs.

The hourly velocity values for pupal development (Table I) may be used also for incubation, but the normal developmental total is 3864 instead of 6480. Standard time for incubation, calculated on a basis of 3840 developmental units (from Glenn's 1916 data), is shown in Table X, together with the actual time for groups of 60 eggs for all the Olney data. The method by which the theoretical time for each of these groups was calculated is shown in Table IX. The ratio of actual to theoretical time averaged 98.4 per cent for all eggs recorded; it would be 100 per cent if 3864 developmental units had been used as the normal total. Deviations from standard time for all generations of all years for which data were at hand, are shown in Fig. 28, p. 421.

d. Larvae in Apples.

Hourly velocity values for development of larvae in apples are shown for various temperatures in Table V, p. 323. It is noteworthy that lower temperatures are more effective on larvae in apples than on pupae or eggs. The normal total for the period in the apple is 15,600 developmental units, but an empirical number, 18,000, may be used to cover the entire development of the larvae (except when hibernating) from the time it enters the apple until it pupates, the normal total for the period in the cocoon thus being taken to be 2,400 developmental units. The calculated and actual time for these two parts of the larval period is shown, for means of groups of 10 individuals, covering all of the Olney data (1915-1917), in Table XI and in Fig. 28. The larval period is much more variable than the other stages. The ratio of actual to calculated time for larvae in apples, when averaged by generations for those three years, ranged from 90.5 to 108.0 per cent, with a mean of 98.7 per cent. The second generation of 1916 and the first generation of 1917 fell below the standard time, while all generations of 1915 and the first generation of 1916 were above the standard. On the other hand, the ratio of actual to calculated time in the cocoon, ranging from 95.7 to 104.4 per cent (generation means), was lowest when the ratio for larvae in apples was 101.6 per cent, in the second generation of 1915, and next lowest when the ratio for larvae in apples was 108.0 per cent, in the first generation of 1916. That is, when the time in the apple was comparatively long, the time in the cocoon was comparatively short. This is in accord with the supposition that enzymes are concerned.

In all these calculations, it was assumed that the velocity values derived from the larva in the apple would hold good for the pre-pupal stage in the cocoon at the same temperatures and humidities. The deviation from calculated time may be taken as evidence that these values need to be modified; it is likely, however, that individual variation would still cause considerable deviation even if new velocity values were established for this part of the larval life.

e. Pupation after hibernation.

It is possible to make only a rough, unreliable estimate of the time at which larvae will begin to pupate after hibernation. This has been based upon January 1 as an average date for the beginning of preparation for pupation. The actual time of beginning has varied six weeks on either side of this date in experimental stocks which were under identical conditions except for varying amounts of moisture. This leaves an unsound basis for a beginning, until the subject of hibernation has been thoroughly investigated. It was hoped that the determination of the enzyme content of larvae from time to time might indicate their condition relative to pupation, and the only enzyme, catalase, which has been investigated (see below, p. 443), gave promise of results of value, but a definite correlation has not yet been established. The work of Townsend ('26) has shown that the amount of rainfall and the frequency of rains are of very great importance. The whole subject deserves a thorough investigation. Reliable estimates of progress toward pupation in the spring of an unusual year, when estimates are most needed, are not possible now.

f. Pupae from Hibernated Larvae.

The time of the first pupations will, for the present, have to be ascertained from individual larvae under observation. The pupations are strung out over a long period in spring. There are usually two maxima, as shown in Glenn's charts 1, 2, and 3 and in Fig. 25 of this paper. In Glenn's three cases the first maximum came eight to ten days after the first pupation, and the second maximum came ten to twenty days later. These maxima also occur under uniform temperature and after uniform treatment (Fig. 25), but a correlation with weather is also shown by Glenn's data.

THE EFFECTS OF CONDITIONS OTHER THAN TEMPERATURE AND HUMIDITY.

It is evidently possible to calculate time of appearance of stages and to estimate progress to any date with a fair degree of accuracy from temperature and humidity alone (Tables VII-XI). The calculation of standard time for stages with respect to these two factors has another important value, namely, the estimation of the effects of *other* factors (amount and distribution of rainfall, seasonal march of mean daily temperatures, solar radiation, etc.). Unfortunately, the responses of different stages to these other factors are different, just as in the case with temperature and humidity. This renders it imperative that the different stages be calculated separately.

a. Rainfall.

Autumn and winter rainfall has important effects upon the rate of development of hibernated larvae and of pupae derived from them: when rainfall is heavy, the larvae are more abundant, more of them pupate, and the pupal stages are shorter than when following an autumn and winter with less precipitation. Compare graphs for 1915, 1916, and 1917 in Fig. 3 showing this relation. In all cases, the pupal life is long in all the later formed pupae. A comparison with Glenn's charts 1, 2, and 3 shows that the great mass of pupae had emerged previous to those whose mid-date of pupal life came on May 15. It will be seen that the pupal life of the large groups was longer than normal in 1915, following a dry autumn and winter, and shorter than normal in 1916, following a wet winter; 1917 is intermediate in length of pupal life and in amount of autumn rainfall.

The difference in length of the pupal stage is quite marked, even in the case of Glenn's pupae which were not exposed to rain. The most marked case was that of the 1917-18 larvae which hibernated in very dry conditions in the laboratory and were put out of doors in the spring; the actual time was 119 per cent of the standard time. This is higher than any other recorded.

b. Combinations of Rainfall and Seasonal March of Temperature.

The annual march of temperature and rainfall by months for a year in which the codling moth *flourishes* in southern Illinois are shown in Fig. 4, graph A, beginning with September of the preceding year; the autumn is rainy, and the spring only moderately so. In graph B, which is for a year when the codling moth is scarce in southern Illinois, the autumn is very dry, and the spring very wet. The summer of graph B is cooler than that of graph A; otherwise there is little difference in mean temperature. Graphs A and B in Fig. 5 show, respectively, the general limits of temperature and rainfall for the months of years when codling moths are scarce and abundant; that is, the mean monthly temperature and rainfall for such years fall within the areas marked. Data for the year 1914, when codling moths were more abundant and spraying seemed less effective than in many years, constituted the chief basis for the establishment of the limits shown in graph A of Fig. 5. Answers to a questionnaire sent out by Mr. W. P. Flint to a number of orchardists showed moths abundant near Mount Vernon and Charleston in 1920, and the data for most of the months fit the diagram very well. (See Fig. 30 p. 424.) Data for 1923, a "scarce" year, were taken as a model for most of the months shown in graph B of Fig. 5, but by being extended they have been made to include two-thirds of six years in localities where moths were declared scarce by orchardists. The crosses in Fig. 4 are the centers of the areas outlined in Fig. 5. (See Fig. 25 and explanation.) Graph A of Fig. 6 is a diagram of similar data for 1921-1922 at Olney, a year which A. J. Wharf marked "scarce early" and "abundant late"; it shows a fairly favorable autumn, an unfavorable spring, and a favorable summer. The great influence of rainfall is here illustrated by the fact that the temperature for some months of this year (and for some of the months shown in Fig. 30) was as low as, or lower than, for the corresponding months in the years in which the moths were scarce.

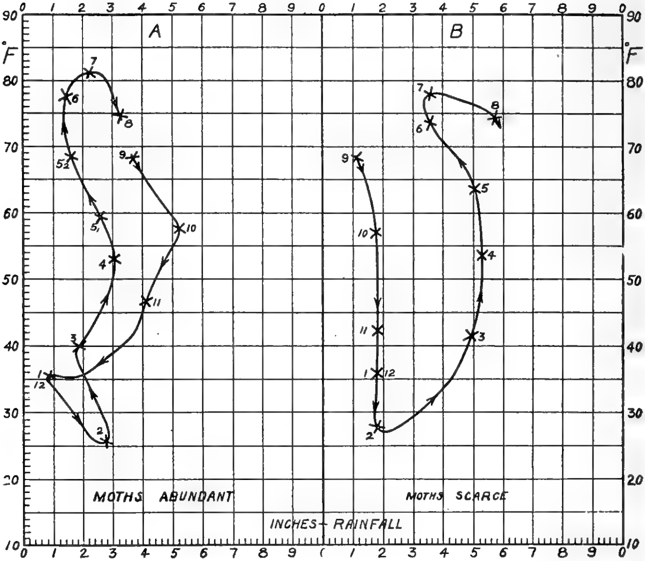

Fig. 4. Ball-Taylor diagrams of temperature and rainfall. A is for a typical year when codling moths are abundant in Southern Illinois; B is for a typical year when they are scarce. The numbers 1—12 on each diagram indicate the months January—December, and the cross beside each number indicates the amount of rainfall and mean temperature for the month. (5_1 = 1st half of May. 5_2 = 2d half of May.) Note that in the abundant year the rainfall is comparatively heavy (4—5 inches) in September, October and November and comparatively light (1—3 inches) in the spring and summer; while in the scarce year it is light (1—2 inches) in the autumn and winter and heavy (4—6 inches) in the spring and summer. Note also the higher temperatures in May (5_2), June (6), and July (7) in the abundant year.

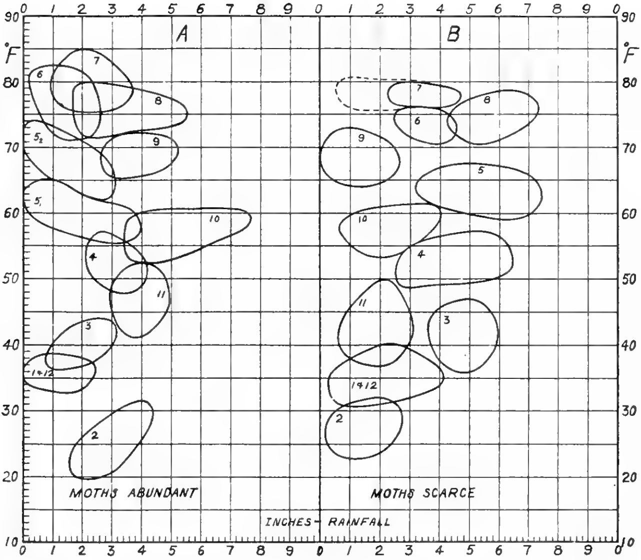

Fig. 5. Limits within which the mean monthly rainfall and temperature fell when plotted for years when the codling moth was scarce and abundant, respectively, in southern Illinois. The areas enclosed by graphs numbered 1—12 include the data for the months January—December over a period of ten years (1914-1924). The centers of these areas are represented by crosses numbered similarly in Fig. 4 (Cf. Figs. 30 and 31).

Figure 7 shows temperature-rainfall graphs (A, B, and C) made up from Weather Bureau records for the years 1914-1917 at Olney. The year 1914-1915, which Mr. Flint rated "moderate" in moths, was most unfavorable in the autumn and, generally, the least favorable of the three years: there was no rain in later winter to compensate for the dry autumn; the spring was too dry except May; and the summer was too wet. In 1915-16, a year for which Mr. Flint rated moths "moderately abundant," the early autumn was still drier, but later rains compensated.

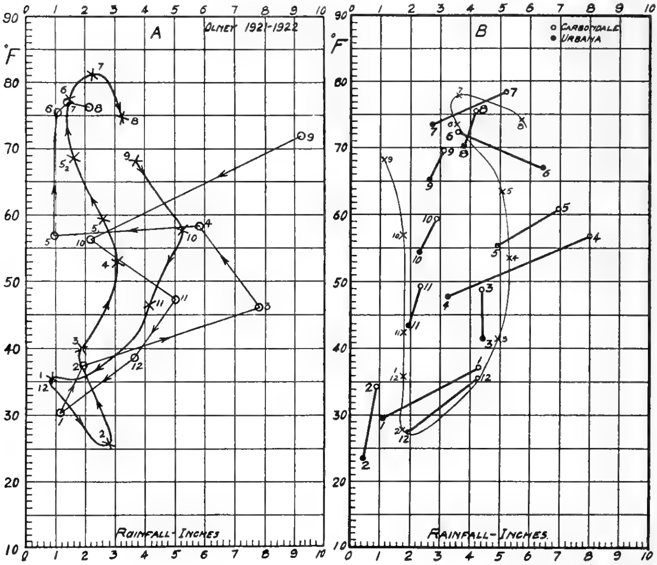

Fig. 6. (A) Rainfall-temperature diagram for a year in which moths were reported "scarce early" and "abundant late," indicating a fairly favorable fall and winter, an unfavorable spring, and a favorable summer. The typical graph for an "abundant" year (Fig. 4) is also shown here for comparison.

(B) Mean monthly temperatures for the year Sept. 1, 1916, to Aug. 30, 1917, at Urbana and Carbondale where the "late" larvae were scarce. (They were more numerous at Springfield and Carlinville where July was warmer and drier. This correlation, however, is not clear enough to justify a definite conclusion.)

May was nearly normal in total precipitation for an abundant year, but the summer distribution of rain was unfavorable to moths. The autumn and winter were too dry in 1916-17, in which Mr. Flint rated the moths "moderate." Of these three years, graph C conforms most nearly to that of a scarce year.

c. Number of late larvae.

The damage to the apple crop of 1914 was, to a considerable extent, due to a large number of late larvae. As nearly as can be judged, such abundance of late larvae is one of the characteristics of the autumn of an "abundant" year. The conditions favoring the development of a third generation are shown in Figs. 4 and 5. The season 1916-17 (September 1-August 31) was especially significant in this respect, as there were few or no late larvae at Urbana and Carbondale, while at Springfield and Carlinville there was a small late or third generation of larvae. The rainfall-temperature diagrams (Fig. 6B) for the two localities without late larvae show dry autumn and wet spring characteristic of "scarce" years. The difference from the "abundant" years is striking. The absence of late larvae in this one year was associated with a rainy July at Carbondale and with low temperatures at Urbana.

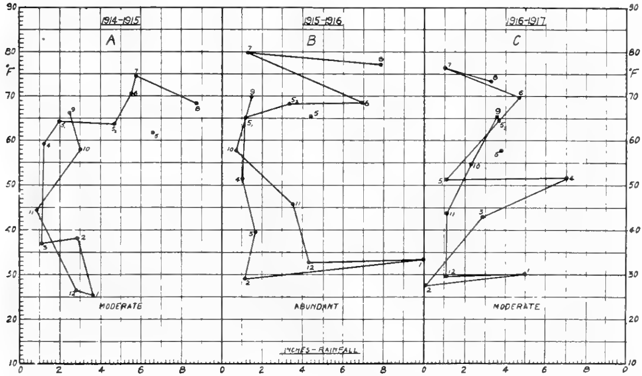

Fig. 7. Ball-Taylor diagrams, or hythergraphs, for three years at Olney.

MODIFICATION OF NORMAL DEVELOPMENTAL TOTALS.

Corrections of developmental totals must be made relative to rainfall, variability of temperature, and individual variation. Rainfall corrections are given in Tables III and IV. Rising and falling mean daily temperature and humidity affect the development of pupae and eggs. When the mean daily temperature rises from day to day, the length of the pupal stage is increased to as much as 10 per cent higher than average; that is, the developmental total may be 110 per cent of the normal number of developmental units. When temperature begins to fall from day to day in the middle of August, the developmental total decreases steadily until in the third generation. The decline is about 2 per cent per week, beginning with the first week of falling temperatures in August. The third generation normally requires only 5,952 developmental units for the pupal period and 3,360 developmental units for the incubation period. Pupal and incubation time for the central portion of the second generation in 1915 and 1916 was about standard. For such conditions, Table VI shows corrections to be made.

All estimation is on the basis of average data. Individual variation, however, makes the developmental total for some of the first-generation larvae in the apple 16 per cent less than normal. Corrections of this kind may be made for other stages by subtracting 8 per cent from the normal, when the date of first appearance is desired. When maximum emergence is to be predicted, the correction for individual variation is, of course, unnecessary.

CORRECTION OF LOW TEMPERATURES APPLICABLE TO GLENN'S METHOD.

It would involve considerable calculation to bring Glenn's corrections of high temperatures into accord with the findings by our methods. His corrections, however, proved very valuable and his original data indispensable. His normal pupal total of 265 "degree-days" above 50° F. as the "starting point", or 241 "degree-days" above 52° F., is useful for the medial range of temperatures. The "maximum rate" for pupae and eggs should probably be set at 89° instead of 87° F. At the lower temperatures, between 44° and 60° F., corrections may be applied to his calculations as follows:

To each two-hour reading, add $0.7\,\frac{(60-x)}{2}$.

Thus, if the reading is 46° F., add $0.7\,\frac{(60-46)}{2}$, or 4.9°, making a corrected temperature of 50.9° F. to be used in getting an effective sum. Such a sum should correspond fairly closely to the *substitution-quotient*, or one-twenty-fourth of the normal developmental total.

PART THREE.

METHODS OF EXPERIMENTATION AND CALCULATION.

1. THEORY OF THRESHOLDS AND RATES OF DEVELOPMENT.

Calendars of periodic events have been used in connection with agricultural practice for thousands of years. Becquerel (1853) published a Chinese calendar of 700 B. C. which does not differ in its essential features from various published spray calendars. For several centuries attempts have been made to predict development by summing temperatures. According to Becquerel, Reaumur (1735) was one of the early investigators who contended that the mean daily temperature multiplied by the number of days should be used. De Candolle made important contributions and is most often quoted, but one of the outstanding investigations in the last century is that of Von Oettingen (1879) on the Dorpat woody plants, who used the term, "threshold" (perhaps first) for the temperature at which development begins and made his sums from that. De Candolle also recognized the threshold but made his sums above zero Centigrade.

Thresholds. This summing of temperatures has been done on the assumption that the time-temperature relation is accurately represented by an equilateral hyperbola and that the hyperbolic zero marks the actual threshold development.* This assumption is false. The velocity of development does not always bear a fixed ratio to the temperature. Only a portion of the velocity curve, that for medial temperatures, is a straight line. Valuable as this straight-line portion is—it is the only proper basis for beginning any accurate calculation of the effects of temperature and other factors influencing the rate of development of organisms—it alone does not tell the whole story. The complete velocity curve shows a "lag phase" at lower temperatures and falls off at higher temperatures. The hyperbolic zero (*alpha* value) does not mark the actual threshold of development; in fact, the threshold is not a fixed point but varies for different individuals of the same species and for different species. It is, therefore, no simple matter to derive a velocity value for any given temperature. The problem involves the establishment of an absolute unit of development in which to express the effects of all weather phenomena, and the determination of a normal total of developmental units required for the completion of each stage in the life-history of the organism. Ideally, the developmental unit, defined with reference to the straight-line limits of the velocity curve under conditions normal to the habitat of the species

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* The product of the ordinates and abscissas establishing any point on an equilateral hyperbola is a constant; and the reciprocals of the ordinates, when multiplied by the constant and plotted on their abscissas, give a straight line which crosses the temperature axis at a point called the hyperbolic zero (represented by the Greek letter *alpha*) and which exactly bisects the angle between the two axes.

in the region of its greatest abundance, is the difference in the hourly velocity of development (based on the time to complete the stage) at two mean temperatures differing by one degree Centigrade,* these two being averages of temperatures varying at an average rate of approximately one degree per hour in the medial range, e. g., between 20° and 30° C. Practically, the medial range of the conditions in the region where the investigator finds the species thriving is used as standard, and the developmental unit is approximately established by the use of data from experiments which simulate these conditions as nearly as possible. Furthermore, there is a great amount of individual variation, even in the most carefully selected stocks, which necessitates the use of large lots in order to arrive at dependable averages. The variation of the *alpha* value renders the calculations very laborious. The problem is still further complicated by the fact that the developmental total is not a constant, but varies for different individuals of the same generation and for different generations of the same year. (See definitions of terms, pp. 330-333.)

Von Oettingen, in his attempts to find the threshold of development, assumed a series of *alpha* values, calculated time-temperature products for each one, and selected that one which gave the most nearly constant products for different mean temperatures. He also calculated the probable error in his method. Reibisch ('02) calculated the *alpha* value by the formula $(x - \alpha)y = k$, where x is the temperature and y is the time. Krogh ('14), in his work with Johansen on fish eggs, discovered that the threshold so calculated is not the real one, and he undertook in 1914, by studying the time required for embryonic stages of frog development, to determine the relation of the actual threshold to the *alpha* value obtained by Reibisch. He found that the graph representing the velocity of development is flattened out at the lower end and falls off at the upper end, whereas it had always been assumed to be straight. He worked over the published data of Loeb and Wastenys, performed experiments on several additional animals, and thus compiled a table showing the straight-line limits of two species of echinoderms, six species of fishes, one frog, one aquatic insect, and one land insect. This discovery was the culmination of a long series of papers on fish eggs by Apstein ('11), Dannevig ('94), Earll ('78), Reibisch ('02), Williamson ('10), and Johansen and Krogh ('14). Up to the present time all of this work on fishes appears to have been ignored by entomologists, as also the work of phenologists, by investigators of both insects and fishes.

Velocity curves. As was pointed out in PART TWO, pp. 334-338, temperatures above *alpha* may be summed for that part of the velocity curve which is a straight line, but not outside the straight-line limits. Temperatures would probably never have been summed except for the coincidence that, for a part of the temperature range, "effective temperatures" and amounts of development are numerically equivalent. Whenever the results were satisfactory, it was, in fact, amounts of development and not

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* The Fahrenheit scale is used in this paper.

degrees of temperatures that were being summed. A day at 60° F., as shown in curve A of Fig. 8 would give 10 "degree-days" reckoning from 50° (which was assumed as the starting point of development in this hypothetical case). As the curve A is drawn, the same number of developmental units have accumulated. But the century-old assumption that the velocity curve is always a straight line, is erroneous.

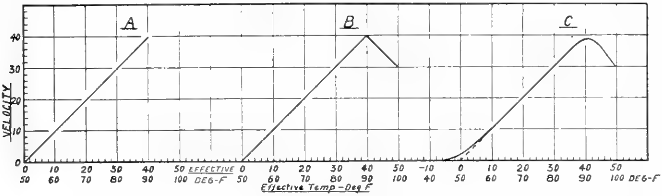

Fig. 8. Curves of velocity of the development. (A) Curve ordinarily assumed by those who sum temperatures. (B) Curve assumed by Glenn ('23) relative to the codling moth. (C) Type of curve found by many experimental investigators.

Glenn ('22) used curve B of Fig. 8 in correcting his sum of temperatures. He first corrected temperatures in the usual way by giving all temperatures below his *alpha* the value of zero. He found it necessary to assume (see pp. 222 and 233 of his article) that the rate of development increased regularly up to an optimum temperature and then decreased at the same rate. For example, if the maximum rate was at 90°, he considered 100° equivalent to 80° as shown in curve B of Fig. 8. He made no comparable corrections, however, for the lag phase at the lower temperatures (see curve C). His work was the first step in the application of correct methods to the summing of temperatures in applied entomology, and his success in the use of temperature data was due to his corrections. He deducted twice the excess above the maximum; and his data were of such a character that such a correction was the best that could then be made. For the pupa he used 87° F. as the maximum. It will be seen, however, that, with the lower temperatures uncorrected for curvature, and the curve turning down sharply at the upper end (compare curves B and C), errors may be large under certain temperature conditions. Where sums of temperatures are used, even if such corrections as Glenn's are applied, the effects of variations of humidity, rainfall, light, and other conditions have ordinarily not been taken into account. The investigation described herein shows that they should be considered.

Evidences of the nature of the velocity curve. Since summing of temperature would be practicable if the velocity curve were a straight line, it is important to bring in more evidence that it is not. Proof that the curve deviates at either the upper or the lower end is to be found in nearly all the data of Peairs ('14) and Sanderson and Peairs ('13) relating to eggs of *Samia cercropia* Linn., *Malacosoma americana* Fabr., *Carpocapsa (Cydia) pomonella* Linn., and *Margaropas annulatus* Say; and in the full life history of the grain louse and its parasite, as given by Headlee ('14). The development of the Indian corn plant shows a similar curvature, but drops to zero again at high temperatures. (See Lehenbauer, '14, pp. 279-80.) Some work has been done on the germination of fungus spores (Weimer and Harter, '23; Jones, '23), in which similar relations have been found. The authors of the papers did not plot reciprocals or make extended interpretations. These plant curves are similar to the curves for animal activity. Verworn ('99) showed an irritability curve conforming in its main features to curve C in Fig. 8.

The physiologists have studied velocities of development according to a special principle. By chance, the rule published by Van't Hoff to the effect that an increase of 10° C. approximately doubles the rate of chemical reaction, was found by physiologists to apply roughly to the rate of development of organisms (*i. e.*, Q_{10} is about 2). It was assumed to be a constant within the optimum temperature range. They immediately seized upon this as evidence with which to combat vitalism and anti-evolution and show that life is a physico-chemical process, and the Q_{10} has been and still is the chief method of expressing the temperature relations of many physiological processes. Until Krogh's 1914 paper there was no important attempt at analysis by other methods. The only matter in point here is that the lower end of the velocity curve is of such a nature as to fit (for a short distance) a Q_{10} curve with Q_{10} as a constant. Its application by physiologists may be taken as evidence for the curvature of the lower end of the velocity curve. On further analysis, however, it is evident that, as Krogh has pointed out, the Q_{10} is not a constant but, as he shows in the case of the frog's egg, ranges from 53.0 at the lowest temperature to a little more than unity at the highest. This makes it useless for most purposes.

There is, in addition, a large amount of work on toxicity of salts and other drugs to fishes and crustaceans (Warren, '00; Pittenger and Vanderkleed, '15; Powers, '17) in which the concentration-time-to-death curve is very similar to our time-temperature curve. The reciprocal, or the curve for the velocity of the toxicity, is similar to our temperature-velocity curve except in its upper limits. Powers, in particular, has made contributions of much importance to the mathematical relations of such curves. He developed a theory of metabolism suited to his facts.

Altogether, the evidence for the deviation of the developmental velocity from a straight line at low and at high temperatures is strong, and there is no reason why procedure should not be based upon the facts. Glenn ('22) recognized the nature of the upper end of the curve and reduced the high temperatures accordingly. He did not, however, take into account the deviations from a straight line at the lower temperatures. The result is that he figured his sum too small for the pupae; but the corrections which he did make were largely responsible for the superiority of his work over that of many others.

Evidences of a constant total in metabolism. The usual index of the rate of growth and metabolism is the amount of carbon dioxide produced. In the case of insects, the amount produced during definite stages in the life history is probably a *constant* for an insect of a given weight and species. This has been demonstrated for the pupal stage of the meal worm (Krogh '14). Although the amount given off is a constant total, the rate, however, is not the same throughout the pupal life. It is fairly high at the beginning of the pupal period, falls for the middle pupal period, and rises to a very high rate toward its end. It is obvious, then, that the amount of carbon dioxide given off for a given period is not an index of the amount of progress toward completion of the pupal period unless the amount of progress is ascertained by some other method. It is, therefore, necessary to use units based upon the total amount given off during the time necessary for the completion of the stage. The constant holds good under various temperatures. In the case of the meal worm pupa, one degree centigrade within the medial range for one day corresponds to 10/1015 of the total carbon dioxide, or 581.2 cc. (At one temperature above the medial range the "degree-day" produced less than this amount.) There is then an actual basis in the metabolism of growth and activity for the temperature-velocity units.

Further evidence as to a basis in activity is found in a recalculation of Crozier's work on the rates at which a centipede crawls at different temperatures, as shown in Fig. 2, which has already been discussed in PART TWO (pp. 334-337). The form of the curve is the same as that for rate of development.

The constants for different organisms and for different stages of the same organism are different. Though a given velocity value, i.e., a given number of developmental units per hour, may be shifted a little way up or down the temperature scale in different cases, the effect of one degree remains of the same quantitative value for all organisms within the medial temperatures of each. The constants vary according to the amount of work to be done.

Evidence from the standpoint of basal metabolism is found in the fact brought out by Krogh ('14b) that the standard metabolism in relation to temperature is the *same per unit of weight* (respiratory exchange basis) for a dog as for a fish. The curve for the meal-worm pupa was of the same type and the readings of the same order of magnitude; the only difference was that the entire curve was shifted up the temperature scale.* In this comparison of animals from such radically different groups,

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* The readings were taken when the CO_2 output was at a minimum and when respiratory movements and heart beat were also probably at a minimum. This value is more nearly true basal metabolism than the other values. It must be borne in mind that the standard metabolism curve is based upon comparison of metabolism at different temperatures while the pupae were at a particular stage, and that the curves for total growth and development under different temperatures do not agree with the standard metabolism curve at all.

the differences are of the same order of magnitude as the differences in velocity of development of different insects and of different stages of the same insect when the developmental totals are correctly determined. (It must be remembered that these developmental totals are constants only for the same stock and conditions aside from temperature.)

Other methods. Quite independently, botanical workers and climatologists have developed various other methods of estimating stages in life-histories. Koeppen ('86) developed a method of temperature classes. This was modified by Zon ('14) and others. MacDougall ('14) used the area between freezing and the actual temperature tracing as an indicator. Livingston ('13), McLean ('17), Hildebrant ('17), and Clements ('24) grew standard plants as indicators, using the amount of growth as an index in each case. Animals, especially insects, doubtless could be better used as indicative of the favorability of season to economic pests.

2. PURPOSE OF THE PRESENT INVESTIGATION.

It is the purpose of this paper to show:

(a.) That various factors besides temperature have important effects on development.

(b.) That experimental results may be made to have direct bearing on the interpretation of results under actual climatic conditions.

(c.) That the threshold* of development is a variable point and that the approximations used by various workers in summing temperatures are of little or no physiological significance.

(d.) That under actual climatic conditions there is no such thing as a "thermal constant" or "sum of temperatures" in the ordinary biological sense, and that temperature should not be summed without various corrections and adjustments for the effects of other factors.

(e.) That interpretations of conditions may be based on equal-velocity charts for combinations of important factors.

(f.) That conditions of hibernation are of great importance.

(g.) That rainfall and many other factors are of importance at particular periods of the life history.

The difficulties of investigating the relation of organisms to climate are such that, with a few outstanding exceptions, investigators have tried almost everything in the way of short-cuts. Furthermore, the methods necessarily used in climate-simulation experiments on confined animals are complicated. In view of the necessarily long discussion of these methods, the usual order in scientific papers is here violated; the results and conclusion are presented first and are followed by a discussion of methods.

In Illinois, hibernating larvae of the codling moth pupate in April and May, emerge in May and June, and deposit eggs within a few days; these hatch quickly, and the larvae enter the apples in May and June. These first-generation larvae pupate chiefly in July, giving rise to a second generation. There is usually also a small third generation, the larvae of which enter the apples in September.

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* The term "physiological zero" should not be used because metabolism is probably not at a standstill while the animal is alive. The term "threshold" has long been in use and gives better expression to the facts.

The proper beginning point, for a study of life histories in relation to environment, is the adult, since it places the eggs under conditions to which the later stages are subject. In the work in hand, however, studies made of the adult were not sufficient to warrant such a procedure; therefore, to illustrate the methods used, the pupa will be taken up first.

(A) GENERAL RESULTS ON PUPAE.

The series of approximately constant temperature experiments was conducted with a total of 4,000 larvae belonging to the following generations: summer 1917, spring 1918, spring and summer 1919 and 1920. Of these, about 2,000 pupated and 1,100 emerged. About 800 larvae from the 1917, 1918, and 1919 generations were started in variable temperature experiments. Of these, 515 pupated and 370 emerged. About 1,200 larvae, chiefly of the 1921 spring generation, were used in experiments on hibernation and related processes. About 800 of these emerged. The rather high mortality brought the net results of handling 6,000 larvae down to about 50 per cent of our expectation. The 3,000 pupae, however, yielded an ample mass of data from which to draw fundamental conclusions.

Tables XII and XIII show full data on the pupae reared under approximately constant temperatures, and Tables XVIII and XIX show the data from the variable-temperatures. The experimental methods and apparatus are described on pp. 426-435. The containers in which the pupae were held are described on p. 432 and illustrated in Fig. 34. Nearly all containers were ventilated, and records included air velocity, evaporation from the porous cup atmometer, humidity, and temperature, all of which are shown in some detail in appropriate columns. The designations given in the first column of each table refer to stocks, places, and conditions as explained below and in notes at the proper places.*

Each figure for pupal life in days is the average for the number of individuals pupating. An idea of the variation may be had from the data (Table XII) indicating the extreme range in days (the difference between the longest and the shortest time); also from the range for 80 per cent or more of the pupae. This 80 per cent group merely excludes the extreme, though their inclusion often does not modify the average greatly. The winter treatment is given, and the time intervals between

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* In addition to the letters used to designate the various experimental chambers, as explained in the description of methods (p. 434), the following letters were used with meanings as indicated: For Humidity D, dry; M, medium moist; W. moist; WW, very moist.

For air movement and evaporation: H, high air velocity; I, intermediate air velocity; L, low air velocity.

For light: D, dark; L, light; LL, lighter.

For unit R (an ice-box): L, lower shelf; LL, lower left shelf; M, middle shelf; T, top shelf, etc.

O is out of doors; P, in the glass-roofed house; NC, indicates no container covered the sticks in which the larvae and pupae were held.

a, b, c, etc., indicate different experiments under the same or approximate conditions and from the same generation but started on different dates in order indicated by the alphabet.

NV indicates that no air was forced through the container, hence not ventilated.

TABLE XII. *Pupae at approximately constant temperature, first generation 1917.*

Designation (see page 363.	No. of adults emerging.	Pupal life in days.	Mean temperature.	Mean humidity.	Maximum temperature.	Minimum temperature	Maximum humidity.	Minimum humidity.	Air velocity mm. per sec.	Evaporation cc. per day.	Variation in time (da.)				% failure to pupate.	Total individuals.	Total pupae.	% Pupal mortality.
											Range of days for pupal life in 80% cases.		Longest and shortest time.					
H*	1	42.	51.8	85	55.4	50	90	80	0	0	......	......	......	......	0	5	5	80
H*	4	47.2	53.5	95	56	50	100	90	0	0	......	......	......	......	0	9	9	55
Z	8	39.4	57.9	45	59	57	55	40	0	0	37	42	37	42.5	10	22	20	60
K	13	23.8	61.7	97	62	61	100	90	0	0	23	25	21	28.5	5	22	21	38
JW	3	21	64.5	70	65.3	63	80	60	10	1.7	21	......	......	......	7	15	14	78
JD	8	22.1	64.5	40	65.3	63	44	36	10	8.9	21	24.5	18	24.5	9	23	21	62
LD	2	?	69	40	70	67	48	35	11	8.3	......	......	......	......	87	16	2	0
LW.	13	13.1	69.5	82	70	67	83	81	11	8.4	12.5	14	12	14	0	19	19	31
MWb	16	10.2	76.7	95	77	76	100	90	8	11.4	9	11	7	12.5	12	24	21	24
MWab	19	9.5	76.5	95	77	76	100	90	8	11.6	9	11	7	12.5	0	42	42	39
MWa	25	10	75.9	95	77	75	.....	mean	.....	11.2	9	11	8	12.5				
MWab	22	10.5	75.8	95	76	75	100	90	8	10.6	8.5	11	8	11	....	....	....	....
MMc	2	8.8	76.6	65	77	76	77	57	38	13.7	8	9.5	8	9.5	84	19	3	33
MMb	12	10.2	76.6	65	77	76	77	57	38	14.6	9.5	10.5	9.5	11	21	19	15	2
MMa	5	11.5	75.7	65	77	73	77	57	30	18.6	11.5	12.5	10	......	0	21	21	75
MDb	8	10.8	76.6	35	78	75	53	28	50	7.7	9.5	13	......	......	19	16	13	38
NWb	13	7.3	89.3	97	93	87	100	95	15	10.6	7.5	8.5	7	9.5	9	22	20	35
NWa	7	7.1	89.6	100	80	89	100	....	10	7.2	6.5	7.5	6.5	7.5	....	....	....	....
NWa	10	7.5	89.3	97	93	87	100	95	10	11.7	6.5	7.5	6.5	7.5	10	20	18	44
NWa	3	8.1	88.7	100	....	......	....	....	.....	11.9	8.0	8.5	......	......	....	....	....	....
NMb	8	7.8	90	58	93	87	65	50	10	15.1	7.5	8.5	6.5	9	13	22	19	58
NMa	10	7.6	89	58	90	89	65	50	10	9.8	7.5	8.5	6.5	......	6	18	17	42
NMab	6	8.1	90.1	58	90	89	65	50	10	....	6.5	8.5	......	9	....	....	....	....
NMab	5	7.4	89.6	58	90	89	65	50	.....	....	7	7.5	......	......	....	....	....	....
NMab	7	7.7	88.6	58	89	88	65	50	.....	....	7	8.5	6	......	....	....	....	....
NWb	5	8	88.7	97	89	88	100	95	.....	5	7.5	8.5	......	......	....	....	....	....
NWb	4	7.6	89.6	97	90	89	100	95	.....	....	7	9.5	......	......	....	....	....	....
NWb	4	7.4	90.1	97	90	89	100	95	.....	....	7	8.5	......	......	....	....	....	....
NDb	5	6.9	90.1	55	93	90	60	50	15	22.3	6.5	8.5	5.5	......	45	22	12	57
NDa	2	9.2	88.8	55	90	89	60	50	15	18.5	8.5	10.0	......	......	0	19	19	88

(*First two items, starred, belong properly to variable temperature.)

TABLE XIII. *Data for approximately constant temperature experiments on hibernated pupae, 1918.*

Designation (see p. 363).	No. of adults emerging.	Pupal life in days.	Mean temperature.	Mean humidity.	Maximum temperature.	Minimum temperature.	Maximum humidity.	Minimum humidity.	Evaporation cc. per day.	Range in days, 80% or more pupae.		Date started.	Interval between beginnings of sets.	% failure to pupate.	Total individuals.	Total pupae.	% pupal mortality.
HDa	13	34.8	58.5	60	65	55	65	55	30	33	37	4/11	...	24	25	19	32
HDb	7	36.7	58.2	60	65	54	65	55	33	34	42	4/25	15	22	19	15	53
HMa	2	39	58	50	65	54	60	45	5	35	43	4/2	...	50	14	7	71
HMb	4	38	57.9	50	65	53	65	45	5.9	36	42	4/25	23	0	5	5	20
HWa	1	33	58.6	90	65	54	100	80	5	.....	33	4/2	...	95	18	1	0
HWb	3	34.6	58.3	90	65	54	100	80	6	30	37	4/25	14	62	8	3	0
HNv	1	35	58.7	97	65	54	99	95	0	35	.....	4/2	...	90	20	2	50
HJDb	1	33	58	50	65	54	65	45	6.8	33	.....	4/25	23	50	6	3	66
LD	14	27.8	63	60	65	59	65	55	2.5	25	30	4/11	0	27	34	25	44
LM	19	26.1	63	75	66	60	80	70	2.3	24	28	4/11	0	40	47	28	32
LW	15	26.1	63	90	65	59.5	98	88	1	24	28	4/11	0	15	21	18	17
KD	6	28.3	62.6	60	67	60	65	55	6.3	27	30	4/6	0	45	20	11	45
KW	14	27.3	62.7	95	67	60	100	90	1.6	26	29	4/6	0	35	31	20	30
AncD	6	17.2	69.5	50	70.5	69	60	35	16	16	18	4/23	0	85	55	8	25
AD	22	20.2	69.5	50	71	68	55	45	6.8	19	21.5	4/11	0	36	45	29	24
AM	17	20.9	69.6	60	71	68	65	55	4.7	19.5	20.5	4/11	0	43	37	21	19
AW	31	20	69.6	70	71	68	75	65	4.4	19	21	4/11	0	30	52	36	14
BADa	4	11.6	80.3	35	83	79	40	30	20.1	10	12.5	4/11	0	76	29	7	43
BDa	24	11.8	80.3	50	83	79	55	45	5.3	10.5	13.0	4/11	0	31	48	33	27
BMa	41	11.2	80.3	60	83	79	65	55	.....	9.5	12.5	4/11	0	27	67	49	17
BWa	27	11	80.3	70	83	79	75	65	.....	10	12	4/11	0	24	50	38	29
BS*DK*	15	11.6	81.5	60	82	80	60	55	0	.....	.....	4/23	...	48	31	16	7
BS*L*	5	10.7	81.5	60	82	80	60	55	0	.....	.....	4/23	...	75	24	6	17
MADc	1	7	90	29	92	90	40	20	16	7	7	4/18	16	50	12	6	83
MADc	14	8.5	90.2	29	92	90	40	20	15	8	9	4/27	25	0	20	20	30
MDc	6	8.1	91	37	92	90	50	35	6.8	8	8.5	4/27	25	50	16	8	25
MMa	1	9	90	44	90	90	60	40	4.6	.....	.....	4/2	...	97	31	1	0
MMc	8	8.2	91.2	44	92	90	60	40	6	8.5	9	4/27	8	65	17	6	33
MWa	1	8	90	51	90	90	70	50	7.4	8	.....	4/4	...	96	27	1	0
MWb	8	8.4	90.3	51	91	90	70	50	6.4	8.5	9	4/19	15	23	13	10	20
MWc	10	7.9	91.2	50	92	90	60	40	6	7.5	8	4/27	23	66	32	11	9
MWWa	8	8.4	91.7	85	92	91	90	80	2.2	8.5	9.0	5/1	...	50	30	15	45
MNv	1	9	90	97	90	90	99	95	0+	9	.....	4/2	...	64	14	5	80
MNv	8	8	91	97	91	91	99	95	0	.....	.....	4/28	...	8	12	11	27
NDa	1	8.5	95	35	95	95	35	35	71	6	.....	2/14	...	90	32	3	66
NWb	1	8.5	95	65	95	95	65	65	27	8.5	.....	3/23	...	87	23	3	66
NWc	3	8.1	95	65	95	95	65	65	13.6	8.5	8	4/17	...	44	25	14	78
NNVc	3	9.5	95	30	95	95	35	25	0+	8.5	10.5	4/17	...	60	33	13	77

The winter treatment of larvae is described on p. 407. The various stocks are indicated by Roman numerals.

The dates of beginning are given to indicate change in stock in storage. See p. 374 for history of stocks mentioned.

Air velocity 8 mm. per sec. except in experiments not ventilated (nv).

HDa, HDb, HMb, HWb, HJDb were from stock III. HMa, HNv, KD, KW, AncD, BS*DK*, BS*L*, MAD, MD, MN, MW, MWW, NWC were from stock IV. LD, LM, LW, AD, AM, AW, BAD, BD, BM, BW, NDa, NWb, were from stock V.

TABLE XIIIa. *(Continuation of Table XIII), 1918.*

Designation (see p. 363).	No. of adults Emerging.	Mean temperature.	Mean humidity.	Maximum temperature.	Minimum temperature.	Maximum humidity.	Minimum humidity.	Evaporation cc. per day.	Date started.	Interval between beginnings of sets.	Total individuals.	% failure to pupate.	Total pupae.	% pupal mortality.
HJda	0	57.4	50	65	54	55	45	6.8	4/2	....	22	96	1	100
H2Wa	0	58	70	65	54	75	65	4.8	4/2	....	11	100	0	0
HJWb	0	58	70	65	54	75	65	4.8	4/25	23	4	0	4	100
JDa	0	58	50	65	54	55	45	5.8	4/2	....	14	100	0	0
JDb	0	58	50	65	54	55	45	5.8	4/25	....	14	71	4	10
HTPnv	0	58	97	65	54	99	95	0	4/26	24	18	0	18	....
KM	0	62.2	75	67	60	80	70	6	4/6	0	16	88	2	....
AncL	0	69.5	50	70.5	69	60	35	16.4	4/23	0	37	100	0	....
BTP	0	80.1	60	.....	.....	.....	.....	0	4/24	....	29	0	29	100
MADa	0	90	29	92	90	40	20	8.1	4/2	....	21	95	1	100
MDa	0	90.3	37	94	88	50	35	6.1	4/2	....	24	5	23	100
MDc	0	90.8	37	91	90	50	35	9.2	4/19	17	22	23	17	100
MMb	0	90	57	90	90	60	40	10.3	4/19	17	5	100	0	0
NDb	0	95	35	95	95	35	35	62	2/25	....	6	100	0	....
NDc	0	95	35	95	95	35	35	37.5	4/17	....	4	25	3	100
NMa	0	95	52	95	95	55	50	19.5	2/14	....	47	96	2	100
NMb	0	95	52	95	95	55	50	19	3/23	34	14	100	0	....
NMc	0	95	52	95	95	55	50	18.9	4/17	59	20	90	2	100
NWa	0	95	65	95	95	....	....	23	2/14	....	32	98	1	100
NNva	0	95	30	95	95	35	25	0+	3/23	....	10	70	3	100
NNVb	0	95	30	95	95	35	25	0+	4/2	....	23	44	13	100

NNva was from stock I. HJWb, JDa, JDb, HTP, BTP, were from stock III. HJda, H2Wa, KM, AncL, MADa, MDa, MDc, MMb, NDc, NMc, were from stock IV. NDb, NMa, NMb, NWa, NNVb, were from stock V.

HJda, H2Wa, KM, AncL, MADa, MDa, MDc, MMb, NDc, NMc, were F (Frozen). HJWb, JDa, JDb, HTP, BTP, NDb, NMa, NMb, Nwa, NNva, NNVb, were NF (Not Frozen).

See p. 374 for history of stocks mentioned.

TABLE XIIIb. *Pupae for hibernated generation at approximately constant temperature, 1919.*

(From stock 45° F., RW, RD, and RM).

Designation (See p. 363).	No. of individuals.	Pupal life in days.	Mean temperature.	Mean humidity.	Maximum temperature.	Minimum temperature.	Maximum humidity.	Minimum humidity.	Air velocity mm. per sec.	Evaporation cc. per day.	% failure to pupate.	Total individuals.	Total pupae.	% Pupal mortality.
(A)RNV	0	....	49.5	100	51	46	100	100	8	0	....	....	....	....
RNVR	0	....	49.5	100	51	46	100	100	8	0	100	6	0	0
RDA	0	....	52.2	36	54	50	40	18	8	0	60	10	4	100
RD	0	....	52.2	36	54	50	40	18	8.9	5.3	100	15	0	0
RM	0	....	52.2	65	54	50	77	43	8	1.9	100	8	0	0
RMA	0	....	52.2	65	54	50	77	43	8	.6	33	3	2	100
RWA	7	86.7	52.2	85	54	50	90	80	8	.6	36	22	14	50
RW	0	....	52.2	85	54	50	90	80	8	.6	100	0	0	0
RMidnv	0	....	52.2	97	54	50	100	93	8	0	100	3	0	100
RtopA	1	50	53.9	97	55	53	100	93	8	0	29	7	5	80
Rtop	0	....	53.9	97	55	53	100	93	8	0	100	6	0	0
HDR	0	....	59.8	68	60	58	75	53	.....	8.5	70	16	5	100
HD	1	42	59.2	68	60	58	72	55	7	7.7	72	11	3	66
HW	4	34.7	59.8	87	62	58	94	75	8	5.5	25	12	9	56
LD	0	....	66.6	55	68	64	67	52	8	3	93	16	1	100
LW	5	19	66.6	71	68	64	90	68	9	10.5	40	10	6	17
ANV(R)	7	15.5	68.7	97	69	67.1	100	93	.....	0	46	21	11	36
BNV	2	7	80.7	97	81.5	80	100	93	.....	0	9	22	20	90
SWS	3	8.3	87.6	96	89	86	100	92	8	0	33	6	4	25
SW	1	9.5	84.3	85	85	83	87	70	9	7.4	80	10	2	50
SAD	0	....	84.3	40	85	83	63	38	8	15.5	100	18	0	0
SADD	0	....	84.3	30	85	83	50	25	7	17	100	13	0	0
MD	0	....	91.8	22	92	90	28	15	9	36	100	14	0	0
MW	2	9.5	91.8	95	92	90	100	92	10	4.2	54	17	8	75
ND	0	....	92.3	14	95	92	16	12	7	23.0	100	29	0	0
NW	1	9	92.3	77	95	92	96	77	11	6.4	83	18	3	66
NWS	1	8	95.3	92	96.0	95	100	90	9	0	66	9	3	66
TH	1	9	81.2	70	81.5	79	72	68	425	15.4	76	13	3	66
TI	2	10.5	81.2	70	81.5	79	72	68	109	12.9	86	15	2	0
TL	9	10.6	81.2	70	81.5	79	72	68	15	8.4	6	18	17	47

Pupal life in 80% cases, for HW, LW, ANV(R), BNV, SWS, MW, TI, TL, was 32-37, 18-20, 14-16, 7, 7.5-9, 9-10, 10.5, 10-11, days respectively.

Longest pupal life for ANV(R) was 16.5 days. Longest and shortest time for TL, was 13.5 and 8.5 days respectively.

TABLE XIIIc. *First generation pupae at approximately constant temperature, 1919.*

Designation (See p. 363).	No. of adults emerging.	Pupal life in days.	Mean temperature.	Mean humidity.	Maximum temperature.	Minimum temperature.	Maximum humidity.	Minimum humidity.	Air flow mm. per sec.	Evaporation cc. per day.	% Failure to pupate.	Total individuals.	Total pupae.	% Pupal mortality.
RLL	0	....	47.5	99	50	45	100	98	8	2.1	100	10	0	0
RLR	0	....	49.3	95	52	48	98	90	8	1.1	73	15	4	100
RMS	1	62	51.9	80	53	50	90	75	8	2.1	62	8	3	66
RD	0	....	51.9	45	53	50	48	28	8	1.6	0	11	11	100
RM	0	....	51.9	72	53	50	82	62	9	2.1	25	12	9	100
RW	1	68	51.9	85	53	50	96	80	9	0.6	21	14	11	91
RRT	0	....	53.6	80	55	52	90	75	7	1.0	72	11	3	100
HIW	1	46	55.4	92	56.3	53.9	100	80	10	4.0	77	9	2	50
HIM	6	44.2	55.4	81	56.3	53.9	88	60	10	9.8	43	23	13	54
HID	2	49.5	55.4	73	56.3	53.9	82	58	10	10.4	63	13	5	60
TH	3	8.5	82.4	62	84.	81	79	44	620	37.3	96	19	3	0
TI	1	7.5	82.4	62	84	81	79	44	720	21.9	90	10	1	0
TL	0	....	82.4	62	84	81	79	44	3	3.8	70	14	4	100

For HIM, the number of days for pupal life in 80% of cases was 42 to 46. The longest and shortest time was 47 and 42, respectively.

TABLE XIIId. *First lot of hibernated generation pupae, 1920, at approximately constant temperature, including tests of air movement and evaporation.*

Designation (See p. 363).	No. of adults emerging.	Pupal life in days.	Mean temperature.	Mean humidity.	Maximum humidity.	Minimum humidity.	Air flow mm. per sec.	Evaporation in cc. per day.	% failure to pupate.	Total individuals.	Total pupae.	% pupal mortality.
RW*	0	......	48	95	......	......	......	......	100	9	0	0
AWW$_{I}$	0	......	63.5	92	95	90	14	2.4	94	18	1	100
AWW$_{II}$	2	25.5	62.8	93	95	90	10	4.9	75	8	2	0
AW$_{I}$	0	......	63.5	82	90	70	14	10.0	100	10	0	.....
AW$_{II}$	0	......	62.8	80	89	72	14	3.8	100	5	0	0
AD$_{bac}$	0	......	63.5	68	80	60	14	10.7	100	24	0	0
AD$_{bac}$	3	22.1	62.8	65	70	55	14	11.0	62	16	6	50
AD	0	......	63.5	46	60	40	13	22.2	91	11	1	100
AD	0	......	62.8	50	70	45	14	26.4	100	3	0	.....
ADac$_{I}$	0	......	63.5	27	30	22	14	15.7	100	9	0	.....
ADac$_{II}$	0	......	62.8	30	30	27	14	17.9	.....	.....	.....	.....
BWW$_{I}$	1	7.0	83	91	96	90	14	3.2	66	3	1	0
BWW$_{II}$	......	......	83	96	96	94	14	1.3	100	1	0	.....
BW$_{I}$	0	......	83	85	90	84	14	8.6	100	6	0	0
BW$_{II}$	0	......	83	88	92	84	14	9.7	100	3	0	0
BW$_{III}$	1	9.0	83	95	95	Nv	0	0	0	1	1	0
BM	0	......	83	75	76	50	13	7.0	100	6	0	0
BM	0	......	83	75	80	73	14	10.3	0	0	0	0
BD	1	9.5	83	34	47	31	12	18.9	75	4	1	0
BD	0	......	83	43	55	35	14	26.0	0	0	0	0
BADac	0	......	83	21	30	13	15	19.9	94	18	1	100
BADac	0	......	83	30	31	23	14	26.5	100	7	0	0
BEV$_{I}$	0	......	83	62	80	40	2	1.6	100	6	0	0
BEV$_{II}$	0	......	83	80	85	70	2	5.9	100	1	0	0
BEV$_{2a}$	0	......	83	62	80	40	10	5.5	100	12	0	0
BEv$_{2b}$	0	......	83	80	85	70	10	7.2	66	3	1	100
BEv$_{4a}$	1	?	83	62	80	40	45	13.8	75	8	2	50
BEv$_{4b}$	1	7.0	83	80	85	70	50	14.7	66	3	1	0
BEv$_{6a}$	1	9.5	83	62	80	40	120	15.0	90	10	1	0
BEv$_{6b}$	0	......	83	80	85	70	113	15.0	100	6	0	.....
BEv$_{6c}$	1	?	83	80	85	70	113	15.0	0	1	1	0
BEv$_{10a}$	1	?	83	62	80	40	403	31.0	88	8	1	100
BEv$_{10b}$	0	......	83	80	85	70	403	24.5	100	2	0	0
BEv$_{12a}$	1	9.0	83	62	80	40	520	41.0	83	6	1	0
BEv$_{12b}$	0	......	83	80	85	70	520	55.4	.....	0	.....	.....
BW$_{15}$	12	10.0	83	86	90	80	78	9.5	27	26	19	33
BW$_{25}$	6	10.0	83	86	90	80	78	9.5	40	15	9	33

Max. and Min. temp. any day were respectively, 68° and 61° F. for A; 85° and 81° F. for B.

Pupal life in 80% cases for BW15 and BW25, was 9.5-10.5 days respectively.

Longest and shortest pupal life for AWW$_{II}$, ADBac, BW15, BW 25, was 29 and 22, 24 and 27, 11 and 7, 10.5 and 9.5 days respectively.

(?) indicates that length of pupal life was not ascertained.

(*) Some pupae at beginning.

TABLE XIIIe. *Second and third lots of pupae at approximately constant temperature, 1920, (hibernating generation).*

Designation (See p. 363).	No. of adults emerging.	Pupal life in days.	Mean temperature.	Mean humidity.	Maximum humidity.	Minimum humidity.	Air flow mm. per sec.	Evaporation in cc. per day.	Range of days for pupal life in 80% cases.		% Failure to pupate.	Total individuals.	Total pupae.	% Pupal mortality.
ANv*	3	21.0	63.5	97	100	97	0+	0+	18	24	0	7	7	57
AWW	2	24.0	63.5	93	95	92	50	3.7	23	25	60	5	2	0
AW	2	27.2	63.5	88	92	84	50	5.2	25	29	28	7	4	50
A(BD)	....	....	63.5	65	80	60	50	9.3	......	......	85	7	1	100
AD	....	....	63.5	55	75	45	48	14.0	......	......	83	6	1	100
ADac	....	....	63.5	30	32	24	50	18.6	......	......	100	6	0	....
BWW	2	9.5	83	95	96	90	52	0.8	9.5	9.5	57	7	3	33
B(ADac)	2	10.3	83	29	30	16	50	20.9	10.0	10.5	80	10	2	0
BEv1	4	9.4	83	85	90	80	1	2.7	7.5	10.5	64	14	5	20
BEv2	3	10.3	83	85	90	80	10	7.3	10	11	64	11	5	40
BEv4	1	10	83	85	90	80	50	12.4	10	......	50	4	2	50
BEv6	6	10.7	83	85	90	80	120	13.3	10	10.5	46	13	7	14
BEv10	0	....	83	85	90	80	400	31.9	9.5	10.5	100	5	0	....
BEv12	9	9.8	83	85	90	80	300	24.9	......	......	8	12	11	17
AWW	1	25	63.5	92	95	90	15	4.3	......	......	50	8	4	75
AW	2	27	63.5	88	90	82	14	5.5	......	......	50	6	3	33
ABD	0	....	63.5	65	85	65	14	10.0	......	......	100	7	0	....
AD	2	28	63.5	58	60	45	14	14.0	......	28	55	9	4	50
ADac	0	....	63.5	30	30	24	14	18.4	......	......	100	11	0	....
BW	10	9.3	83	83	92	82	15	11.6	90	9.5	23	13	10	0
BD	1	9	83	42	55	35	13	22.2	......	......	66	6	2	50
EV_4	2	10	83	76	80	70	13	21.3	......	......	60	10	3	33
EV_{10}	2	8.5	83	76	80	70	400	26.0	......	......	75	8	2	0

Second Lot. (All except ANv* larvae collected from bark of trees, March 2.)

The Max. and Min. Temp. any day were, respectively, 66° and 60° F. for A; 85° and 81° F. for B.

Longest pupal life was as follows: For BEvI, BEv6, BEv10,—18, 11, 19, days respectively; the shortest for BEv10 was 5 days.

Third Lot. (Below black line), larvae collected from bark of trees March 22.

The Max. and Min. Temp. any day were respectively, 66° and 63° F. for A; 85° and 82° F. for B.

Longest pupal life for BW and EV_4 was 10 days; the shortest, 8.5 and 9.5 respectively.

Table XIIIf. *Three lots of first generation pupae, 1920, at approximately constant temperature.*

First lot above first line; second lot below first line; final lot below second line.

Designation (See p. 363).	No. of adults emerging.	Life in days.	Air flow mm. per sec.	Evaporation in cc. per day.	Variation of time.				% failure to pupate.	Total individuals.	Total pupae.	% pupal mortality.
					Range of days for pupal life in 80% cases.		Longest and shortest time.					
Ev. 1	12	8.9	.002	5.4	8.5	9.0	8.0	10.0	14	14	12	0
Ev. 2	9	8.7	.011	6.2	8.0	9.0	7.5	9.5	12	16	14	36
Ev. 4	4	8.8	.030	16.6	8.5	9.0	......	......	46	13	7	42
Ev. 6	5	9.0	.112	15.1	8.5	9.0	......	10	35	14	9	45
Ev. 10	10	8.4	.400	28.5	8.0	9.0	......	......	18	17	14	28
Ev. 12	......	......	.500	27.2	......	......	......	......	20	5	4	100
Ev. 12a	8	9.0	.450	38.5	8.0	10.0	7.5	......	18	11	9	11
Ev. 1a	4	8.5	.002	......	8.5	9.0	......	......	8	12	11	63
Ev. 2a	3	7.5	.011	7.2	6.5	8.5	......	......	70	20	6	50
Ev. 4a	11	8.8	.030	14.6	8.0	9.0	......	10	40	20	12	8
Ev. 6a	8	9.1	.112	16.4	8.0	9.5	......	10	19	16	13	38
Ev. 10a	8	8.9	.400	32.2	8.5	9.5	7.5	......	36	14	9	11
Ev. 12b	5	8.9	.500	46.0	8.0	9.5	......	......	45	13	7	28
BW	5	19.6	.39	25.5	18	21.5	17.5	......	70	33	10	50
BD	14	18.7	.39	58.6	17.5	21.5	14	23	34	32	21	33
Ev. .0	11	18.1	0	+0	18	20	16	......	11	18	16	31
Ev. 0.0	14	19.4	0	+0	18	19.5	14.5	20	0	25	25	44
Ev. 1.5	16	19.7	.005	7.1	17.5	21.5	16	......	12	25	22	27
Ev. 2.0	5	18.7	.01	9.8	16.5	18.5	......	21.5	16	25	21	75
Ev. 4.0	24	19.1	.02	19.8	17.5	21.5	15.5	25	3	37	36	33
Ev. 5.0	14	20.1	.04	23.4	17.5	21.5	......	27	14	36	31	55
Ev. 6.0	17	21.2	.10	28.7	17.5	24.5	......	26	22	41	32	47
Ev. 8.0	16	22.0	.20	32.7	17.5	24.5	......	27	14	35	30	47
Ev. 10.0	22	19.8	.39	36.2	17.5	21.5	......	26	17	41	34	34
Ev. 12	7	18.1	.47	66.8	18	20.5	15.5	......	28	25	18	61

For the first and second lot the Mean Hum. was 77%, the Mean Temp. 82° F.

For the first lot the Max. and Min. Hum. was 79% and 75% respectively. The Max. and Min. Temp. 83° and 75° F., respectively.

For the sec. lot the Max. and Min. Temp. was 90° and 75°, respectively. The Max. and Min. Hum. 80% and 75% respectively.

For the final lot the Max. and Min. Temp. was 89° and 84° F. respectively. The Max. and Min. Hum. was 65% and 55% respectively for all except BD which was 22% and 18%. The Mean Temp. was 86° F. The Mean Hum. was 20% for BD and 57% for the rest.

TABLE XIIIg. *Pupae, 1918; (above line), light effects; (below line), evaporation and humidity effects.*

Designation (see p. 363).	No. of adults emerging.	No. of days.	Mean temperature.	Mean humidity.	Maximum temperature.	Minimum temperature.	Maximum humidity.	Minimum humidity.	Evaporation in cc. per day.	Date begun.	Total individuals.	% failure to pupate.	% pupal mortality.	Total pupae.
ANC*L*	0	......	69.5	50	70.5	69	60	35	16.4	.....	40	100	0	0
ANC*DK*	6	17.2	69.5	50	70.5	69	60	35	16.4	.....	68	88	25	8
B*L*	5	10.7	81.5	60	82	79	65	50	0+	4/24	23	65	37	8
B*DK*	15	11.6	81.5	60	82	79	65	50	0+	4/24	29	21	6	16
a 203*L*	0	......	77	40	82	72	46	35	.....	4/18	11	64	100	4
a 203*DK*	1	10	77	40	82	72	46	35	.....	4/18	23	91	50	2
b 203*L*	5	8.4	83	60	86	81	66	55	.....	5/23	12	67	0	4
b 203*DK*	12	9.1	83	60	86	81	66	55	.....	5/23	16	25	0	12
a 203*DL*	4	9.6	77	40	82	72	46	35	.....	4/18	26	69	50	8
b 203*DL*	9	9.2	83	60	86	81	66	55	.....	5/23	13	23	10	10
a 203*B*	2	10.7	77.2	40	82	72	46	35	.....	4/18	18	78	50	4
b 203*B*	5	9.2	83	60	86	84	66	55	.....	5/23	10	40	17	6
a 203*G*	0	0	77	40	82	72	46	35	.....	4/18	22	86	100	3
b 203*G*	6	8.7	83	....	86	82	66	55	.....	5/23	13	46	14	7
a 203*R*	1	9.5	78.5	40	82	72	46	35	.....	4/18	16	63	84	6
b 203*R*	2	8.2	83	60	86	82	66	55	.....	5/23	15	80	33	3
TH	3	9.5	79.0	75	83.6	75.1	86	75	14.5	8/14	20	65	57	7
TI	5	9.7	79.0	75	83.6	75.1	86	75	7.9	8/15	21	66	28	7
TL	7	9.5	79.0	75	83.6	75.1	86	75	4.3	8/14	22	45	42	12
TH	3	8.5	82.4	60	.....	.....	79	44	.....	.....	....	....	....	....
TI	1	7.5	82.4	60	.....	.....	79	44	.....	.....	....	....	....	....
TL	0	......	82.4	60	.....	.....	79	44	.....	.....	....	....	....	....
TH	1	9	81.2	70	.....	.....	....	....	15.4	.....	....	....	....	....
TI	2	10.5	81.2	70	.....	.....	....	....	12.9	.....	....	....	....	....
TL	9	10.6	81.2	70	.....	.....	....	....	8.4	.....	....	....	....	....
HHa	13	34.8	58.5	55	65	55	65	55	30.0	.....	....	....	....	....
HMa	2	39.0	58.5	55	65	55	65	55	5.0	.....	....	....	....	....
HHb	7	36.7	58.2	55	65	55	65	55	33.0	.....	....	....	....	....
HMb	4	38.0	58.2	55	65	55	65	55	5.9	.....	....	....	....	....
ANCD	6	17.2	69.5	50	70.5	69	60	35	16.4	.....	....	....	....	....
AD	22	20.2	69.5	50	71	68	55	45	6.8	.....	....	....	....	....

Italic capitals indicate the following: *L*—weak light; *DK*—dark. *DL*—under daylight glass; *B*—blue glass; *G*—green glass; *R*—red glass. Where colored glasses were used the source of light was a 110 v, 60 watt, nitrogen filled incandescent lamp, at a distance of 18 m.

Table XIV. *Mortality of hibernating generation of the codling moth at Olney.* (Data supplied by P. A. Glenn, in personal communication.)

Date collected	Number larvae	Number pupae	Number adults	Mortality prior to:	
				pupation, %	emergence, %
A. Cocoons were disturbed to observe pupation.					
1915-1916					
Aug. 30–Sept. 2	86	65	35	24	59
Sept. 2–14	124	74	57	40	54
Sept. 14–17	240	149	116	38	50
Sept. 25–29	159	110	80	31	50
	609	398	288	33	53
1916-1917					
Aug. 22–25	757	545	496	28	34
Aug. 28–31	446	349	299	22	33
Aug. 31–Sept. 2	284	221	186	22	35
Sept. 2– 6	260	184	138	29	47
Sept. 6– 9	204	145	119	29	42
Sept. 9–12	280	211	171	25	39
	2231	1655	1409	26	38
B. Cocoons were not disturbed.					
1915-1916					
Sept. 4– 8	296		251		15
Sept. 8–11	264		196		26
Sept. 11–14	290		234		19
Sept. 17–20	145		114		21
Sept. 20–23	105		77		27
Sept. 23–25	99		83		16
Sept. 29–Oct. 5	147		124		16
Oct. 5–11	63		54		14
Oct. 11–18	100		85		15
Oct. 18–25	75		61		19
	1584		1279		19
1916-1917					
Sept. 12–15	110		87		21
Sept. 15–18	217		180		17
Sept. 18–21	206		172		17
Sept. 21–23	204		179		12
Sept. 23–25	201		179		11
	938		797		16

the placing of lots of the same designation under approximately the same experimental conditions are shown.* The mortality and failure data are also given.

The data were first brought into this form, and much of the material used throughout the paper was drawn from these tables. In the application of experimental results to the interpretation of actual weather effects, *velocity* of development under different conditions is of first importance. Velocity values may be determined in relative terms, without reference to theoretical questions, from the reciprocals of the average *times* (shown in the tables referred to) multiplied by some convenient factor. The velocity values used in this paper were determined largely on that basis.

Mortality and Failure to Pupate.

Mortality and failure to pupate have important relations to the success of the species. Failure to pupate amounted to about 50 per cent in the constant-temperature experiments taken as a whole. Cases in which dormancy had begun in the autumn and in which it was not broken, due to known lack of proper treatment, were entirely eliminated from consideration. Only failures to pupate on the part of larvae of lots in which other larvae did pupate were considered. However, in all of the hibernated stock, incomplete hibernation changes were no doubt a factor in failure to pupate.

Mr. Glenn, in a personal communication, supplied data on mortality in hibernation (Table XIV) which fall into two groups: In one group the cocoons of the larvae were torn open in the spring for the purpose of observing pupation, and in the other group they were undisturbed. Possibly some of the larvae included in these numbers may have died in the fall before cold weather set in. The notes do not show this fact, but they show the number of larvae which spun up in the cages in the fall of 1915 and 1916. The percentage of mortality of the hibernating generation of 1916-17 was less than that of 1915-16. Possibly this was partly due to greater care in handling the hibernating generation in 1916-17, though reasons are not evident. It could not have been due to the winter cold,

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* Stocks I-V used in 1917-18 were as follows: I and II were collected September 12 at Champaign; III, IV, and V were collected early in October a few miles south of Springfield, shipped to Champaign, and placed with the other stocks. All were held at about 60° F. until Oct. 19 when I, II, and III were transferred to a temperature varying from 28° to 38° F. and later transferred directly to the experimental conditions without "freezing", in all probability, as the 28° temperatures were of short duration. Stock IV was in similar conditions until Jan. 23 when it was put at a constant temperature of 40° F. until experiments were started. Stock V was "frozen" at 25° F. for 24 hours and transferred to the 40° constant temperature.

All other stocks were merely stored at temperatures varying from 35° to 45° F. Subsequent experience has shown that this is as important a period as any in the life history; and in future work, dates of collection, full control, and full record of all conditions must be kept. The work of Townsend shows the importance of this period and indicates that all storage should be at or below 32° F.

because the winter of 1915-16 was, if anything, warmer than that of 1916-17.

Data from Tables XII-XIIIG were used in making Fig. 9, which shows smoothed curves of percentages of larvae failing to pupate in experiments conducted at approximately constant temperatures. The actual failure per cent is shown by circles, and mean data for experiments within two degrees of each other, by crosses. Curves were first drawn through the average points. These were then plotted on cross section paper as in Fig. 10, and the same per cent of mortality connected between the different humidities, and smoothed. (See Huntington '19, p. 252.) The original curves were then corrected to fit the *isofailure* lines of Fig. 10. To make relations of the two figures clear, compare the failure per cent at different temperatures on humidity 95% of Fig. 10, with temperature and failure per cent on that humidity in Fig. 9. (For fuller explanation of these methods of graphic representation of results, see below, pp. 383-393.)

Townsend's ('26) results indicate that prolonged exposure to a temperature of 50° F. decreases the percentage of pupation. Baumberger ('17) secured similar results. Townsend showed, further, that soaking in water increases the percentage of pupation and that the number of soakings and the temperatures at which soaking is done are important. Soaking frequently at 50° F., is most effective. The data graphed (Figs. 9 and 10) are representative, however, as they show a great many weather possibilities in combination.

Pupal mortality in constant-temperature experiments is shown for the several mean humidities in Figs. 11 and 12. The method of drawing the curves and smoothing them was the same as in Figs. 9 and 10. In both cases (compare Figs. 10 and 12), the conditions are most favorable, i. e., show low mortality (20% or less) and failure (50% or less), in the neighborhood of 74° F., and 70–75% humidity. There are differences in detail, but a drop in the mortality and failure lines at high temperature for humidities of 75–85% occurs in both, leaving an upward extension of favorable conditions at high temperature, both wet and dry. The diagrams represent the relations in question only roughly, as the data were few and quite irregular. This irregularity was evident in laboratory-hibernated larvae (probably because of differences in contact with water), some lots showing higher mortality and failure to pupate and others showing little or none.

It is evident that variability is very important at the lowest temperatures. One lot of larvae kept at 48°–50° F. showed no signs of pupation until an accident to the thermostat sent the temperature up to 78° for an hour. In about two days several larvae pupated when the temperature was about 48°., but all the pupae died without emerging. In one large series of hibernating individuals, none pupated at 52° F. except within a day or two after being transferred from 70° F. The influence of the higher temperatures apparently persisted a few days. This may result from one or more of the following causes: (a) lag in change of metabolic

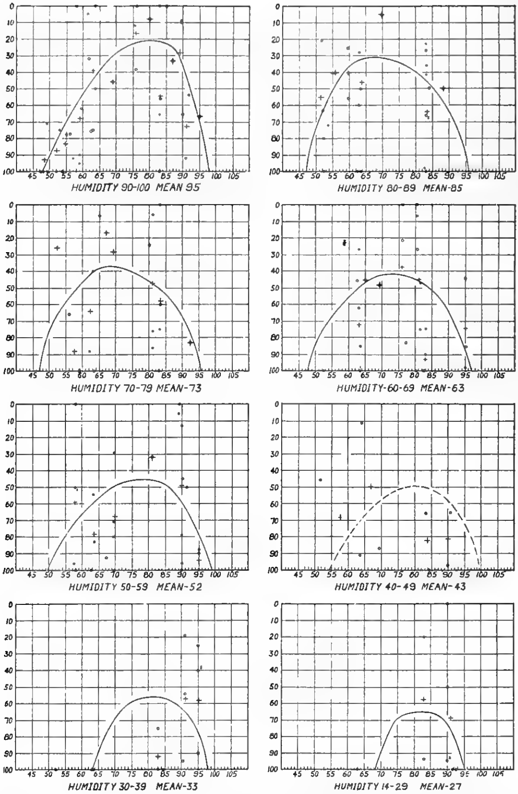


Fig. 9. Curves showing percent failure to pupate under various conditions of temperature and humidity. The circles indicate actual observations and the crosses indicate averages. Circles with crosses inside are single data for the temperature in question. The curves pass through the average of the crosses as well as it was possible to make them. This relation was improved by smoothing the curves shown on Fig. 10.

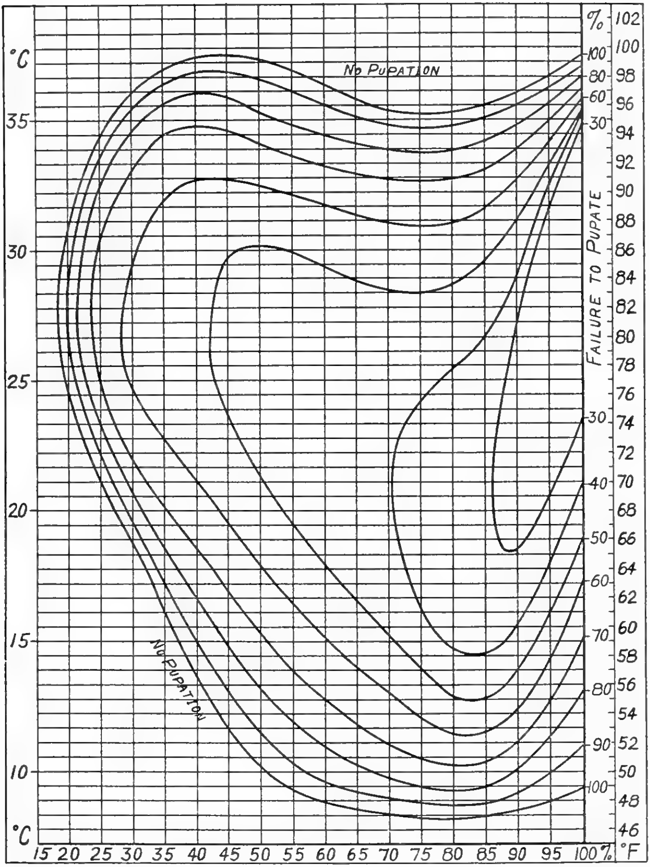
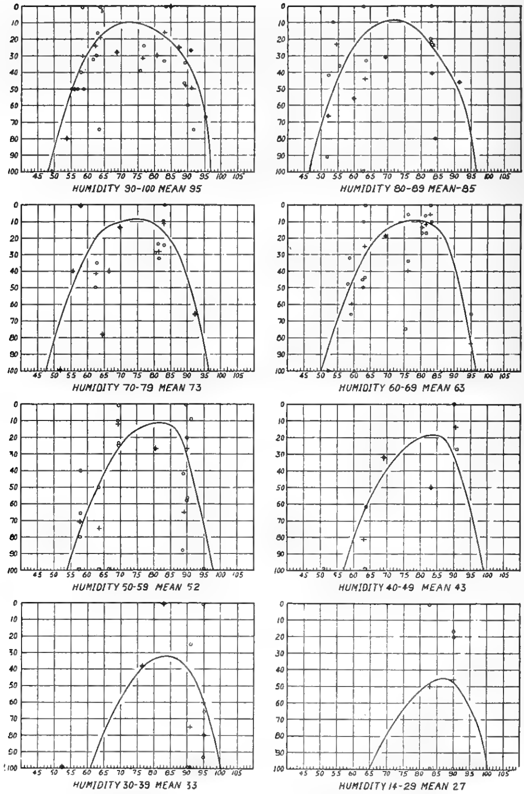


Fig. 10. Chart showing equal failure-to-pupate curves made by connecting the same percent failure on a temperature and humidity chart. Least failure to pupate may be assumed to fall between humidity 90% temperature 70° F. and humidity 100% temperature 88° F.



HUMIDITY 90-100 MEAN 95

HUMIDITY 80-89 MEAN-85

HUMIDITY 70-79 MEAN 73

HUMIDITY 60-69 MEAN 63

HUMIDITY 50-59 MEAN 52

HUMIDITY 40-49 MEAN 43

HUMIDITY 30-39 MEAN 33

HUMIDITY 14-29 MEAN 27

Fig. 11. Curves showing the percent mortality of pupae at different humidities and temperatures. For meaning of symbols see Fig. 9.

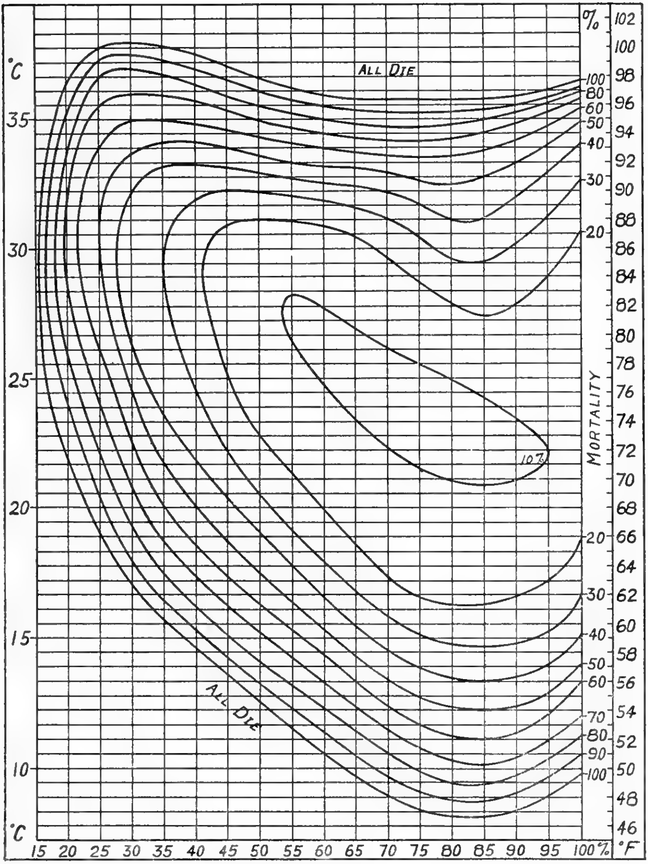


Fig. 12. Chart showing equal mortality curves on a temperature-and-humidity chart. Least failure to pupate may be assumed to lie between humidity 85% temperature 71° F. and humidity 55% and temperature 81° F.

rate or acclimation; (b) stimulation due to change of temperature; (c) development of enzymes at the higher temperature.

The failure to pupate in the variable-temperature experiments was 36%, and the pupal mortality was 28%. This reduced loss is due at least in part to the more favorable effect of variable temperatures as compared with constant ones. In the early approximately constant-temperature experiments, there was more variation and smaller loss than in the later experiments in which the variation was reduced by improving the equipment.

In Townsend's experiments with the 1923-24 generation, the stocks were stored at 50° F. (10° C.); 32° F. (0° C.); and 71.6° F. (22° C.). The percentage of pupation was highest in stocks stored at 50° F., next at 32° F., and lowest at 71.6° F. This indicates that changes go on at 32° F., and that temperatures as low as freezing must be taken into account in considering failure to pupate or the breaking of dormancy.

TABLE XV. *Showing data used in calculation of alpha values by formula* $y\ (x - a) = K$.

	Case.	Designation.	T. °F.	H. %	No. of days.	No. of individuals.	Cases used.	Alpha value calculated.
Spring generation 1918.	a	HNV	58.5	97	34.4	5	c & g	49.0
	b	LW	62.1	95	26.1	15	d & g	53.6
	c	KW	62.8	70	27.3	14	d & f	54.5
	d	AW	69.5	70	20.0	31	f & g	50.9
	e	BW	80.3	70	11.0	27	c & f	48.6
	f	BWW	80.3	95	11.6	7	c & e	49.8
	g	MWW	91.5	85	8.4	8	c & d	44.4
							d & e	56.3
							e & g	44.1
			Mean alpha value for humidities 70-97 per cent.........50.1					
	h	HM	57.9	50	38.2	4	j & n	52.0
	i	LD	61.9	60	27.8	14	k & n	54.6
	j	KD	62.6	60	28.3	6	k & m	54.9
	k	AD	69.5	50	20.2	22	m & n	47.0
	l	BM	80.3	50	11.2	41	j & m	47.7
	m	BM	80.3	60	11.8	25	j & l	50.0
	n	MW	91.8	51	8.1	18	j & k	45.4
							k & l	56.1
							l & n	55.1
			Mean alpha value for humidities 50-60 per cent.........51.4					
Summer 1917.	o	KNV	61.7	97	23.8	13	p & s	50.7
	p	JW	64.5	70	21.0	3	p & r	53.7
	q	LW	69.5	82	13.1	13	r & s	37.8
	r	MW	76.2	96	10.6	41	q & r	47.3
	s	NW	89.3	95	7.5	10	p & q	56.2
							q & s	41.2
			Mean alpha value for humidities 70-97 per cent.........47.8					
	t	Z	57.9	45	39.4	6	u & w	52.7
	u	JD	64.5	40	22.1	8	u & v	52.9
	v	MD	76.6	35	10.8	8	v & w	46.3
	w	ND	89.9	58	7.5	7	t & u	48.3
			Mean alpha value for humidities 35-58 per cent.........50.0					

CALCULATION OF THRESHOLDS AND VELOCITIES.

a. Thresholds. Krogh ('14) showed that the zero of the equilateral hyperbola to which the time-temperature curve partly conforms, is not the actual threshold of development. Values calculated for those parts of the time-temperature curve which conform to the equilateral hyperbola (within the straight-line limits of the velocity curve) do have a significant relation to the actual limits, however, and correct methods of obtaining them are important.

In Table XV are shown the results obtained from a simple formula in calculating *alpha* values for high-humidity and low-humidity experiments of 1917. The humidities above 69% and below 61% have been grouped separately, and the data here serve chiefly to bring out the fact that the calculated *alpha* is lower in the high-humidity experiments than in the low-humidity experiments and also that it is lower in the summer generation than in the spring generation.

TABLE XVI. *Showing the use of Von Oettingen's phenological method of determining the alpha value.**
(See Fig. 13, curves for 95% humidity.)

Assumed alpha values.			56° F.			54.3° chosen first.		52.2° chosen second.	
No. of Pupae.	Days.	Mean temp. °F.	Effective temp. °F.	Product.	Depart.	Product.	Depart.	Product.	Depart.
1	50	53.9	0	0	—191	0	—221	85	—172
1	46	55.4	0	0	—191	51	—170	147	—110
3	34.6	58.4	2.4	83	—108	142	— 79	215	— 42
1	33.0	58.6	2.6	86	—105	142	— 79	211	— 46
1	35.0	58.7	2.7	95	— 96	154	— 67	227	— 30
13	23.8	61.7	5.7	136	— 55	176	— 45	226	— 31
14	27.3	62.7	6.7	183	— 8	229	+ 8	287	+ 30
2	25.5	62.8	6.8	173	— 18	217	— 4	270	+ 13
15	26.1	63.0	7.0	183	— 8	227	+ 6	282	+ 25
1	25.0	63.5	7.5	188	— 3	230	+ 9	282	+ 25
2	24.0	63.5	7.5	180	— 11	221	0	271	+ 14
3	21.0	63.5	7.5	157	— 34	193	— 28	237	+ 20
7	15.5	68.7	12.7	197	+ 6	223	+ 2	256	— 0
22	10.5	75.8	19.8	203	+ 12	221	0	241	— 16
25	10.0	75.9	19.9						
19	10.2	76.7	20.7	211	+ 20	228	+ 7	250	— 7
2	7.0	80.7	24.7	173	— 18	185	— 36	†199.5	— 57.5
2	9.5	83.0	27.0	256	+ 65	273	+ 52	293	+ 36
1	7.0	83.0	27.0	189	— 2	201	— 20	216	— 41
3	8.3	87.6	31.6	262	+ 71	276	+ 55	294	+ 37
5	8.0	88.7	32.7	262	+ 71	275	+ 54	292	+ 35
13	7.3	89.3	33.3	246	+ 55	259	+ 38	275	+ 18
10	7.5	89.3	33.3						
4	7.6	89.6	33.6	255	+ 64	268	+ 47	284	+ 27
1	9.0	90.0	34.0	306	+115	321	+100	340	+ 83
4	7.4	90.1	34.1	252	+ 61	265	+ 44	280	+ 23
8	8.0	91.0	35.0	280	+ 89	294	+ 73	310	+ 53
2	9.5	91.8	35.8	340	+149	356	+135	376	+119
1	8.0	95.3	39.3	314	+123	328	+107	345	+ 88
			K=191 mean for 62.7°-83.0°			K=221 mean for 62.7°-83.0°		K=257 mean for 68.7°-89.6°	

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* Only results at the same temperature and humidity were averaged together. With a weighted average, the *alpha* value is 54.8° F.

† With 199.5 omitted, the mean is 263.

The calculation of *alpha* values by this simple formula is by no means the best method, for it gives various results depending on how many and which combinations are used. The graphic method commonly used consists of drawing a straight line through the velocities for the different temperatures. Such a line will cross the temperature axis at *approximately* the hyperbolic zero (*alpha* value). If averages for points within one degree of each other are used, the results of the graphic method are fairly satisfactory. Where conditions in the different experiments varied as to humidity, air movement, temperature variation, light, etc., weighted averages should not be used, because the variation in mortality leaves widely different numbers completing their transformations.

The *alpha* value is best determined by Von Oettingen's method, in which the time is multiplied by the temperature above various assumed *alpha* values, that one being chosen as correct which gives the most nearly constant product within the widest range of temperatures. To illustrate this method, Table XVI shows the data used in calculating *alpha* values and in drawing the curve for all experiments having 95 per cent mean humidity (range 90–100%). The *alpha* value to be used in drawing the curve is the one giving nearest a constant for the data which appear to give an approximate constant. Thus, 54.3° F. (in Table XVI) was used because it gave least deviation for the data between 62.7° and 83° F. Higher and lower temperatures were considered as being outside the range within which the data conform to the equilateral hyperbola.

The 95 per cent humidity data are shown here, not because they are best to illustrate the principle, but because they indicate the difficulties. The experimental data were unusually heterogeneous and gave much trouble. Some experiments were ventilated, some were not ventilated, and several generations were included. The date were worked over by all three methods and combined and segregated according to conditions, with unsatisfactory results, suggesting strongly that such experiments for such a purpose should be carried out in the same way and with the corresponding generations. Furthermore, an inspection of the data in Table XVI for the *alpha* value 52.2° F. shows that extending the range of temperatures assumed to conform to the hyperbola would give only a slightly larger deviation from a constant.

b. Velocities of Development of Pupae. Relative velocity is merely the *reciprocal* of the *time* for the completion of a process. Usually, for convenience, and for practical reasons, the reciprocal is multiplied by a rather large number such as 100 or 1000, *ad lib.* Relative velocities based on 300* times the reciprocals of the days from pupation to emergence were computed from the average length of the pupal stage in all the different experiments under approximately constant temperatures. The data (Tables XII, XIII, etc.) were segregated into humidity classes: 14–29%, mean 22%; 30–37%, mean 31%; 40–58%, mean 49%; 60–68%, mean 61%; 70–77%, mean 73%; 80–88%, mean 85%; 90–100%, mean

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* This multiple was chosen at first to place the velocity curve approximately on a 45° angle with the temperature axis.

95%. These classes were then treated as though all the experiments had been run at the mean humidity for the group. It would have been desirable to keep the different generations separate, but this was impracticable because of the small number of emerging moths. The results were segregated according to humidity, regardless of generation or history. A few discordant values shown in the tables were not used in the calculations.

The relative velocities for each humidity were plotted on coordinate paper. Since velocities for temperatures between 62° F. and 87° F. usually fall into an approximately straight line, it was assumed that lines drawn through these points crossed the temperature axis at a point approximating the hyperbolic zero. These several approximate *alpha* values were checked by Von Oettingen's method as in Table XVI, and in some cases by the use of the formula as in Table XV. Each curve was drawn through means of ordinates and abscissas of groups of points, and to the best calculated *alpha* value. (Weighted means, taking into account the number of individuals, were not used, because the stock was different in history, and because the number of individuals put into the experiment was different in practically every case.)

Fig. 13 shows relative velocities $\frac{270}{\text{days}}$ plotted for each average-humidity group of pupae in the constant-temperature experiments. The curves are placed one above the other for convenience and indicate the general form of the first rough curves which had been drawn. The scale at the left indicates the mean humidity for the data included in the curve, the base of each curve being on the mean humidity. The curves were first drawn, as shown by broken lines, for 95, 85, 73, 61, and 49 per cent humidity, and then harmonized as shown by the solid lines. The velocities had been originally plotted as $\frac{300}{\text{days}}$ and were later changed to $\frac{270}{\text{days}}$ on the basis of the crucial experiments AD and AW with variable temperatures (Table XVII, Fig. 15). The final survey of the entire relationship showed that the use of $\frac{289}{\text{days}}$ would have properly compensated for the retarding effect of constant-temperature conditions. The use of these different factors does not change the relations of the relative velocities in any way. It is perhaps impossible to be sure of the correct factor to use in the early stages of a study. This final factor, 289, was the average obtained by a recalculation of the data for all constant-temperature experiments except five out of the fifty-five experiments, which were rejected because they fell too far below the average. Only temperatures between 62° and 89° F. were used in getting the average. A few cases which appeared to have very rapid development, especially with a combination of high humidities and rather high temperatures (which seems to give greater variation than other combinations), were regarded

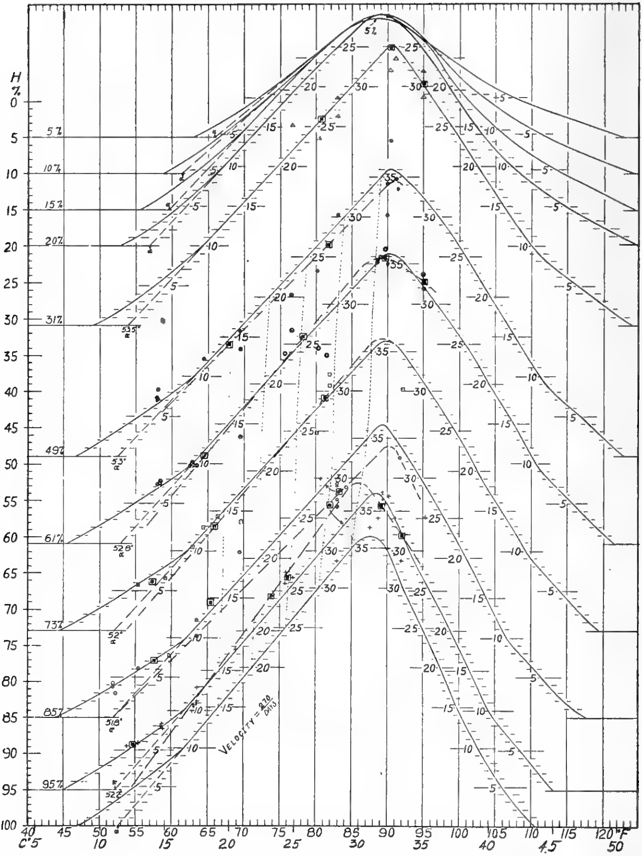

Fig. 13. Curves showing the average velocity of development of pupae under different conditions of approximately constant temperature and humidity. The velocities are derived, from data in Tables XII and XIII, by dividing the mean pupal life in days into 270, and are shown immediately adjacent to the curves. Each curve has its base on the humidity which is mean for the observations; this mean is shown at the left as a scale applicable to the beginnings of all curves. The double squares indicate the mean points through which the curves were originally drawn. The broken lines indicate the curves drawn through these double squares. The solid lines, which are the curves used in subsequent work, resulted from smoothing the various velocity lines of Fig. 14A.

as properly omitted from averages, though the computation of these alone would give a much lower *alpha* value. In these cases, moreover, there was possibly a considerable error in determining the time of pupation.

In the preliminary rough drafts of these curves, the velocity values for the experimental data at medial temperatures fell fairly close to a straight line, but those at lower temperatures did not. It was with some difficulty that a curve was found which would fit these lower points. A hint was taken from the insistence of physiologists upon Q_{10} as a constant, for this suggested some form of concave curve. Accordingly, a curve with the formula $y = \frac{x^{1.5} K}{10}$ was chosen (K being a factor by which the curve should be multiplied to make it fit the experimental data) and was slightly modified for each humidity group until it would pass through the plotted velocity values. Each of these curves thus marked approximately the velocity values from the lower straight-line limit to the approximate threshold of development.* It is noteworthy that the threshold is higher for lower humidities, as is also the lower straight-line limit.

The highest points of the velocity curves for humidities of 95, 61, and 49 per cent give a fair indication of the temperatures at which development is most rapid, namely, 88°, 90°, and 90.5°, respectively, showing that the maximum velocity shifts to a higher temperature as the humidity is lowered. The downward curvatures at the higher temperatures were taken roughly through points plotted from the data available at that stage of the calculations and were later brought into their present position by use of the equal-velocity chart described below.

Another step preliminary to the drawing of the solid-line curves which are shown in Fig. 13 was the harmonizing of the equal-velocity values. For this purpose, velocity values at 5-unit intervals were taken from the straight-line portions of the broken-line curves of Fig. 13 and plotted on co-ordinate paper scaled for humidity and temperature, as shown in Fig. 14A, and the plotted points were connected by broken-line curves.

The waves in these curves are not in accord with our general knowledge of the effects of external conditions on the behavior of organisms. The curves should be more regular. The irregularities probably result, first of all, from the heterogeneity of the material, the extent of which is suggested in Tables XVIII and XIX. For example, the 95 per cent data include various conditions, ventilated and unventilated, and different generations, etc. Secondly, the crookedness of these curves may be partly due to errors in the observation and interpretation of the process of development, particularly as regards the beginning and the ending of the pupal stage. Finally, there is the possibility of errors in the calculation, for the methods used give only approximate results at best.

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*Since a curve with this formula does not pass through O, a formula of the form $y = K (\log x) + c$ is more nearly correct.

The curves in Fig. 14A were, therefore, smoothed as shown, in order to counteract the heterogeneity of the data and to compensate for the probable errors of experimentation and interpretation. This smoothing is not to be construed as a merely mechanical process, but as a kind of averaging of results with a view to the best possible expression of the real effects of temperature and humidity upon the rate of development. The more regular lines in Fig. 14 are thus more truly representative of equal-velocity values than the crooked lines. The best proof that smoothing is justified, lies in the fact that the use of the chart made from these curves gives consistent results.

The harmonized velocity values obtained by the method shown in Fig. 14A were then used in the plotting of the straight-line portions of the solid-line curves in Fig. 13, which are presumably more nearly correct than the corresponding portions of the broken-line curves originally plotted. (The dotted vertical lines through points of equal velocity values in Fig. 13 may be compared with the solid lines in Fig. 14A.) The *alpha* values of these new curves were checked by the Von Oettingen method

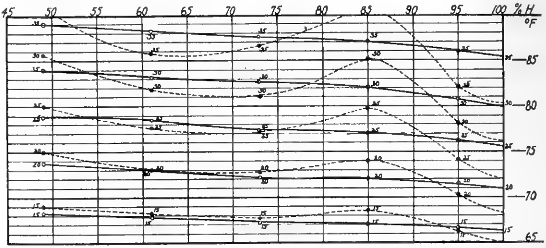

Fig. 14A. Method of smoothing velocity curves of Fig. 13. Velocities from Fig. 13 are indicated by dots. The broken lines were drawn connecting these dots, and the solid lines were then drawn by smoothing these lines to bring them into harmony.

and found to be more satisfactory than those of the old curves. The use of 52.2° F. as the *alpha* value for the 95 per cent data gave a nearly constant time-temperature product over a wider range of temperatures than when 54.8° F. was used. This widening of the straight-line limits is in better accord with the data for other humidities; also, the time-temperature product is larger and, accordingly, nearer the presumably correct value for the constant. For the 85 per cent humidity data, 51.8° F. similarly proved to be the best *alpha* value. The data at approximately 83° F. were from air-movement experiments in which the rate of air-flow was not that used as standard in the other experiments; these data were plotted in the absence of other data. The solid line curve, however, is practically an interpolated curve for the plotted points, and it has the same *alpha* value (51.8° F.) as the broken-line curve. In the case of the

73 per cent data, for which 52.0° proved better than 54.0°, the use of the lower *alpha* value is further justified by the fact that some of the hibernated pupae included in these data had not been soaked, winter dryness accounting partly for the low velocity values at 83° F.

PREPARATION OF THE EQUAL-VELOCITY CHART.

After the curves for data covering medial temperatures and experimental humidities (roughly 65°–87° F. and 45–95%) had been smoothed as in Fig. 14A, the points with velocity 35 at the various combinations of temperature and humidity shown in the solid-line curves of Fig. 13 were plotted on a large sheet of co-ordinate paper scaled for temperature and humidity as in Fig. 14B, and a line was drawn through these plotted points, both below and above the maximum velocity, and connected around the low humidity to make the greater part of an ellipse, as shown between 85° and 90° in Fig. 14B. In the same way, other equal-velocity lines were drawn roughly parallel to the 35 line until the scheme was completed for the high temperatures. The velocity values on the lower ends of curves similar to those in Fig. 13, but drawn according to the formula $10\ y = x^{1.5}\ K$, were transferred to the equal-velocity chart, and lines were drawn through them so as to complete that portion for low temperatures. (Fig. 14B is the final form, resulting from much refinement of this rough draft.)

Data from the variable-temperature experiments was then plotted on this rough draft of the chart. The march of temperature and humidity is shown on Fig. 15 for each of these experiments. Only about half of these experiments were sufficiently accurate to use. The velocity values for the experiment DD in Table XVIII (indicated by the line DD on Fig. 15) were then plotted, as is shown in Fig. 16, to determine the *alpha* value. The *alpha* values for experiments AW and AD were determined similarly.

As indicated in Fig. 16, the velocity curves in part of the experiments turn downward at high temperatures. The "summing of temperatures" is done on the assumption that the velocities for the temperature fall on a straight line. In these curves it may be seen that they do not fall in a straight line. Throughout this part of the paper, therefore, wherever the velocity for a temperature does not fall on the straight line, a straight-line *temperature with the same velocity value is substituted* for the actual temperature recorded by the thermograph for the hour in question. The high-temperature slope of the curve shown in Fig. 16 was modified until the sum of temperatures above *alpha* came out approximately 6,480 (or, in other words, until the substitution-quotient came out approximately 270) as it did with AW and AD in Fig. 15, which were concerned with variations within the straight-line limits only. Thus, in Fig. 16, instead of 90°, 95°, 100°, and 105°, which were recorded for two-hour readings, the following temperatures were used respectively: 89.5°, 84.1°, 74.6°, 64.6°. By means of trials with the data of the variable-temperature experiments, the upper part of the equal-velocity chart was tentatively

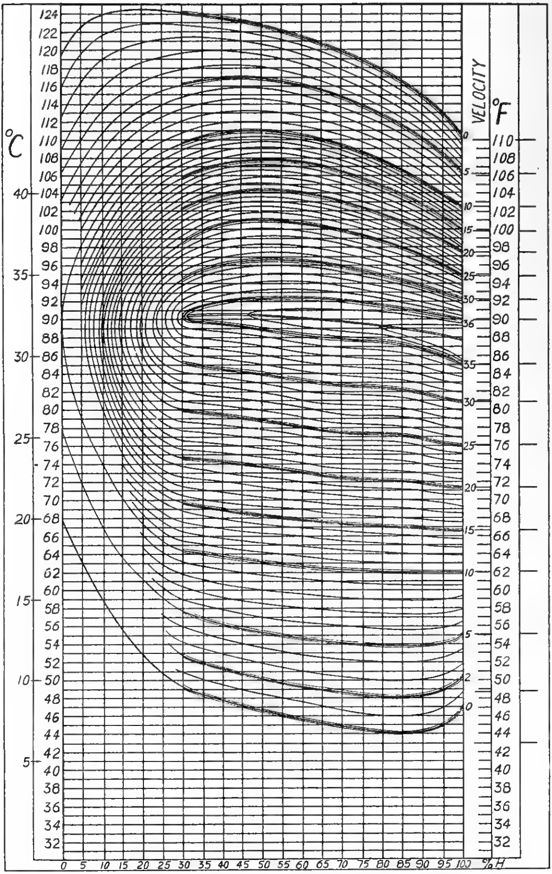

Fig. 14B. Chart of equal-velocity lines for the pupal stage. These velocities were multiplied by 1.07 to correct for variability (see Table I). The curves pass through combinations of temperature and humidity which give the same velocity of development. The curves in Fig. 13 may be likened to cross sections of a hill of which these are contour lines.

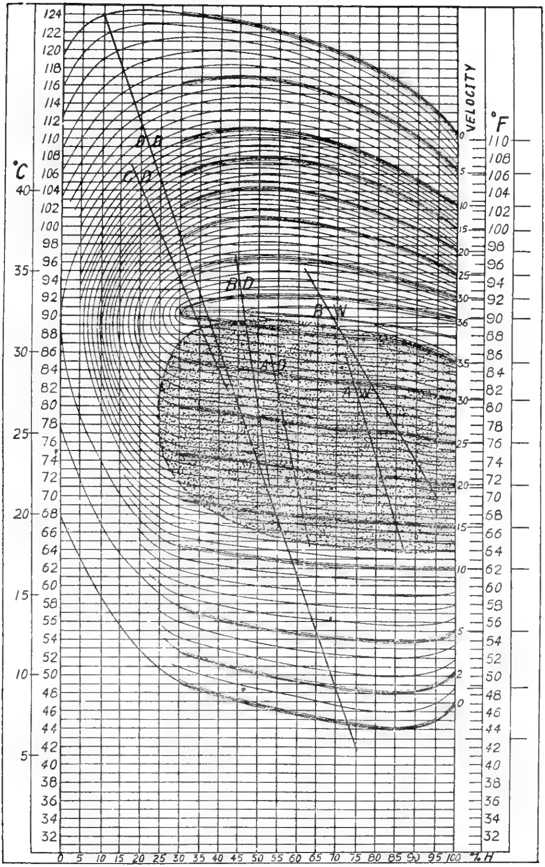

Fig. 15. Equal-velocity chart for the pupal stage, with lines CD, DD, BD, AD, BW, and AW showing the daily march of temperature and humidity in the variable-temperature experiments of the same designation. The shaded area covers medial conditions, that is, conditions within the straight-line limits of the velocity curve. (See Table XVIII, p. 398.)

drawn; while it did not purport to be extremely accurate, it was an approximation serving to check the data available.

With a view to further corrections and adjustments of the chart, the readings of temperature and humidity were taken for representative pupae of spring and summer groups from Glenn's 1915, 1916, and 1917 data, and plotted on the chart in the manner shown in Fig. 17, a dot being placed on the chart for the temperature and humidity of each two hours during the pupal period for each group. The dots between each pair of heavy velocity lines (representing 5 velocity units, except at the low temperatures where the first interval is 2 units and the second is 3 units) were taken together, and mean humidities, H, mean temperatures, P, and mean velocities, V, were computed for numbers of dots, N, as shown at the right of Figs. 17, 19, 21, and 22. The mean velocities were then plotted on the mean temperatures to make a curve similar to Fig. 18. When temperature substitutions were made, it was found that the substitution-quotients were too large for those groups of pupae subjected

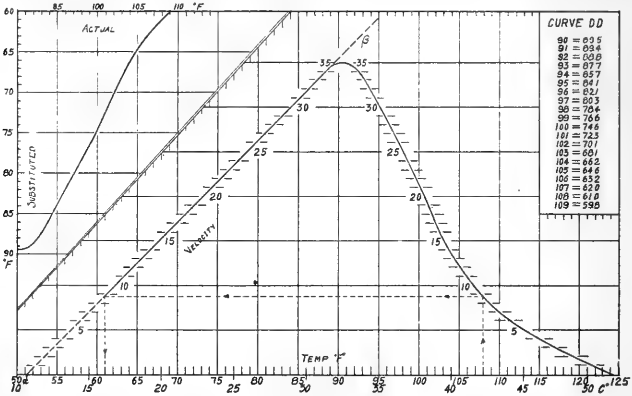

Fig. 16. The long curve is the full-length velocity curve for the experiment DD made by plotting the velocities crossed by the line DD in Fig. 15, on the corresponding temperatures. The curve in the upper left-hand corner is a curve of correction for reducing temperatures outside the staight-line limits to a value with the same velocity on the straight line. Read from the right-hand side of the curve, 109° equals 59.8° on the straight line, etc., as shown in figures at the right. Follow the arrows and broken line beginning on 108° F.

NOTE: The curves in this article are not drawn with the straight-line portion making an angle of 45° with the base line, as all are trial curves. Figures 16, 18, and 20 were intended to be so drawn, but the draftsman made the vertical scale 1.1 times the horizontal instead of 1.07 (see page 383). The values in Table I, when plotted for average daily variations, make a 45° angle within the shaded area of Fig. 15 when the scale is such that one developmental unit equals one degree of temperature.

to the greater amount of low temperature. The curve for the lower temperature data was then changed to $y = \frac{x^{1.3}}{10} K$, giving a curvature which fitted the data.

Final Correction of the Equal-Velocity Chart.

With the equal-velocity chart thus revised, the entire record of variable-temperature experiments on pupae was worked over, in order to check the values on the chart. Table XVII indicates the difference between the substitution-quotients used for this purpose and the uncorrected sums of "effective temperatures." Note that the difference amounts in some cases to thirty or more units. See also Tables XVIII–XIX.

Table XVII. *Showing substitution-quotients for variable temperature experiments, in comparison with other methods of calculation.*

Designation.	Range of temperature.	*Alpha* value.	Actual mean daily temperature.	Actual time in days.	Sum of temperature "degree-days" above *alpha* value.	Mean of temperatures corrected by substitution-method.	Substitution-quotient.
First Generation 1917							
AD	65— 84	51.5	69.9	14.9	274	69.9	274
AW	65— 84	51.3	69.5	14.7	267	69.5	267
BD	71— 95	51.6	82.7	9.9	307	79.4	275
BW	71— 95	50.5	82.7	9.1	288	79.4	272
CD.	84—103	50.5	88.8	8.0	306	83.9	267
DD	82—103	51.2	87.6	8.3	302	82.8	268
Hibernated Generation 1919						Mean	270.5
RWA*	50— 54	52.8	52.2	89.3	—36	55.8	269
First Generation 1919							
RWB*	50— 53	51.6	51.9	68	+19	55.6	272

* It is not possible to determine a fair *alpha* value in these cases. Various alpha values and curves were tried until a substitution-quotient of 270 was approximated. Note development below alpha in RWA. The day degrees may be derived by subtracting the *alpha* value from mean temperature and multiplying by days because the means are based on actual hours.

Note: When the substitution-total is correct, it is numerically the same as 1/24 the total of developmental (hour) units as defined on p. 332.

In order to check the equal-velocity chart still further, our outdoor and greenhouse observations on pupae at Champaign and Glenn's observations on pupae at Olney were entirely worked over (except where hygrothermograph records were missing for part of 1917). The two-hour temperatures and humidities for the entire periods in which pupae were

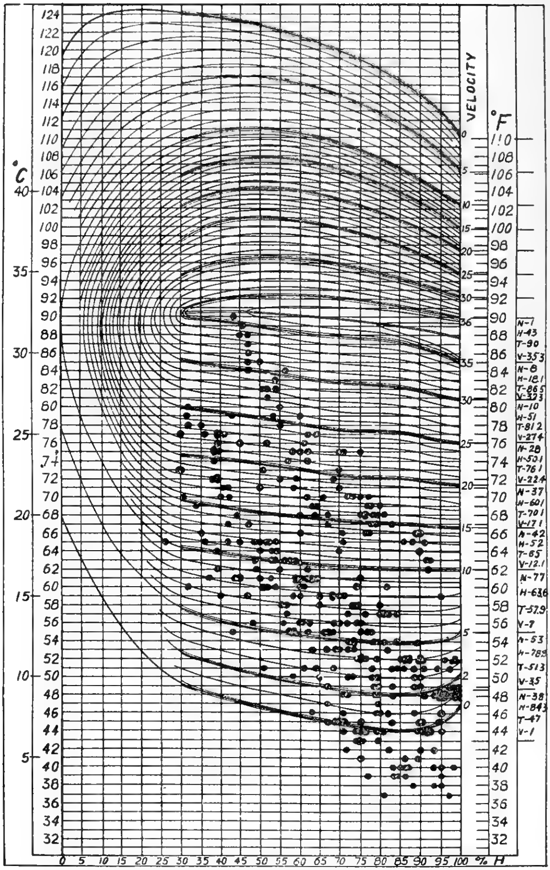

Fig. 17. Pupal velocity chart showing the two-hourly readings of temperature and humidity from April 17 to May 15 at Olney, 1916. Each black dot represents the condition of temperature and humidity at some even hour. The number of items (N), the mean temperature (T), the mean humidity (H), and the mean velocity (V) are for the dots falling between the triple velocity lines (5-unit intervals) are shown in the margin at the right.

under observation had been transcribed in the manner shown in Table II and were now plotted for each group of pupae on the equal-velocity chart as shown in Figs. 17, 19, 21, and 22. The dots lying between the lines which separate the even 5-velocity units were taken together, and the temperatures of the groups averaged together, the velocities averaged together, and humidities averaged together. For example, the averages for the interval between velocity 5 and velocity 10 in Fig. 17 are shown at the right as follows: N, number of readings, is 77; H, mean humidity, is 63.6; T, mean temperature, is 57.9; V, mean velocity, is 7. These mean velocities were then plotted on the mean temperatures as shown in Fig. 18, where velocity 7 will be found plotted on temperature 57.9°, and all other plotted points corresponding to the figures in the margin of Fig. 17.

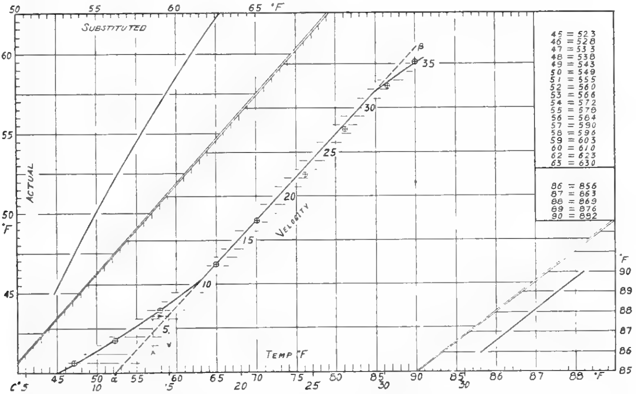

Fig. 18. Curve drawn through the mean velocities (crossed circles) and temperatures shown at the right of Fig. 17. The corrections applied to the actual temperatures are shown in the insets at the corners of the figure. Follow the dotted line and arrows from 57° to 59° F. The actual threshold was estimated to be 45° and the alpha value to be 52.3°. The substitution-quotient was 270.

A curve was next drawn through the points plotted in Fig. 18. The temperatures not on the straight line were dropped out and the temperatures with the same velocity on the straight line were substituted by the method explained on p. 387. To use this method, take for example, temperature 57° F., on Fig. 18, run up to the velocity curve, over to the straight-line extension, then downward as indicated by the arrow, and note that 59° F. is the temperature to be substituted for 57° F. The equal-velocity equivalents of all the temperatures not on the straight line

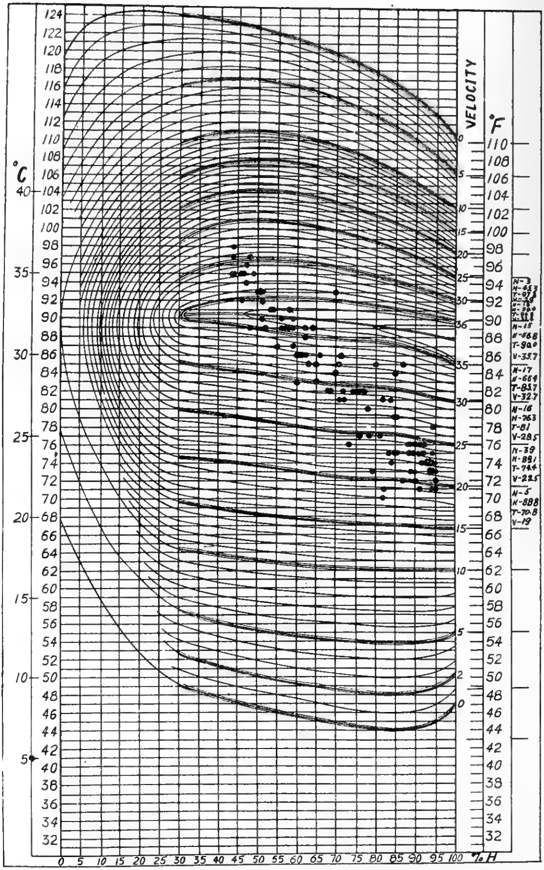

Fig. 19. Pupal velocity chart showing the distribution of temperature and humidity Aug. 1-10, 1916, at Olney. For explanations, see Fig. 17.

are shown in the upper right-hand corner of Fig. 18. For an illustration of the conditions and correction processes for a summer period, see Figs. 19 and 20. Note arrows indicating the equivalent of temperature 96°, which is 83°. The *alpha* values and substitution-quotients for the larger groups of individuals were calculated by the methods indicated above, and those for the smaller groups were interpolated. The substitution-quotient as here derived is practically the same as one-twenty-fourth of the number of developmental units for the stage. The *alpha* value varies with the angle of the average daily march of temperature and humidity (Figs. 15 and 29). The substitution-quotients for the various determined *alpha* values were derived from the temperatures thus corrected by the method explained above.

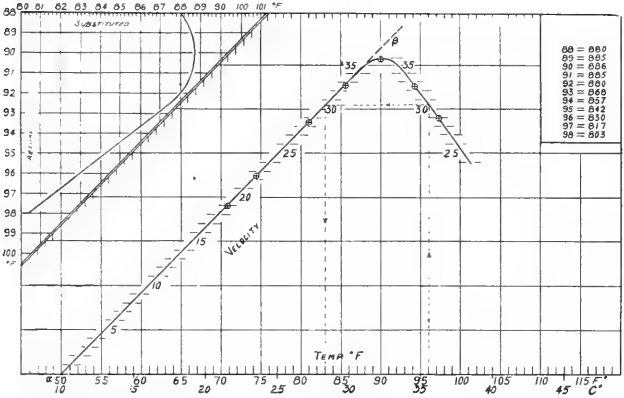

Fig. 20. Showing the velocity curve, alpha value and corrections for temperatures for the weather data recorded on Fig. 19.

For Glenn's 1915 data, this method gave 283 substitution-quotient as the mean of the means of thirty-individual groups of pupae, beginning April 13 and ending May 19 (five aberrant individuals were omitted), and a mean *alpha* value of 51.3° F. for the actually calculated cases. Mortality was low. Of the 1,400 larvae under observation, about 1,054 pupated and emerged. For the first generation, which began pupation June 19, and ended August 7, the mean of the means was 266, and the mean *alpha* value for all calculated cases was 50.6° F. The second generation, which was taken as beginning with the pupation of an individual on August 8 and ending with the last emergence on September 9, consisted of 36 pupae with a mean of 249. This was among the largest deviations from 270. The mean *alpha* value was 50.8° F.

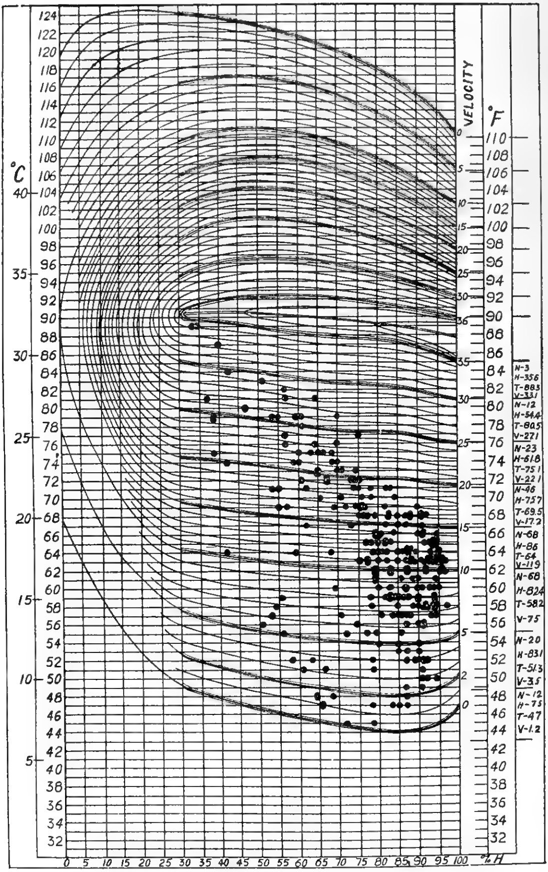

Fig. 21. Pupal velocity chart showing distribution of temperature and humidity May 14-June 4, 1915, at Olney.

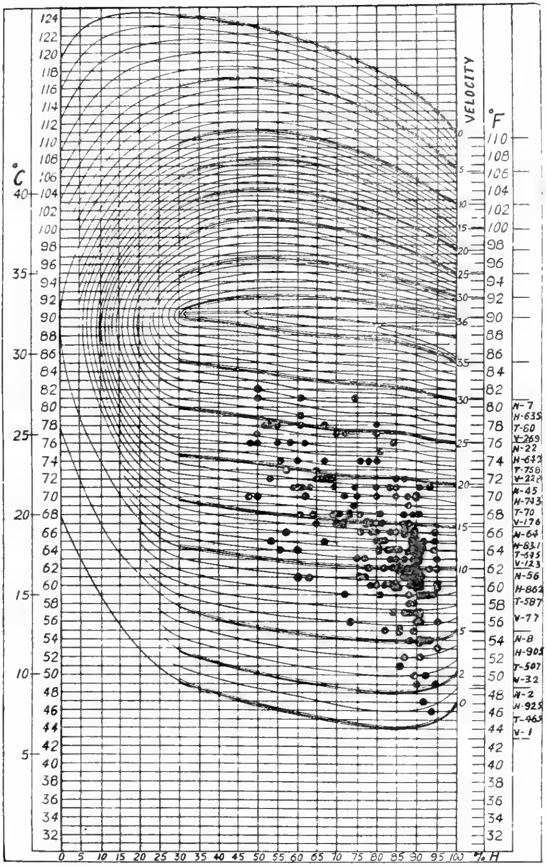

Fig. 22. Pupal velocity chart showing the distribution of temperature and humidity from Aug. 17 to Sept. 3, 1915, at Olney.

TABLE XVIII. *Pupae at variable temperature, first generation, 1917 and 1919.*

Designation.	No. of adults emerging.	Days to pupation.	Mean temperature.	Approximate mean-humidity.	Base temperature.	Elevation in degrees.	Base humidity.	Depression in %.	Maximum temperature.	Minimum temperature.	Maximum humidity.	Minimum humidity.	Evaporation in cc. per day.	% failure to pupate.	Total individuals.	Total pupae.	% pupal mortality.
AD	14	14.9	69.9	55.0	65.6	18.3	50.0	15.0	84.0	65.0	60.0	45.0	8.2	5	20	19	26
AW	9	14.7	69.5	80.0	65.6	18.3	85.0	35.0	84.0	65.0	90.0	50.0	4.1	5	20	19	53
Oa	4	11.4	72.0	73.0	64.3	25.1	86.4	38.7	89.3	60.5	92.6	47.6	16.2	....	....	....	....
Ob	5	11.3	73.0	72.8	64.0	24.8	86.6	39.5	89.2	60.5	92.7	47.6	16.4	....	....	....	....
Oc	4	8.9	73.9	73.9	66.0	23.7	85.8	37.6	89.6	62.0	91.9	48.5	16.9	....	....	....	....
Od	1	8.0	74.8	73.5	67.5	23.2	86.1	36.6	90.7	62.7	91.8	49.0	17.5	....	....	....	....
O (all)	14	9.9	73.4	73.3	65.5	24.2	86.2	38.1	89.7	61.4	92.3	48.2	16.8	9	22	20	30
P	6	11.0	79.1	68.0	71.0	21.7	90.0	36.0	97.5	54.0	95.0	54.0	13.7	15	20	17	65
Oaa	10	9.6	80.6	75.8	73.9	22.7	87.1	35.8	96.4	69.6	93.6	51.7	14.6	....	....	....	....
Obb	4	10.9	81.2	75.3	74.4	23.0	87.0	36.3	97.4	69.9	93.8	49.9	17.3	....	....	....	....
Occ	3	9.3	82.5	70.0	74.0	25.1	83.1	38.1	99.0	69.4	90.7	46.8	19.7	....	....	....	....
O (all)	17	9.9	81.4	73.7	74.1	23.6	85.7	36.7	97.6	69.6	92.7	49.5	17.2	3	35	34	50
BD	14	9.9	82.7	......	74.0	21.0	46.0	20.0	94.5	71.0	57.6	44.2	10.8	0	20	20	30
BW	15	9.1	82.7	......	74.0	21.0	87.6	12.6	94.5	71.0	88.0	75.0	3.9	0	20	20	25
DD	3	8.3	87.6	......	85.0	18.8	98.0	6.0	103.0	82.0	100.0	25	1.5	6	17	16	81
EW	7	8.3	88.5	......	84.5	13.0	99.0	6.0	101.0	84.0	100.0	93.0	1.2	15	20	17	60
CD	9	8.0	88.8	......	86.0	16.0	70.0	35.0	103.0	84.0	70.0	35.0	24.7	5	2	20	54
GW	5	8.6	91.5	......	86.1	23.3	99.0	6.0	109.0	85.0	100.0	93.0	0	48	21	11	54
FD	12	8.3	92.2	......	88.5	12.1	99.0	6.0	103.0	87.0	90	20	1.1	11	19	17	30
D	1	6	82.9	67	76	20	65	20	97.7	70.7	70	45	4.0	63	11	4	75
O	2	11.5	74	69	65	16.2	84.5	44	90.4	60	96	44	17.9	60	5	2	0
P	4	9.4	78.7	60	68.2	23.5	72	38	94.7	68	78	34	13.0	42	7	4	0

Dates of beginning were: AD, AW, BD, BW, CD, CW,—7/25; EW, FD,—7/31; O (all),—8/2. (1917 above, and 1919 below black line.)

For 1916, the hibernated generation showed first pupation on April 13 and last emergence June 17. The mean substitution-quotient was 269 and the mean *alpha* value was 52° F. The first generation began pupating June 20 and ended September 11, with a mean quotient of 266 and a mean *alpha* value of 50.4° F. The second generation consisted of 46 individuals (August 28 to September 27) divided into two groups: 30 with a mean of 246, and 27 with a mean of 277. The mean *alpha* value is 50.9° F.

For 1917, the hibernated generation (first pupation April 3, last emergence June 21), at Olney, gave a mean of 276 and a mean *alpha* value of 51.7° F. The first generation (first pupation June 27, and last recorded emergence August 6) gave a mean of 249. The second generation mean was 254 for 7 individuals. The mean *alpha* value was 50° F.

The mean of all generation means for the Olney data was 266 (substitution-quotient). Omitting third generations and the 1917 second generation, it was 272.

The substitution-quotients for the Champaign data with the number of individuals shown in parenthesis were as follows:

Summer	1917	(15)	267
Summer	1917	(5)	271
Spring	1918	(26)	275
Summer	1919	(2)	263
Summer	1919	(4)	272

The mean substitution-quotient, when the different generations and experiments on different generations are considered separately, is 266; with the third generation omitted, it is 270. The mean *alpha* value is approximately 51.0° F. The lowest value was 49.8° and the highest was 52.5° (at Olney) and 52.9° (in a variable-temperature experiment). These *alpha* values have *no physiological significance.* They are merely important in calculation work. The value is fixed by the ratio between velocities at high temperatures and those at low.* The actual threshold is lower, probably as much as 9° F.; development drops off slowly at the lowest temperatures.

Variation in the substitution-quotient is illustrated by a comparison of the two groups of 1915 pupae. Those appearing on May 14 and emerging June 4 (time 21 days) had a quotient of *287*; while those appearing August 17 and emerging September 3 (time 17 days) had a quotient of *245*. A comparison of Figs. 21 and 22 shows that the distribution of temperature and humidity is about the same for the mass of readings. Very radical changes in the equal-velocity lines would be necessary to make the quotients alike. The velocity curves (see Fig. 20) were identical. The standard time (mean velocity per day divided into

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*Variation in the *alpha* value may be illustrated as follows: Through the two natural groups of dots on Fig. 17, draw two lines (for example, one from H 45% T 88° to H 75% T 67°, and the other from H 35% T 96° to H 70% T 50°); plot any two velocity values crossed by each line against the corresponding temperatures on the scale, and produce the line joining these two plotted points to the temperature axis; note the *alpha* values thus obtained.

270) is 21.7 days for the May lot and 20 days for the August lot, the observed times being 21 and 17 days respectively. No modification of the velocity chart consistent with the experimental or phenological work will correct all these differences. The cause of the differences is to be sought in other conditions and will be taken up later in connection with effects of temperature variability.

TABLE XIX. *Pupae at variable temperatures.*

Designation.	No. of adults emerging.	No. of days.	Mean temperature.	Mean humidity.	Base temperature.	Elevation in degree.	Base humidity.	Depression in %.	Max. temperature.	Min. temperature.	Max. humidity.	Min. humidity.	% Failure to pupate.	Total individuals.	Total pupae.	% Pupa mortality.	Evaporation cc. per day.
HNV8-14	1	42.0	52.7	90	53.6	1	93	3	57	52	95	89	...	...	...	...	0+
HNV16	3	47.0	53.8	90	53.6	1	93	3	55	52	95	89	...	...	...	...	0+
HNVall	4	44.5	53.3	90	53.6	1	93	3	56	52	95	89	30	17	12	66	0+
VNV	1	28.0	57.1	97	55.0	4	99	6	59	51	100	93	...	...	...	...	0+
VNV	3	19.6	60.5	97	63.0	4	99	6	67	54	100	93	...	...	...	...	0+
VNV	4	16.5	62.9	97	64.0	4	99	6	68	57	100	93	...	...	...	...	0+
VNVall	8	21.4	60.2	97	60.7	4	99	6	64	54	100	93	47	24	13	38	0+
RLLNV	7	30.7	56.0	97	55.0	4	99	6	59	51	100	93	0	13	13	46	0+
RLRNV	5	17.7	60.8	97	60.0	4	99	6	63	51	100	93	16	6	5	0	0+
RMRNV	7	17.5	62.4	97	61.4	4	99	6	65	57	100	93	23	13	10	30	0+
RURNV	0	.....	68.0	97	64.0	4	99	10	70	62	100	93	0	17	17	100	0+
SNV	9	8.5	84.5	97	82.5	5	98	6	87	81	100	92	54	39	18	50	0+
ZNV	10	8.9	77	97	76	4	98	6	79	75	100	92	23	22	17	41	0+
VNV	1	103	51.0	90	50.5	4.0	93	3	52.5	50.2	95	89	...	...	...	...	3.0
203*DK*	1	10	77	40	75	8.0	45	10	80	73	46	35	89	18	2	50	....
HID	1	33	58.7	50	57	4.0	55	10	61	56	60	40	...	...	...	...	6.4
B*DK*	15	11.6	81.5	60	80	4.0	65	10	82	79	65	50	50	32	16	6	....
BTP	2	10.0	82.4	60	80	4.0	65	10	84.2	80.6	65	55	0	3	3	33	.0
BADa	8	10.8	83.0	35	81.7	9.5	40	10	91.2	80.4	40	30	56	22	10	20	9.9
BDa	14	10.6	83.0	50	81.7	9.5	55	10	91.2	80.4	55	45	73	30	15	7	8.8
BMa	10	10.4	83.0	60	81.7	9.5	65	10	91.2	80.4	65	55	41	27	16	38	6.9
BWa	7	10.4	83.0	70	81.7	9.5	75	10	91.2	80.4	75	65	45	22	12	42	6.7
BADac	9	10.3	83.0	25	81.7	9.5	30	10	91.2	80.4	30	20	38	21	13	31	10.4
BADb	7	10.6	83.0	35	81.7	9.5	40	10	91.2	80.4	40	30	52	21	10	30	8.1
BDb	8	10.2	83.0	50	81.7	9.5	55	10	91.2	80.4	55	45	40	20	12	33	10.6
BM	5	10.8	83.0	60	81.7	9.5	65	10	91.2	80.4	65	55	70	20	6	16	8.1
BWb	5	10.7	83.0	70	81.7	9.5	75	10	91.2	80.4	75	65	75	24	6	20	13.2
BWWb	0	.....	83.0	90	81.7	9.5	98	18	91.2	80.4	100	72	100	24	0	...	11.3
203*DK*	12	9.1	83.0	60	80	8.0	65	10	88	78	66	55	25	16	12	0	....
BWc	3	9.3	83.0	70	81	9.3	75	10	88.0	80	78	65	80	25	4	0	7.0
BWWd	8	.....	80.8	90	79	8.3	98	18	87.6	78.3	100	72	45	20	8	0	10.1
BWd	3	11.7	80.8	70	79	9.3	75	10	87.6	78.3	75	65	44	9	5	40	70
Oa	6	18.5	64.1	74.7	57.6	21.2	86.1	36.2	77.6	52.8	93.9	49.8	...	...	...	...	18.5
Ob	4	17.4	65.5	74.4	58.5	20.9	86.3	37.5	78.3	54.7	93.4	50.2	...	...	...	...	18.2
Oc	2	12¾	71.7	73.1	64.4	24.0	85.8	38.8	87.3	61.1	92.3	47.4	...	...	...	...	25.9
Od	1	13.0	73.0	71.6	65.5	24.3	85.1	39.1	88.6	61.6	92.1	45.6	...	...	...	...	22.6
Oe	8	12.0	73.4	72.5	66.3	23.8	85.1	38.7	90.1	62.7	92.2	46.6	...	...	...	...	25.0
Of	3	12⅔	74.8	71.4	67.1	23.4	83.7	38.0	91.2	63.9	91.4	46.7	...	...	...	...	21.0
Og	4	12.5	75.8	72.0	68.2	22.9	82.2	38.1	90.6	64.7	89.4	45.2	...	...	...	...	22.2
O (all)	28	.....	....	....	....	....	....	....	....	....	.....	....	20	50	40	30	....

Above first line; first generation 1917.

Above second line; hibernated generation 1918.

Air velocity 8 mm. per sec. except 203DK, BDK which was O+. The italic capitals indicated light condition.

Below second line; hibernated generation 1918, out of doors, segregated into temperature classes. Air movement was not recorded.

(B) ADULT MOTHS.

No experiments were successfully performed on adult moths. The difficulties are great, and little work was attempted. Isely and Ackerman ('23), however, have done some important work. The maximum oviposition at Bentonville, Ark., was on the second, third, and fourth days after emergence, and did not occur except in very weak light.

(C) EGGS AND LARVAE.

Incubation Period. (Data by C. S. Spooner.)

The only complete series of experiments on incubation was that carried on in unventilated phials where the humidity ranged high, as shown by precipitation on the glass walls at the time of many observations, and was arbitrarily taken to have averaged 95 per cent, though there were no readings (Table XX). Data plotted (Fig. 23) for other humidities are based on a limited number of readings. The *alpha* values graphically estimated to be between 50° and 52° F., were approximately the same as those calculated by Spooner. The deviation from the straight line is fairly well indicated at the lower temperatures and also somewhat uncertainly suggested in the neighborhood of 91° F.

These velocities in Fig. 23 are based on an arbitrary total of 161 taken from Glenn's Table I. When placed on the pupal velocity chart, they conform quite closely to the pupal velocities. Bringing them into conformity with the pupal velocities does not shift them more than is to be expected in smoothing. This conformity is also indicated by a comparison of Glenn's velocity (reciprocal) curves for incubation and pupal development. A review of Glenn's data (shown in his Table I), by the Von Oettingen method, gives 155 as the substitution-quotient when 51° F. is used as the *alpha* value. This makes the relative pupal velocities approximately 10/17 of the relative egg velocities. When pupal velocities are reckoned on the basis of 289 as the substitution-quotient, the egg velocities should be reckoned on the basis of 172 for the constant-temperature experiments and 160 for the weather-variable temperatures. This indicates that temperature variability has the same effect on eggs as on pupae. For variable-temperature experiments, 161 proved to be the correct substitution-quotient.

The 95 per cent humidity series calculated on 160 conforms very well with the pupal velocities calculated on 270. The aberrant values at the high temperatures are possibly due to too infrequent observation of progress before the experiment began. Evidently, in these cases there had been progress before the eggs were placed at experimental temperatures. Since these abnormally high velocity values occurred in the 95 per cent set, their presence in the others, where in some cases the humidity was in doubt, was not considered serious. The *alpha* value as determined for the 95 set by the Von O. method is 52.4°, and the substittuion-quotient is 157. Experience with pupae indicates that the actual weather combinations of temperatures and humidities should give about 51.0° as the

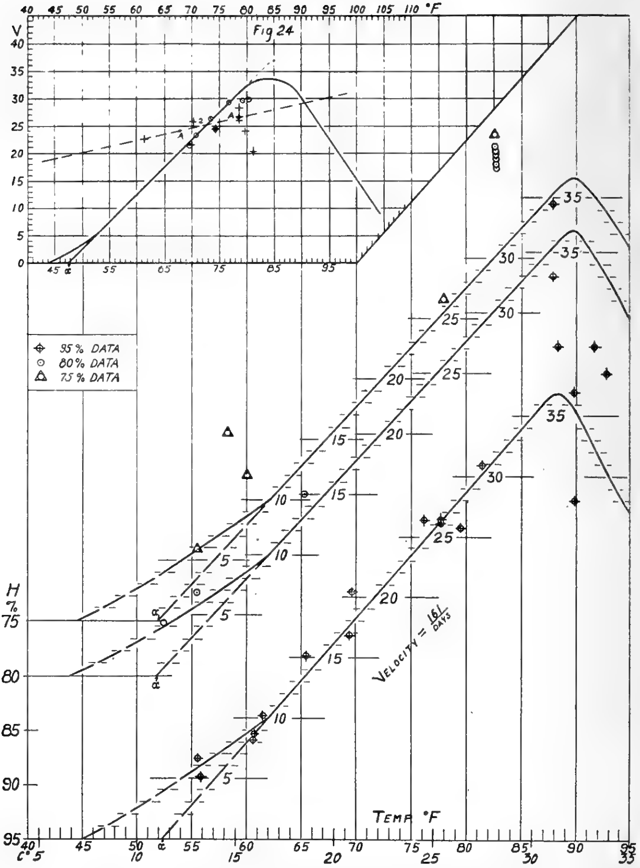

Fig. 23. Velocity curves for the incubation of eggs under approximately constant temperatures, plotted values being obtained by dividing the mean number of days into 161. These are drawn above the humidity shown at the left for the beginning of each curve.

Fig. 24. See explanatory note on opposite page.

alpha value and, therefore, a larger and presumably more nearly correct product of time and temperature above *alpha*. It will be noted that the maximum velocity appears to be at a higher temperature than in the case of the pupae. This introduces a slight error when the pupal velocities are used for incubation at high temperatures. In Fig. 23 this might have been corrected by adding 2 to each velocity value for all temperatures above 89° F. Such a correction is unnecessary in prediction work, as the duration of such high temperatures is usually very short.

Time from Hatching to Leaving the Apple. (Data by C. S. Spooner.)

Newly hatched larvae were placed in small cuts in apples. All experiments at 53° and 83° F. were failures. The number successful at each temperature was small (Table XXIII). The small series suggests a relatively smaller effect of temperature increases than is shown by the other stages. One item (temperature 81.0° F and time 32.1 days) was omitted in the calculation of time-temperature products, as its longer time suggested that 81.0° may be above the straight-line limits. The other temperatures and velocities were averaged together in two groups. The lower temperature, with a mean of 67.9°, gave a mean velocity of 24.1. The higher temperatures, with a mean of 78.8° were associated with an average velocity of 26.3. These two points are shown and marked A on Fig. 24. A continuation of the line passing through them would reach 0 velocity at about 40 degrees below the Fahrenheit zero, making it obvious that reasonable thresholds cannot be determined from such a few data with so much variation.

Glenn's data, however, proved much more workable. A comparison of the tangents and *alpha* values of Glenn's reciprocal (*i. e.,* relative velocity) curves for the pupal and larval periods shows that the pupal velocity is 2.8 times that for the larval period. Thus, when the substitution-quotient for the pupa is 270, that of the entire larval period should be about 756. Glenn found an average of 673 "degree-days" for this period. An examination of his Table III, by the Von Oettingen method, gives an *alpha* value of 47.5° F., an uncorrected sum of 763 "degree-days" and a substitution-quotient of 744. A curve was drawn (see circles in Fig. 24) to fit Glenn's data when his reciprocals were multiplied by 763 and plotted on mean temperatures above 47.5° for the larvae from hatching to pupation, and the upper curvature was copied from the curve for the larval development after hibernation (see Fig. 26). Velocities were read from this trial curve and applied to Glenn's original data, in order to correct the upper curvature. (When the upper straight-line limit is too high, the calculated time becomes smaller as the number of high tempera-

Fig. 24. Curve for velocity of development of the larva in the apple. The curve was estimated from experimental data (shown by crosses) and from Glenn's observations shown by circles. The dotted peak is for hibernated larvae under average weather conditions. The velocities are based on dividing the mean number of days into 650 for the period from hatching to leaving the apple, and into 750 for the period from hatching to pupation. The latter figure was obtained from Glenn's corrected temperatures by applying the Von Oettingen method.

ture readings increases, and *vice versa.*) Various curves were thus tried until the velocities shown in Table V were found to give fairly consistent results. The use of the velocities shown in Table V gave calculated time for Glenn's data consistent with the average actual time. There was, however, much greater variation than in other stages. This has been discussed in PART ONE and PART TWO.

TABLE XX. *Showing conditions and incubation period of eggs under approximately constant temperatures.*

The original data are from experiments by C. S. Spooner.

Designation.	No. of individuals.	Year.	Generation.	Mean time to hatching days.	Mean humidity. %	Mean temperature. °F.
R L L	9	1919	......	......	99	46.2
R L R	10	1919	......	......	95	48.0
V N V	10	1918	......	......	95	48.9
V N Vc	12	1918	......	......	95	48.9
R t r	1	1919	......	......	80	51.8
R W	7	1919	......	......	85	52.2
R D	3	1919	......	......	45	52.2
R	1	1919	3rd	37.0	80	52.3
R M	8	1919	......	......	72	52.5
R W	8	1919	......	......	85	53.1
R M	2	1919	......	......	72	53.3
R D	5	1919	......	......	45	53.8
H I D	1	1919	3rd	27.0	75	55.4
H I W	6	1919	3rd	24.1	92	55.4
H I M	9	1919	3rd	23.0	80	55.4
H I N V	1	1918	3rd	30.2	95	55.9
H D	2	1919	1st	13.5	60	57.7
H D R	3	1919	1st	10.5	75	58.1
L N V	4	1918	3rd	19.5	95	60.6
L N V	3	1918	3rd	18.4	95	60.7
L N V	5	1918	3rd	15.7	95	61.5
K W	4	1918	3rd	10.0	90	64.4
A W	18	1920	2nd	10.8	82	65.1
A W	3	1920	2nd	10.8	92	65.5
A N V	10	1918	3rd	9.6	95	69.3
A N V	7	1918	3rd	7.9	95	69.6
B. N. V	2	1918	3rd	6.2	95	76.1
B D	3	1918	3rd	6.3	50	77.0
B. N. V.	4	1918	3rd	6.1	95	77.7
B N V	2	1918	3rd	6.9	95	77.7
B D	6	1918	3rd	6.6	50	78.0
B N V	2	1918	3rd	6.1	70	79.5
B N V	3	1918	3rd	5.3	95	81.4
B N V	3	1919	......	......	95	82.0
B W	9	1920	2nd	3.8	80	82.5
B W	12	1920	2nd	3.7	80	82.5
B W	15	1920	2nd	3.8	80	82.5
B D	15	1920	2nd	4.1	43	82.5
B M	14	1920	2nd	4.1	75	82.5
B W	7	1920	2nd	3.9	80	82.6
B W	11	1920	2nd	3.8	80	82.6
B W	10	1920	2nd	3.9	80	82.6
Q N V	2	1918	3rd	3.5	95	87.8
Q N V	2	1918	3rd	3.1	95	87.8
N N V	1	1918	3rd	4.0	95	88.2
M N V	3	1919	......	......	95	89.1
N N V	3	1918	3rd	4.4	95	89.8
N N V	4	1918	3rd	4.6	95	89.9
M N V	13	1919	3rd	4.0	95	91.6
M N V	1	1919	3rd	4.2	....	92.8

These velocities, when used to calculate standard time for the period in the apple from Glenn's Olney data, were divided into 650, which was regarded as an approximately correct substitution-quotient, though the average time calculated on that basis was 1.3 per cent higher than the actual time. (See Table XI.)

A substitution-quotient of 100 was tried for the time in the cocoon. This gave an average calculated time 0.4 per cent lower than the average actual time. When 750 was tried for the total larval life, it gave a mean calculated time 1.6 per cent higher than the actual average time (Table XI). A substitution-quotient of 738 would make the average calculated time agree with the average actual time for Glenn's data. In view of the small series of observations and the striking variation in time, it was deemed unnecessary to change the quotients used.

It will be noted that 750 and 738 are materially smaller than the 763 used in plotting Glenn's data (circles Fig. 24). This is to be accounted for by the fact that the period of the stage under variable temperature is longer because of the inclusion of temperatures at which development is slower or even at a standstill. Glenn's corrected sum calculated on this basis was 744. His correction, which amounted to 2.5 per cent for mean temperatures between 68° and 78° F., apparently should be 3.4 per cent. For the higher temperatures there are even greater differences between the substitution-quotient and the uncorrected sums.

Turning again to the meagre experimental data, to consider them in the light of the results with the Olney records, we find them in keeping with expectations based on other stages. When plotted on 650 as the substitution-quotient, the curve should fall a little below the curve for variable temperatures, because constant temperatures give slightly slower development. (This difference amounted to 7 per cent in the case of the pupae.) Since the experimental data are so meagre, all are plotted on a 650 basis, and only mean points are shown. With the exception of the 81° point, all data are in the straight-line limits (where means are correct). The 81° point, apparently, is only slightly outside. The mean value of all experimental temperatures and all velocities calcuated on the 650 basis falls on 74.2° F. and velocity 24.65 (see Fig. 24). The variable-temperature velocity line passes through 26.7, and an increase of 8 per cent places the mean of experimental data approximately on the line which is within the range of expectations. The marked variability of the experimental data is, in part, due to differences in kinds of apples (see Table XXI).

Hibernated Larvae.

It has not been possible to make a careful investigation of the period of dormancy, commonly called hibernation, into which the mature larva of the codling moth lapses in the month of August or even earlier, and in which it remains until it has passed the winter or has received special treatment in the laboratory. Many experiments were tried, but the results were inconsistent.

In a large series of experiments on the length of the pupal stage conducted during the summer of 1917, very few of the larvae collected after July pupated; of those collected on August 18th, only 15 per cent pupated; and none of those collected later. The larvae failing to pupate in the August experiments, together with those collected early in September, after being left until October 19th under the experimental conditions supposedly suitable for pupation, were subjected to various treatment.*

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* Stocks used in the experiments on the length of the larval and pupal periods received better treatment. See pp. 374-380.

TABLE XXI. *Showing conditions and period of growth of larvae in apples under approximately constant temperature. Experiments by C. S. Spooner.*

Designation	Larvae in apple.		Time spent in apple. Days.	Mean temp. ° F.	Kind of apple.
	Into apple 1st observation.	Out of apple.			
L	9/20 10a	10/13 10a	28.8	61.4	Red crab
A	9/10 9a	10/3 11a	29.7	70.0	Maiden blush
A	9/10 9a	9/27 9a	25.0	70.2	Duchess
A	9/10 9a	9/27 9a	25.0	70.2	Red crab
B	9/10 9a	9/25 2p	23.2	78.5	Duchess
B	9/10 9a	9/25 2p	24.1	78.6	Duchess
B	9/2 8a	9/25 9a	24.0	78.6	Yellow crab
B	9/20 10a	9/29 9a	27.0	79.4	Maiden blush
B	9/10 9a	10/3 2p	32.1	81.0	Maiden blush

TABLE XXII. *Pupation and emergence as affected by temperature and humidity. Autumn larvae (1917) soaked in water for 20 hours, Nov. 14th, and placed at 75° F.*

Date started.	Lot used.	Temperature degrees F.	Humidity Per Cent.	Evaporation.	No. of larvae.*	No. of pupae.	No. of adults.	Dead larvae. Per Cent.
9/8	AD	65–85	50	High	16	4	2	75
9/24	AM	65–85	75	Low	13	0	0	100
9/8	BD	75–95	50	Low	12	0	0	100
9/8	BW	75–95	85	High	10	0	0	100
9/11	CD	85–105	40	High	13	0	0	100
9/8	DW	85–105	95	Low	7	0	0	100
9/10	EW	85–105	95	Low	10	0	0	100
8/23	JD	64	44	High	19	9	9	57
8/21	JM	64	80	Low	18	6	4	67
9/9	MD	78	35	High	14	0	0	100
8/23	MW	78	95	High	17	4	4	77
9/5	MM	78	65	Low	12	0	0	100
9/13	RNV	40–75	#	None	9	1	1	89
9/22	RNV	40–75	#	None	19	11	7	42
8/29	SD	69–82	(Dry)	High	19	0	0	100
8/27	SM	69–82	(Moist)	Medium	17	0	0	100
8/29	SW	69–82	(Wet)	Low	12	0	0	100
9/11	TH2	85–95	60	High	22	1	0	96
9/11	TI2	85–95	60	Medium	19	0	0	100
9/11	TL2	85–95	60	Low	14	0	0	100
9/22	TH3	85–95	60	High	14	2	2	86
9/22	T13	85–95	60	Medium	10	0	0	100
9/22	TL3	85–95	60	Low	10	0	0	100

* No. of larvae alive after soaking for 20 hours. The dead were not counted here.

Six sets of about 20 larvae each, which were kept in conditions supposedly suitable for late summer pupation, all died. (a.) Three sets collected August 23d, August 26th, and September 19th, totaling 58 larvae, were held at a temperature of 87° F. and humidities of 80, 60, and 40 per cent, respectively. All larvae in the two sets at the lower humidities died by October 9th, while those in the moistest condition lived to January. There were no pupations. (b) A single set collected August 23d and kept at 90° F. and 55 per cent humidity all died by October 9th. (c) A set collected July 26th and kept at 46°—57° F. all died without pupation by November 14th. (d) A set collected September 10th and subjected to daily variations of temperature between 80° and 100° F. and a mean humidity above 90 per cent, all died by December 19th without pupation.

Five other sets of autumn larvae, which had been kept under conditions the same as the above six sets, were transferred on or before December 19th to an approximately constant temperature of 70°—75° F. and a 90 per cent humidity. (a) Larvae collected September 10th and held at a temperature with daily variation between 80 and 100° F., and a variable humidity with mean about 60 per cent, were transferred to 75° F. on November 20th; and all died by March 20th without pupation. (b) Others kept at 65° F. and 40 per cent humidity and transferred to 75° F. on November 25th, all died by December 19th, without pupation. (c) A set collected September 19th, kept at a temperature varying from 40° to 76° F. to February 15th, and then transferred to a constant temperature of 70° F., showed one pupa. (d) A set collected August 28th was kept at 77° F. and a humidity of 95 per cent until October 25th, and then transferred to 70° F. By March 19th, five had pupated, and the others had died. (e) A set kept at 62° F. and a humidity above 90 per cent was transferred to 70° F. December 19th. By February 15th, five moths had emerged, and the others had died. (Note: Larvae kept at 77° F. would not ordinarily pupate with the treatment described, but those in sets having been subjected to a low temperature might be expected to do so under ordinary conditions.)

Seventy-one larvae, collected between July 25th and August 18th and failing to pupate under the experimental conditions designed for pupation, were kept 18-20 days below 60° F., being at 22° F. for 6 or 7 days, but failed to pupate when returned to the experimental conditions for pupation.

Four-hundred larvae, placed under conditions shown in Table XXII between August 24th and September 22d, 1917, and kept there until November 14th, were then submerged 20 hours in water and placed at 75° F. Those kept at temperatures below 65° F. and those kept at higher temperatures subjected to greatest amount of evaporation, pupated and emerged in greatest numbers. Representative data are shown in Table XXII.

For the spring experiments of 1918, 1919, and 1920, some of the hibernating larvae were kept at temperatures at or below 32° F. (freezing) for a day or more, but without effect on the number pupating when placed under favorable conditions. In general, no attempt to freeze the larvae was made. They were merely kept at temperatures near 50° F. (This temperature proved to be too high, and pupation results will be discussed later.) The stock usually reached a condition where pupation would take place between December 20th and January 20th, January 1st being an average date.

In the spring experiments, larvae given uniform treatment during the winter showed variation in the length of time to pupation at constant temperatures, regardless of the date of leaving the apple, the date of collection, and the conditions under which they were kept, either before or during the period of low temperatures. In 1920 a large series of larvae was collected, beginning August 16th and running through September 28th. They were kept at a temperature of 70° F. and humidity of approximately 45 per cent until September 23d; between this date and October 23d the temperature was lowered at 50° by steps, first falling to 59° only at night, and then being lowered to a constant 50° on October 8th, and finally to 50° on October 23d. A temperature between 50° and 52° was maintained until December 27th, when it was lowered to 37° and held between 35° and 37° until February 14th, when it was gradually raised to 48°, and on March 15th, to 72°. The larvae were then kept at 72° F. and 85 per cent humidity for observation as to time of pupation and emergence. Owing to apparent discrepancies in the time of pupation recorded by the assistant in charge of daily observations of this experiment, it was deemed best to use only the time of emergence, concerning which there was no doubt. Fig. 25 shows the distribution of emergence in May, 1921. The number of times the groups had spun cocoons, the dates of collection, and the relative humidities are indicated in the margin of Part A of Fig. 25.

There is apparently no consistency in the different numbers of times which the cocoons were spun in the sets of the same humidity and collecting date, nor is there any consistent relation to the moisture treatment during the hibernation period in this experiment. (Fig. 25.) The earliest individuals to appear are by no means consistently from either the "wet" or "dry" lots. The lots labelled "W" had been stored at humidities of 100 per cent and submerged in water once a month long enough to saturate the pasteboards and surround the cocoons with water. Those labelled "D" had been stored at 90 per cent humidity but had not been submerged at all. The lack of results from this submergence has been shown by Townsend to be due to the infrequency of the wetting. (There is an essential difference in the times of emergence if rainfall is heavy.)

The three emergence groups, when added together (Fig. 25B) and compared with Glenn's data on emergence, show main maxima corresponding with his main maxima; and an explanation of the variation in the time required to overcome dormancy (variations in the pupal stage are of a different nature) must be sought in other causes, such as heredity, conditions of the food supply, or weather conditions during autumn.

Field observers have stated that the initiation of dormancy in summer and autumn larvae is due to a temperature of 50° F. or thereabout. Two hundred and five larvae were collected in the summer of 1920 between July 22 and August 14 and subjected to temperatures varying from 39° to 54° F. These larvae were divided into four classes: (a) pupating, (b) failing to pupate, (c) escaping from the corrugated pasteboards, and (d) dying. Those dying and escaping were ignored; only those remaining alive in the pasteboards were considered as having been experimented upon. After those dying and those escaping were deducted, the

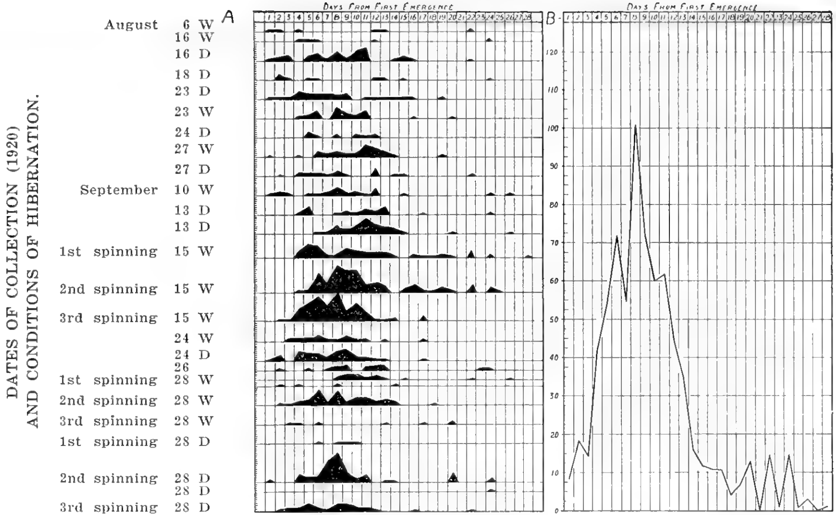

Fig. 25. Part A shows the order of emergence of moths beginning on May 3, which is number 1 of the top scale, and continuing for 28 days; the close scale at the left indicates number of individuals emerging each day in each set. The treatment of the larvae and the date of collection of each set is indicated at the left. W is wet (100% humidity and soaked in water once a month), and D is dry (90% humidity without any soaking in water). All were otherwise kept at the same temperature (72° F.) throughout.

Curve B represents the sum of all emergences shown in Part A. This curve shows three groups commonly recognizable in pupations out of doors, viz., a small group at 2 days, a very large one with its maximum at 8 days, and a somewhat drawnout group beginning at 20. Cf. Glenn's Charts 1, 2, and 3, noting pupation.

remaining 118 larvae (divided into 18 lots) were grouped as follows:

July 22d to 28th,	18 larvae,	17% failure to pupate.
July 31 to August 3d,	37 larvae,	38% failure to pupate.
August 7 to 8th,	28 larvae,	89% failure to pupate.

During the period July 22d to August 8th there had been no minimum outdoor temperatures below 57° F.; all larvae collected in that period, therefore, were experimentally subjected to temperatures below 50°, in order to make them comparable with larvae collected on August 9th and 10th, when outdoor temperature in the early morning fell to 52° F. The lots collected August 9th to August 14th (35°) showed 88 per cent failure to pupate. These experiments showed no indication of cool night effects but rather indicated a seasonal increase in the number of individuals failing to pupate, beginning about August 1st, regardless of minimum temperatures.

The effect of summer and autumn rainfall on the length of time to pupation of hibernating larvae is suggested by the following data: *Case a:* One hundred and eight larvae collected August 20th to September 12th, 1919 (kept at a temperature of 70° and humidity of 40 per cent until August 30th if collected before that date), were subjected to temperature near 32° F. and humidity of approximately 100 per cent until January, when they were placed in conditions favorable to pupation. Between January 26th and February 24th, only 5 larvae, or approximately 3 per cent pupated. The average time to pupation was 19.3 days at 83° F. and 21.5 days at 63.5°. *Case b:* Larvae collected October 20th of the same year (1919) were treated exactly the same as those in *Case a,* and 60 per cent of them pupated, the length of the prepupal stage being as little as 11 days and averaging 17.8 days at 83° F. The pupal life was about 10 per cent shorter than in the case of the sets collected earlier. The differences between those collected on or before September 12th and those collected on October 20th were thus very striking, both in the per cent pupating and in the time to pupation, when the larvae were placed under favorable conditions. The differences lie in the time of emergence from the apple, and in the weather conditions between September 12th and October 20, 1919. There was very little rain during the period of collection in August and the first twelve days of September, but during the latter part of September and the first 20 days of October there were 5 rainy periods and great variations in temperature (26° to 96°). These observations do not show whether it was the condition of food, temperature, moisture, or variability which produced the result. They serve, however, to indicate the necessity for year-round experimentation.

The calculation of velocity values for larvae which had passed the winter under known conditions afforded unusual difficulties because their pupation showed essentially the same seasonal curve as the emergence of moths (Fig. 25). Larvae kept in the laboratory at temperatures of 40°-

50° F. during October (and November and December if desired) and then put under proper conditions, will pupate in the latter part of November, in December, or during January or February. January 1st is about a mean date for pupation outdoors, but the variation is so great as to leave no scientific basis for a starting point in calculations at the present stage of knowledge. January 1st was used by Glenn as a starting point for summing larval temperatures. The time to pupation at 85° (or any other suitable temperature) after dormancy is broken, apparently varies with the length of the dormant period at all temperatures above freezing, if not lower. Townsend demonstrated that changes took place at 32° F. The 1918 experimental series was largely useless for this purpose because they were stored at higher temperatures. The temperatures should be near freezing in the case of larvae designed for determining the time to pupation after dormancy is broken. The 1919 larvae (*Cases a* and *b* described on p. 410) were important in this connection because they were kept at approximately 32° F. for several months and then put into conditions for progress in the latter part of January. These fell into three groups, the first pupating with about 285 accumulated degrees, the second with about 535 accumulated degrees, and the third with about 716 accumulated degrees,—each reckoned above 50° F, as the starting point. (These are uncorrected sums of temperatures obtained by the method which this paper aims to supplant for all purposes except rough estimation.) All hibernated larvae on which data are available fall generally into these three groups, the last being most variable. (Cf. Fig. 25 and Glenn's Charts 1, 2, and 3, showing a small early group, a large middle group, and a final prolonged group of pupations.) All the experiments used in the calculation of relative velocities were constant-temperature ones, and the sum of temperatures above fifty is much more significant for them than for variable conditions. On this basis, a provisional set of velocity curves were constructed (Fig. 26), and a provisional larval-velocity chart was drafted (Fig. 27). Glenn's data beginning January 1, 1916, were worked over, using all temperatures above 43° F., though only those above 44° (the temperature suggested by the experimental data) were considered as affecting development.

The 1918 series included many larvae that pupated. These had been stored at 48° F. or lower, on the assumption that the "threshold" was 50° F. There was, however, some variation in temperature, with the result that when the last experiments were started the larvae were nearly ready to pupate.* Baumberger and Townsend also found that this was a very detrimental temperature. The three groups (early, middle, and delayed) were strikingly shown in nearly all cases, but they seemed unduly crowded together in later cases, suggesting that prolonged mild temperatures tend to reduce the differences between the groups. The earlier and larger groups were used for estimating velocities. This was done by dividing the time into the average sum of temperatures above 50° F. for

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* For this reason the tables of 1918 data are not given here. The other tables, which are given, do not show the three-group pupation.

each group. By this method, the velocity tends to remain constant for any one temperature, but the sum changes. This variation in the sum is evidence that the developmental total is not the same for different individuals; that is, the developmental processes, especially where enzymes are concerned, require varying amounts of metabolism to complete the stage. For example, 280 larvae which pupated at various approximately constant temperatures ranging from 53° to 80° were in three successive groups. When an approximately constant velocity value was obtained by dividing the mean substitution quotient for the group by the time (in days) for each individual at a constant temperature, that velocity value was used for that temperature in making the equal-velocity chart. This calculation was based on the fact that all groups at constant temperatures within the straight-line limits showed a fairly uniform rate of reduction of the time-temperature product, as illustrated in Table XXIII for two collections of larvae wintering out-of-doors.

TABLE XXIII. *Differences in "Pre-pupal" Time-Temperature Products (above 50° F.) for Two Collections of Hibernated Larvae Pupating in Three Successive Groups (Spring of 1920) in Constant-Temperature Experiment.*

Groups of pupations.	1st	2nd	3rd
Assumed Maximum Product for "Pre-pupal" Period, as of January 1st............	300	525	675
Mean Product for Larvae Collected March 3d............	238	439	602
Mean Product for Larvae Collected March 22d..........	155	245	390
Approximate Per cent Reduction of Product to March 22d	48	53	42
Approximate Per cent Reduction of Product March 3rd—22d	27	37	30

A large series of calculations of *alpha* values, taking the means of the three groups separately, showed no conclusive difference in the "threshold". Some apparent differences were rendered questionable by irregularity of time and small numbers of temperatures within the straight-line limits. There is a suggestion of a slightly lower "threshold" for the later groups, but this is not borne out by calculations based on an assumed *alpha* value of 50° F. For practical purposes the assumption of the same threshold for all three groups is the simpler.

On the basis of 300, 525, and 675 as the respective time-temperature products above 50° F. for the different groups, roughly segregated for

1919 and 1920 larvae (see Tables XXIV to XXVII), the curves shown in Fig. 26 were drawn, and on the basis of these curves the velocity chart (Fig. 27) was constructed. It is a provisional attempt, but it summarizes our experience with hibernated larvae. The method described for the pupae was used with this chart. All two-hourly readings of temperature and humidity above 40° F. from January 1st to the first pupation were entered on the chart. A curve was drawn with *alpha* as 47.5° and the recorded temperatures were corrected; the substitution-quotient proved to be 197 for the first pupation; mean for the first thirty, 227; first maximum, 265; mean of first modal group, 283; second maximum, 441; mean of second modal group, 443; mean of third modal group, 725; mean of last group to first blank day, 758. The figures are quite close to those predicted from the constant-temperature experiments. It was not possible to check over other years, as hygrothermograph records were wanting.

TABLE XXIV. *Hibernated larvae at approximately constant temperature, 1918.*

Designation.	No. of individuals.	Larval life in days.	Mean temperature.	Mean humidity.	Maximum temperature.	Minimum temperature.	Maximum humidity.	Minimum humidity.	Evaporation in cc. per day.	Date		Lot
										Begun.	Last pupae.	
NDa	3	13	95	35	95	95	35	33	22.7	2/14	2/26	V
NMa	2	12.5	95	52	95	95	52	52	12.1	2/14	2/28	V
NWa	2	12.25	95	65	95	95	65	65	10.9	2/14	2/26	V
NNva	14	13.2	95	30	95	95	30	30	+0	3/23	4/15	I
NW	4	11.2	95	65	95	95	65	65	27	3/25	4/5	V
Vnv*	13	26.0	49.1	99	57	44	100	98	0+	4/1	5/9	V
HIDa	1	25	52.7	50	53	50	55	45	5.5	4/2	......	IV
HNV	3	39.7	52.6	97	53	50	99	95	....	4/2	5/12	IV
HMa	7	48.0	52.7	50	53	50	60	45	8.5	4/2	6/1	IV
HWa	1	39.0	52.7	90	53	50	100	80	9.9	4/2	5/11	IV
KM	2	16.5	61.7	75	62	59	80	70	3.0	4/2	4/22	IV
MM	3	8.1	90.0	44	92	88	60	40	0+	4/2	4/13	IV
MAD	2	9.2	90.0	60	92	88	70	50	7.1	4/2	4/15	IV
MN	4	7.0	90.0	95	92	88	99	92	0+	4/2	4/11	
KD	14	19.3	62	60	63	60	65	55	4.0	4/6	5/15	IV
KW	21	17.2	62	95	63	60	100	90	2.9	4/6	5/7	IV
HD	18	50	53	60	53	51	65	55	36.7	4/11	6/12	III
LD	28	21	60.4	60	62	58	65	55	3.3	4/11	5/30	V
AD	31	15.5	69.5	50	72	68	55	45	7.0	4/11	5/23	V
AM	29	14.6	69.5	60	72	68	65	55	4.4	4/11	5/15	V
AW	37	14.6	69.5	70	72	68	75	65	4.4	4/11	5/11	V

Air flow was 8 mm. per sec. for all cages except AW, which was 10.

In working over these data, a new method was devised. The weather data were plotted on the chart only once; and the sum and mean were determined for temperature, humidity, and velocity from January 1st to May 20th, when the last larva pupated. The data were carried forward from day to day in tabular form. This saves time, but the other method with overlapping of plotting on the charts, generally has the advantage of showing the distribution of the two-hour readings associated with the various groups.

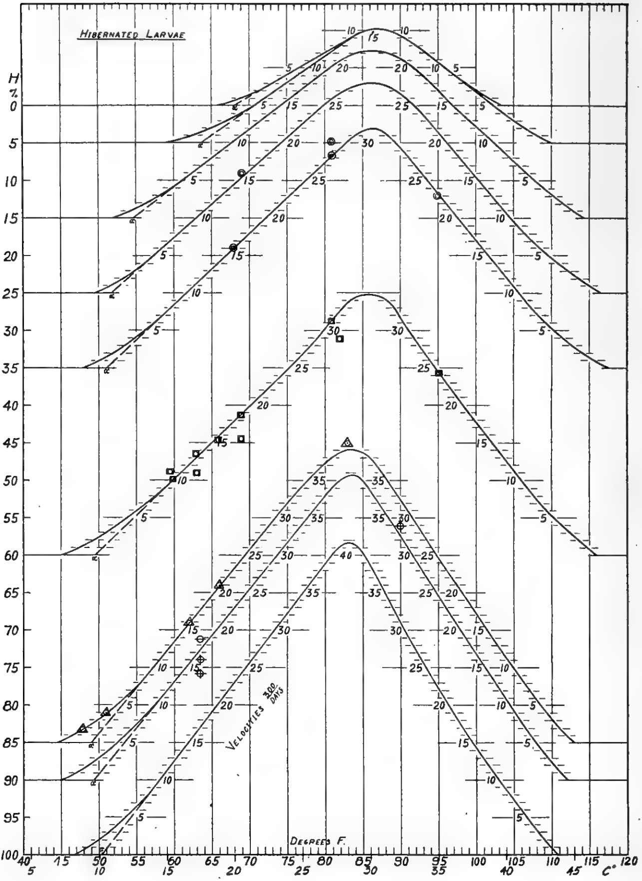

Fig. 26. Showing the data and velocity curves for the "prepupal" period of hibernating larvae. See Figs. 13 and 14 and explanations in text.

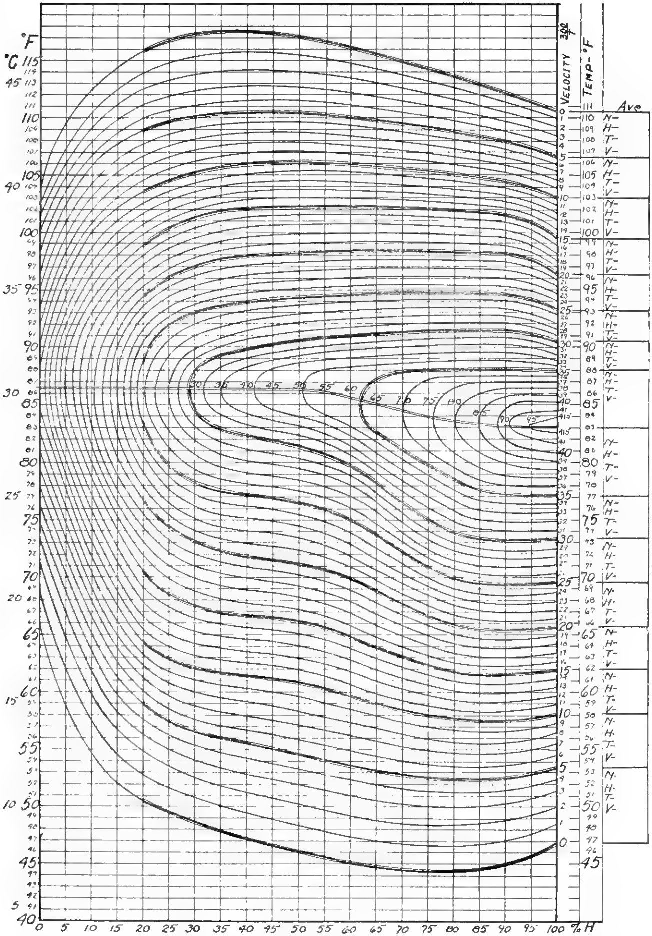

Fig. 27. Trial "prepupal" velocity chart for hibernating larvae (See explanations of Figs. 13 and 14.) The velocities must be multiplied by 1.125. (See p. 416.)

The sum of developmental units for the period January 1 to April 13 in 1916 amounted to 4,992 (after multiplying each velocity value by 1.125 to bring the angle of the velocity curve to 45°). This divided by 24 gives 208 as the substitution-quotient, which is as near as can be expected to the 197 for a first checking of the two methods. This difference is not surprising, for under treatment which did not differ, larvae in one case pupated when put at 85° F. or other temperatures suitable for pupation, as early as December 19, but in other cases did not pupate until March. In general, February 1st seems too early for most larvae.

TABLE XXV. *Hibernated larvae at approximately constant temperature, 1918 (continued).*

Air flow was 8 mm. per sec. for all cages.

Designation.	No. of individuals.	Larval life in days.	Mean temperature.	Mean humidity.	Maximum temperature.	Minimum temperature.	Maximum humidity.	Minimum humidity.	Evaporation in cc. per day.	Date		Lot
										Begun.	Last pupae.	
LM	29	18.3	60.2	75	62	58	80	70	4.2	4/17	6/3	V
LW	18	23.0	60.2	55	62	58	60	50	0.7	4/17	5/8	—
NDc	4	7.25	95	35	95	95	35	35	38	4/17	4/26	IV
NMc	2	6	95	50	95	95	50	50	19	4/17	4/24	II
NWc	14	8.7	95	65	95	95	65	65	13	4/17	4/29	V
NNV	13	8.4	95	95	95	95	95	95	......	4/17	4/30	V
M(A)D	6	13.4	90.5	30	92	88	40	20	8.0	4/18*	5/6	IV
MD	5	8.8	90.5	40	92	88	50	35	11.6	4/19*	5/1	IV
WW	10	10.6	90.5	52	92	88	60	45	4.1	4/19*	5/6	IV
ANcDk	8	15.7	90.8	60	92	88	65	55	16	4/23	5/16	—
HHung	9	9.4	54.3	60	56	52	65	55	33	4/25	5/19	III
HMb	7	7.0	54.3	50	56	52	50	50	6.0	4/25	5/10	III
HW	3	12.3	54.3	90	56	52	100	80	6.0	4/25	5/15	III
HIW	4	5.8	54.3	70	56	52	75	65	5.0	4/25	5/5	III
ID	6	4.5	54.3	50	64	52	50	45	5.8	4/25	5/9	III
HID	3	3.3	54.3	60	64	52	65	55	3.4	4/25	5/2	III
Vv	1	42	48.8	98	53	48	100	95	5.4	4/25	6/6	III
VSh.	19	4	49.0	56	42	60	90	60	......	4/25	5/20	III
VTP	1	1	48	90	54	42	90	90	......	4/26	4/28	V
MAD	19	8.6	91.3	29	92	89	35	20	15.3	....	......	
MD	8	8.4	91.3	37	92	89	40	30	11.7	4/27	5/8	IV
MM	12	10.3	91.3	44	92	89	50	40	9	4/27*	5/12	?
MW	11	9.0	91.3	51	92	89	55	45	7.4	4/27*	5/11	IV
MNv	11	8.0	91.3	95	92	89	100	90	0+	4/28	5/11	?
MWW	17	9.5	91	85	92	90	90	80	......	5/1	5/9	IV

* Submerged.

Townsend got pupation in November in a lot of 1923–24 larvae put in suitable conditions. While they were in-door stocks, there appeared to be no tangible reason for this early pupation. Obviously, winter phenomena are not understood; and, until they are, over-wintering probably can not be put on a scientific basis.

Prediction of the First Pupation of Hibernating Larvae. Our experience with the larvae of the codling moth leads to the conclusion that hibernation is concerned with two physiological conditions: (1) the true dormant period, and (2) the "pre-pupal" period, not as yet distinguishable from the dormant period, but concerned with the changes which lead to pupation. Late autumn larvae which pupate when put at 85° F. have passed the first phase of the process. Larvae may pupate, when put under proper conditions, in November, December, January, or February, or may fail to pupate as late as February. Attention has already been called to the fact that this leaves no scientific basis for a starting date, though January 1 is about average. However, to test the relations of hibernating larvae still farther, a table showing the velocity value for each degree Fahrenheit and each 5 per cent humidity was prepared from Fig. 27. (These velocities were multiplied by 1.125, as before.) The temperature above 43° F. and the corresponding humidity on even hours were transcribed from hygro-thermograph records made by W. P. Flint near Springfield in 1918. The beginning of development was assumed to be January 1. The velocities were then written opposite the combined temperature and humidity, and the developmental units were summed to the date of the first pupation, April 4. The developmental total, from January 1 to the first pupation, was only 3312 instead of 4992 as in 1916. In Flint's Springfield records for 1918 there were no temperatures above 43° F. in January, and temperatures in subsequent months were lower than in 1916. This makes evident that progress at low temperatures takes place, or that January 1st was not the proper date for beginning the calculation for this year. Both are probable inferences, and this trial of the 1918 data confirms the conclusion that we as yet have no means of determining the date at which the larvae pass from the true dormant phase to the "pre-pupal" phase. Accordingly, the table of velocities is omitted. The velocities for average weather conditions as shown on the omitted chart, how-

TABLE XXVI. *Hibernating larvae at approximately constant temperature, 1919.*

Designation.	No. of individuals.	Days to pupation.	Mean temperature.	Mean humidity.	Maximum temperature.	Minimum temperature.	Maximum humidity.	Minimum humidity.	Evaporation in cc. per day.	Date started.	Last pupae.
Anv	3	11.6	69.4	97	71.1	68.2	100	90	0+	5/2	5/17
BNv	2	7.0	80.8	97	81.5	79.7	100	90	0+	3/22	4/4
HW	8	36.2	60.6	85	63	57	90	80	5.5	3/20	5/5
HD	3	47	61.7	63	63	59	65	60	7.7	3/20	5/21
HDR	5	47	61.7	63	63	59	65	60	8.5	3/20	5/4
LD	1	30	66.1	57	67	65	70	50	3.0	3/24	4/24
LW	6	15.6	65.7	86	66.5	65	90	80	10.7	3/24	4/12
MD	0	....	90.1	35	91.0	89	38	20	36.0	3/20	....
MW	10	10.0	90.1	92	91	89	95	90	4.0	3/20	4/2
NS	2	7.0	93.6	97	94	93	100	95	0+	3/22	5/9
NW	3	9.8	95.1	70	96	93	79	60	9.0	3/22	5/4
ND	0	....	95.1	25	96	93	33	16	21.0	3/22	....
RRT	0	....	53.9	97	54	51	100	90	0+	2/15	....
RLRWn	0	....	52.2	97	53	51	100	90	0+	2/15	....
RD	0	....	52.2	40	53	51	44	35	5.3	2/15	....
RM	0	....	52.2	70	53	51	84	54	1.9	2/15	....
RW	0	....	52.2	90	53	51	94	85	0.6	2/15	....
SNV	3	12.5	88.7	96	89.6	86	100	92	0+	5/2	5/19
SW	2	12.0	85.0	85	86	84	100	80	7.0	3/20	9
SAD	0	....	85.0	50	86	84	56	34	15.0	3/20	....
SADD	0	....	85.0	40	86	84	46	25	17.0	3/24	....
TH	.....	....	81.2	70	81.5	79	72	68	15.4	3/20	4/1
TI	.....	....	81.2	70	81.5	79	72	68	12.9	3/20	3/30
TL	.....	....	81.2	70	81.5	79	72	68	8.4	3/20	4/8

Air flow 8 mm. per sec., except TH, TI, TL; these were 425, 109, 1.5, respectively.

TABLE XXVII. *Larvae at slightly varying temperatures; light effects.*

Designation.	No. of individuals.	Days to pupation.	Mean temperature.	Mean humidity.	Base temperature.	Elevation in degrees.	Base humidity.	Depression in %.	Maximum temperature.	Minimum temperature.	Maximum humidity.	Minimum humidity.	Date started.	Last pupae.
BAD	8	10.2	81.5	35	80.2	6.1	38	8	86.2	79.0	40	30	4/11	5/1
BD	36	9.9	81.5	50	80.2	6.1	54	10	86.2	79.0	56	44	4/11	5/1
BM	49	12.1	81.5	60	80.2	6.1	64	•10	86.2	79.0	68	54	4/11	4/30
BW	43	11.3	81.5	70	80.2	6.1	72	12	86.2	79.0	76	60	4/11	5/14
203*DK*	2	23.2	81.1	50	80.0	5.7	52	10	85.5	78.6	55	42	4/18	5/17
BSh*DK*	16	11.8	81.5	50	80.0	5.0	47	10	85.3	78.6	55	42	4/23	6/6
Test Pup. B	4	4.1	79.9	50	79.5	3.6	52	8	83.1	77.9	55	44	4/24	4/30
Test Pup. V	1	1	......	......	......	......	......	......	......	......	......	......	4/26	4/27
203*DK**	12	5.8	81.5	50	80	5.0	52	10	85.3	78.6	55	42	5/23	6/3
BADac	13	6.1	83.5	25	81.5	5.0	30	10	85.3	78.6	30	20	......	......
BAD	21	6.7	83.5	35	81.5	5.0	37	7	90	80.4	40	30	5/23	......
BD	12	8.3	83.5	50	81.5	5.0	52	10	90	80.4	54	42	5/23	6/6
BM	6	5.4	83.5	60	81.5	5.0	62	12	90	80.4	66	50	5/23	6/6
BW	12	7.7	83.5	70	81.5	5.0	72	18	90	80.4	75	54	5/23	6/7
BW	4	10.2	82.9	70	80.4	5.7	76	22	90.9	79.9	82	54	6/5	6/22
BWW	8	12.4	82.9	90	80.4	5.7	76	22	90.9	79.9	100	80	6/5	6/21
B*DK*	16	11.8	81.5	50	80	5.0	52	10	85.3	78.6	55	42	4/23	6/6
B*L*	7	10.7	81.5	50	80	5.0	52	10	85.3	78.6	55	42	4/23	6/8
203*L*	4	14.2	81.5	50	80	5.0	52	10	85.3	78.6	55	42	4/18	5/7
203*DK*	2	23.2	81.5	50	80	5.0	52	10	85.3	78.6	55	42	4/18	5/17
203*L*	4	9	83.5	50	80	5.0	52	10	85.3	78.6	55	42	5/23	6/6
203*DK*	13	6.1	83.5	50	80	5.0	52	10	85.3	78.6	55	42	5/23	6/3
203*DL*	8	25.4	81.5	50	80	5.0	52	10	85.3	78.6	55	42	4/18	5/29
203*B*	......	25.7	81.5	50	80	5.0	52	10	85.3	78.6	55	42	5/18	5/20
203*G*	3	29	81.5	50	80	5.0	52	10	85	78.6	55	42	4/18	5/18
203*R*	6	15.7	81.5	50	80	5.0	52	10	85.3	78.6	55	42	4/18	5/17
203*DL*	10	8.1	83.5	50	80	5.0	52	10	85.3	78.6	55	42	5/23	6/6
203*B*	6	7.1	83.5	50	80	5.0	52	10	85.3	78.6	55	42	5/23	6/1
203*G*	7	7.6	83.5	50	80	5.0	52	10	85.3	78.6	55	42	5/23	6/5
203*R*	3	4.3	83.5	50	80	5.0	52	10	85	78.6	55	42	5/23	5/28

Air velocity was 8 mm. per sec. for BAD, BD, BM, BW,BWW. It was O+ (trace) for 203DK, BShDK, Test pupae B, BDK, BL, 203L, 203DL

The evaporation for BM, BW, BAD, BD, was 7, 6 and 6.7, 10, 8.8, cc. per day respectively.

The individuals used in BAD, BD, BM, were from lot V; in BshDK, BDK, BL, from lot IV; in test pupae from lot III. (See p. 374 for history of lots mentioned.)

ever, coincide almost exactly with the velocities for the larva in the apple as derived by entirely different methods (see Table V), up to 80° F. The top of the curve for the larva in the apple is about four velocity units lower at the maximum (see broken-line peak in Fig. 24.) This is in accord with expectation, as the larva in the center of the apple would probably not be warmed to the same extent as the larva in the cocoon, during the brief period of daily maximum temperature.

(D) VELOCITIES AS AFFECTED BY FACTORS OTHER THAN TEMPERATURE AND HUMIDITY.

The foregoing considerations of the development of the codling moth have been presented with reference to temperature and humidity as if no other factors operated to modify the results. It remains to consider how other factors modify the velocity values based on temperature and humidity data. The following are known to be of importance: (1) variability of temperature and humidity, (2) rainfall which soaks the larvae or pupae, (3) wind or air movement, (4) quality and intensity of light, (5) food, (6) mechanical stimuli, (7) seasonal march of temperature and humidity.

(1.) Variability of Temperature and Humidity in Weather Conditions.

Variability of weather conditions has to be considered, first, from two view-points: (a) variation of temperature and humidity in the form of daily rhythm, as contrasted to constant temperatures; (b) rising and falling of general temperature for the day, as shown by higher or lower maxima, minima, and means, under actual weather conditions.

(a) All available data on pupae, taken together, indicate that the length of the stage under variable temperatures is approximately 7 per cent shorter than under constant temperatures, although no experiments were especially designed to verify this difference. Such experiments, to give results comparable with those under actual weather conditions, would have to include temperatures outside the straight-line limits. The crucial experiments AD and AW (Fig. 15), with temperatures varying slowly within the straight-line limits, showed the same acceleration as the weather conditions. In some exceptional experiments, however, with small numbers of individuals, when the temperature rose suddenly and dropped again within a few hours, the velocity seemed to be decreased as compared with that for the corresponding constant temperatures. Although this retarding effect was obscured by other variations in conditions, the fact deserves mention, and the exceptional data are listed here: In one case, the temperature varied 4°–10° F. during 2 hours at mid-day, being constant most of the other hours, and the velocity was decreased 9 per cent. In another case (two lots of presumably uniform material in the 1917 experiments), with a rise of 15°–20° F. at mid-day, which is of the order of magnitude of the out-door rise in our region, the velocity differed by 12 per cent as follows: in constant conditions, with temperature 69.5° and humidity 80 per cent, the pupal time was 13.1 days; in variable conditions, with mean temperature 69.5° and mean humidity 82 per cent, showing a rise of 18° F. at mid-day, the time was 14.7 days. This decrease in velocity, correlated with the sharp mid-day rise followed by a rapid return to normal, suggests acclimation, temperature regulation, or a lag in the warming of the pupal body. No experiments with a sharp fall in temperature followed by a quick return to normal have been tried.

The effect of the normal daily variations of out-door temperatures, when corrected to the velocity curve and compared to the constant-temperature results, amounts to 7–8 per cent more rapid development than that under constant temperatures, for the pupae. The egg data suggest a difference of about 7 per cent, and the larval data about 8 per cent. In every stage, development is more rapid under the normal out-door variations.

(b) The effect of rising or falling mean daily temperature is reflected in the developmental total for the pupal stage and probably also for the other stages. Fig. 28 shows rainfall, minimum and maximum temperatures, and the relative rate of development for the groups of pupae, eggs, and larvae indicated for 3 years, 1915-17. A curve drawn so as to connect the mean centers for the period covered by the thirty pupae from pupation to emergence, rises and falls with the daily temperatures, suggesting that rising temperatures retard development and falling temperatures stimulate it. This may be explained on the basis of acclimation (Jacobs '19). Presumably, the velocity of development does not increase or decrease as rapidly as temperature changes. A close inspection of Fig. 28 shows that, as a rule, when the number of rises in temperature exceeds the number of drops, the developmental total is high, and vice versa. There are some exceptions to this, but these are due to the combining of several groups that pupated on different days. Taking merely the groups that pupated on the same day, there is usually not very much difference in time; it appears that they string out when rising temperatures come at the end. The correlation in general is good, but more and detailed study will be necessary to make clear its exact meaning. Doubtless direct measurement of CO_2 given off in relation to changes of temperature would be significant. It is not clear but that phenomena such as are shown by Lehenbauer ('14) may be the cause. He found that the maximum rate in relation to temperature varies with the length of exposure.

(2.) Rainfall and Submergence in Water. (See Figs. 3 and 28.)

During the "pre-pupal" period in hibernated larvae, submergence in water appeared in some cases to have little or no effect, while in other cases it accelerated development. Townsend has shown that submergence must be frequent to have any effect. None of Glenn's larvae were submerged or exposed to rain; so, rainfall had only an indirect effect through humidity. Hibernation in dry conditions lengthens the *pupal* period. This is shown in the 1918 experiments and in Glenn's 1915 material after an unusually dry late winter and early spring. The average time was nearly

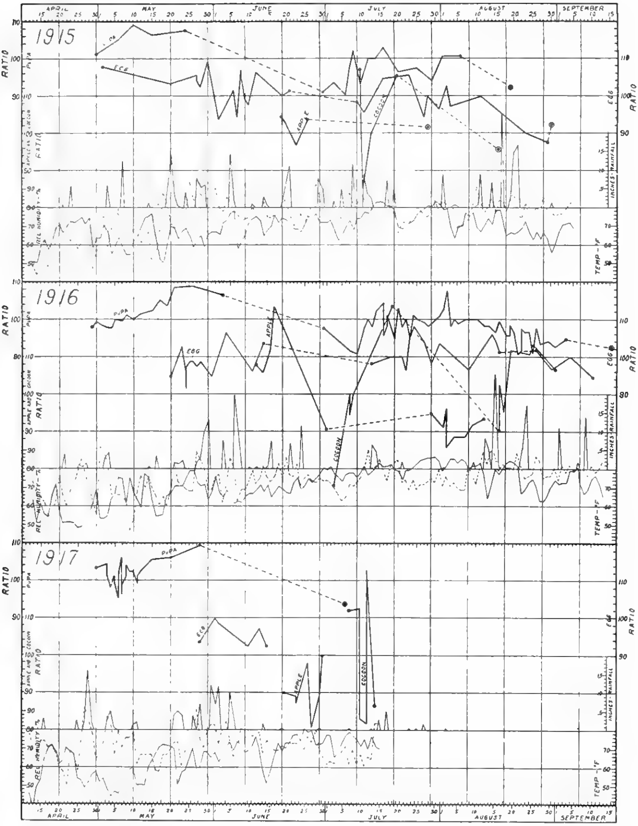

Fig. 28. Showing rainfall and mean temperature and humidity for the summer of 1915, 1916, and 1917 at Olney, Illinois. (See Table XI.) The pupa, egg, apple, and cocoon curves are plotted with reference to a standard or average time as follows:—The standard or average is plotted as 100; pupal scale, upper left; egg scale, middle right; apple and cocoon scale, lower left. The data are plotted on the median date of the first and last occurrence in each group of 30 pupae, 50 eggs, and 10 larvae in the apple and in the cocoon, a dot marking the first and the last dates of each series. Correlations of time (length of stages) with rainfall and rising and falling temperatures are indicated.

a day longer when the temperature remained the same or when, if different, it was reduced to the same velocity value. Heavy rainfall lengthens time in the apple (Fig. 28). Little or no rainfall shortens it.

(3.) Air Movement and Evaporation.

A large series of larvae were subject to various rates of evaporation measured by the porous cup atmometer. Mortality was high, and complete losses in certain evaporation rates rendered some sets useless. The excellent success attending the use of the porous cup atmometer with plant work has not attended our efforts. The reason for this is that higher temperature, which accelerates development, increases evaporation; while increased rainfall and humidity, which accelerate development, decrease evaporation. Although high mortality and failure to pupate render conclusions uncertain, the relative number of individuals emerging and the length of their pupal life may be taken as some evidence of the effects of evaporation when other conditions are considered. Accordingly, the data are shown: In 1917, temperature 79°, humidity 75 per cent, evaporation 4.3 cc. per day seemed most favorable. In 1918, temperature 58°, humidity 60 per cent, evaporation 30 cc. per day seemed most favorable. In 1919, first generation, temperature 80.2°, humidity 70 per cent, evaporation 8.4 (lowest) cc. per day seemed most favorable. In 1919, second generation, results were contradictory. In 1920 first results were contradictory, due to mortality. In 1920, one set, the shortest time was with 66.8 cc. evaporation, but this also showed the greatest failure to pupate. The 1920 second generation showed temperature 82°, humidity 77 per cent, evaporation 28.5 cc. to be best on the whole, although one rate was higher and four were lower. It appears that higher failure to pupate and higher mortality are accompanied by *shortest pupal life* under conditions of very rapid evaporation.

TABLE XXVIII. *Showing the emergence of moths from hibernated larvae (1920-21).*

All were kept at the same temperature during hibernation (37-48°) until March 15th, when the temperature was raised to 73.5° F.

	Soaked Humidity 100%				Dry Humidity 90%	
Collected.	Sept. 15.		Sept. 28.		Sept. 28.	
No. Spinnings	No.	Time	No.	Time	No.	Time
1(	(41	29.5	4	26.4	8	30.9
(	(53	30.6	4	26.4	8	30.9
2(	(75	28.7	40	27.7	56	28.0
(	(89	31.1	42	28.2	60	28.8
3(	(81	26.4	3	23.7	28	26.9
(	(81	26.4	3	23.7	29	27.3

(4.) Quality and Intensity of Light.

(a). *Intensity.* As compared with diffused daylight, the length of the pupal stage is longest in the dark. This is uniformly true in our experiments. Isely and Ackerman ('23) have shown that light checks egg-laying of the codling moth, and that temperatures above 62° after sundown are essential to laying.

(b). *Color.* A series of experiments on color gave inconsistent results. Red, blue, and green were less favorable, in all cases, than darkness or Mazda lamp light through daylight glass. See Table XIIIg (p. 372).

(5.) Food.

It is a well-known fact that the larvae develop in picked apples more quickly than in apples on the tree and in some varieties of apples than in others, but no analysis of the cause has been made. (See Glenn '22.)

(6.) Mechanical Stimuli and Number of Spinnings.

Some investigators have maintained that the time to pupation is increased by the number of spinnings and the large amount of mechanical stimulation due to opening the cocoons several times for observations. The results shown in Table XXVIII are on larvae that had spun one, two, or three times in the fall, but were not disturbed in the spring. The second item includes all that came through, while the first is only to May 20.

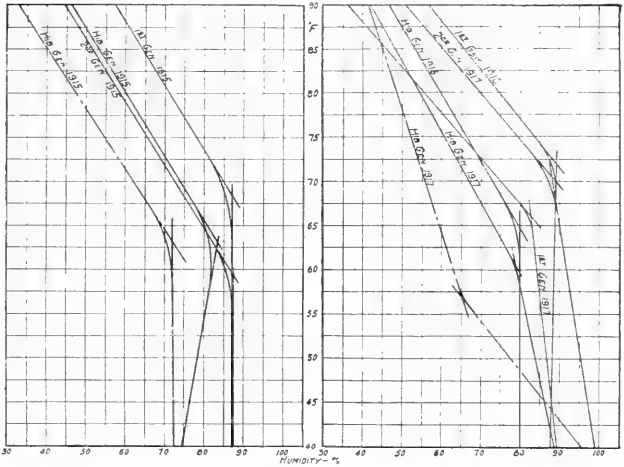

Fig. 29. The average daily march of temperature and humidity 1915-17 at Olney.

If number of spinnings has any effect, the evidence indicates that it decreases the length of stages. In an experiment in 1920 there was no difference in the length of pupal life related to number of spinnings. A decrease in time might be inferred from Bishop's ('23) work on the honeybee larva. In the codling moth, it may be assumed that the increased acidity due to several spinnings helped to complete processes which are essential to rapid development, and which take place over a long period.

(7.) Seasonal March of Temperature and Humidity.

Fig. 29 shows the average daily variation of temperature and humidity for the different generations at Olney. The curves are roughly drawn through the plotted records of temperature and humidity as shown in Fig. 17, and they represent the conditions encountered by several sets of pupae. Although slightly different from the curves which would result from the use of data unselected from a biological point of view, they serve to indicate the marked difference between different seasons and thus emphasize the reason for taking humidity into account.

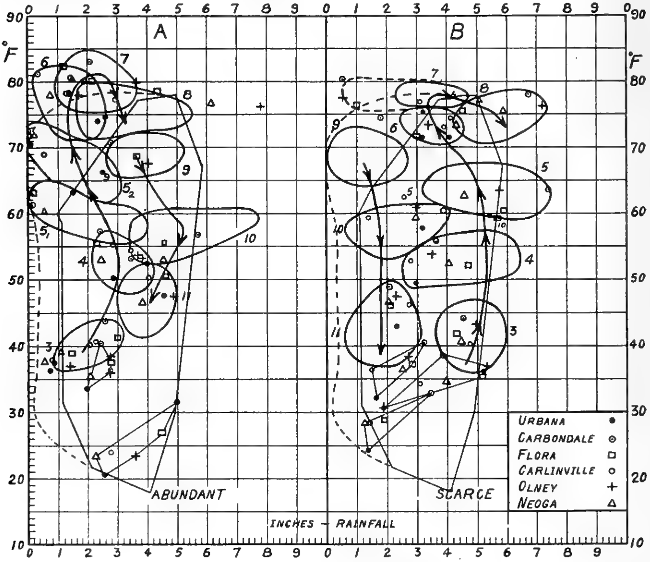

Fig. 30. Ball-Taylor diagrams and hythergraph of scarce and abundant codling-moth years in Southern Illinois localities.

Experiments on combinations of temperature and humidity, where the series is limited, should follow the general trend of the weather of the region and of the season to be studied. This plan will save much time and unnecessary experimentation, provided hygro-thermograph records have been kept; otherwise, some means of using vapor-pressure tables will have to be devised. The changes in humidity do not follow the trend shown by air warmed by other means.

Fig. 30 shows complete data for the Ball-Taylor rainfall-temperature charts, or hythergraphs, for "abundant" and "scarce" years at six localities, with the amount of variation. The conclusions from this study have already been expressed in PART TWO, pp. 350-355, where the parts are shown separately in Fig. 3-7.

Hythergraphs form a basis for interesting speculation as to the original home of the codling moth. The heavy line in Fig. 31 shows the average monthly temperature and rainfall for a typical year in three apple-growing districts in south-eastern Europe. The large area (enclosed by the solid line) in each part of the figure indicates the limits of average data for all the great apple-

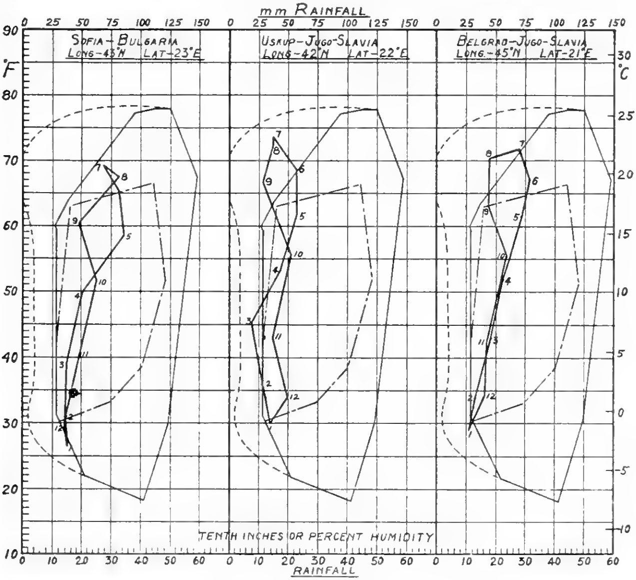

Fig. 31. Hythergraphs for apple-growing regions.

growing regions of the world* except the irrigated districts of the western part of the United States, which are shown by the extension of this large area by dotted lines at the left. The inner area (enclosed by the dot-dash line) in each part of the figure indicates the limits of average data for European countries alone, which may be considered as the most favorable conditions because extremes of temperature and rainfall are thus excluded. The Sophia data fall generally within these medial conditions; while the data for the other two localities, which are at a higher altitude, do not. It is probable that a complete analysis of the climatic relations of the apple and the codling moth would help to settle the question of the origin of the moth. On the hypothesis that this origin was in the territory around the eastern Mediterranean, where conditions fall within the small area shown in Fig. 31, the difference between a "scarce" and an "abundant" year in Illinois is explicable. Since the hythergraph for southern Illinois does not always fall entirely within this area of favorable conditions, both winter and summer temperatures sometimes reaching extremes, the codling moth is abundant here only in years when these general limits are not exceeded. At least, the important effects of autumn and winter rainfall, as pointed out in this paper, suggest the Mediterranean region as the original habitat of the codling moth.

(E) EXPERIMENTAL METHODS.

In the experiments reported in this paper many important innovations were employed, especially in the controlling and recording of variable conditions of temperature, humidity, air movement, and evaporation. Most experimental work has formerly been done with constant temperatures. We know of no other attempts to use variable temperatures of an interpretable type, with factors all recorded, as a means of bridging the gap between constant-temperature experiments and actual weather conditions. The chambers for constant-temperature work are unique in that they allow the use of several humidities at the same temperature. This feature is essential, because variation in stock necessitates the running of a large series started at the same time from the same stock. This is a very important feature for climate-simulation work.

A. General Equipment.

1. *Building.* This work was done in the Vivarium of the University of Illinois. The greater part of the work was carried on in a glass-roofed house of greenhouse construction. The room was provided with center-roof and side ventilators, and a door at the end. To facilitate air circulation, three fans were placed on the bottom of the side ventilator on the south. The room was heated by steam radiators regulated by a Johnson automatic temperature control, as described by Harding and Willard ('16).

2. *Apparatus.* The constant-temperature experiments were conducted with the apparatus regularly used in the Vivarium, which will be

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* The following countries were included in this category: Great Britain, Spain, France, Germany, Denmark, Australia, Tasmania, Canada, and the United States.

described in a forthcoming book.* The apparatus for variable-temperature-experiments consisted of five chambers of a type shown in perspective in Fig. 32. The three smaller chambers (C, D, and E), which were 25½ inches long by 20¾ inches wide by 42 inches high, were designed first; when found to be too small, they were supplemented by two other chambers (F and G), which were 39 inches by 20 inches by 48 inches. These smaller chambers were of two kinds: two, (C and D), with glass slides; ane one, (E), with opaque sides. The water tank above chamber D was provided with a glass bottom and glass sides so as to admit skylight through the water. Water from the general supply flowed in through the tank and out through a waste pipe so as to maintain a water level two inches below the top of the water tank. This made it possible to control the supply of cold running water to keep down the temperature of the main chamber on hot summer days. The main chamber was provided with a wooden shelf, as shown in Fig. 32, leaving an opening from below the shelf up into the main body of the chamber when the door was closed. The coils which turned on the heat during the night were under this shelf (ordinarily the sun caused the temperature to rise to about 100° F. on summer days). To ventilate the cages, the chamber was supplied with humidified air from a compression tank. The wall of the chamber contained four small pipes ending in a slender hose-end on the inside and in a small (⅛-inch) cock on the outside, for the purpose of conducting the atmometer leads, or suction leads, through the wall. The dark chamber (E) was of the same size as the glass-sided chamber and was provided with the water tank above, but received the light only from above, and was intended to demonstrate the effects of light under the same temperature conditions. Difficulty was usually experienced in maintaining a temperature similar to that in the other chambers, which tended to rise higher during the day. The same mean temperature, however, was obtained in this chamber as in the others, although it was done by raising the minimum during the period of the night instead of by raising the maximum at mid-day.

The humidifying device which treated the air supplied to these chambers, is shown in Fig. 33, consisted of a galvanized-iron cylinder so constructed as to stand pressure of from five to ten pounds. Air at reduced pressure entered this cylinder at the right. In the top of this cylinder was a Schutte-Koerting head which sprayed cold water into the space through which the air passed, so as to nearly saturate the air at the temperature of the water, which was about 16° C. during the summer months. The surplus water from the humidifying chamber flowed out through a ball-float cock (steam trap—Harding and Willard, '16, p. 214). The air passed over the galvanized-iron cylinder through a condensation separator, which removed any water. This humidifying process supplied air nearly saturated at the temperature of the running water, and the humidity for any temperature above or below this could readily be calculated. This

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* Experimental Animal Ecology, to be published in 1927 by Williams & Wilkins Co., Baltimore, Md.

was experimentally ascertained for a period of several weeks in July, 1919, by allowing the air after leaving the humidifier to pass through a hood which was slipped over the sensitive parts of a Friez hygro-thermograph. The air was passed through a block tin pipe coil surrounding the temperature-sensitive part, before passing into the hood entrance. This apparatus then recorded the temperature and the humidity of this air

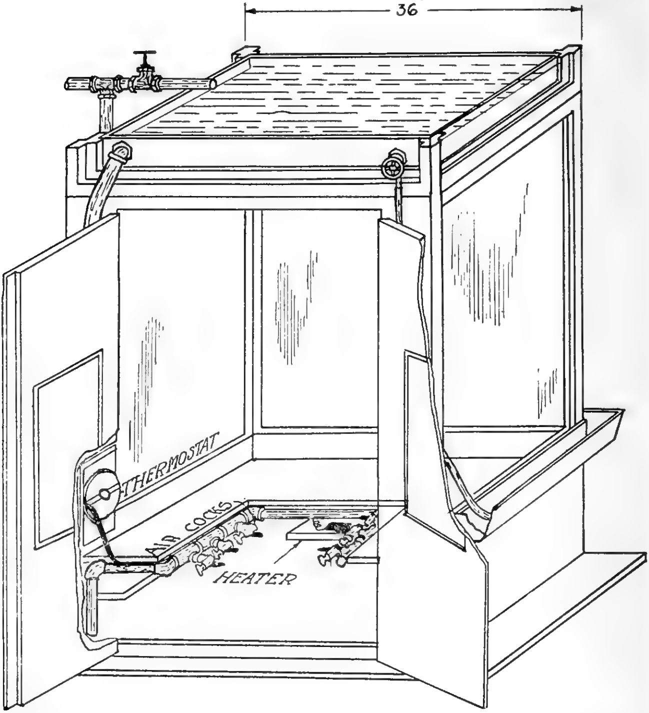

Fig. 32. Showing the unit F for simulating daily rhythm, (U. I. V.). Cooling water tank at the top with high drain at the left and siphon valve at the right to remove all water in cleaning. The C-shaped shelf, air cocks, and one thermostat with heater also appear in the drawing.

when raised to a given degree above the temperature of the water. These results indicated that the air was generally above 90% of saturation, so that the calculations on that basis were approximately correct.

Compressed-Air Supply. Air was supplied at a pressure of 60–80 pounds through pipes from a large piston compressor at the University power-house, about 200 yards from the Vivarium. It appeared to be satisfactory air, although doubtless a better supply should be sought for very refined work. It contained nothing which could be injurious, except a rather large amount of carbon dioxide in some samples. There was a slight odor from the oil used in the pump, which was decomposed under pressure. This odor was not present when the best grade of oil was used, and particularly in the summer time when a large amount of air was drawn. For nearly all of the work the pressure was reduced to 3–5 pounds, the reduction being accomplished by a Mason pressure-reducing valve. This valve has an advantage over others which have come to our attention, as it gives practically constant pressure regardless of fluctuations in the initial pressure and in the rate of flow through the valve.

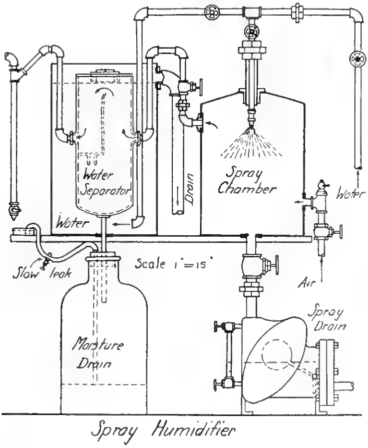

Fig. 33. Showing an assembled spray humidifier (N. H. S.). Air comes into contact with finely divided water at a low temperature in the spray chamber and passes to the separator where any droplets of water are removed by baffles.

B. Measurement of Temperature, Humidity, and Air Movement.

Most of the earlier temperature records were made with standard thermographs placed adjacent to the bottles containing the codling moths or placed in the cages containing insects inhabiting plants. In the latter work a Leeds and Northrup resistance thermometer recorder, carrying ten resistance thermometers, was used. These thermometers are approximately 1 by 8 cm. and can be inserted into small cavities or places in soil or in the branches of a food plant. They are by far the most accurate of all thermometers on the market, being correct to 0.2° (the unavoidable error is due to shifting of the paper). This recorder, furthermore, has the great advantage of eliminating the difficulty which results from having the thermometer in one place and the animals in another with a degree or two difference in temperature, as is usually the case. Where thermographs were used an effort was made to eliminate this difficulty by taking regular readings of a mercury thermometer.

Humidity was recorded by Friez hygrographs (human hair type) which were checked weekly with a sling, or by daily readings of wet and dry bulb thermometers enclosed in a tube.

Evaporation was measured by the Livingston atmometer. The rate of air flow was measured by use of the diaphragm chambers and Ellison gage (Hamilton '17). The flows are readily measured by this method, but it offers no adequate means of maintaining the flow as constant. In practice, flows were set principally by the use of screw compression clamps on rubber hose. In some cases, mercury valves were installed, which consisted merely of a U-tube containing a small amount of mercury. A slight rise in pressure would push the mercury around in the U-tube and allow some air to bubble out. Generally, the flows were simply set by the compression cock at intervals of a few days, and the mean of the readings taken as indicating the rate of flow.

Instrument records. The record sheets from the thermograph and hygrothermograph, except where temperatures were practically constant, and in many cases where they were not, were treated according to a definite routine plan. The means for each two hours of the day were first determined by inspection, a clerk being employed to write with a lead pencil the mean number of degrees and the mean per cent of humidity for the two hours in the proper space immediately below the graphs. Each sheet was then checked by another clerk, corrected if any mistakes were found, and returned for inking. The person doing the checking often did the inking, so that the presence of the two-hour means in ink indicated that the work had been checked over by a second person. The sheets were then gone over a second time and means for half-days computed. These half-days were taken as from eight to eight, and the mean was composed of the sum of six two-hour means. These were then written on the sheets in lead pencil with the eight o'clock hours indicated by vertical lines. The period from eight to eight was taken because in the variable temperatures the temperature begins to rise at eight A. M., reaches a maximum about two P. M., and falls during the following six hours to a point near the average for the night. We made our observations the first thing in the morning and the last thing in the evening, usually beginning at eight or earlier, and ending as late as six or six-thirty, and sometimes seven, in the evening, when the experiments were gone over twice a day. While carrying with it the possibility of a very slight error in the total temperatures, any phenomenon occurring so as to be first noted in the morning observation was recorded as having taken place at 8:00 A. M. Any phenomenon noted in the afternoon observation was recorded as having taken place at 8:00 P. M. With this division of mean temperatures for half days, it was easily possible to compute the means for any number of days with an adding machine, as a one-week period would contain only fourteen items. The humidities were treated in a similar fashion. The accounting was greatly simplified by this routine clerical work, which proved to be on the whole very satisfactory, although done by students who were paid very little.

In experiments with very variable temperature, the sheets were given a third type of inspection. The daily temperature and humidity curves were inspected, and notation was made of the night humidity and the night temperature, which under most of our experimental conditions was intentionally kept at a constant level. The hour at which this low level was ordinarily reached in the evening and at which the temperature began to rise in the morning was noted, and this temperature was called the base temperature, as under the experimental conditions and often under outdoor conditions the points marking this low level approach a straight line. This base temperature had a corresponding base humidity. The base temperature for each day was then noted by inspection and recorded on a separate sheet, together with the absolute maximum and absolute minimum and the amount of elevation above the base for each day. In Tables XVIII, XIX, and XXVII these data are presented in full, for they proved to be significant criteria of the climatic factors influencing the rate of development.

Standard Atmometers. The atmometer used was the Livingston porous cup atmometer, obtained from the Plant World, Tucson, Arizona. The standardized cups ordinarily obtained, after use ranging from one to three months, depending upon air conditions, were standardized. For this purpose a wheel having a diameter of 38 inches was fastened in a horizontal position on a table and turned at the rate of approximately one revolution per second by a belt from a ½ h. p. motor making 1,200 R. P. M. The upper side of the wheel bore twelve upright posts, giving it a capacity of twenty-four atmometers at one time, although only twelve were commonly run at a time. These were standardized against a fresh atmometer, and then scoured, emeried, and re-standardized, and used until the standard fell to 0.50 or rose to 1.00, after which they were used as irrigators in the chinch-bug work. It was desirable to have this piece of apparatus on account of the large number of atmometers installed.

The device cost only $50, but it required some supervision, as it was made too large throughout. At the present time it would be cheaper to purchase the standardized turn-table direct from the Plant World, all ready to use, but of a smaller size.

C. Special Methods.

Special methods and special equipment will be discussed here. The larvae studied were placed in corrugated papers with celluloid covers and backed up by small pieces of wood, after the manner used by Mr. Glenn. In fact, we secured some of his observation cases and merely selected a container which would hold them, modifying them only slightly (Fig. 34). The sticks used were 4 inches (10 cm) long and one inch (2.5 cm) wide. The celluloid covers were supported by wood 2–2.5 mm thick, allowing a space between the celluloid and the wood back. We mounted the back of the piece of wood in order to make two of them approach a cylindrical form. Two were commonly placed face to face, and when only one was used it was provided with a dummy front piece of wood without the pasteboard. The bottles used for most of the experiments were of 250 cc capacity with an inside diameter of about 2¼ inches (56 mm) and an outside diameter of a little less than 2½ inches (61 mm). A pair of sticks with their larvae were dropped into a bottle and the two taken together made an elliptical cylinder with a diameter of one inch by ⅞ inch. Each one of these bottles was provided with a two-hole rubber stopper. Air was introduced through a tube inserted into one of these holes in the rubber stopper, the tube ending at the lower edge of the stopper, and air left the bottle through a tube extending to the bottom. Thus the tube extending to the bottom tended to push the elliptical cylinder to one side and it rested immediately beneath the incoming air which flowed down over the larvae container to the bottom and out. Leaving the bottle, the air was conducted through a small tube into another bottle of the same kind, from which the bottom had been removed by a skilled glass-worker. This bottle rested over a Livingston porous cup atmometer, which is a little more than one inch in diameter and just a little larger than the bottle used as a larvae-container. Thus the apparatus for experimentation was so arranged that the air flowed through the bottle and then over the atmometer at approximately the same rate at which the evaporation was measured. These containers were mounted on pieces of board about 3 inches by 6 inches (7.5 cm by 15 cm). See Fig. 34. The bottle containing the larvae rested on the board and was held in place by three or four slender nails driven into the board. The atmometer, with the recording attachment at its lower end, was supported on a piece of soft aluminum tubing, ⅛ inch inside diameter, bent into the form of an elbow, inserted through a flat stopper, a channel being cut in the lower side so that one arm of the aluminum tubing rested in this, flush with the underside. This was nailed to the end of the board opposite to that to which the bottle was placed. Above this three corks 1½ inch (3.7 cm) by approximately one inch (2½ cm) in diameter were placed on the edge of the large flat cork and fastened there with long slender nails so that the circumference was divided into three.

Additional slender nails were shoved into the top of this cork to hold the bottomless bottle in position over the atmometer. In this manner, units for measuring evaporation and controlling the conditions of the air surrounding the larvae were made up in numbers and used in all experiments in which the rate of evaporation is given. A number of experiments were made with larvae in the celluloid-fronted cases already described. When a saturated atmosphere was desired, they were dropped into a bottle which contained an open vial of distilled water. Evapora-

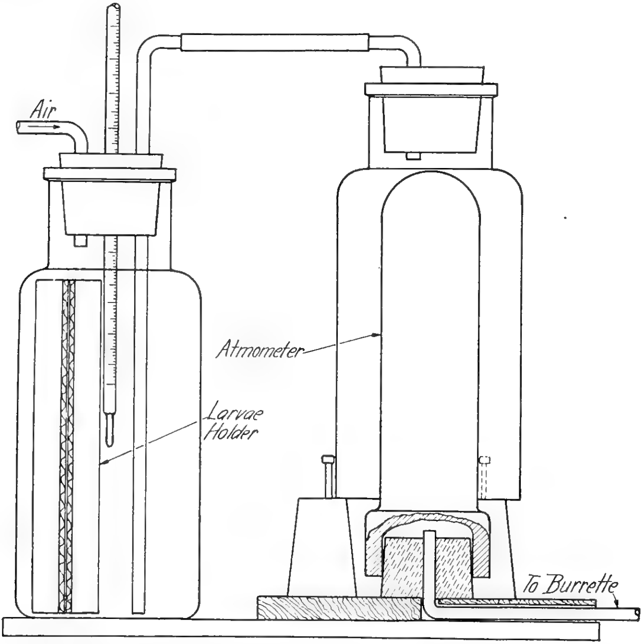

Fig. 34. Showing the arrangement of the bottle, thermometer, larva holder, and atmometer used in the experiments on the codling-moth larvae and pupae. In some cases egg-bearing leaves were fastened to the larva containers.

tion from this water made a practical saturation, as indicated by the almost continual presence of condensation on the walls. Experiments of this type were not ventilated. The rate of flow of air through the experimental bottles was determined by the use of the Ellison differential gage and diaphragm chambers. A 2 mm. aperture and 5 mm. reading were used in the standard experiments, but the rate of air flow was not checked up as closely as it should have been in the earlier experiments, because various difficulties with the equipment rendered it impracticable to make frequent measurements. This commonly gave a flow of a little more than one mm. per second through the bottle. A series of variable-temperature experiments was run with paired larval containers simply placed out of doors, or in a greenhouse, or in the experimental case where various chinch-bug experiments were being made and many data were being reported. The experiments with light were made with single containers under conditions as described on p. 427 Table XIIIg (p. 372).

D. Recording of Data.

Records of experimental work were copied on large sheets, legal size, 8½ by 14, printed with a special heading bearing the name of the survey and calling for the name of the observer in the upper right hand corner, with experiment number, date, and species immediately below this; while at the right of the center were the words "Subject of Experiments." Below this was the description of apparatus, and a line calling for notes on light and temperatures, together with previous history and condition of the stock. The lower 11 inches of this paper was ruled horizontally at quarter-inch intervals, with 21 vertical rulings at ⅜-inch intervals, and leaving a square space of one-half inch at each margin. Down the center of the page was a double blue ruling, which constituted one of the equidistant sets, and, on each side of this, three red rulings, which constituted three of the equidistant sets. This type of paper was found to be particularly useful where a large number of individuals had to be checked up, as the numbers were put at the heads of the vertical columns and the dates in the left-hand margins, the checkings in each square to show the condition of the individuals from day to day. The upper left-hand corner of this paper was clear of printing or writing for the equivalent of a triangle with its sides three inches. This left a space in which no writing was ever placed, which made easy the fastening together of the sheets with various types of clips without interfering with the writing of the notes. These were got up for the current experiments and placed on legal size board clips, which the investigator carried about with him as he observed the conditions of the experiments from day to day. The different chambers in which these experiments were going on were lettered, beginning with the large constant-temperature rooms, which were lettered A and B; then the variable units, lettered C, D, E, F, and G, as already noted; then the smaller units inside the constant-temperature rooms, lettered H, I, L, and V (the intervening letters having been used for temporarily installed incubators during the series of experiments in which they were so designated). With the maximum amount of experimental work going on, the entire alphabet was used in designating chambers and places in which animals were kept; and some such plan is needed for convenience of records and conversation with assistants and caretakers. When once adopted, these letters were allowed to stand in subsequent years for all the permanent pieces of the equipment. (For the meanings of other alphabetical designations, see p. 363.)

The records of the codling moth work were kept on the special ruled paper already mentioned, the heading being proportionally filled out; and the numbers were inserted on the celluloid above the individual larvae and corresponding numbers at the heads of the long columns on the experimental sheet. When the observer looked over the experiments morning and evening, he recorded the condition of each individual, as follows: A small check indicated that the larvae were present and alive; the letter P indicated that the larvae had pupated; E, that adults had emerged; D, that larvae had died; M, that they were missing; and K, that they were accidentally killed. The use of the check mark was very desirable, ordinarily, to indicate that the animal was actually observed, because later on, if there had been no such record kept, or if something new had occurred, one might otherwise wonder whether he had actually looked at it or not. The check marks avoided this form of doubt in working over the results. In counting the days which elapsed from the time of pupation to the time of emergence or any other period, clerks were first put to work ruling the sheets into days, where the observations were made twice a day, which was the case in all except the low temperatures. They were warned especially to look out for any irregularities of times when observations had been missed, as was sometimes necessary, particularly with the heavy program, and in some of the lower temperatures where little progress was made, which were ordinarily looked over twice a day. These clerks drew a horizontal red line across the paper, separating the days; then, starting with the data of pupation, for example, they checked each corresponding reading. Thus, if the pupation occurred in the forenoon, they checked each subsequent forenoon reading; if in the afternoon, each subsequent afternoon reading. All readings were checked to the first. At the same time, the clerks counted the number of days from the time of pupation until the time of emergence, or whatever other phenomenon was being observed; and the number of days which had elapsed was written at the bottom of the column or at the end of the record of the particular individual. This made it possible for any person to rapidly check the work of the clerks, who were found to have carried out this plan with a great deal of precision, having rarely made any errors.

SUMMARY OF CONCLUSIONS.

(1) Temperatures cannot be summed correctly for biological purposes unless readings are taken at intervals of one or two hours instead of daily and corrected for the effects of other conditions besides temperature so as to fit the true curve for velocity of development. Such correction, here called the *temperature-substitution* method, is possible only through preliminary experimentation or observation affording temperature and humidity data for the defining of *standard conditions.*

(2) The temperature-substitution method, when correctly used, translates the observed conditions into terms of the response of the organism, that is, into *developmental units,* which can be summed for biological purposes.

(3) The use of a *normal total* of developmental units for a stage in the life-cycle of an organism makes possible the calculation of *standard average time* for the stage. This permits estimation of the amount of individual variation in any given case and the effects of factors other than temperature and humidity which make the developmental total larger or smaller than normal.

(4) Autumn and winter rainfall influence the time of first pupation in spring and the length of the pupal stage.

(5) Ball-Taylor rainfall-temperature diagrams (hythergraphs) show characteristic differences between years when the codling moth is abundant and years when it is scarce.

(6) Rainfall influences the time which the larva spends in the apple and probably the length of other stages.

(7) The falling of the mean temperature from day to day in late summer is correlated with increased rate of development; the rising of the mean temperature from day to day in spring is correlated with decreased rate of development.

(8) The falling of mean temperatures, or at least minimum temperatures, has no apparent effect on the initiation of hibernation.

(9) The explanation of hibernation phenomena is probably to be sought in the activity of enzymes.

(10) There is no reliable basis for predicting the time of the first spring pupation.

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BIBLIOGRAPHY.

Apstein, C.
1909. Die Bestimmung des Alters pelagisch lebender Fischeier. Mitt. d. Deutschen Seefischerei-Vereins, 25: 364-73.
1911. Die Verbreitung der pelagischen Fisheier und larven in der Beltsee und den angrenzenden Meeresteilen. Wissensch. Meeresunters, N. F., Kiel, 13: 227-280.

Babcock, S. M.
1912. Metabolic Water: its Production and Role in Vital Phenomena. Research Bull. 22, Univ. Wis. Agr. Exper. Sta.

Bachmetjew, P.
1907. Experimentelle Entomologische Studien, Bd. II., Sophia.

Ball, J.
1910. Climatological Diagrams. The Scientific Journal, Cairo, Vol. IV, No. 50.

Baumberger, J. P.
1914 Studies of the Longevity of Insects. Ann. Ent. Soc. Am. 7: 323-353.
1917. Hibernation a Periodic Phenomenon. Ann. Ent. Soc. Am. 10: 179-186.

Becquerel, M.
1853. Des climats et de l'influence qu'exercent les Sols boises et non boises. Paris.

Bishop, C. H.
1923. Body fluid of the honey bee larva. Jour. Biol. Chem., 58: 543-564.
1923. Autolysis and Insect Metamorphosis. Jour. Biol. Chem. 58: 567-582.

Candolle, A. de.
1855. Geographie Botanique, Raisonee. Paris (Cites 1830 paper).

CLEMENTS, F. C., AND GOLDSMITH, G. W.

1924. The Phytometer Method in Ecology. Pub. 356, Carnegie Institution, Wash.

CHILD, L.

1918. Seasonal Irregularities of the Codling Moth. Jour. Ec. Ent., 11: 224-31.

CROZIER, W. J.

1924. On the critical thermal increment for the locomotion of a diplopod. Jour. Gen. Phys. 7: 123-136.

DANNEVIG, H.

1894. The Influence of Temperature on the development of the Eggs of Fishes. 13th Ann. Rept. of the Fisheries Board for Scotland, pp. 147-153.

DAVENPORT, C. B.

1898. Experimental Morphology, Part II. Ch. 18. (New Ed., 1908.)

EARLL, R. E.

1878. A Report on the History and Present Conditions of the Shore Cod Fisheries. U. S. Fish. Com. Rept. Pt. IV, 685-731.

GLENN, P. A.

1922. Codling-Moth Investigations of the State Entomologist's Office, 1915-17. Bull. Ill. Nat. Hist. Surv., 14: 219-288.

GREELEY, A. W.

1901. An Analogy between the Effects of Loss of Water and Lowering of Temperature. Am. Jour. Phys., 6, No. 2.

HAMILTON, C. C.

1917. The Behavior of Some Soil Insects, etc. Biol. Bull. 32: 159-182.

HARDING, L. A. AND WILLARD, A. C.

1916. Mechanical Equipment of Buildings: Vol. II. Heating and Ventilation. New York.

HEADLEE, T. J.

1914. Some Data on the Effects of Temperature and Moisture on the Rate of Insect Development. Jour. Ec. Ent. 7: 413-417.

1917. Some Facts Relative to the Influence of Atmospheric Humidity on Insect Metabolism. Jour. Ec. Ent., 10: 31-38.

HILDEBRANT, F. M.

1917. Climatic Conditions in Maryland as indicated by plant growth. Phys. Researches 2: 341-405.

HERTWIG, O.

1896. Ueber den Einfluss verscheidenen Temperatur auf dies Entwicklung der Froscheier. Sitzung a Ber. Akad. Jan. 1896, 105-108.

1898. Uber den Einfluss der Temperatur auf die Entwicklung von Rana fusca and Rana esculenta. Arch. fur Micro. Anat. 51: 319-381. Jan. 1898.

HUNTINGTON, E.

1915. Civilization and Climate. New Haven.

1919. World Power and Evolution. New Haven.

ISELY, D., AND ACKERMAN, A. J.

1923. Life history of the codling moth in Arkansas. Univ. of Arkansas Agr. Exper. Sta., Bull. 189.

JACOBS, M. H.

1919. Acclimation as a factor affecting the upper thermal death points of organisms. Jour. Expt. Zool. 27: 427-442.

JOHANSEN, A. C., AND KROGH, A.
1914. The Influence of Temperature and Certain Other Factors on the Rate of Development of Fishes. Conseil Internat. p. l'expl. de la mer. Pub. de Circonstance, No. 68 (Copenhagen).

JONES, E. S.
1923. Influence of Temperature, Moisture, and Oxygen on Spore Germination. Jour. Agr. Res. 24: 593-598.

KOEPPEN, W.
1884. Die Warmezonen der Erde. Meteor. Zeit. 1: 215-226.

KROGH, A.
1914. On the Influence of the Temperature on the Rate of Embryonic Development. Zeit. f. Allg. Phys., 16: 163-177.
1914a. On the Rate of Development, and CO_2 Production of Chrysalides of *Tenebrio molitor* at Different Temperatures Zeit. f. Allg. Phys., 16: 178-190.
1914b. The Quantitative Relation between Temperature and Standard Metabolism in Animals. Inter. Zeit. physikchem Biol., 1: 491-508.

LATHROP, F. H.
1923. Influence of temperature and evaporation upon the development of *Aphis pomi* de Geer. Jour. Agr. Res., 23: 969-987.

LEHENBAUER, P. A.
1914. The growth of Maize seedling in relation to temperature. Phys. Researches, 1: 247-288.

LILLIE, F. R., AND KNOWLTON, F. P.
1897. Effect of temperature on the development of animals. Zool. Bull. 1: 179-193.

LIVINGSTON, B. E., AND LIVINGSTON, G. J.
1913. Temperature coefficients in plant geography and climatology. Bot. Gaz. 56: 349-375.

MASTERMAN, A. T.
1894. On the Rate of Growth of the Marine Food Fishes. 13th Ann. Rept. of the Fisheries Board for Scotland, pp. 289-96.

MACDOUGAL, D. T.
1914. Auxo-thermal integration of climatic complexes. Am. Jour. of Botany 1: 186-202.

MCLEAN, F. T.
1917. Preliminary study of climatic conditions in Maryland as related to plant growth. Phys. Researches 2: 129-208.

MENDEL, L. B.
1914. Viewpoints in the Study of Growth. Biochem. Bull., 3: 156-176.

MERRIFIELD, F.
1890. Systematic Temperature Experiments on Some Lepidoptera in All their Stages. Trans. Ent. Soc. London. 1890, 131-160.

OETTINGEN, A. J. VON.
1879. Phaenologie der Dorpater Lignosen. Archiv. fur die Naturkunde Lov-Ehst and Kurlands. 8: Lief 3, (Dorpat).

OSBORNE, T. B., AND MANDEL, L. B.
1914. Suppression of growth and capacity to grow. Jour. Biol. Chem. 18: 95-103.

PEAIRS, L. M.
1914. The relation of temperature to insect development. Jour. Ec. Ent., 7: 174-179.

PIERCE, W. D.
1916. A New Interpretation of the Relationships of Temperature and Humidity to Insect Development. Jour. Agr. Res., 5: 1183-1191.

PITTENGER, P. S., AND VANDERKLEED, C. E.
1908. Preliminary Notes on a new Pharmacodynamic Assay Method. Jour. Amer. Pharm. Assn. 4: 427-433.

Powers, E. B.

1917. The Goldfish as a Test Animal in the Study of Toxicity. Illinois Biol. Monographs. Vol. IV, No. 2. (Bibliography.)

Reibisch, J.

1902. Ueber den Einfluss der Temperatur auf die Entwickelung von Fischeiern. Wiss. Meeresuntersuch., N. F., Abt. Kiel, 6: 215-231.

Sanderson, E. D.

1908. Relation of Temperature to the Hibernation of Insects. Jour. Ec. Ent., 1: 56-65.

1908a. Distribution of Insects. Jour. Ec. Ent., 1: 245-262.

1910. Relation of Temperature to the Growth of Insects. Jour. Ec. Ent., 3: 113-140.

Sanderson, E. D., and Peairs, L. M.

1913. Relation of Temperature to Insect Life. N. H. Agr. Expt. Sta., Tech. Bull. 7.

Shapley, H.

1920. Thermo-kinetics of *Liometopum apiculatum Mayr.* Proc. Nat. Ac. Sci. 6: 204-211.

Shelford, V. E.

1918. Physiological problems in the life histories of animals with particular reference to seasonal appearance. Am. Nat., 52: 129-154.

1920. Physiological Life Histories of Terrestrial Animals and Modern Methods of representing Climate. Trans. Ill. Ac. Sci., 13: 257-271.

Simpson, C. B.

1903. The Codling Moth. U. S. Dept. Agr. Div. Ent. Bull. 41. 105 pp. (Bibliography).

Snyder, C. D.

1908. A comparative study of the temperature coefficients of the velocities of the various physiological actions. Am. Jour. Phys. 22: 309-334.

1911. On the Meaning of Variation in the Magnitude of Temperature Coefficients of Physiological Processes. Am. Jour. Phys., 28: 167-175. (Good bibliography appended.)

Strachey, Richard.

1887. Computation of the Quantity of Heat in Excess of any Fixed Base. Quarterly Weather Rept. of the Meteorological Office for 1878: 13-32.

Taylor, G.

1916. Control of Settlement by Humidity and Temperature. Commonwealth Bureau of Meteorology, Bull. No. 14.

1919. The Settlement of Tropical Australia, Geog. Rev. 8: 84-115.

Townsend, M. T.

1926. Breaking up of Hibernation in the Codling Moth. Ann. Ent. Soc. Am. 19: 429-439.

Verworn, M.

1909. Allegemeine Physiologie. Jena.

Warren, E.

1900. On the Reaction of *Daphnia magna* (Straus) to Certain Changes in its Environment. Quart. Jour. Micr. Sci. 43: 199-224.

Weimer, J. L., and Harter, L. L.

1923. Temperature Relations of Eleven Species of Rhizopus. Jour. Agr. Res. 24: 1-40.

Williamson, H. C.

1910. Experiments to Show the Influence of Cold in Retarding the Development of the Eggs of Herring, etc. (Fisheries Board of Scotland, 27th Rept. (for 1908).

Wodsedalek, J. E.

1917. Five Years' Starvation of Larvae. Science, N. S. XLVI: 366.

STATE OF ILLINOIS
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Vol. XVI. BULLETIN Article VI.

A Study of the Catalase Content of Codling Moth Larvae

BY

C. S. SPOONER

AUG. 26TH 1818

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URBANA, ILLINOIS
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Article VI.—*A Study of the Catalase Content of Codling Moth Larvae.* By C. S. Spooner.

At the suggestion of Professor Shelford, a series of experiments was undertaken to test the hypothesis that the enzyme catalase might be a determining factor in the dormant period of codling-moth larvae. The method devised by Professor Burge ('16) was used with a few minor modifications in determining the catalase content of the larvae. This method consists in collecting and measuring the oxygen gas liberated from neutral hydrogen-peroxide by the catalase present in the crushed larvae.

The most surprising fact discovered in these experiments was the comparatively enormous quantities of oxygen obtained from the catalase in a single larva—over 650 cc. being obtained in some cases. The reaction was extremely violent, and the gas bubbled off at a surprising rate. The large quantity of gas necessitated an enlargement of the apparatus, with a consequent loss in accuracy.

All tests were run for a period of twenty minutes. The quantity of gas was read every minute for the first ten minutes, then at the end of 15 minutes, and finally at the end of 20 minutes. Although the reaction had not entirely ceased at the end of twenty minutes, it had become so slow as to make the continuation of readings useless. The experimental error, though large, is thought to be practically constant and always in the same direction; that is, the recorded results are proportionally low for all larvae. Table I gives four typical records obtained during the course of these experiments.

Table I. *Typical Records of the Volume of Oxygen (in cc) Obtained from Codling-Moth Larvae.*

Time in Minutes	1	2	3	4
1	20	35	63	17
2	32	62	106	25
3	42	85	150	35
4	50	110	196	41
5	60	135	245	50
6	68	155	300	57
7	77	180	340	65
8	85	202	375	72
9	92	223	405	80
10	100	244	430	85
15	132	312	500	113
20	155	338	530	135
Weight of larva in gms.	.036	.047	.034	.022
Gas in cc. per gm. of larval wt.	4305.5	7191.4	15588.2	6136.3

It will be noticed that approximately two-thirds of the gas is given off in the first ten minutes. At the end of twenty minutes the reaction has slowed down so that very little gas is given off after that time.

TABLE II. *Summary of Data on Catalase Content of Codling-Moth Larvae.*

Date. 1920	Wt. of larva in gms.	Gas obtained in cc.	Gas in cc. per gm. of larval weight.
July 14	.030	228	7105.2
July 14	.035	276	7953.8
July 14	.032	298	9463.1
July 14	.040	378	9460.3
July 14	.039	348	8945.7
July 15	.066	451	6833.3
July 15	.038	355	9078.7
July 15	.034	396	1164.7
July 16	.020	773	3650.0
July 16	.055	494	8981.8
July 16	.033	193	5848.5
July 16	.064	438	6843.7
July 20	.046	508	1104.3
July 20	.040	245	6125.0
July 20	.042	400	9523.8
July 22	.034	260	7764.7
July 22	.053	378	7132.0
July 22	.039	276	7076.9
July 22	.062	509	8209.7
July 22	.052	425	8173.0
July 22	.048	457	9956.5
Aug. 5	.050	368	7360.0
Aug. 5	.044	295	6704.5
Aug. 5	.055	508	9236.0
Aug. 5	.034	242	7117.0
Aug. 5	.042	414	9857.1
Aug. 13	.061	348	5704.9
Aug. 13	.053	226	4264.1
Aug. 13	.052	169	3250.0
Aug. 13	.061	335	5498.8
Aug. 13	.076	520	6842.1
Aug. 13	.067	655	9786.1
Aug. 13	.072	602	8361.1
Aug. 13	.053	508	9236.3
Aug. 16	.054	286	5296.3
Aug. 16	.043	160	3720.9
Aug. 16	.075	446	5946.6
Aug. 16	.064	333	5203.1
Aug. 20	.062	405	6532.2
Aug. 20	.054	355	6574.0
Aug. 20	.054	595	11018.5

An examination of Table II shows that there is a very great variation in the catalase content per unit of larval weight. One cause of this variation was undoubtedly the difference in the age of the larvae. Food, conditions of the environment after leaving the apple, and individual variation are other possible causes. It seems reasonable to suppose that there is a gradual increase in catalase content up to the time of pupation. This is not proved by these experiments, but the general results seem to indicate that it is a point well worth further investigation. Experiments are planned for this purpose.

While it is always a question what any given larva used in the experiment would have done if left alone, experience with several thousands of larvae leads to the belief that the general appearance of an individual when the pupation time arrives, indicates whether it will pupate or not. The plump, healthy-looking individuals nearly all pupate, while those which appear thin and shrivelled remain dormant and eventually die without pupating. The plump, well-conditioned larvae always gave a high catalase content, 5,000 cc per gram or more, while those which appeared dried and shrivelled gave a low catalase content, usually about 3,000 cc per gram. In the absence of better criteria by which to tell those larvae which would pupate from those which would remain dormant, it is justifiable to suppose that, if the catalase content increases as the larva advances toward the time for pupation, then the catalase content may be a determining factor or at least a correlated factor in the dormancy.

Table III shows the results obtained from nine larvae which had been kept over winter in a cool place and subjected to a flow of dry air. Five of these appeared plump and healthy and gave a high catalase content (Nos. 1, 4, 5, 8, 9). The other four were shrivelled and gave a low catalase content. A control set, which was kept and allowed to pupate, showed that about one-half of the lot would probably have pupated.

TABLE III. *Catalase Content of Larvae Kept Over Winter in Cool Dry Air.*

No.	Weight of larva in gms.	Gas obtained in cc.	Gas per gm. of larval weight.
1	.036	325	9027.7
2	.036	155	4305.5
3	.035	106	3028.5
4	.047	338	7191.4
5	.030	253	8433.3
6	.037	187	5054.0
7	.030	102	3400.0
8	.034	530	15588.2
9	.022	135	6136.3

Conclusions.

1. Codling-moth larvae contain large quantities of the enzyme catalase.

2. The quantity of catalase per unit of larval weight varies considerably in different individuals.

3. Catalase content is directly correlated with the health and continued life of larvae.

4. Catalase content may be directly correlated with pupation and dormacy. In order to test this conclusion a large series of tests should be made covering each day of larval life from the time the larvae leave the apple until time of pupation.

Bibliographical Reference.

Burge, W. E.
1916. Relation between the amount of catalase in the different muscles of the body and the amount of work done by these muscles. Am. Jour. Physiol. 41: 153-161.

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Vol. XVI. BULLETIN Article VII.

The General Entomological Ecology of the Indian Corn Plant

BY

STEPHEN A. FORBES

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DIVISION OF THE
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STEPHEN A. FORBES, *Chief*

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The General Entomological Ecology of the Indian Corn Plant

BY

STEPHEN A. FORBES

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ARTICLE VII.—*The General Entomological Ecology of the Indian Corn Plant.*[*] BY STEPHEN A. FORBES.

Ecology being the science of the interactions between an organism or a group of organisms and its environment, and between organisms in general and their environment in general, this complex of relations may, of course, be divided in various ways. The division here used implies a centripetal grouping of the facts of relationship around single kinds of organisms, and the group of facts to be discussed is that of which the corn plant is the center and the insects of its environment are the active factors.

A prolonged study, extending over many years, of the entomology of the corn plant, the economic results of which have been published in my seventh and twelfth reports as State Eutomologist of Illinois (the Eighteenth and Twenty-third of the office series), has left in my possession a considerable body of information capable of treatment from the standpoint of pure ecology, and the beginnings of such a treatment are here assembled because of the rising interest in ecological investigation and the promise which it gives of interesting and important results, and because of a wish to illustrate in some measure the general scientific value of such materials of which, it scarcely need be said, the economic entomologists of this country have accumulated a large amount.

INSECT INFESTATION OF THE CORN PLANT

We know of some two hundred and twenty-five species of insects in the United States which are evidently attracted to the corn plant because of some benefit or advantage which they are able to derive from it. The principal groups of this series are ninety species of Coleoptera, fifty-six species of larvæ of Lepidoptera, forty-five species of Hemiptera and twenty-five species of Orthoptera. The other insect orders are represented by seven or eight species of Diptera and one or two of Hymenoptera. Every part of the plant is liable to infestation by these insects, but the leaves and the roots yield the principal supplies of insect food, either in the form of sap and protoplasm sucked from their substance by Hemiptera or in that of tissues and cells devoured by the subterranean larvæ of Coleoptera and by caterpillars, grasshoppers and beetles feeding above ground.

LACK OF SPECIAL ADAPTATIONS

Notwithstanding the great number of these insects and the variety and importance of the injuries which they frequently inflict upon the corn plant, there is little in its structure or its life history to suggest any spe-

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[*] Reprinted from The American Naturalist, Vol. XLIII, No. 509, May, 1909.

cial adaptation of the plant to its insect visitants—no lure to insects capable of service to it or special apparatus of defense against those able to injure it. The fertilization of its seed is fully provided for without reference to the agency of insects. It has no armature of spines or bristly hairs to embarrass their movements over its surface or to defend against their attack its softer and more succulent foliage. It secretes no viscid fluids to entangle them and forms no chemical poisons or distasteful compounds in its tissues to destroy or to repel them. The cuticle of its leaf is neither hardened nor thickened by special deposits; its anthers are neither protected nor concealed; and its delicate styles are as fully exposed as if they were the least essential of its organs. Minute sucking insects are able at all times to pierce its roots and its leaves with their flexible beaks, and, with the single exception of its fruit, there is no part of it which is not freely accessible at any time to any hungry enemy. Only the kernel, which is supposed to have been lightly covered in the wild corn plant by a single chaffy scale or glume, has become in the long course of development securely inclosed beneath a thick coat of husks, impenetrable by nearly all insects; and we may perhaps reasonably infer that, among the possible injuries against which this conspicuous protective structure defends the soft young kernel, those of insects are to be taken into account.

There are, of course, many insect species, even among those which habitually frequent the plant, which are unable to appropriate certain parts of its substance to their use, but this is because of the absence of adaptation on their part and not because of any special defensive adaptation on the side of the plant. Thus we may say that, with the exception of the ear, the whole plant lies open and free to insect depredation, and that it is able to maintain itself in the midst of its entomological dependents only by virtue of its unusual power of vigorous, rapid and superabundant growth. Like every other plant which is normally subject to a regular drain upon its substance from insect injury, it must grow a surplus necessary for no other purpose than to appease its enemies; and this, in a favorable season, the corn plant does with an energetic profusion unexampled among our cultivated plants. Insects, indeed, grow rapidly as a rule, and most of them soon reach their full size. Many species multiply with great rapidity, but even these the corn plant will outgrow if given a fair chance, provided they are limited to corn itself for food.

Turning to the other side of the relationship, we may say that the corn insects exhibit no structural adaptations to their life on the corn plant—no structures, that is to say, which fit them any better to live and feed on corn than on any one of many other kinds of vegetation. This was, of course, to be expected of the great list of insects which find in corn only one element of a various food, and that not necessarily the most important; but it seems equally true of those which, like the corn rootworm or the corn root-aphis, live on it by strong preference, if not by absolute necessity.

Aphis maidiradicis, the so-called corn root-aphis, is not especially different in adaptive characters from the other root-lice generally, and it lives, indeed, in early spring on plants extremely unlike corn. Finding its first food on smartweed (Polygonum) and on the field grasses (Setaria, Panicum, etc.), it is scarcely more than a piece of good fortune for it and for its attendant ants if the ground in which it hatches is sometimes planted to corn, in which it finds a more sustained and generous food-supply than in the comparatively small, dry and slow-growing plants to which it would otherwise be restricted.

The larva of *Diabrotica longicornis,* usually known as the corn rootworm, is, of course, well constructed to burrow young corn roots, but it differs from related Diabrotica larvæ in no way that I know of to suggest a special adaptation to this operation except in the mere matter of size. If it were larger it would probably eat the roots entire, as does the closely related and very similar larva of *D. 12-punctata.* Indeed, there is some reason to believe that *D. longicornis* may breed in large swamp grasses, since the beetle has been found abundant in New Brunswick in situations where it is difficult to suppose that it originated in fields of corn and where such grasses are extremely common. Even the special corn insects seem, in short, structurally adapted to much more general conditions than those supplied by the corn plant alone, and if they are restricted largely or wholly to this plant for food, this seems due to other conditions than those supplied by special structural adaptations.

In short, in the entomological ecology of the corn plant we see nothing whatever of that nice fitting of one thing to another, specialization answering to specialization, either on the insect side or on that of the plant, which we sometimes find illustrated in the relations of plants and insects. The system of relations existing in the corn field seems simple, general and primitive, on the whole, like that which doubtless originally obtained between plants in general and insects in general in the early stages of their association.

Such adaptations to corn as we get glimpses of are almost without exception adaptations to considerable groups of food plants, in which corn is included—some of these groups select and definite, like the families of the grasses and the sedges to which the chinch-bug is strictly limited, and others large and vague, like the almost unlimited food resources of the larvæ of Lachnosterna and Cyclocephala under ground. These are evidently adaptations established without any reference to corn as a food plant, most of them very likely long before it became an inhabitant of our region, and applying to corn simply because of its resemblance, as food for insects, to certain groups of plants already native here.

Entomological Ecology of Corn and the Strawberry

Corn being, in fact, an exotic or intrusive plant which seems to have brought none, or at most but one,[1] of its native insects with it into its new

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[1] *Diabrotica longicornis* Say.

environment, it will be profitable to compare the entomological ecology of this introduced but long-established and widely cultivated plant with that of some native species which is also generally and, in some districts, extensively grown.

We may take for this purpose the strawberry plant, whose insect visitants and injuries I studied carefully several years ago. About fifty insects species are now listed as injurious to the strawberry and about twenty of these also infest corn. Two fifths of the known strawberry insects are thus so little specialized to that food that they feed on other plants as widely removed from the strawberry as is Indian corn. On the other hand, six species, all native, are found, so far as known, only, or almost wholly, on the strawberry, at least in that stage in which they are most injurious to that plant. These are the strawberry slug (*Emphytus maculatus*); the strawberry leaf-roller (*Phoxopteris comptana*), occasionally abundant on blackberry and raspberry, to which it spreads from infested strawberry plants adjacent; two of the strawberry root-worms—the larvæ of *Typophorus aterrimus* and of *Scelodonta nebulosus;* the strawberry crown-borer (*Tyloderma fragariæ*); and the strawberry aphis (*Aphis forbesi*).

Not even one of this considerable list exhibits, so far as I can see, any special structural adaptation to life on the *strawberry* plant. The two root-worms mentioned, for example, are no better fitted to feed on strawberry roots than is a third strawberry root-worm—the larva of *Colaspis brunnea* which lives on the roots of corn and timothy also. *Emphytus maculatus* might feed, for all the structural peculiarities which one can see, on the leaves of roses as well as does the common slug or false-worm of those shrubs, and so of the others of the list. Even the strawberry crown-borer, which lives in all stages solely on that plant, might, so far as structure and life history are concerned, feed and develop in any other thick-rooted perennial. The difference seems to be one of habit or preference solely, and not of structural adaptation.

Our impressions of the extent, nicety and frequency with which insects and plants are mutually adapted are indeed commonly much exaggerated, owing to the fact that our attention is especially drawn to notable cases of curious, precise or particularly advantageous adjustments between organisms, while no general study is made of the entire system of relations obtaining between all the members of an associate group, varying widely, as these do, in respect to the intimacy, importance and exclusiveness of the association. For this same reason in part, we ordinarily have no accurate idea of the relative frequency and primacy of structural, or static, adaptations—particularly obvious, especially interesting, and seemingly ingenious as they often are—and of those more obcure adaptations of preference, behavior, habit and the like, which, taken together, we may call dynamic.

CLASSIFICATION OF ADAPTATIONS TO FOOD

A plant-insect group—a group, that is, composed of a plant and its insect visitants—is not in fact usually marked, either as a whole or in any of its several parts, by the presence of adaptive structures special to that group. The structural adaptations of insects are as a rule much too broadly shaped to fit them closely to any one plant, and where such a fitting is found, it is clearly due to some other than the structural factor. Such facts bring us to a consideration of the whole subject of the variations and classification of the adaptations of insects to their food resources.

These adaptations may be classed as structural, physiological, psychological, synethic,[2] local, biographical and numerical. All structural adaptations are, of course, physiological in a sense, but I use the word physiological, as a matter of convenience, for functional adaptations not based on obvious structural peculiarities, as where an insect equally capable of feeding on the sap of two plants and readily availing itself of either, nevertheless thrives and multiplies better on one than on the other, the adaptation being evidently digestive or assimilative rather than obviously structural. The San José scale, for example, feeds readily on a great variety of trees and shrubs, on some of which it thrives poorly and spreads but little, while on others it multiplies enormously and spreads with great rapidity. The word psychological may be applied to cases of apparent choice or evident inclination, as between the various available food plants of the environment. Those fixed peculiarities of habit or behavior which adapt an insect to one food plant or class of food plants rather than to another we may call synethic adaptations, in the absence of any existing word applicable in this sense; local adaptations are those in which the usual haunts and places of resort of an insect species, however determined, bring it into common contact with an available food plant, the frequency of this contact being quite independent of the degree of the fitness of such plant for its food; biographical adaptations are those based on a correspondence between the life history of the insect and its organic food supply, such that the latter shall always be accessible in sufficient quantity to meet the varying needs of the dependent insect at the various stages of its growth; and numerical adaptations are the consequence of such an adjustment of the rate of insect multiplication to the plants or animals of its food that only the unessential surplus of this food shall be appropriated, its maximum essential product being left undiminished.

These several classes of adaptations limit each other variously, the most desirable food of an insect being that which is found within the area common to all of them. That is, the most important food plants of a vegetarian species will be those which are well within its structural capacities of discovery, access and appropriation; within its physiologi-

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[2] Adaptations of habit.

cal powers of easy digestion and profitable assimilation; and within its habitual range and location; and which are consistent with its usual preferences and habits of action, and are well adapted to furnish continuously amounts of food answering to its varying necessities during the different stages of its life.

Advantages of Biographical Adaptation

It is obviously to the advantage of any insect species that it shall have its largest possible food supply coincident with its own largest demand for food—that is, at the climax of its period of growth. In a species restricted to one annual food plant the most favorable relation will usually be that in which the life history of the plant and that of the insect coincide, the egg-laying period of the one corresponding to the seeding period of the other, the hatching of the insect being virtually simultaneous with the germinating period of the plant, and the period of most rapid growth being coincident in both. This kind of adaptation is well illustrated by the life histories of *Diabrotica longicornis* and the corn plant. This beetle lays its eggs in fall when the ear is maturing, and the larvæ hatch in spring when the corn plant is young and growing slowly, and they feed on the roots during the entire growing season of the plant. It is evident that such a well-adjusted insect will have an advantage, other things being equal, over a poorly adjusted competitor for food from the same plant, since it will be able, as a rule, to leave a more vigorous and abundant progeny; and similarly, any part of a species which, by aberration of life history, may come to be poorly adjusted to its food plant, will suffer as a consequence in comparison with the normal members of the species, with the result that these biographical characters of the insect will tend to become permanent and characteristic in the same sense in which its structural characters are.

It should be noticed also that such an adjustment is an advantage to the host plant as well as to the dependent insect, since it distributes the depredations of the latter in a way to make them relatively slight when but little injury can be borne, and concentrates them, on the other hand, where the largest injury can be supported with the least serious consequences. Such a well-adjusted insect will get the maximum amount of food with the minimum injury to the plant, and such a plant-insect pair will have a competitive advantage over a poorly adjusted pair in which a greater injury is done to the plant than is necessary to the maintenance of the insect.

The same reasoning applies and the same rule holds good for species with a more heterogeneous food, except that in respect to them we must substitute for the single plant the entire group of plants to which the insect resorts for food. At this point, however, the facts become too complicated for successful analysis, especially in view of the difference of abundance from year to year of the plants of a considerable list and the effects on the food supply of variable competitions among the various species resorting to it. It may be said in general terms, however, that when the life history of a food plant or the common history of a group of such plants exhibits sufficiently constant characters to serve as an adaptive matrix, an adaptation to it of the life history of those insects strictly or mainly dependent on it for food is more or less likely to follow.

MUTUAL BIOGRAPHICAL ADJUSTMENTS OF COMPETITORS

An example of the competitive relations into which corn insects of widely different character, origin, habit and life history may be brought by their dependence on the same food plant may be found in *Diabrotica longicornis* and *Aphis maidiradicis.* Both pass the winter as eggs in the earth of the corn field, the aphis hatching sooner than the root-worm and developing two or more of its short-lived generations before the Diabrotica larva is out of the egg, gaining thus the advantage of an earlier attack in greater numbers. It is also able to take much more rapid possession of a field of corn because of its command of the services of ants in finding its way to the roots of the plants which the tiny and feeble Diabrotica larva must search out for itself.

Later the root-aphis gives origin to young, many of which acquire wings and may thus disperse as their local attack upon the plant becomes unduly heavy, while the root-worm must take its chances for the year in the field where the eggs were left the previous fall. The aphis feeds at first on the sap of young weeds common in spring in all cultivated fields, and may thus save itself even though the ground is planted to wheat, or oats, an event which causes the death by starvation of every root-worm hatching from the egg.

In respect to rate of multiplication, the root-aphis has of course a truly enormous advantage as compared with the corn root-worm, and yet, notwithstanding all these facts favorable to the aphis, its injuries to corn in Illinois are seemingly no greater than those done by the corn root-worm. This is due partly to the fact that, through the winged members of the early generations, the percentage of which increases as conditions become locally less favorable, the aphis largely leaves the field in which it originally started and early breaks the force of its attack by a general distribution of it. The depredations of the root-worm, on the other hand, increase with the growth of the insect until about September first, and increase also at a rapid rate from year to year in a field kept continuously in corn. It follows as a consequence that the principal damage by *Aphis maidiradicis* is done to the corn while it is young, and that by Diabrotica to the well-grown plant.

This serial order of injuries to the corn plant, due to the relation of the life histories and rates of multiplication of these two competing insects, is an advantage to both of them and, indeed, to all three, corn included, since the plant would be more seriously injured or more certainly destroyed if both its insect enemies attacked it together than it is where their attacks are made successively. Competitors for food from a living plant find it to their advantage, and to that of the plant they feed upon, to avoid a simultaneous competition; and such a plant-insect group would, of course, prevail, other things being equal, over a competing group not so adjusted. Natural selection tends, no doubt, to establish these mutually advantageous relations between a plant and its constant insect visitants. With respect to these two corn insects, however, it must be admitted that no proof is apparent that such adaptation of life histories and habits as we here see is due to anything more than an accidental collocation of species whose significant peculiarities were already established when they came together.

A similar but more striking example of a serial succession of injuries to the same plant is to be found among the strawberry insects, as I showed several years ago.[3] Three coleopterous larvæ belonging to the same family (Chrysomelidæ) but to different genera (Colaspis, Graphops and Typophorus), and to species native in the United States, are all so closely adapted to underground life and to the root-feeding habit that they are distinguishable from one another only by rather slight and inconspicuous characters. They are often associated in large numbers in the same fields, living wholly on the roots of strawberry plants, which they affect in an identical manner, so that from the appearance of the injury itself one could not possibly tell which of the three species was present in the field. One of these root-worms, the Colaspis larva, feeds also on the roots of other plants, especially on those of timothy and corn, but the other two larvæ have been found only among strawberry roots. They seem thus to be strict competitors for food from the same part of the same plant, and as their locomotive capacity is poor, they are unable to avoid one another's company by migration under ground.

The strawberry plant, however, grows continuously throughout the season, and each of these three insects, having a short larval period, feeds on strawberry roots for only a part of this growing season. It is an interesting and striking fact that the life histories of the three competing insects are so related that the larvæ do not infest the plant at the same time, but follow one another in close succession, beginning early in May and ending late in fall. The first of the species, the Colaspis larva, feeds from about May to the end of June, the Typophorus larva follows in July and August, and the Graphops larva begins in August and continues until fall.

Consistently with this difference, the species concerned hibernate in different stages of development—Colaspis apparently as an egg, Typophorus undoubtedly as an adult, and Graphops as a larva in its subterranean cell, from which adults emerge the following June to lay their eggs in July. With such a distribution of their attack, each of these three species is able to maintain itself on the strawberry in numbers as

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[3] "On the Life Histories and Immature Stages of Three Eumolpini," *Psyche*, Vol. 4, Nos. 117-118, January-February, 1884; and No. 121, May, 1884.

large as would be possible for all three taken together if they made their assault on the plant simultaneously. The advantage to both plant and insects of this adjustment of life histories—if one may call it such—is obvious at once.

That some actual adjustment of larval periods has here been made is rendered somewhat more probable by the fact that a closely related species of Graphops which infests the wild primrose (*Œnothera biennis*) in southern Illinois, has a life history different from that of the species which breeds in the strawberry—hibernating as an adult, like Typophorus, and not as larva, like the strawberry species of its own genus.

Maladjustment of Competitions

The corn plant is in greater danger from insect ravage during the first month of its life than at any later time. This is because it offers then a comparatively scanty supply of food, so that a small number of insects may work great destruction; because the single small plant is much more easily killed than a larger one; and because a larger number of active rival insects infest corn when it is young than at any other time, some of them beginning with the recently planted or just sprouting seed. The young roots, the underground part of the stalk, the stalk above ground, and the leaves, both before and after they unfold, are all liable to infestation by several species at the same time. The seed is injured by the wireworms, the seed-maggot, the Sciara larva and the larva of *Systena blanda;* the roots, by the wireworms, the root-aphis, the corn root-worms, and the white-grubs; the stalk under ground, by the wireworms, the root-aphis, the southern corn root-worm, and the bill-bugs; the stalk above ground, by the bill-bugs, the cutworms, the web-worms, the stalk-borers, and the army-worm—sometimes by the chinch-bug also; and the leaves, by the bill-bugs, the web-worms, the cutworms, the army-worm and the first generation of the ear-worm.

This concentration of injury upon the corn when it is young is a case of maladaptation, since the plant has least to offer when it is most heavily drawn upon. It will be noticed, however, that this early spring attack is mainly delivered by insects which come into corn from some other vegetation, chiefly from grass, and whose occurrence in the corn field is scarcely more than accidental. The motive to an adjustment of habits and life histories to the capacities of the plant is therefore virtually wanting, and seems at any rate impossible, owing to the variability and inconstancy of the several factors involved.

Conclusion

From the foregoing it will be seen that the corn plant is not only an exotic in its origin, but that, aside from its relation to man, it still remains an unnaturalized foreigner, not sufficiently adapted to our conditions to survive without the constant supervision of a guardian and the services of a nurse. The corn field contains an artificial "association" persistently maintained by human agency in the midst of a hostile environment to which it would promptly succumb if left to itself, and as such it would seem to offer to the ecologist all the advantages of a vast and long-continued experiment, by a study of whose results he may learn something of the manner in which ecological relations may be affected when a plant takes advantage of a single favoring condition to push its way into a territory foreign to its former habits.

This corn plant, at least, which has certainly lived in our territory under the care of man for several centuries, and perhaps for some millenniums, has even yet no specialized friends active in its service, and no structurally adapted enemies enlisted against it, such specializations of injurious relationship as one detects being clearly due to other than structural differentiations. During all this long period, it has been widely and steadily forced into a strange ecological system which has nevertheless scarcely yielded to it at any point. It has produced, it is true, by its enormous multiplication and extension, a profound effect on the numbers and distribution of some insect species, reducing the area of multiplication for several, which, like the cutworms and the army-worm, formerly bred in the turf of our native prairies but can not breed in fields of corn; and immensely extending the range and increasing the number of others which have found in this plant a better and far more abundant food supply than that originally available to them. Insect species which, like *Diabrotica longicornis* and *Aphis maidiradicis,* were almost unknown fifty years ago within our territory, have now, through their increase in corn fields, arisen to the rank of dominant species.

But the few discernible insect adaptations to the offerings of the corn plant are physiological, psychological, synethic and biographical, and apparently not structural at all. Slight and seemingly incipient as they are, we have no sufficient reason to conclude that they are recent results of the association of the corn plant with the insect; both parties of the association may have been substantially what they now are when they first found each other, and such mutual fitness as they exhibit may be merely like that of angular stones shaken together in a box until like surfaces seem to cohere, simply because in this position the fragments can not readily be shaken apart.

We may also derive from this discussion support for the idea that adaptations of insects to their environment are largely, and often primarily, psychological—that they are often, in the first instance, specializations of preference or choice, or, as we may perhaps more safely say, of tropic reaction. Species which would otherwise compete with each other, with disadvantageous consequences to each, escape these disadvantages by acquiring, one or both, different habits of reaction, under the influence of which they separate, one going for its principal food to the corn plant, for example, and the other continuing on the strawberry, although structurally each remains equally fit to feed on either. Physiological, or even structural, adaptation may follow the psychological, but as secondary to it. This is only saying in other words that the central nervous system, on whose special functioning peculiarities of habit depend, is subject, like any other, to adaptive variations, and that these variations may either follow and reinforce those of some other organ or organs tending to the same end, or that they may arise independently of any other; and this is merely extending to insects a generalization very obvious with respect to man, finding warrant for the extension, as we do, in the facts disclosed by an examination of the general economy of insect life.

NOTE.—Changes of nomenclature since this paper was written call for the following data of synonymy:

Pp. 449, 453, 456.
  Aphis maidiradicis = *Anuraphis maidi-radicis* (Forbes).
  Lachnosterna = *Phyllophaga.*
Pp. 450, 454, 455.
  Emphytus maculatus = *Empria maculata* (Norton).
  Phoxopteris comptana = *Ancylis comptana* (Fröhl.).
  Typophorus aterrimus = *Paria canella* (Fab.).
  Scelodonta nebulosus = *Graphops nebulosus* (Lec.).

INDEX*

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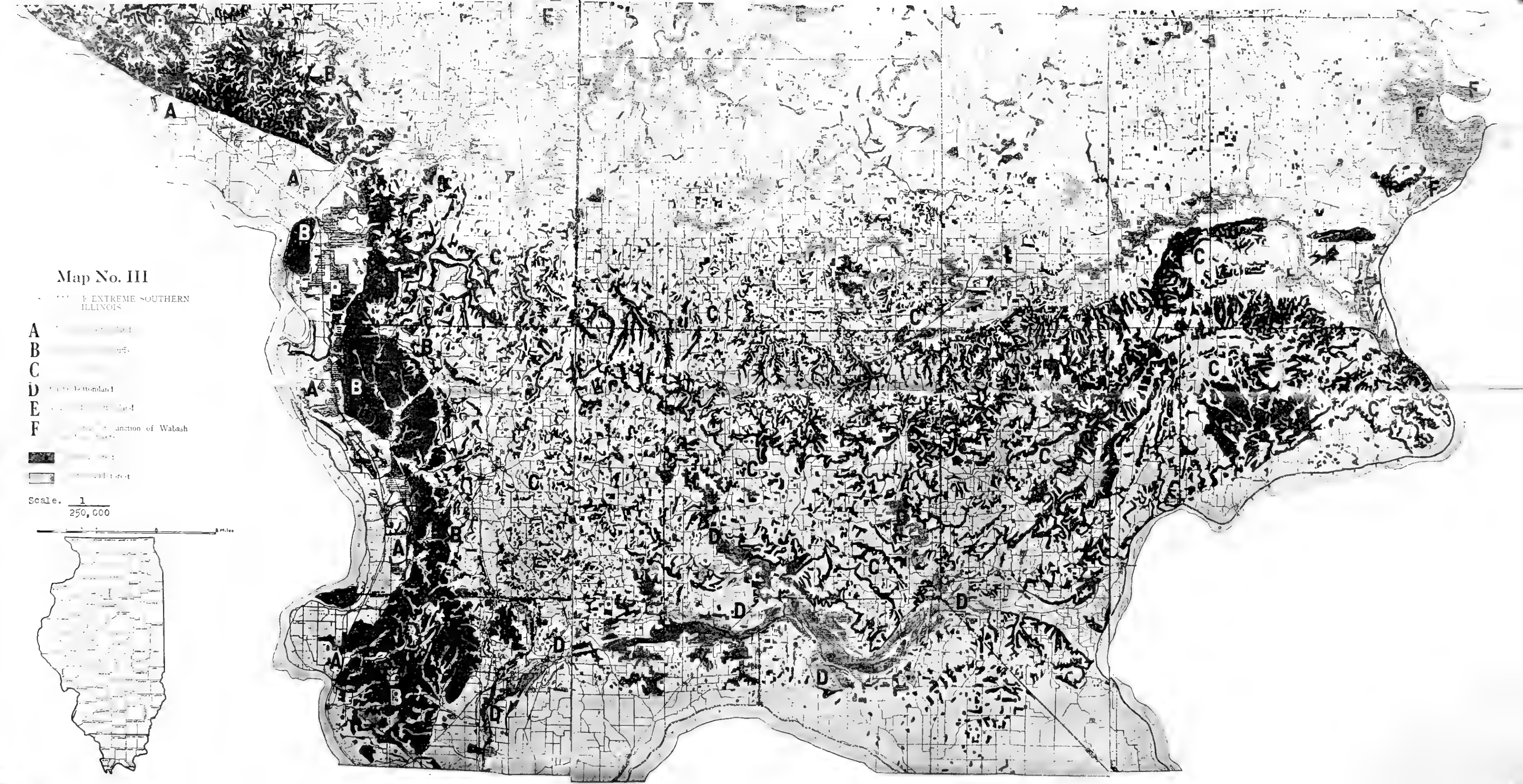
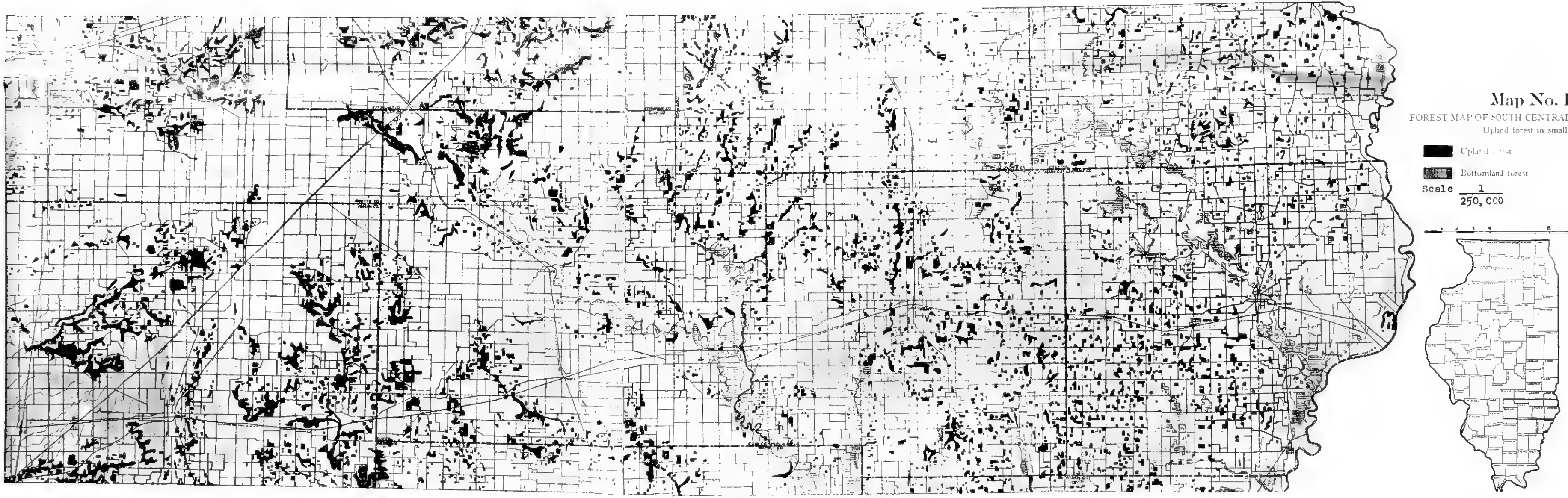
* See pages 271 to 309 for index to insect types in the collections of the State Natural History Survey and the University of Illinois. See also in this connection pages 269 and 270.



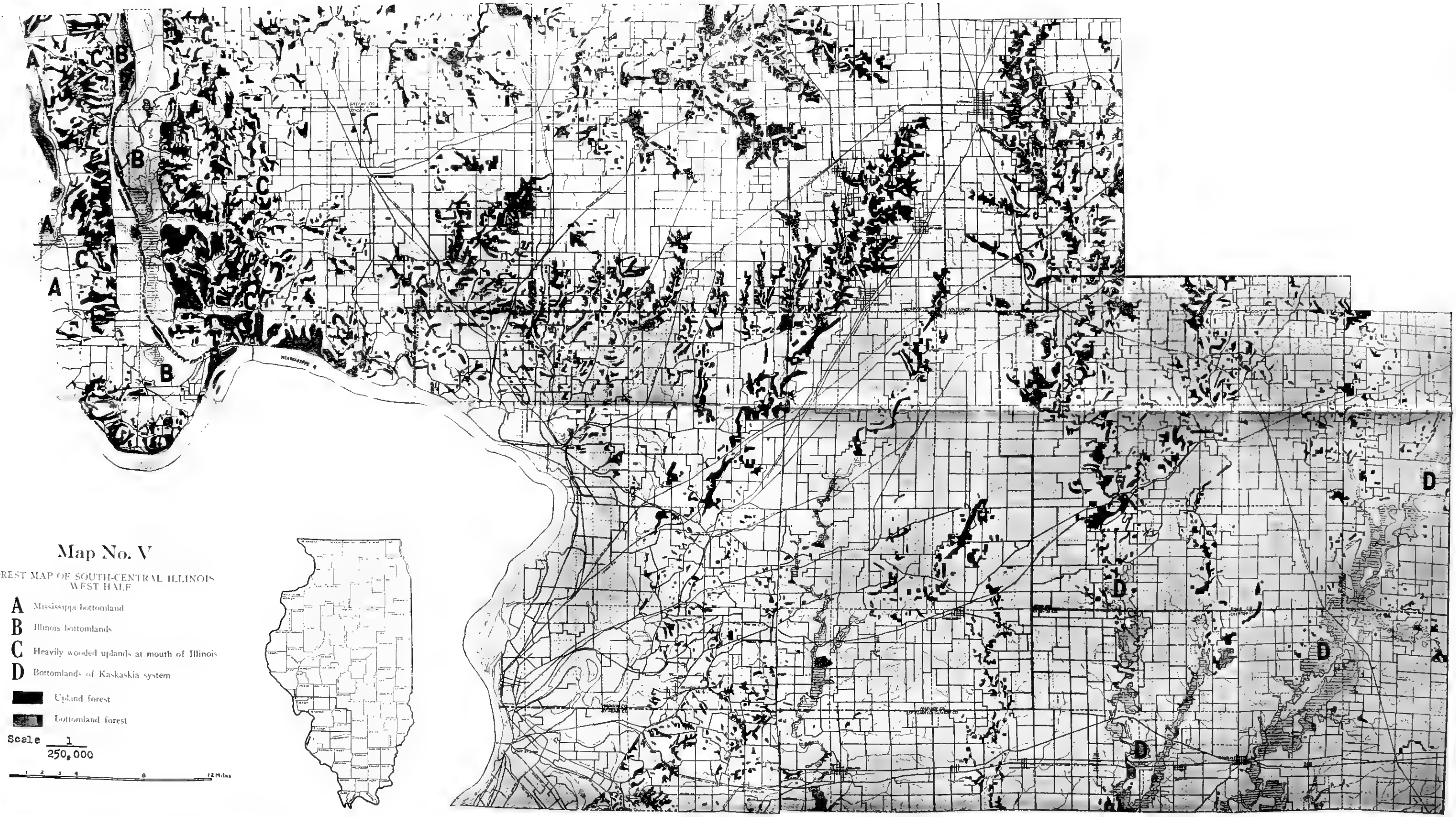
Map No. III
E EXTREME SOUTHERN ILLINOIS
A
B
C
D bottomland
E land
F junction of Wabash
Scale. 1/250,000
Miles
A
B
C
D
E
F



Map No. IV

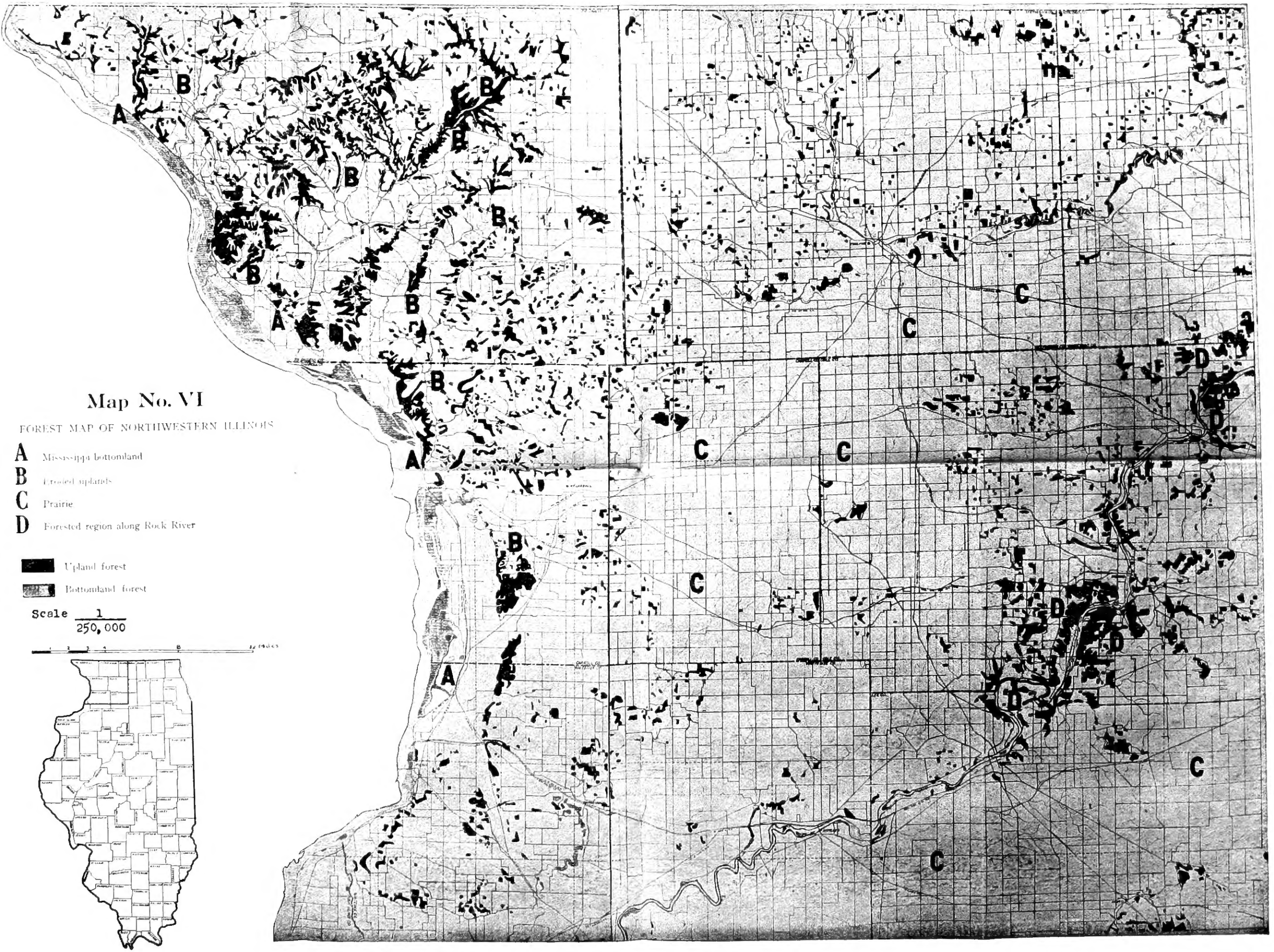
FOREST MAP OF SOUTH-CENTRAL ILLINOIS. EAST

Upland forest in small wood-lots



Map No. V

FOREST MAP OF SOUTH-CENTRAL ILLINOIS
WEST HALF



Map No. VI

FOREST MAP OF NORTHWESTERN ILLINOIS